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Models for Healthy Older People

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Short Abstract

This document represents the deliverable D2.1 (Models for Healthy Older People) and it is the main product of the first six month activities of WP2 (End user profiling and Virtual Coaching Guidelines). The document contains the results of the activities performed during Task 2.1 (Modelling of physiological status and physical activity behaviour), Task 2.2 (Modelling of nutritional behaviour), Task 2.3 (Modelling of cognitive and mental status and social behaviour).

The document reports the general framework for Healthy Ageing (Chapter 1) and the current empirical findings about age-related trajectories relative to the physical and psychological well-being target domains faced in NESTORE (Physiological Status and Physical Activity Behaviour, Nutrition, Cognitive and Mental Status and Social Behaviour) (Chapter 2). The analysis of the relevant approaches and interventions currently adopted for healthy ageing in the clinical/psychological practise is described in Chapter 3. In Chapter 4, a detailed description of the SOC and HAPA motivational models is presented, since these models will be adopted in NESTORE. After a short excursus on previous IT-based EU projects on Healthy Ageing (Chapter 5), the NESTORE model of healthy ageing is described (Chapter 6). In conclusion the specificity of NESTORE in the frame of Healthy Ageing is reported in Chapter 7.

The NESTORE model is aimed at providing a structured knowledge, built on expertise of the NESTORE experts (exercise physiologists, nutritionists, psychologists, geriatricians), able to characterize the person in terms of both status and behaviour. In NESTORE, the final user is an older adult, which is living on her/his own (at home or assisted home living), male or female, from 65 to 75 years old, mainly retired or recently retired, with an autonomous life and interested in maintaining or promoting her/his wellbeing and quality of life, without any impairment and/or pathology.

Based on this user definition, the model adopts a multi-domain classification, which includes three main different dimensions related to well-being: Physical/Physiological, Nutritional, Cognitive/Mental/Social. For each domain, the model includes:

a) **Definition of the domain variables** useful for the characterization and monitoring of the person. This aspect is specifically thought to support the development of the NESTORE ontology (Task 2.5) and also for profiling activities and, consequently, for personalization purposes (WP4 and WP5).
b) **The relationships among the domain variables and the variable ranges and/or trends** corresponding to normal ageing status and behaviour in that domain. These aspects are specifically thought for the ontology and to support WP4 in the development of the NESTORE Decision Support System
c) **The measurement scenarios of the NESTORE system variables**. This part provides the functional system requirements from the point of view of the domain experts, in support to WP3 and WP5, for the development of the NESTORE Monitoring System.
d) **The measurement scenarios for pilots**. This part is thought to support the definition of Virtual Coach Validation Plan to be used in the pilots to assess the impact and the effectiveness of the Virtual Coach on the elderly subjects' status and behaviour (Task 2.6).

Such a product forms the background for the development of the coaching guidelines, which represents the main activity of Task 2.4 and the main focus of the Deliverable D2.2 of WP2 (Guidelines for the virtual coach in all the target domains).

Key Words

Healthy ageing models, multi-domain characterization, Physiological status, Physical Activity Behaviour, Nutrition, Cognitive and Mental Status, Social Behaviour, SOC model, HAPA model.

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1 WHO Framework of Healthy Ageing

Nowadays, for the first time in history, most people can expect to live into their 60s and beyond (World economic and social survey, 2007). In low- and middle-income countries, this is largely the result of large reductions in mortality at younger ages, particularly during childhood and childbirth, and from infectious diseases (Beard et al., 2012). In high-income countries, continuing increases in life expectancy are now mainly due to declining mortality among those who are older (Lloyd-Sherlock et al., 2012).

Older people contribute to society in many ways – whether it be within their family, to their local community or to society more broadly. However, the extent of these human and social resources, and the opportunities available to each of us as we age will be heavily dependent on one key characteristic: our health. If people are experiencing these extra years in good health, their ability to do the things they value will have few limits. If these added years are dominated by declines in physical and mental capacities, the implications for older people and for society may be much more negative.

Most of the health problems of older age are the result of chronic diseases. Many of these can be prevented or delayed by engaging in healthy behaviours. Indeed, even in very advanced years, physical activity and good nutrition can have powerful benefits for health and wellbeing.

Two international policy instruments have guided action on ageing since 2002: The Political declaration and Madrid international plan of action on ageing (Aboderin & Beard, 2015) and the World Health Organization’s Active ageing: a policy framework (Aboderin & Kizito, 2010).

1.1 Diversity in Old Age

One major challenge arises from the sheer diversity of health and functional states experienced by older people. These reflect subtle physiological changes that occur over time but are only loosely associated with chronological age. Trajectories of physical capacity across the life course are different between individuals. Thus, while some 70-year-olds may enjoy good physical and mental functioning, others may be frail or require significant support to meet their basic needs. In part, this is because many of the mechanisms of ageing are random, but it is also because these changes are strongly influenced by the environment and behaviours of the individual.

1.2 What is Ageing?

The changes that constitute and influence ageing are complex (World economic and social survey, 2007). At a biological level, ageing is associated with the gradual accumulation of a wide variety of molecular and cellular damage (Beard et al., 2012; Lloyd-Sherlock et al., 2012). Over time, this damage leads to a gradual decrease in physiological reserves, an increased risk of many diseases, and a general decline in the capacity of the individual. Ultimately, it will result in death.

However, these changes are neither linear nor consistent, and they are only loosely associated with age in years (Beard et al., 2012).

Beyond these biological losses, older age frequently involves other significant changes. These include shifts in roles and social positions, and the need to deal with the loss of close relationships. In response, older adults tend to select fewer and more meaningful goals and activities, optimise their existing abilities through practise and the use of new technologies, and compensate for the losses of some abilities by finding other ways to accomplish tasks (Smith, 2010). Goals, motivational priorities and preferences also appear to change (Butler, 1980), with some suggesting that older age may even be the stimulus for a shift from materialistic perspectives to more transcendent ones (Steves et al., 2012; Commission on Social Determinants of Health, 2008). Although some of these changes may be driven by adaptations to loss, others reflect ongoing psychological development in older age that may be associated with “the development of new roles, viewpoints and many interrelated social contexts" (Smith, 2010; Dannefer, 2003). These psychosocial changes may explain why in many settings older age can be a period of heightened or at least well sustained subjective well-being (Lee et al., 2005).

1.3 Ageing, Health and Functioning

With increasing age, numerous underlying physiological changes occur, and the risk of chronic disease rises. By age 60, the major burdens of disability and death arise from age-related losses in hearing, seeing and moving, and non-communicable diseases, including heart disease, stroke, chronic respiratory disorders, cancer and dementia

Yet the presence of these health conditions says nothing about the impact they may have on an older person's life (Kite & Wagner, 2002). High blood pressure in one older person may be easily controlled with medication, while in another it may require multiple treatments which lead to significant side effects. Similarly, older people with an age-related visual impairment may retain full functioning with the aid of glasses, but without them, they may be unable to perform simple tasks, such as reading or preparing food. Moreover, since ageing is also associated with an increased risk of experiencing more than one chronic condition at the same time (known as multi-morbidity), it is simplistic to consider the burden from each of these conditions independently. The multifaceted dynamics of underlying physiological change, disease and multi-morbidity can result in health status in older age that is not captured by traditional disease classifications. These states can be chronic (for example, frailty, which may have a prevalence of around 10% in people older than 65 years) (Aboderin & Kizito, 2010) or acute (for example, delirium, which can result from multiple determinants as diverse as the side-effects of medication or surgery) (McIntyre, 2004)

1.4 Healthy Ageing

The term healthy ageing is widely used in academic and policy circles, yet there is surprisingly little consensus on what this might comprise or how it might be defined or measured (Nussbaum, 2003; Kirkwood, 2008; Baltes et al., 2005; Carstensen, 2006). Furthermore, it is often used to identify a positive disease-free state that distinguishes between healthy and unhealthy individuals. This is problematic in older age because many individuals may have one or more health conditions that are well controlled and have little influence on their ability to function. Therefore, in framing the goal for a public-health strategy on ageing, WHO considers healthy ageing in a more holistic sense, one that is based on life-course and functional perspectives. The UE report on healthy ageing, defines Healthy Ageing as the process of developing and maintaining the functional ability that enables well-being in older age. Functional ability comprises the health-related attributes that enable people to be and to do what they have reason to value. It is made up of the intrinsic capacity of the individual, relevant environmental characteristics and the interactions between the individual and these characteristics. Intrinsic capacity is the composite of all the physical and mental capacities of an individual. The final combination of the individual and their environments, and the interaction between them, is the individual's functional ability.

Well-being is considered in the broadest sense and includes domains such as happiness, satisfaction and fulfilment. Healthy Ageing starts at birth with our genetic inheritance. The expression of these genes can be influenced by experiences in the womb, and by subsequent environmental exposures and behaviours.

At any point in time, an individual may have reserves of functional ability that they are not drawing on. These reserves contribute to an older person's resilience. The Healthy Ageing model conceptualizes resilience as the ability to maintain or improve a level of functional ability in the face of adversity (either through resistance, recovery or adaptation). This ability comprises both components intrinsic to each individual (for example, psychological traits that help individual frame problems in a way that can lead to a positive outcome, or physiological reserves that allow an older person to recover quickly after a fall) and environmental components that can mitigate deficits (for example, strong social networks that can be called on in times of need, or good access to health and social care).

1.5 Key Behaviours that Influence Healthy Ageing

Because most of the disease burden in older age is due to non-communicable diseases, risk factors for these conditions are important targets for health promotion. Strategies to reduce the burden of disability and mortality in older age by enabling healthy behaviours and controlling metabolic risk factors can, therefore, start early in life and should continue across the life course (Michel et al., 2008). The risks associated with these behaviours and metabolic risk factors continue into older ages, although this relationship may attenuate (Haveman-Nies et al., 2002; Hrobonova et al., 2011; Gupta & Mehta, 2000). Strategies to reduce their impact continue to be effective in older age, particularly for reducing hypertension (Musini et al., 2009), improving nutrition (Michel et al., 2008; Estruch et al., 2013) and stopping smoking (Peto et al., 2000), although evidence in advanced old age is limited. Furthermore, there is some evidence that reducing exposure to cardiovascular risk factors can also reduce the risk of at least some types of dementia (Andrieu et al., 2011). Moreover, there is growing evidence that key health-related behaviours, such as engaging in physical activity and maintaining adequate nutrition, may exert powerful influences on intrinsic capacity in older age that are quite separate from their action in reducing the risk of non-communicable diseases (WHO, 2015).

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2 Empirical Findings on Age-Related Trajectories in Key NESTORE Target Domains

Healthy Ageing reflects the ongoing interaction between individuals and the environments they inhabit. This interaction results in trajectories of both intrinsic capacity and functional ability. To illustrate how these might be conceptualized and used, Figure 1 shows three hypothetical trajectories of physical capacity for individuals beginning from the same starting point in midlife. From the original starting point, the goal would be for each individual to experience the same trajectory as individual A. Experience in monitoring trajectories of intrinsic capacity suggests that it is already possible to assess individuals and predict their likely future trajectories given information on behaviours, health characteristics, genes and personal factors.
To foster functional ability is the main goal in the promotion of Healthy Ageing. This can be achieved in two ways: by supporting the building and maintenance of intrinsic capacity, and by enabling those with a decrement in their functional capacity to do the things that are important to them.

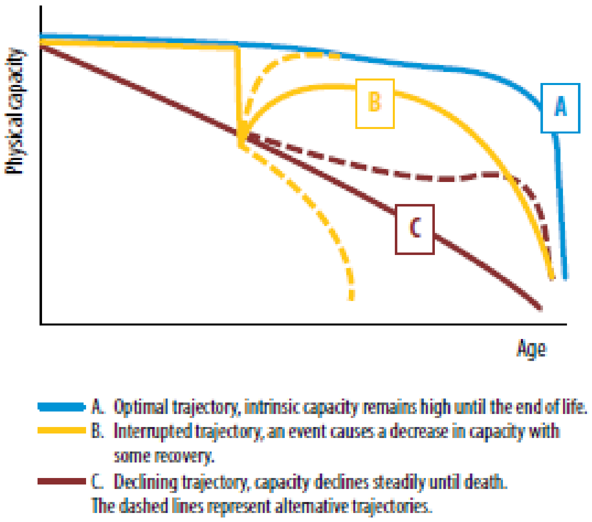

Figure 1. Three hypothetical trajectories of physical capacity for individuals beginning from the same starting point in midlife (from WHO, 2015).

We summarize below some of the underlying changes that tend to occur to some degree in all humans as they age. Although there is marked diversity in how these changes are experienced at an individual level, general trends are seen when the population as a whole is considered (Hoover et al., 2002).

2.1 Physiological Status and Physical Activity Behaviour

With advancing age, structural and functional impairment occurs in most physiological systems, even in the absence of discernible disease. These age-related physiological changes affect a broad range of tissues, organ systems, and functions, which, cumulatively, can affect activities of daily living and the preservation of physical independence in older adults. Moreover, out-of-range values in middle-aged women and men predict future risks of disability, chronic disease and death. Declines in maximal aerobic capacity (VO2max) and skeletal muscle performance with advancing age are two examples of physiological ageing. Changing body composition is another hallmark of the physiological ageing process, which has profound effects on health and physical function among older adults. Specific examples include the gradual accumulation of body fat and its redistribution to central and visceral depots during middle age and the loss of muscle (sarcopenia) during middle and old age, with increased metabolic and cardiovascular disease risks.

Cardiorespiratory Function

The cardiovascular system, composed of the heart and the blood vessels, circulates blood throughout the body. The pulmonary system consists of the lungs and the respiratory tract. The lungs receive blood from the heart and fill the blood with oxygen (from the inhaled air). Then the carbon dioxide is carried off and expelled through the respiratory tract (exhaled). The work that the cardiovascular system and the pulmonary system do together to provide oxygen to the rest of the body is called the cardiopulmonary or cardiorespiratory function and it is usually evaluated by the maximal oxygen consumption (˙VO2max). VO2max is generally considered a primary determinant of endurance performance among young endurance-trained athletes as well as it has been well recognized that it declines with advancing age with the average rate of ∼10% per decade after the age 25 to 30 in healthy but sedentary adults of both sexes (Tanaka et al., 2008). Since VO2max is determined by maximal cardiac output × maximal arteriovenous O2 difference (Fick's equation), a contribution of the central (i.e., cardiac) and peripheral (i.e., oxygen extraction) factors to the age-related decline in VO2max can be hypothesized. Given the well-established fundamental relation between oxygen consumption (i.e., metabolism) and cardiac output (i.e., blood flow), it is reasonable that maximal cardiac output decreases with advancing age as VO2max declines. The age-related reductions in maximal cardiac output are mediated by reductions in both maximal stroke volume and maximal heart rate. Maximal heart rate decline with age appears to be mediated by a slower conduction velocity, a reduced responsiveness of the myocardium to β-adrenergic stimulation. Maximal stroke volume is also reduced with advancing age in older adults (60-65 years of age) to 80% to 90% of that measured in young adults. It is unclear if a reduction in left ventricular filling plays a role in the age-associated decline in maximal stroke volume but other factors of the cardiac preload, including LV end-diastolic pressure, venomotor tone, myocardial compliance, and/or a combination of these factors, have been considered as possible determinants. On the other hand, maximal arterio-venous O2 difference, which reflects the capacity of the skeletal muscle to extract and consume oxygen from the blood for ATP production, clearly declines with advancing age. These findings fit well with the results of histochemical and enzymatic studies demonstrating marked reductions in capillary density per unit fiber area and mitochondrial enzyme activities with age (Lanza et al., 2008). Moreover, the decline in oxygen extraction with age is associated with ∼25% reduction in mitochondrial enzyme activity in the span of 20 years.

Motor function

Structural changes of skeletal muscle: the human body consist of more than 500 skeletal muscles which are controlled by the nervous system. Muscles are made of muscle fibres, each containing small repeating functional units called sarcomeres. Skeletal muscle is essential for optimal physical performance. Physiological changes, such as a loss of motor units, changes in fibre type, muscle fibre atrophy, and reduced neuromuscular activation, could affect the velocity, force and strength of movements, leading to reduced physical performance, potentially leading to functional disability and institutionalisation (Reid KF, 2012)

Skeletal muscle atrophy occurs with advancing age. After a peak in early adulthood, muscle mass tends to decline with increasing age, and this can be associated with declines in strength and musculoskeletal function (Lin et al., 2012). The median decline in muscle mass throughout the lifespan is 0.37 % per year in women and 0.47 % in men. Muscle mass is lost at a rate of 0.64-0.70 % per year in women and 0.80-0.98 in men (Mitchell WK, 2012). Muscle atrophy is substantially accelerated with the physical inactivity. For instance, immobilization in bed can produce 1 Kg loss of muscle mass in 10 days (Cortebein P, 2007). The loss of skeletal muscle mass is accompanied by a major decline in strength between 0.3 % and 4.2 % per day. One way of measuring muscle function is to measure hand grip strength, which is a strong predictor of mortality, independent of any disease-related influences (Stewart et al., 2013; Jagger et al., 2008). The final consequence of muscle atrophy is the degradation of muscle and physical performance and, as such, increases the risk for physical disability at later life.

Muscle atrophy is the result of the decrease in muscle fibre size. During the ageing process, the reduction has been shown to be 10-40 % specifically for the type II fibres, while Type I fibre size seems to be sustained with ageing. This reduction may result in muscle strength and may decrease the ability to perform some activities daily living like rising from a chair.

The primary cause of muscle loss is the disruption in the regulation of skeletal muscle protein turnover, leading to a negative balance between muscle protein synthesis and muscle protein breakdown.

In addition to the muscle atrophy, a reduction in the force per unit area of skeletal muscle is also observed at the single fibre and whole muscle level in the older adults. One of the causes of this intrinsic reduction in the force-generating capacity of elderly muscle is changes in the excitation-contraction coupling processes. This process is important to convert the neural signal for muscle activation into muscle contraction and subsequently into force development.

Other physiological contributors to reduced muscle quality with age include a change in the elastic fibre system and an increase in fat infiltration of skeletal muscle. Intramuscular adipose tissue was observed to increase 30 % in the mid-thigh for women and nearly 50 % for men. The intramuscular adipose tissue has been shown associated with the loss of physical performance and limited mobility in older adults.

Architectural changes also include an increased level of muscle fibrosis as a result of series of events including injury, infiltration of inflammatory cells, tissue degeneration and proliferation of fibroblasts.

Impairment of nervous system activity: Integrity of the nervous system is capital to produce movement. Different areas of the brain, prefrontal or posterior parietal cortex, cerebellum, basal ganglia, spinal interneurons and lower motor neurons, are involved in produce movement. Alterations at any level of the nervous system contribute to declines in skeletal muscle impartment with age, namely diminished motor coordination, muscle strength and power. Age-related morphologic changes are: > 40 % of the volumetric reduction in the premotor cortex neural (Haug, H 1991); reduced cerebellar grey matter (Chen WT, 2015) and also changes in white cerebral matter mas and length of myelinated nerve fibres (Marner L, 2003). Some studies have demonstrated that these changes are associates to performance measures like slower gait speed. In addition to this morphometric changes, some abnormalities have been found in the neurotransmitters including serotoninergic, cholinergic, adrenergic, dopaminergic, GABAergic and glutamergic systems. All of these changes could lead to delayed and uncoordinated motor function (Hayashy T, 1994).

Skeletal system, joints and tendons: Ageing is also associated with significant changes in bones and joints. With age, bone mass, or density, tends to fall, particularly among postmenopausal women. This can progress to a point where the risk of fracture is significantly increased (a condition known as osteoporosis), which has serious implications for disability, reduced quality of life and mortality.

Articular cartilage undergoes significant structural, molecular, cellular and mechanical changes with age, increasing the vulnerability of the tissue to degeneration. As cartilage erodes and fluid around the joint decreases, the joint becomes more rigid and fragile (Olshansky et al., 2012). Although softening of the cartilage commonly occurs with age, this does not universally result in joint pain or the cartilage degeneration responsible for osteoarthritis, although the prevalence of this disorder is strongly associated with age (Chatterji, 2015).

These and other age-related declines ultimately impact on broader musculoskeletal function and movement. This is reflected in a decrease in gait speed – that is, the time someone takes to walk a specified distance. Gait speed is influenced by muscle strength, joint limitations and other factors, such as coordination and proprioception, and has been demonstrated to be one of the most powerful predictors of future outcomes in older age (Polivka, 2001).

Differences between individuals may reflect a mix of genetics and early-life factors and behaviours, such as nutrition or physical activity (Olshansky et al., 2012).

Sleep quality

People experience changes both in mental and physical aspect, especially as they age. One of these changes is related to the characteristics of their sleep habits: changes in pattern, sleep duration, and quality (Goktas et al., 2006). Older people exhibit difficulty of falling asleep, sleep fragmentation and maintaining sleep. According to (Zeitlhofer et al., 2000), sleep disturbances increases of 50% for people over 65 years old. Many factors can influence these phenomena in older adults: heart failure, allergies, depression, Alzheimer's, social isolation, loneliness, and drug use. An accurate sleep monitoring is fundamental in order to detect early signs of sleep deprivation and insomnia, evaluating their sleeping habits, and consequentially implementing mechanisms and systems for preventing and overcoming these problems (Foley et al., 2004). As a conclusion, better quality of life in elderly people may be achieved by increasing sleep quality (Urponen et al., 1988).

2.2 Nutrition

Ageing is accompanied by physiological changes that can negatively impact nutritional status. Sensory impairments, such as a decreased sense of taste or smell, or both, may result in reduced appetite. Poor oral health and dental problems can lead to difficulty chewing, inflammation of the gums and a monotonous diet that is poor in quality, all of which increase the risk of malnutrition (Kshetrimayum, 2013). Gastric acid secretion may be impaired, leading to reduced absorption of iron and vitamin B12. The progressive loss of vision and hearing, as well as osteoarthritis, may limit mobility and affect elderly people's ability to shop for food and prepare meals. Along with these physiological changes, ageing may also be associated with profound psychosocial and environmental changes, such as isolation, loneliness, depression and inadequate finances, which may also have significant impacts on a diet. Insufficient intake can be the consequence of reduced muscle and bone mass and increases the risk of frailty. Malnutrition has also been associated with the diminished cognitive function, a diminished ability to care for oneself, and a higher risk of becoming care-dependent. A thorough nutritional assessment of older people requires performing anthropometric measurements, clinical biochemistry and dietary assessment. One study from the United Kingdom using these comprehensive approaches showed that the risk of protein-energy malnutrition was between 11% and 19%, and found that it was accompanied by deficiencies of vitamins C and D, and low levels of carotenoids (Elia & Stratton, 2005). In a study from the Philippines conducted among older people living in the community, energy intake was approximately 65% of the amount required based on total energy expenditure (Risonar et al., 2009). A study from rural Malaysia identified problems related to both undernutrition and overnutrition, as well as low levels of thiamin, riboflavin and calcium (Shahar et al., 2007). Furthermore, higher levels of malnutrition (15–60%) have been documented in many countries in older patients who are hospitalized, live in nursing homes or are in homecare programmes (Morley & Silver, 1995; Pérez Llamas et al., 2011; Rodríguez et al., 2005; Shabayek & Saleh, 2000). A questionnaire-based approach has been used in several studies to provide a simple assessment of older patients in outpatient clinics, hospitals and nursing homes (Vellas et al., 1999). A study among older people living in rural areas of South India used this approach and found that more than 60% of the participants had low protein–energy intakes (Vellas et al., 1999). A study from the Islamic Republic of Iran revealed a 12% prevalence of malnutrition among older people, with higher prevalence in lower socioeconomic groups (Aliabadi et al., 2008).

2.2.1 Ageing related changes

Metabolic and physiological changes occurred during ageing are characterized by multifactorial aspects, where the hormonal changes, the neurological decline and the inflammatory pathway activation –among others – explains the alterations of this biological process. The role of nutrition in these changes is vital to make opportune and effective interventions in order to achieve a healthy ageing. Moreover, the ageing process involves changes in social and psychological conditions of a person that can also influence nutritional intake and needs. Due to its complexity, and for practical purposes, only essential aspects of those changes will be addressed in this report:

Inflammation

Ageing is associated with the development of a systemic low grade chronic inflammatory state known as "inflammaging" (Calçada et al., 2014) which is characterized by the increase in the concentration of a number of pro-inflammatory molecules in the circulation (Calder et al., 2017). This pro-inflammatory state can lead to

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functional decline across multiple physiological systems even in the absence of pathologies. Evidence suggests that obesity and sedentary behaviour can increase significantly this condition (Francesch, 2017).

Metabolism dysregulation

Glucose metabolism: Glucose tolerance progressively declines with age. Multiple factors are involved in this alteration: increased adiposity decreased physical activity and insulin secretory defects associated to a decrease in beta-cell mass and function (Szoke et al., 2008; De Tata, 2014). Medications and coexisting illness can contribute also to the alteration of glucose homeostasis.

Lipid metabolism: Age-related physiological deterioration is associated with a reduction of the organism´s capacity to metabolize lipids. Thus, there is a decrease in fat oxidation (Toth & Tchernof, 2000), and a dysregulation of lipoprotein metabolism (mainly by a decreased number of hepatic LDL-cholesterol receptors and a reduced lipoprotein lipase activity) that leads to increased serum lipids. This effect is incremented by the changes in body composition in terms of higher levels of adiposity (Chen et al., 2017).

Alterations in the cardiovascular system

Normal ageing is associated with a decrease in cardiac functions, structure and molecular mechanisms. In addition, there is a progressive alteration of the arterial wall media (hypertrophy, thickness, calcium deposits) the same as the vascular endothelium, which is characterized by being increasingly dysfunctional, resulting, therefore, in an impaired endothelium-dependent vasodilation and a pro-coagulant state (Strait J,2012; Fleg JL & Strait J, 2012; Seals DR, 2012).

Decrease in Gastrointestinal function

As a consequence of ageing, gastric, pancreatic, salivary and intestinal secretion, as well as enzymatic activity, is diminished (e.g.: Lactase enzyme). Thus, the capacity of digestion and absorption is affected by different mechanisms. The impaired secretion of gastric acid can compromise protein digestion as well as vitamin B12 and iron (Fe2+) absorption, thereby considerably increasing the risk of developing anaemia. In addition, there is also a decrease in calcium, zinc, magnesium and vitamin D absorption in the small intestine (Pray et al. 2010). Moreover, as renal function decreases with age, the capacity to synthetize 1,25 (OH)2D (the active form of Vitamin D) decreases significantly (Gallagher, 2014). This condition is accentuated by the decline of the cutaneous capacity to synthetize the vitamin, aggravated even more by the commonly decrease in sunlight exposure in this population (Holick et al., 2011). Due to all these factors, there is a high prevalence of vitamin D deficit in the elderly (Veldurthy et al., 2016). Another factor involved in the decline of the gastrointestinal function is the decrease in the intestinal motility, which is often associated with constipation (De Giorgio et al., 2015).

Sensory, oral, neuroendocrine and psychosocial changes

Changes in taste and in the olfactory sense occurred during elderly are associated with a reduction of the appetite which can affect considerably the eating habits and, therefore, the nutritional status of this population. This reduction of the appetite is also influenced by psychosocial factors, where the accessibility to the food and the emotions have an important role (Landi et al., 2016). The loss of teeth and complications on the denture also contributes to altering their dietary patterns, which requires in many cases the adequacy of the consistency of their meals in order to avoid malnutrition.

Furthermore, older adults are highly vulnerable to dehydration because of their dysfunction in regulating their fluid balance where the impaired central nervous system to control thirst, the decreased renal function and diuretic medications (associated to hypertension), have a key role (Miller, 2009).

Changes in body composition

Normal ageing is related to body fat mass increase as well as a decrease of lean mass and bone mass density. In this sense, the reduction of muscle mass generates a decrease of the basal metabolic rate (BMR) which explains the decrease of the energy requirements of the older population (Pray et al., 2010). It is important to underline that one factor involved in the decrease of muscle mass is the lower responsiveness to the anabolic stimulus of dietary amino acids.

Nutritional status and drug therapy

Elderly individuals are often poly-medicated. This is relevant to take into account since depending on the treatment and the medications consumed, there can be not only an interaction with nutrients absorption and metabolism but can also generate a negative effect on the nutritional status of the person because of the potential adverse effects (nausea, diarrhoea, etc.) associated to the medication (Ortolani et al., 2013).

2.2.2 Ageing as a risk factor for disease

Malnutrition by the excess (over nutrition) or by a deficiency (undernutrition) is one of the most relevant conditions that can negatively influence the health of the elderly population (Leslie & Hankey, 2015). Thus, not only all the stated metabolic and physiological alterations but also the presence of malnutrition, raise the risk of developing the following pathologies:

Type 2 Diabetes: insulin resistance and Diabetes Mellitus type II are important health conditions for the ageing population. It is estimated that one-quarter of people over the age of 65 years have diabetes, and one-half of older adults have prediabetes (American Diabetes Association, 2018).

Hypertension: arterial hypertension is highly prevalent among the elderly population. According to the European Society of Hypertension, the prevalence among this population is 50% approximately (European Society of Hypertension, 2013).

Cardiovascular disease: cardiovascular disease is considered the leading cause of death in geriatric population (Jackson & Wenger, 2011).

Alterations in skeletal and muscle system: such as osteoporosis and sarcopenia –respectively-. These pathologies have a major impact in the quality of life and health because of their highly risk to develop injuries, disabilities, premature death, and other comorbidities like obesity (Tieland et al., 2017).

2.3 Cognitive and Mental Status and Social Behaviour

Cognitive decline is common in old age. There are 4.6 million new cases of dementia every year in the world. “A new case every seven seconds”. It is estimated that by 2050 there will be 100 million people with dementia in the world (Prince & Jackson, 2009).

In Spain, a considerable ageing of the population is foreseen. It supposes an increase of neurological diseases, including Alzheimer Disease (AD). It is estimated that by 2049 there will be 18 million of people over 60 years old with neurological diseases, 570.000 people suffering AD (Instituto Nacional de Estadística, 2012). On the other hand, large numbers of older adults in the earlier phases of later life are not demented and these cognitively healthy adults need as much attention as those experiencing clinically relevant levels of cognitive decline (Wagster et al., 2012)

2.3.1 Cognitive ability

Cognition is among the most widely studied domains in the ageing literature. Despite the possible stereotype and assumption of prevailing losses, cognitive functioning does not show uniform decline as people age. One prominent theoretical model of cognitive ageing and intellectual development across adulthood is the Two-Component Theory of Cognitive Ageing proposed by Cattell (1963) in the early years of psychological ageing research. According to this theory, two components of intelligence can be distinguished: on the one hand, the model proposes the more biologically driven so-called fluid intelligence that includes the ability of reasoning and novel problem-solving. On the other hand, the model proposes crystallized abilities as those intellectual domains that are more knowledge- and experience-based, well-practiced and accumulated across the lifespan. Much in line with lifespan theoretical notion of multidirectional development (Baltes et al.., 1999), the two components show distinct trajectories of age-related change: whereas fluid abilities such as processing speed and working memory tend to decline with increasing age, crystallized abilities such as vocabulary, knowledge, and autobiographical memory tend to increase or be maintained (Hedden & Gabrieli, 2004; Salthouse, 2010). Overall, in addition to the broad distinction between fluid and crystallized cognitive abilities, there is quite some complexity and heterogeneity in trajectories of stability and change across cognitive domains (Hartshorne & Germine, 2015). In the following, we will briefly summarize the empirical findings regarding the different cognitive ability domains and ageing (cf. Oschwald et al., submitted). Due to the limited space available, we will keep this summary short and highlight select domains that we chose to assess in NESTORE to obtain cognitive status (i.e., trait-like) information of the users.

Memory

Several different subfacets of memory can be distinguished (Naveh-Benjamin & Old, 2008). Explicit memory involves episodic and semantic memory. Episodic memory represents the recollection of events from one's past and is typically tested by requiring participants to learn a set of stimuli such as words and to then recall them immediately or after a delay or recognize them from a list of test and novel words. This memory domain shows significant age-related declines across adulthood and old age, particularly regarding the free recall and a bit less regarding recognition, with longitudinal evidence suggesting the decline onset to be about age 60 (Rönnlund et al., 2005; Schaie, 2005). Semantic memory reflects memory for factual knowledge (e.g., vocabulary) and longitudinal evidence suggests this ability to increase or remain stable at least until the mid-fifties (Rönnlund et al., 2005) and a less steep decline in old age than for episodic memory. Implicit memory, in contrast to explicit memory, captures the unconscious effect previously learned information has on current performance. Current cross-sectional and longitudinal evidence suggests there are little age-related losses in this ability (Fleischman et al., 2004; Light et al., 2000).

Executive functioning (EF)

These are higher-order abilities that are required for complex tasks such as planning, organizing and the goal-direction of behaviour. Several basic abilities are summed within the EF domain, including inhibition of dominant/prepotent responses, the shifting between different mental representations and the updating of information and representations stored in working memory. Overall, age-related changes in the sense of decline are found for tasks that require more as opposed to less executive control, but empirical evidence on the amount and range of age-related deficits in inhibitory and shifting abilities is rather inconsistent to date (e.g., Verhaeghen, 2011; Wasylyshyn et al., 2011).

Attention

This cognitive ability is about explicitly focusing on a given set of stimuli in the environment. Several attentional subdomains are differentiated (sustained attention = vigilance over longer time spans, selective attention = focusing on some stimuli while ignoring others, divided attention = focusing on two stimuli simultaneously; Drag & Bieliauskas, 2010). Of these three subdomains, only selective and divided attention seem to decline with age, which fits well with findings of age-related deficits in related domains such as the inhibition of task-irrelevant responses and the shifting ability included in executive functioning (e.g., Berardi et al., 2001; Drag & Bieliauskas, 2010; Verhaeghen et al., 2003).

Working memory

This memory domain describes the ability to simultaneously store, process and/or update information (e.g., Baddeley, 1998; Oberauer, 2009), and shows close linkages with fluid intelligence, despite its independent explanatory value (Salthouse & Pink, 2008). Longitudinal evidence spanning different phases of the adult lifespan indicate decreases in working memory performance from young adulthood onwards (Brockmole & Logie, 2013; Hultsch et al., 1992).

Processing speed

This cognitive ability encompasses the speed with which information can be processed and is a key component of higher-order cognitive functioning that underlies and drive age-related changes in various cognitive domains (Robitaille et al., 2013; Salthouse, 1996). Despite cross-sectional evidence that suggests quite an early onset of processing speed declines, longitudinal data support the notion that performance decrements do not begin until the age of about 60 years (Salthouse, 2011; Schaie, 2005).

In sum, losses in cognitive performance are mainly evident for some domains (episodic memory, executive functioning, selective and divided attention, working memory and processing speed) whereas maintenance of functioning has been shown for others (implicit and semantic memory, sustained attention). Cross-sectional data have shown age differences that suggest the onset of decline to be in young and middle age already, but longitudinal data provides counterevidence and a much later onset of performance losses.

2.3.2 Mental status

Mental health is an integral and essential component of health. According to WHO, mental health includes "subjective well-being, perceived self-efficacy, autonomy, competence, inter-generational dependence, and self-actualization of one's intellectual and emotional potential, among others (WHO, 2014). It is fundamental to the wellbeing of individuals, their families, the community, and society as a whole. Although the majority of older people enjoy good mental health, a considerable proportion of older people experience one or more mental health problems. The most prevalent of these are depression and anxiety. However, advancing age is not a risk factor in itself (Batchelor et al., 2016).

In addition, some older people suffer from social isolation and feel lonely, which can affect their mental health. There is strong evidence of a direct link between social connectedness and mental health outcomes (Cohen et al., 1997). Mental health problems in late life are treatable and effective treatments are available. Collaborative approaches, involving older adults in planning, implementation and evaluation of programs, using evidence-based approaches, addressing local needs, using existing resources and utilising volunteers, are important when developing programs aimed at improving mental health.

The National Institute for Health and Care Excellence -NICE- quality standard (NICE, 2013) covers the mental wellbeing of older people (65 years and over) receiving care in all care home settings, including residential and nursing accommodation, day care and respite care. This quality standard uses a broad definition of mental wellbeing and, includes elements that are key to optimum psychological functioning and independence, such as life satisfaction, optimism, self-esteem, feeling in control, having a purpose in life, and a sense of belonging and support. In NESTORE, we consider three broad constructs as indicators of mental (i.e., psychological) health and well-being status: Self and personality, subjective well-being, as well as social relations and social integration.

Self and personality

Several facets of self and personality are well suited to describe and understand differences between individuals' take on life, behaviour patterns and preferences. In the NESTORE project, we will focus on three key self and personality domains: The Big Five personality traits, sense of control/control beliefs, and self-efficacy.

Big Five personality traits: Personality structure is commonly defined to include five characteristic dimensions along which people differ: Extraversion, Neuroticism (vs. Emotional Stability), Openness to experience, Agreeableness, and Conscientiousness (Costa & McCrae, 1985). This taxonomy can be used to describe how individuals differ from one another and to describe the dispositional characteristics of individuals that conceptually predispose them to behave and feel in specific ways.

Despite the long-standing belief that personality traits develop until young adulthood and then remain stable (i.e., the core definition of a trait or disposition is stability over time), there is evidence for change at different levels across the Big Five personality trait factors. In the context of assessing stability and change in personality traits, different types of stability and change have been considered and cross-sectional and longitudinal research on personality trait development indicate a differential picture of stability and change depending on the type considered.

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Mean-level stability and change refers to the type of change one typically have in mind when considering whether psychological and other characteristics change or remain stable into later life. For this type of average longitudinal change trajectories, meta-analytic evidence from Roberts and colleagues (Roberts et al., 2006) suggest a multidirectional pattern of stability and change across the Big Five traits with most mean-level changes occurring between the ages 20-40, but with evidence for mean level changes also during and into old age:

- Extraversion (social dominance facet): increase during adolescence
- Conscientiousness & Emotional Stability (i.e., the opposite of Neuroticism): increase during midlife
- Agreeableness: increase during adulthood and particularly old age
- Extraversion (social vitality facet) & Openness to experience: increase in young adulthood, decrease in old age.
- The pattern for old and very old age are less clear and less well studied. Existing evidence indicates either no average changes or some increase in agreeableness and decrease in extraversion.

Structural stability refers to the degree of interrelation among the personality traits in a given population sample and the extent to which this covariation remains similar over time. Whereas both cross-sectional and longitudinal studies point to a high degree of structural stability in personality traits from young to later adulthood, findings are scarce for old and very old age. Similar to the structure of different cognitive abilities, there is some indication that the personality structure becomes less differentiated in old age (cf. Allemand et al., 2017).

Differential or rank-order stability and change describe the degree to which the ordering of individuals on a variable of interest remains the same over time (are the more extroverted persons at one point in time still the more extroverted persons compared to others in the sample at a second point in time?). This type of stability can be tested using test-retest correlations. Meta-analytic evidence from longitudinal studies (Roberts & DelVecchio, 2000) shows that differential stability in all Big Five traits increases from childhood to middle age, after which a plateau is reached until about age 70. During old and very old age, differential stability decreases again to some extent.

Control beliefs: The sense of control or control beliefs reflect the degree to which people perceive they are capable of influencing according to their wishes and goals the events in their life. The sense of control has been studied both as a general belief of having a sense of mastery versus constraints or internal and external control over life in general as well as over specific life domains such as health, finances, transport and others (Lachman, 1986; Lachman, 1991; Rotter, 1966). Large-scale cross-sectional studies indicate significant but small age differences in the sense that older adults report greater constraints and less overall sense of mastery, but greater control over life in general and several specific life-domains (marriage, work and finances) than young and middle-aged adults (Lachman & Weaver, 1998). Longitudinal evidence suggests that slight declines in personal mastery can be observed in young adulthood and in later adulthood and older age, but mean-level stability prevails during much of midlife (Lachman et al., 2009). For the subdomain of perceived constraints, the pattern almost perfectly mirrored those for mastery in the opposite direction (increasing constraints during young adulthood and older adulthood and old age), but in addition, a slight decrease in constraints was reported in later midlife (Lachman et al., 2009).

General self-efficacy: This construct describes the degree to which individuals perceive their ability to achieve desired outcomes through their own actions. This aspect of the self tends to show little to no correlation with age, corroborating the conceptual idea that general self-efficacy beliefs should be age-invariant (e.g., Scholz et al., 2002). It should be noted, however, that longitudinal research in this area is scarce or even missing and that domain-specific self-efficacy beliefs, similar to the sense of control domain reported above, can show differential age-related trajectories and patterns (cf. Lachman & Weaver, 1998; McAvay et al., 1996).

Subjective well-being

In contrast to the many sub-domains in the cognitive domain that show negative age-differences and age-related decreases, subjective well-being is a domain that remains quite intact over the adult lifespan (e.g., Charles & Carstensen, 2010). Typically, three facets of well-being are distinguished: Life satisfaction, positive affect, and

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negative affect (Diener, 1984). Life satisfaction refers to the evaluation of how satisfied individuals are with different life domains (e.g., health, family, living environment, finances) and with life in general. Due to the explicitly evaluative nature of life satisfaction assessments, this component has been termed the cognitive component of well-being. Complementary to this, the emotional component of well-being is captured by the negative and positive emotions experienced by individuals, typically rated for life in general or during the past year. With regard emotional well-being, research has mainly focused on the frequency and intensity of experiencing broader positive and negative affect dimensions in different age groups and over as well as emotion regulation, emotion-cognition linkages and emotional complexity (for review, e.g., Lawton, 2001; Scheibe & Carstensen, 2010).

The most striking finding with regard to ageing in many domains is that in contrast to many other domains such as cognition, sensory functioning, physical health, older adults often fare better or just as well compared with younger and middle-aged adults when it comes to their well-being, especially from young adulthood into the sixth decade of life (Charles & Carstensen, 2010; Lachman et al., 2008; Röcke & Lachman, 2008). This pattern of stability and the little decline has also been termed the “well-being paradox” (Staudinger, 2000), referring to the apparent stability in feeling well and satisfied despite objective losses in other domains of psychological and physical functioning. In old age, the pattern is less consistent across studies, but both cross-sectional and longitudinal work indicates that the changes reported in the later decades of life tend to be small in size, often linked to functional health (Kunzmann et al., 2000) and in general, even the oldest-old report quite high levels of subjective well-being (Jopp & Rott, 2006). Only in the last few years preceding death do researchers observe a so-called terminal decline pattern in subjective well-being (e.g., Gerstorf et al., 2008).

There is a wide range of theoretical models to describe the affective space and the structure of emotions (Cowen & Keltner, 2017). Whereas in the literature on emotional ageing most work has adopted a dimensional affect approach, investigating the frequency and intensity of both high and low arousal positive and negative affect, recent work has also taken a closer look at specific discrete emotions such as anger and sadness and examined age-related trajectories in these. Findings from this work further corroborate the multidimensionality of age-related development, as even within the negative emotional domain not all facets/emotions show the same direction of change. Sadness vs. anger, often subsumed under a broad negative emotion or negative affect “umbrella”, show differential age-related trajectories (anger: older < young, sadness: older > or = young). Different facets of empathy show differential age differences which get lost when considering a single positive affect domain (e.g., Kunzmann, Kappes, & Wrosch, 2014; Kunzmann & Wrosch, 2017; Wieck, & Kunzmann, 2015; see also Sykora et al., 2013).

In addition to studying whether mean levels of emotional well-being undergo changes or how these play out in daily life (see Section 2e), research on emotional ageing has also focused on whether different age groups differ in (i) the processing and remembering of emotional stimuli (in short: yes, there are age differences), (ii) the regulation of emotions (in short: mixed evidence), and (iii) emotional reactivity in terms of subjective reports and physiological responses (in short: mixed evidence). As this is beyond the scope of the NESTORE project, we will not outline this line of emotional ageing research here any further (for details, see Charles & Carstensen, 2010; Scheibe & Carstensen, 2010).

Social relations (incl. social integration & social support)

Social participation, that is having a social network of close others available to draw upon in good and bad times represents a strong correlator and predictor of physical and mental health as well as survival (Dahan-Oliel, Gélinas, & Mazer, 2008; House, Landis, & Umberson, 1988; Seeman, 1996). Prominent theories of the development of social relations and social integration as well as social motives have made partially competing hypotheses about how social participation and social networks should be maintained or change and the consequences for successful ageing and well-being. Whereas Activity Theory proposed that older adults would need to remain as actively involved as in younger years to maintain their well-being, Disengagement theory (Cumming & Henry, 1961) proposed that older adults would find happiness and contentment by actively withdrawing from many social roles and make room for younger generations. Neither of these has found empirical support.

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The two approaches that have guided the research on social trajectories across the lifespan and adulthood are the Social Convoy Model proposed by Antonucci and colleagues (Antonucci, Ajrouch, & Birditt, 2013) and the Socio-Emotional Selectivity Theory (SST, Carstensen et al., 1999). Both of these propose that older adults can maintain a social network consisting of trusted and emotionally close social network partners with whom they exchange different types of social support across the lifespan. In addition, SST proposes that social motives shift from a stronger orientation towards information-related goals in social relations to a relatively stronger focus on emotion regulation, with older adults thus actively shaping their social networks to match these shifting goals (Carstensen et al., 1999). This notion has been empirically supported.

The social networks of older adults tend to be overall smaller than during midlife and young adulthood, but the number of emotionally close other persons remains fairly stable until old age on average (Fung et al., 2001, 2008) and the availability of social support is also maintained (Ertel et al., 2009). This decrease in network size is not based on age-related losses but rather the result of an active pruning process during which emotionally less relevant social partners are voluntarily removed from one’s network (Fung et al., 2001; Lang & Carstensen, 1994) and social network changes are also linked with normative life events and transitions such as transition into parenthood and into retirement (Ertel et al., 2009; Wrzus et al., 2013). Further, findings from several large-scale longitudinal survey studies indicate that widowhood is related to increases in informal social participation (Utz et al., 2002) and despite lacking a confidant, widows receive social support from other groups such as relatives and friends to a larger extent than married individuals (Ha, 2008), but there is also evidence that widowhood can be a risk factor for reductions in social participation and integration (cf. Ertel et al., 2009).

Consistent with the notion that emotionally close others remain available in the networks from young up to old age, certain social relationship types show greater changes than others. For instance, the family network shows stability from adolescence/young adulthood to old age, whereas the friendship and personal network show decreases into old age and networks with co-workers or neighbours play an important role only in defined periods during the life span (Wrzus et al., 2013). Social and emotional functioning shows reliable interplay. Older adults tend to report greater satisfaction with their networks than younger adults (Carstensen, 1992) and they report fewer negative social interactions than their younger counterparts (Birditt & Fingerman, 2003).

2.3.3 Mental states and social behaviour

Much research on mental states (as opposed to status such as trait variables) in older adults has focused on emotional processes and stress, so we will summarize this briefly below before reviewing research on social behaviour in later life.

Subjective (emotional) well-being in daily life

Whereas early work on well-being was mainly based on trait-like retrospective survey information about life satisfaction, positive affect and negative affect, much recent work has focused on micro-longitudinal ambulatory assessment studies in which participants’ emotional states and their fluctuations within and across days are being tracked using paper or electronic diaries (e.g., Riediger & Rauers, 2014). Findings from this line of research support the evidence that well-being is well-maintained in later life, with higher levels of day-to-day positive affect and lower levels of daily negative affect, more stable and less fluctuating affective experiences in older compared to younger adults (Röcke et al., 2009) and mixed findings with regard to the affective responses to daily stressors in older compared to younger adults (for review, see Riediger & Rauers, 2014).

Whereas the ageing and emotion literature has been mainly concerned with the subjective well-being and thus has employed self-report measures to ask individuals about their feeling states, tools have been developed to extract emotion information from a text-based material, mainly using data from young adults. An example of such tools is, for instance, the PANAS-t scale which focuses on positive affect (PA) and negative affect (NA), and estimates these variables indirectly, that is from the text in Twitter tweets, rather than a direct survey-style tool. In recent years, there has been a significant effort and uptake in the fields of Natural Language Processing (NLP) and Information Retrieval (IR) to develop sentiment analysis algorithms and techniques to help in automatically identify the valence (i.e. positive / negative polarity) within social media based user-generated content (UGC), see Zimmer and Proferes (Zimmer & Proferes, 2014) or Ravi and Ravi (Ravi & Ravi, 2015) for a full review of such approaches. There has been a strong focus within these research communities on micro-blog based approaches – e.g. Zimmer and Proferes (Zimmer & Proferes, 2014) review well over 300 recent studies on micro-blog sentiment mining[1] – partly motivated by the easy access to, and the interesting nature of such in-situ social media data (ibid.), and partly by the many exciting applications that these techniques hold when applied to social media datasets. A number of recent studies encouraged broad research to explore such computational techniques in helping to understand and analyse emotions and well-being at individual, community and population level (e.g., Harlow & Oswald, 2016; Gruebner et al., 2017; Sinnenberg et al., 2017). It is hoped that some of these approaches can be extended and applied in the context of NESTORE, and complement self-report approaches in assessing the emotional state and psychological well-being of NESTORE users.

Social Interactions and social behaviour in daily life

With the rise of experience sampling and ambulatory assessment methods and designs in psychological research, including lifespan developmental and ageing research (e.g., Brose & Ebner-Priemer, 2015; Hoppmann & Riediger, 2009; Trull & Ebner-Priemer, 2013), there have been novel ways of examining social integration more in terms of a behaviour and fluctuating experience and not only as a stable person characteristic and over long-term time spans using survey questionnaires that tap the general/typical or retrospective status of the social network and social support exchanges as well as leisure activities including those that involve social interactions (e.g., Jopp & Herzog, 2011). Much of this research is conducted in young adult samples (e.g., Gable, Gosnell, & Prok, 2012).

There is scarcity as of yet, however, in systematically investigating how social participation and interaction plays out in the daily lives of healthy older adults and thus how the social contexts that shape development throughout adulthood and ageing actually are characterized (Hoppmann & Riediger, 2009). Some studies have investigated age differences in interpersonal stressor occurrence and reactions to these tensions, how being alone in daily life makes people of different ages feel, and some studies on social support in daily life.

For example, older adults have been shown to report fewer interpersonal stressors than middle-aged and younger adults and also that they felt less stressed in reaction to the tensions that occurred than young adults (Birditt et al., 2005; Charles et al., 2009). Older adults, compared to younger age groups, have also been found to report more interpersonal tensions with spouses than with children, unlike younger age-groups which may be due to the fact that older adults' children have likely moved out from home and even further away, so there is less room for tension. In line with the expectation that lifelong experience in dealing with emotional situations, older adults have also been found to show more passive constructive (e.g., do noting) behaviour in response to tensions than middle-aged and younger adults, and less arguing than the younger adults (Birditt et al., 2005).

Given that much of daily time is spent alone, it is also of interest to understand the emotional correlates of this solitary time in different age groups, investigating as well whether being alone is inevitably linked to negative emotions and loneliness. A recent study suggests that this may not be the case, at least when comparing individuals from 20 to 81-year-old in a healthy sample (Pauly et al., 2017). This study suggests that whereas spending much of their time alone can have negative implications in terms of health and well-being, momentary solitude was related to both positive and negative well-being, and particularly for older compared to younger groups, momentary solitude was related to partially better well-being and a weaker stress response. All of these findings from day-to-day social behaviour are in line with theoretical propositions from the socio-emotional selectivity theory (Carstensen et al., 1999) that older adults actively shape their social network - and daily life contexts in general - in a way that allows them to effectively regulate their emotions and that emotion regulation may indeed profit from lifelong experience.

There are only very few studies that investigate other aspects of social participation such as social support in daily life and on the within-person level (rather than only the between-person level) in different age groups including older adults (e.g., Lang et al., 1997; Kim & Nesselroade, 2003; Wolff et al., 2014). This is unfortunate

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[1] Opinion Mining is often considered to be synonymous to sentiment analysis, although opinion mining or social media mining, tends to include broader non-affective tasks. See for instance, Pang and Lee (2008) who provide a useful overview of the various problem formulations in opinion mining (e.g. sentiment polarity and degrees of positivity, detecting viewpoints and perspectives, non-factual information in text such as hate-speech, etc.), hence we won't delve into defining these tasks in depth here as (ibid., pp. 24-32) have done a good job of this.

given that trait- and state-level variables and between- and within-person findings can differ and also have been shown to differ in the area of social support (e.g., Wolff et al., 2014). In one study involving daily diary data on received and needed support, well-being and health from young and older adults, findings indicated that in both age groups, days with more needed support were those days on which more negative affect and more health complaints were reported. Unexpectedly, the balance between support need and receipt was quadratically related to negative affect and health complaints only in young adults indicating that for them, a match between need and receipt was better and both too much and too little received support was associated with lower well-being and health. For the older group, the relation was linear, suggesting that well-being and health were higher the more support they received (Wolff et al., 2013).

In the MacArthur Studies of Healthy Ageing, week-to-week reports of social self-efficacy and perceived relationship availability in a sample of 56 to 88-year-olds were available and their association indicated that individuals who over time perceived their social partners to be more available also reported a greater average social self-efficacy across time. In addition, these individuals with a greater perception of others being available also were much more stable from week to week in the degree to which they perceived having control over and being able to actively shape their social relations (social self-efficacy; Lang et al., 1997)

Another line of research on social relations in daily life using ambulatory assessment methods focuses on dyads, often spouses and how spousal interrelations can shape the development at the individual and at the couple-level across the lifespan (Hoppmann & Gerstorf, 2009). Many of the dyadic studies investigate emotion regulatory and caregiving aspects as well as social support, but few of these have an age-differential focus or even include older adults in their sample (e.g., Berli et al., in press; Horn & Maercker, 2016; Lüscher et al., 2017). One exception is a study on older couples which showed that those romantic dyads reporting greater marital adjustment had more frequent interactions, less conflict in these interactions and found them more agreeable compared to those couples with low marital adjustment (Janicki et al., 2006).

2.3.4 Sensory Functions

Prevalence and severity of sensory limitations increase with age and we briefly summarize them as they are closely linked with cognitive and social factors (e.g., Baltes & Lindenberger, 1997). In Europe, about 18% of persons between 45 and 54 years have a hearing disability (around 3% severe), and rise sharply after 65 until reach 55% in the group of 75 years and over (18% severe). Vision disabilities follow a similar pattern in the aforementioned population affecting around 21% of persons in the younger group (over 1% severe) and up to 39% in the older one (9% severe) (Eurostat, 2017), nevertheless, eye problems may be present in the absence of symptoms.

Perception is a complex process involving several steps in which a physical stimulus is transformed into an electric signal and then is interpreted by the brain. The effects of ageing vary among individuals according to genetic and environmental factors and the presence of concomitant diseases. Furthermore, the onset and the rate of decline is different for each structure and function involved. Ageing is frequently associated with declines in both vision and hearing (https://www.ucalgary.ca/pip369/mod9/ageing), although there is marked diversity in how this is experienced at an individual level.

Age-related hearing loss (known as presbycusis) is bilateral and most marked at higher frequencies. It results from cochlear ageing, environmental exposures, such as noise; genetic predisposition; and increased vulnerability to physiological stressors and modifiable lifestyle behaviours (Arxer & Murphy, 2012). Worldwide, more than 180 million people older than 65 years have hearing loss that interferes with understanding normal conversational speech (Baltes et al., 2005; Gasper, 1997; Kirkwood, 2008; Nussbaum, 2002; Nussbaum, 2003).

In the auditory system (Lee, 2013; Roth, 2015; Yang et al., 2015) the tympanic membrane loss flexibility and the bones of the middle ear suffers a process of calcification, reducing the transmission of the sound vibration to the inner ear. In the cochlea, the membranes transmitting vibration loss flexibility and has less amplitude of movement and they are a loss of both inner and outer hair cells, where the frequency signals are transformed into electric messages. The auditory nerve is affected by a reduction in the number of neurons and a decrease in the strength of the signal transmitted to the brain. In overall, there is a reduction in the sensitivity to higher frequencies and a loss of temporal resolution, which may lead to difficulties in understanding speech.

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Age is also associated with complex functional changes in the eye that result in presbyopia, a decrease in focusing ability that leads to the blurring of near vision, which often becomes apparent in midlife (Carstensen, 2006). In the eye (Grossniklaus et al., 2013; Lin, Tsubota, & Apte, 2016; Owsley, 2011, 2016; Salvi, 2006), the cornea changes its curvature (which leads to astigmatism when the curvature is different in the horizontal and vertical axis) and thickens, and its surface maybe affected by the decrease of tear production (dry eye). Iris diameter shrinks, so there is less light available. Another common change associated with ageing is the degeneration of the crystalline lens. Crystalline lens has structural changes reducing elasticity and so the capacity to accommodate and focus on short-distance (presbyopia), increasing opacity (which may lead to cataracts), scattering the light (increasing sensitivity to glare) and absorbing blue wavelength (making colours yellowish).

These changes can have important implications for the everyday lives of older adults. Untreated hearing loss affects communication and can contribute to social isolation and loss of autonomy, with associated anxiety, depression and cognitive decline (Hicks et al., 2012). The impact of significant hearing loss on an individual's life is often not appreciated by people with normal hearing, and slowness in understanding the spoken word is commonly equated with mental inadequacy, often causing the older individual to withdraw further to avoid being labelled as “slow” or “mentally inadequate” (Dillaway & Byrnes, 2009). Visual impairments can limit mobility, affect interpersonal interactions, trigger depression, become a barrier to accessing information and social media, increase the risk of falls and accidents, and make driving hazardous (Steptoe et al., 2015). Furthermore, as older people develop strategies to compensate for declining sensory functions, the ways in which they perform other cognitive tasks may also be altered and may be less efficient.

3. Current Approaches and Interventions in Healthy Ageing

3.1 Physiological Status and Physical Activity Behaviour

3.1.1Physical activity

Benefits of physical activity

Aerobic/Endurance: There is high-quality evidence that Aerobic Exercise Training (AET) of moderate-high intensity significantly improves VO2 max in older adults. The improvements observed are comparable with those that occur in younger adults until 75 years old, when the rate of improvement is minor. There is also evidence that AET programs, more so in high intensity than moderate intensity, enhance glycaemic control. Improvements in postprandial lipid metabolism have also been evidenced independent of dietary modification (Chodzko-Zajko WJ, 2009). AET programs have well-established benefits for decreasing cardiovascular risk factors, including lower heart rate at rest and during submaximal exercise, smaller increases in blood pressure, increase in glucose transporter content in muscle improved whole-body insulin action and reduction in plasma lipid concentration (Chodzko-Zajko WJ, 2009). The AET benefits also include improvements in large elastic arterial stiffness and vascular endothelial function (Santos-Parker JR 2014).

Resistance/Strengthening: Sarcopenia in the elderly population has been associated with reduced functionality, frailty and disability. The progressive decline in muscle mass and strength accelerates after 65 years of age; by 80 years of age, up to 50 % of peak skeletal muscle mass can be lost.
Strengthening or resistance exercise training (RET) has been effective to counteract the age-related changes of sarcopenia by improving muscle mass, strength and function (Stwart VH 2014). There is high-quality evidence that RET programs produce substantial increases in muscle strength and power in older adults (Chodzko-Zajko WJ, 2009; Churchward-venne TA, 2015). Some reports show favourable changes induced by RET in body composition measured by an increase in fat-free mass and a decrease in total body fat (Chodzko-Zajko WJ, 2009; Stwart VH 2014). Improvements in muscle function after RET, such as increased motor unit recruitment and discharges rates, have shown similar benefits in older adults to those seen in younger adults. Muscular endurance has also shown improvement after RET (Chodzko-Zajko WJ, 2009).
Strengthening programs for the core and hip muscles can improve the mobility of older adults, reduce kyphotic posturing, and reduce the risk of osteoporotic vertebral fractures (Sinaki M 2012). RET has been also demonstrated to improve bone mineral density in lumbar and femoral bones. RET is preferred over endurance AET for maintaining bone mass, and progressive resistance exercises may also induce osteo-genesis.
In older patients with osteoarthritis, strengthening exercises also have favourable benefits. There is high-quality evidence supporting the use of RET programs for persons with hip and knee osteoarthritis to reduce symptoms of pain and improving physical function and quality of life (Fransen M 2009; Fransen M 2015).

Flexibility/Stretching: Flexibility is the range of motion in a joint or a group of joints. It is influenced by muscles, tendons, and bones. By 70 years of age, flexibility declines for hip (20%-30%), spine (20%-30%), and ankle (30%-40%) (Chodzko-Zajko WJ, 2009).
Although there is not enough evidence that demonstrates the beneficial effects of stretching in injury prevention, it has been recognized that chronic stretching can effectually improve joint Range of Movement (ROM). Studies have shown that the decreased flexibility in the elderly also decreases their ability to recover quickly from a perturbation (Reddy RS, 2016).
Poor joint flexibility in addition to muscle tightness, especially in the hamstring groups, can be a predisposing factor for joint and muscle injuries (Onigbinde AT 2013). Researchers have shown that 12 months of stretching is as effective as strengthening exercises or manual therapy in patients with chronic neck pain. Previous studies reported an immediate 94% reduction in pain associated with trigger points after applying a special technique

based on the stretching principle (Page P, 2016). For this, stretching is now being incorporated as a crucial component in pain management programs.

Stability/Balance: Balance is the ability to maintain the body's centre of mass (COM) within the limits of the base of support. Balance disorders in the geriatric population are often a multifactorial condition. Weakness in the core stabilizing muscles, altered muscle activation patterns, loss of proprioception, and an inability to control normal postural control can all result in decreased balance in the elderly (Enix DE, 2011). Static stability is obtained through the structural stability offered by structures such as bones, capsules, and ligaments. Dynamic stability refers to the neuromuscular control of the skeletal muscle affecting a joint to maintain its centre of rotation in response to perturbation (Micheo W, 2012).
The evidence for the benefits of specific balance training exercises is scarce. There is modest evidence that balance exercises included in a multimodal exercise program with strengthening exercises can decrease fall risk (Chodzko-Zajko WJ, 2009). Tsang and Hui-Chan (Tsang WWN, 2004) found that subjects who performed 4 weeks of intensive tai chi demonstrated an improvement in sensory organization test, especially the vestibular component, and in the limits of stability test measures. Also, the improved balance control exhibited by tai chi participants led to a decrease in multiple fall risk by 47.5%. More data are still needed in order to better understand the benefits and effectiveness of balance training programs in the elderly population. Li and colleagues (Li F, 2012) showed that in patients with mild to moderate Parkinson disease, participating in tai-chi training led to reduced balance impairments, reduced falls, and improvements in functional capacity.

Other general benefits: Engaging in physical activity across the life course has many benefits, including increasing longevity. For example, a recent pooled analysis of large longitudinal studies found that people who engaged in 150 minutes per week of physical activity at moderate intensity had a 31% reduction in mortality compared with those who were less active. The benefit was greatest in those older than 60 years (Arem, 2015). More of the programs that have been shown benefits in older people are multicomponent and include aerobic, RET, flexibility and balance exercises.

Physical activity has multiple other benefits in older age. These include improving physical and mental capacities (for example, by maintaining muscle strength and cognitive function, reducing anxiety and depression, and improving self-esteem); preventing disease and reducing risk (for example, of coronary heart disease, diabetes and stroke); and improving social outcomes (for example, by increasing community involvement, and maintaining social networks and intergenerational links).
These benefits can be substantial. For example, both cross-sectional and longitudinal studies have suggested there is a 50% reduction in the relative risk of developing functional limitations among those reporting regular and at least moderate-intensity physical activity (Paterson, 2010; Tak, 2013). Randomized controlled trials have shown similar benefits (Pahor, 2014; Paterson; 2010), and progressive resistance training may give independent benefits (Liu, 2012). Physical activity also appears to preserve, and may even improve, cognitive function in people without dementia (Oaterson, 2010; Jak, 2012), reducing cognitive decline by around one third (Blondell, 2014). In addition, physical activity protects against some of the most important health conditions in older age. Physical inactivity may account for up to 20% of the population-attributable risk of dementia, and it has been estimated that 10 million new cases globally might be avoided each year if older adults met recommendations for physical activity (Norton, 2014). Similarly, stroke causes some of the greatest burdens of disease in older age, and moderate physical activity may reduce the risk by 11–15% and vigorous physical activity has even greater benefits, reducing the risk by 19–22% (Diep, 2010). Yet despite the clear benefits of physical activity, the proportion of the population meeting recommended levels falls with age, and analyses of data from Study on Global Age and Adult Health (SAGE) and the WHO World Health Survey suggests that around one third of 70–79-year-olds and one half of people aged 80 years or older fail to meet basic WHO guidelines for physical activity in older age (Bauman, 2008). However, since the prevalence of inactivity varies significantly among countries, this suggests that cultural and environmental factors that may be amenable to change are likely to be among the underlying drivers of these patterns.

Furthermore, interventions at both a programmatic level and at a broad population level appear to be effective in improving levels of physical activity (Saelens, 2008). Interventions to promote muscle strength and endurance have also been shown to be effective (Liu, 2009).

Essentially all domains of fitness – aerobic, strength and neuro-motor (balance) – are important for older populations. Yet it is prudent to consider that strength and balance training should precede aerobic exercise, with new evidence showing that progressive resistance training has favourable effects not only on muscular strength, physical capacity and the risk of falls (Liu, 2009) but also that its benefits extend to cardiovascular function, metabolism and coronary risk factors (Pollock, 2000) for those without or with cardiovascular disease. However, the benefits of aerobic physical activities, such as walking, which is the main mode of aerobic exercise among older adults, cannot be transferred to improving balance (Howe, 2011), have no effect on preventing falls (Sherrington, 2008; Voukelatos, 2015), and no clear benefit in relation to strength.

The most recent available global comparative estimates from 2010 indicate that worldwide, 23% of adults and 81% of adolescents (aged 11–17 years) do not meet the WHO Global Recommendations on Physical Activity for Health (16). Notably, the prevalence of inactivity varies considerably within and between countries, and can be as high as 80% in some adult subpopulations. Physical inactivity in adults is highest in the Eastern Mediterranean, the Americas, Europe and Western Pacific regions, and is lowest in SE Asia Region. These rates increase with economic development, owing to the influence of changing patterns of transportation, use of technology, urbanization and cultural values WHO, 2001).

3.1.2 WHO global recommendations on physical activity for health

WHO developed the "Global Recommendations on Physical Activity for Health" with the overall aim of providing national and regional level policy makers with guidance on the dose-response relationship between the frequency, duration, intensity, type and the total amount of physical activity needed for the prevention of NCDs (http://www.who.int/dietphysicalactivity/factsheet_olderadults/en/).

For adults of this age group, physical activity includes recreational or leisure-time physical activity, transportation (e.g., walking or cycling), occupational (if the person is still engaged in work), household chores, play, games, sports or planned exercise, in the context of daily, family, and community activities.

In order to improve cardiorespiratory and muscular fitness, bone and functional health, and reduce the risk of Non-communicable diseases (NCDs), depression and cognitive decline, the following are recommended:

1. Adults aged 65 years and above should do at least 150 minutes of moderate-intensity aerobic physical activity throughout the week, or do at least 75 minutes of vigorous-intensity aerobic physical activity throughout the week, or an equivalent combination of moderate and vigorous intensity activity.
2. Aerobic activity should be performed in bouts of at least 10 minutes duration.
3. For additional health benefits, adults aged 65 years and above should increase their moderate-intensity aerobic physical activity to 300 minutes per week, or engage in 150 minutes of vigorous-intensity aerobic physical activity per week, or an equivalent combination of moderate- and vigorous intensity activity.
4. Adults of this age group with poor mobility should perform physical activity to enhance balance and prevent falls on 3 or more days per week.
5. Muscle-strengthening activities should be done involving major muscle groups, on 2 or more days a week.
6. When adults of this age group cannot do the recommended amounts of physical activity due to health conditions, they should be as physically active as their abilities and conditions allow.

Overall, across all the age groups, the benefits of implementing the above recommendations, and of being physically active, outweigh the harms. At the recommended level of 150 minutes per week of moderate intensity activity, musculoskeletal injury rates appear to be uncommon. In a population-based approach, in order to decrease the risks of musculoskeletal injuries, it would be appropriate to encourage a moderate start with gradual progress to higher levels of physical activity.

3.2 Nutrition

As with other aspects of geriatric care, the management of malnutrition in older age needs to be multidimensional. Various types of interventions are effective in reversing these patterns of malnutrition and have been shown to delay care dependency, improve intrinsic capacity and revert frail states (Dorner, 2013). The nutrient density of food should be improved, particularly that of vitamins and minerals, but the energy and protein intake are important targets. Individualized nutritional counselling has been shown to improve the nutritional status of older people within 12 weeks (Beck et al., 2013).

3.2.1 Healthy diet

Consuming a healthy diet throughout the life course helps to prevent malnutrition in all its forms as well as a range of non-communicable diseases and conditions including diabetes, heart disease, stroke and cancer. However, the increased production of processed food, rapid urbanization and changing lifestyles have led to a shift in dietary patterns. People are now consuming more foods high in energy, fats, free sugars or salt/sodium, and many do not eat enough fruit, vegetables and dietary fibre such as whole grains.

Energy intake (calories) should be in balance with energy expenditure.

The effectiveness of different nutritional interventions has been recently revised in an umbrella systematic review (Poscia et al., 2017). It was concluded that vitamin D **supplementation** is highly effective in preventing falls and fractures while other oral supplements (vitamins, amino acids…) and protein-based formulas are effective in promoting weight gain and reducing the risk for malnutrition. On the other hand, **mealtime assistance and dietary enrichment programs** (with conventional foods and/or powdered modules in order to increase the energy and protein density of meals) could have a favourable effect on caloric and protein intake and functional status. **Educational interventions** involving counselling or workshops seems to be beneficial for improving nutritional indices such as caloric and protein intake and risk of malnutrition. It must be taken into account that most of the reviewed studies are focused on malnourished elderly persons.

Recommendations on dietary composition:

a) Daily energy intake should be adapted to total energy expenditure and to the nutritional phenotype, in order to obtain a negative balance in those individuals with obesity (by including nutrient-dense but energy-poor foods) and a positive balance in those individuals with undernutrition (by including energy-dense foods) (Bernstein & Munoz, 2012).

b) Although general dietary guidelines for older people recommend similar dietary protein intake for all adults, regardless of age, the PROTAGE study group (Bauer et al., 2013) suggests to increase protein daily intake up to 1-1.2 g/Kg body weight/day in order to maintain and regain lean body mass and function in elders >65 years old. Moreover, high-quality protein (rich in leucine) should be preferred (Baum, Kim, & Wolfe, 2016; Katsanos, 2006; Komar, Schwingshackl, & Hoffmann, 2015). Another common approach intended to stimulate protein synthesis and, thus, prevent ageing-induced muscle mass loss and sarcopenia, is protein distribution throughout daily meals (that is 25-30 g of high-quality protein per meal) (Paddon-Jones & Rasmussen, 2009).

Recommendations on dietary patterns:

a) Mediterranean Diet: the Mediterranean Diet has been inversely associated with cardio-metabolic disorders and with polypharmacy in older patients (Vicinanza et al., 2017) as well with frailty (Ntanasi et al., 2017). Thus, in the PREDIMED study, aimed to increase adherence to the Mediterranean Diet in community-dwelling men aged 55 to 80 years and women aged 60 to 80 years, the intervention consisted of individual and group nutrition education, including frequent motivational interviews and positive recommendations adapted to the participant's clinical condition, preferences, and beliefs.

b) DASH Diet: the DASH diet has been proposed as an adequate dietary pattern for healthy ageing and disease prevention, especially when accompanied by a higher intensity, brief aerobic training, effort-based, brief resistance training, and structured physical activity (Winett et al., 2014). Importantly, a higher protein intake is also recommended.

3.2.2 WHO recommendations for a healthy diet

Unhealthy diet is a major risk factor for chronic diseases. Reports of international and national experts and reviews of the current scientific evidence led to the WHO recommendations for a healthy diet (WHO Fact sheet N°394. Updated September 2015, http://www.who.int/mediacentre/factsheets/fs394/en/). This document recommends goals for nutrient intake in order to prevent chronic diseases and it is specifically based on the following key points:

a) Intake of Fruits, vegetables, legumes (e.g. lentils, beans), nuts and whole grains (e.g. unprocessed maize, millet, oats, wheat, brown rice). At least 400 g (5 portions) of fruits and vegetables a day. Potatoes, sweet potatoes, cassava and other starchy roots are not classified as fruits or vegetables. In order to improve fruit and vegetable consumption you can:
- Always include vegetables in your meals
- Eat fresh fruits and raw vegetables as snacks
- Eat fresh fruits and vegetables in season
- Eat a variety of choices of fruits and vegetables.

b) The intake of free sugars should be reduced throughout the life course (WHO, 2015). Evidence indicates that in both adults and children, the intake of free sugars should be reduced to less than 10% of total energy intake (FAO, 2010, WHO, 2015) and that a reduction to less than 5% of total energy intake provides additional health benefits (WHO, 2015).
Consuming free sugars increases the risk of dental caries (tooth decay). Excess calories from foods and drinks high in free sugars also contribute to unhealthy weight gain, which can lead to overweight and obesity.
Less than 10% of total energy intake from free sugars (FAO, 2010, WHO, 2015) which is equivalent to 50 g (or around 12 level teaspoons) for a person of healthy body weight consuming approximately 2000 calories per day, but ideally less than 5% of total energy intake for additional health benefits (WHO, 2015). Most free sugars are added to foods or drinks by the manufacturer, cook or consumer, and can also be found in sugars naturally present in honey, syrups, fruit juices and fruit juice concentrates.
Sugars intake can be reduced by:
- Limiting the consumption of foods and drinks containing high amounts of sugars (e.g. sugar-sweetened beverages, sugary snacks and candies); and
- Eating fresh fruits and raw vegetables as snacks instead of sugary snacks.

c) Evidence indicates that total fat should not exceed 30% of total energy intake to avoid unhealthy weight gain (Hooper, 2012; WHO, 2003; FAO, 2010), with a shift in fat consumption from saturated fats to unsaturated fats, and towards the elimination of industrial trans fats (Nishida, 2009).
Unsaturated fats (e.g. found in fish, avocado, nuts, sunflower, canola and olive oils) are preferable to saturated fats (e.g. found in fatty meat, butter, palm and coconut oil, cream, cheese, ghee and lard) (FAO, 2010). Industrial trans fats (found in processed food, fast food, snack food, fried food, frozen pizza, pies, cookies, margarine and spreads) are not part of a healthy diet.
Fat intake can be reduced by:

- Changing cooking habits – remove the fatty part of meat; use vegetable oil (not animal oil); and boil, steam or bake rather than fry
- Avoiding processed foods containing trans fats; and

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- Limiting the consumption of foods containing high amounts of saturated fats (e.g. cheese, ice cream, fatty meat)

d) Keeping salt intake to less than 5 g per day (equivalent to approximately 1 teaspoon) helps prevent hypertension and reduces the risk of heart disease and stroke in the adult population (WHO, 2012a). Most people consume too much sodium through salt (corresponding to an average of 9–12 g of salt per day) and not enough potassium. High salt consumption and insufficient potassium intake (less than 3.5 g) contribute to high blood pressure, which in turn increases the risk of heart disease and stroke (WHO, 2012a; WHO, 2012b). 1.7 million deaths could be prevented each year if people's salt consumption were reduced to the recommended level of less than 5 g per day (Mozaffarian, 2014).
People are often unaware of the amount of salt they consume. In many countries, most salt comes from processed foods (e.g. ready meals; processed meats like bacon, ham and salami; cheese and salty snacks) or from food consumed frequently in large amounts (e.g. bread). Salt is also added to food during cooking (e.g. bouillon, stock cubes, soy sauce and fish sauce) or at the table (e.g. table salt).
You can reduce salt consumption by:

- Not adding salt, soy sauce or fish sauce during the preparation of food
- Not having salt on the table
- Limiting the consumption of salty snacks
- Choosing products with lower sodium content

Potassium, which can mitigate the negative effects of elevated sodium consumption on blood pressure, can be increased with consumption of fresh fruits and vegetables.
The exact make-up of a diversified, balanced and healthy diet will vary depending on individual needs (e.g. age, gender, lifestyle, the degree of physical activity), cultural context, locally available foods and dietary customs. But basic principles of what constitutes a healthy diet remain the same.

3.3 Cognitive and Mental Status and Social Behaviour

Active ageing should encompass all older people, as well as younger age groups, even those who are, to some extent, frail and dependent (WHO, 2002). For many persons, cognitive impairment of the dementia type is as severe as chronic pain (Lawton et al., 1999). Any strategy for active ageing should equally be participative and empowering (Walker, 2002; Walker, 2009). Interventions for Healthy Ageing can be described as all actions taken to facilitate the maintenance of psychophysical well-being in the ageing process until very old age (Lehr, 1979). Numerous interventions are present in the health psychological or general health domain (Abraham & Michie, 2008). Interventions targeting the ageing process have a long tradition in lifespan and geronto-psychology and tend to focus mainly on cognitive functioning but also as a means to prevent or decrease loneliness. Another type of interventions targets specific health behaviours that are particularly or also relevant in older adults, such as medication adherence and physical activity, often in the context of post-surgery interventions that aim to help individuals get back on track (e.g., Inauen et al., 2017; Radtke et al., 2017; Scholz et al., 2006). Whereas intervention strategies will be detailed in a dedicated deliverable (D2.2) within NESTORE, we will here provide a brief overview of a typical intervention approaches in the areas of cognition and social relations that have primarily (cognition) or also (social relations, loneliness) targeted on older adults.

3.3.1 Cognitive status

A NICE guideline (NICE, 2015) makes recommendations on approaches in midlife to delay or prevent the onset of dementia, increasing the amount of time that people can be independent, healthy and active in later life (successful ageing) by:

- helping people stop smoking, be more active, reduce alcohol consumption, improve their diet and, if necessary, lose weight and maintain a healthy weight
- reducing the incidence of other non-communicable chronic conditions that can contribute to the onset of dementia, disability and frailty
- increasing people's resilience, for example by improving their social and emotional wellbeing

More specifically, cognitive status improvement could be faced with different and complementary strategies, as described below.

Cognitive training

Being intellectually engaged may benefit the brain. Interventions for healthy ageing have long mainly targeted cognitive functioning, with the aim to also positively affect feelings of mastery and control, facilitate social interactions and ultimately a person's subjective well-being and psychological health.

People who engage in meaningful activities, like volunteering or hobbies, report they feel happier and healthier; learning new skills may improve the thinking ability (Park et al., 2014). Lots of activities can keep the mind active (National Institute on Ageing, 2017). The most challenging or complex jobs could have a protective effect (Fratiglioni and Wang, 2007). Scientists think that cognitively challenging activities may protect the brain by establishing "cognitive reserve" (Valenzuela et al. 2007; Smith et al., 2009; Carlson et al.; 2009). They may help the brain become more adaptable in some mental functions, so it can compensate for age–related brain changes and health conditions that affect the brain.

Cognitive training can be differentiated as being strategy-based (i.e., teaching and training a particular strategy for problem- and task solving), process-based (i.e., intensive repetition in a particular core cognitive domain thought to underlie functioning in other cognitive domains), or multicomponent trainings (i.e., complex tasks with high ecological validity in which multiple cognitive domains are simultaneously required, such as video-games, learning digital photography etc.; Basak, Boot, Voss, & Kramer, 2008; Binder et al., 2015; Lustig, Shah, Seidler, & Reuter-Lorenz, 2009). Further, cognitive training can only be fully evaluated with regard to training gains if one compares a so-called active control group to the experimental (training) group. That means that the comparison group engages in a task that is structurally similar to the trained task but thought not to tap the trained function (i.e., using the same type of material as used in the training). Only through such a comparison can improvements be attributed to the specific training and not to just any kind of activity engagement.

The current empirical evidence suggests that cognitive training, mainly in the process-based tradition, lead to small-to-moderate **training gains** (i.e., pre- to post-training performance changes) in the trained domain, and that process-based training are more effective than strategy-based training (for review, see Guye et al., 2016; Karbach & Verhaegen, 2014); for other reviews, see Tardif & Simard, 2011; Papp et al., 2009; Wilson et al., 2002).

A Cochrane review of cognitive training (Martin et al, 2011) concluded that cognitive interventions could improve cognitive performance - memory, executive function and proceeding speed- in older adults. However, more standardized protocols were suggested and there was little evidence for a specific training effect when the training intervention was compared to an active control group. As for age-differential training gains, both young and older adults show positive training gains, indicating that the cognitive system is indeed plastic until old age. Some advantages have been shown for younger versus older in strategy-based training, with the opposite pattern found for multi-domain training and little-to-no age differences in training gains due to process-based training (Guye et al., 2016).

There is some indication that the effectiveness of cognitive training is influenced by several moderating factors, including the training setting, the frequency and duration. It seems that trainings in groups in the laboratory are more effective than home-based training interventions (Kelly et al., 2014; Lampit et al., 2014) but questions remain as to the explanatory factors (formal vs. informal instruction; social setting vs. training alone). Whether shorter or longer duration is better also remains to be answered and clarified in future research (Karbach & Verhaegen, 2014; Kelly et al., 2014). The "Grupo de trabajo de la Guía de Práctica Clínica sobre la atención integral a las personas con enfermedad de Alzheimer y otras demencias" (GPC, 2010) recommends the realization of mental exercise for the clear evidence that exists about its benefit in other aspects of health.

Participation in cognitive intervention programs is recommended in patients with mild to moderate AD, to maintain their cognitive function, their functionality and quality of life.

One additional important criterion to evaluate the effectiveness of cognitive trainings is to assess the breadth of the observed performance improvements, and whether these are restricted to the trained domain or also **transfer** to untrained domains (Noack et al., 2009; Shipstead et al., 2012). It is one of the most challenging findings in interventions for healthy ageing that little to no transfer effects have been documented across training types, especially when one considers far transfer (i.e., transfer to ability domains that are only loosely related to the trained domain), but small to moderate near transfer effects after process-based and multi-domain trainings (cf. Guye et al., 2016). There is some evidence of transfer to everyday life performance not immediately after the training but a few years later (e.g., Ball et al., 2010).

The **maintenance** of training and transfer effects has been rarely studied given that this requires long-term longitudinal studies with follow-ups no earlier than 3 or more years post training (Salthouse, 2006). Those available studies indicate maintenance of training gains and transfer effects from 6 months up to several years (Kelly et al., 2014; Rebok et al., 2014; Willis et al., 2006).

Physical activity for cognitive health

Physical activity appears to be one of the strongest factors for delaying or preventing cognitive decline (McKee, 2011; Franco-Martin et al., 2013; Hogervorst, 2017).

In the absence of effective pharmacological strategies to reduce the risk of cognitive decline and Alzheimer’s disease, there has been an increasing call to focus on addressing modifiable risk factors, including physical inactivity. There are several hypotheses to explain the positive influence of physical activity on brain function, including improved cerebral blood flow, increased neurogenesis, angiogenesis and synaptic plasticity, reduced inflammation and improved resistance to brain insults (Batcherlor et al., 2016).

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Healthier eating for cognitive health

Healthy eating is important for all stages of life in including older age (Hogervorst, 2017).

With respect to cognitive decline these include (Batchelor et al., 2016):

- reducing the intake of saturated and trans-unsaturated (hydrogenated) fats (positively associated with increased risk of age-related cognitive decline, mild cognitive impairment and Alzheimer’s disease)
- increasing the intake of polyunsaturated (in particular, n-3 PUFA) and monounsaturated fats (protective against cognitive decline in older people in prospective studies)
- increasing fish consumption (associated with lower risk of Alzheimer’s disease in longitudinal cohort studies)
- ensuring adequate intake of B-vitamins, especially vitamins B9 (folate) and B12 can reduce the risk of cognitive decline and dementia
- results on antioxidant nutrients are more mixed, suggesting a need to balance the combination of several antioxidant nutrients to exert a significant effect on the prevention of cognitive decline and dementia to avoid any adverse effects caused by overdosing on some
- securing adequate intake of fruit and vegetables as a source of protective antioxidants against cognitive decline, dementia and Alzheimer’s disease.
- keeping alcohol use to a moderation. Light-to-moderate alcohol use may be associated with a reduced risk of incident dementia and Alzheimer’s disease, while for vascular dementia, cognitive decline and pre-dementia syndromes, the current evidence is only suggestive of a protective effect (Gillette Guyonnet et al. 2007, Solfrizzi et al. 2011, World Health Organization 2003).

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3.3.2 Mental status

Mental health promotion attempts to reduce inequities by:

- implementing diversity policies.
- providing diversity training.

- creating transitional programs for identified groups (i.e., tailoring programs to make them more inclusive of or responsive to marginalized populations).
- promoting anti-stigma initiatives.

Based on the evaluations of the literature, a number of key strategies has been suggested for successful programs to improve mental health among older people (Batchelor et al., 2016). These include building collaborative partnerships with stakeholders; using an integrated and multidisciplinary approach; taking a holistic view of active ageing; using an evidence-based approach; involving older people in the whole process; addressing the needs of specific target groups and providing training and support for staff and volunteers. Some specific suggestions are: keeping healthy by exercising, eating well and getting adequate sleep; spending time with friends and family, and getting involved in their community, perhaps by volunteering or helping others; maintaining interests and hobbies and participating in enjoyable activities; seeking professional help, if struggling to cope with everyday life (talking to a GP is a good first step); visiting relevant websites in relation to tips on how to maintain mental health.

For example, a Canadian mental health promotion program (Kobus-Matthews et al., 2010) enhances the following elements to be considered:

- focusing on the enhancement of well-being rather than on illness.
- addressing the population, including people experiencing risk conditions, in the context of everyday life.
- being oriented toward taking action on the determinants of health, such as income and housing.
- including protective factors, rather than simply focusing on risk factors and conditions.
- including a wide range of strategies such as communication, education, policy development, organizational change, community development and local activities.
- acknowledging and reinforcing the competencies of the population.
- encompassing the health and social fields as well as medical services.

In this program, the concept of **resilience**, i.e. “the ability to manage or cope with significant adversity or stress in ways that are not only effective but may result in an increased ability to respond to future adversity” (Batchelor et al., 2016), is specifically emphasized.

Subjective well-being

As described in section 2.3.2, most older adults maintain high levels of affective well-being although many people are, indeed, facing mounting physical ailments, psychological stress, social losses, and increased dependency at the very end of life (Scheibe & Carstensen, 2010; see also Kryla-Lighthall & Mather, 2009).

To enhance well-being, emotion regulation can be used to increase positive feelings (using up-regulation) or to decrease negative feelings (using down-regulation), and older adults demonstrate proficiency at both. A study by Kliegel, Jäger, and Phillips (2007) shows that older people are more effective than younger people at “repairing” or down-regulating moods—restoring positive affect after a negative mood induction. It remains overall an open empirical question, whether older adults are indeed better in emotion regulation than young adults or just as good. Most studies only use self-report data rather than actual emotion regulatory behaviors to test this question.

Cognitive strategies can be used to focus on positive and suppress negative information in order to enhance emotional well-being, leading to what has been coined a “positivity effect” in attention and memory (Carstensen & Mikels, 2005).

Thus, the following strategies can improve the mental states in the elderly:

- Having a positive view of life and social relationships (i.e., enhancing the feeling of life satisfaction).
- Using cognitive control strategies to focus on positive and suppress negative information (i.e., remembering the past positively), by selecting a situation by its expected emotional outcome, modifying the emotional impact or meaning of a situation, focusing on select aspects of a situation, altering an ongoing emotional response.

With regard to interventions for well-being, most of the interventions in other domains also intend to help maintain or increase individuals' subjective well-being and sense of the quality of life given the improvement in the target domain (i.e., cognition, social integration, physical activity), even without exclusively targeting well-being itself. Well-being interventions are mainly known from other age groups than those in later life and typically focus on approaches of expressive writing, gratitude, good actions and counting kindness, to name a few (e.g., Gander et al., 2013; Pennebaker, 1997; Seligman et al., 2005; Smyth, 1998). These kinds of interventions have been shown to be effective under certain conditions and particularly in the short run (e.g., Lyubomirsky et al., 2011), the long-term benefits for truly changing not only well-being states but the more stable status/disposition and the particular or sustained benefit for older adults remains an open question. As noted in Brose and Ebner-Priemer (Brose & Ebner-Priemer, 2015), despite generally high levels and successful maintenance of subjective well-being in older adults, especially the young old of the Third Age (i.e., ca. 65-80 or 85 years of age; Baltes, 1997; Laslett, 1991), later life does bring about challenges to well-being and vulnerabilities, particularly in very old age. The identification of general and person-specific risk factors such as the loss of close confidants and health-related impairments that pose severe constraints to compensatory strategies and thus to the pursuit of important personal goals appears to be essential and ambulatory assessment and smart digital approaches appear to be ideally suited for this endeavour. In NESTORE, the aim will be to continuously monitor individuals' subjective well-being as well to be able to detect changes that may indicate problems or challenges with regard to a persons' goal progress in the NESTORE domains of physical activity, nutrition, cognition and social behaviour.

Social relations/social integration

Social activities can be classified according to the level of social interactions and a taxonomy of social activities (Levasseur et al., 2010) can be useful to determine levels of social engagement in social interactions and thus possible starting points and outcomes for interventions regarding social relations:

- Doing an activity in preparation for connecting with others.
- Being with others (alone but with people around).
- Interacting with others without doing a specific activity with them.
- Doing an activity with others (collaborating to reach the same goal).
- Helping others.
- Contributing to society.

Many interventions in the social domain do not target older adults (Ertel et al., 2009). Of those that do explicitly have the older population in mind, many have a strong focus on decreasing or preventing loneliness and aim on improving social skills, enhancing social support, increasing opportunities for social interaction and social cognitive training (Masi et al., 2011). These target domains reflect theoretical models of loneliness that propose an individual difference concept such that lonely and non-lonely individuals approach and appraise social encounters differently, including more sceptical and negative perceptions of and during interactions and behaviours that are more likely to lead to rejection on the side of the lonely persons (cf. Masi et al., 2011). Many loneliness interventions thus intend to increase the quantity and quality of relationships. Two main approaches to reducing loneliness can be distinguished: (a) **Approaches that focus directly on the individual**, and (b) **approaches that focus on so-called structural enablers**.

The first type of intervention tends to include a two-step procedure, in which initially lonely persons need to be reached, their personal loneliness situation understood and they need to receive support to be able to access appropriate loneliness-reduction services (Jopling, 2015). These typically involve social group and befriending approaches which can take one of three categories: Supporting and maintaining existing relationships, supporting new social connections, and psychological approaches (i.e., help individuals to reappraise their social connections; see also Figure 2).

Whether or not such interventions, in fact, work can be evaluated against several criteria, such as which types of groups of older adults are targeted, what kind of training and support is provided to the facilitators, to what degree the older adults are actively participating in the group decision-making, planning and implementation of a given intervention and whether external community resources are being utilized and community capacity built, to name a few and there are by now a number of reviews and meta-analyses discussing such interventions in different age groups (e.g., Cattan et al., 2005; Chen & Schulz, 2016; Dickens et al., 2011; Findlay, 2003; Masi et al., 2011).

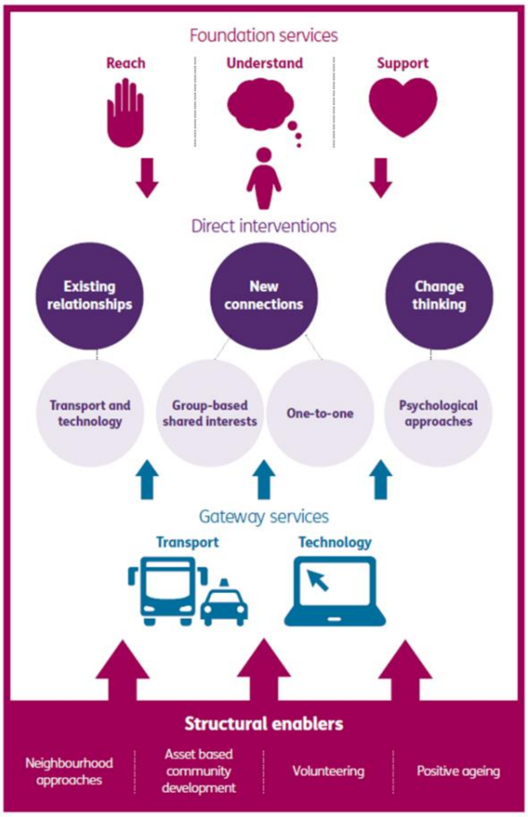

Figure 2 Overview of Framework for Promising Approaches to Reducing Loneliness and Isolation in Later Life (cf. AGE UK).

The second type of intervention does not target the individual directly but focuses on the community and on building new structures that facilitate social connections. This second group of intervention programs involves those that target the smaller neighbourhoods that people identify as their “home turf”, asset-based community developments that make use of existing structures, volunteering and overall approaches that foster a positive ageing image and highlight opportunities rather than constraints of later life (e.g., Age-Friendly Cities).

Transport and technology are often used in services to improve the quality of existing relationships and play a wider role as enablers of effective intervention. They have been characterized as “gateway services” as they play a critical role in directly facilitating existing relationships and a vital supporting role in interventions designed to support new social connections.

Whereas many reviews have shown interventions to be most successful when focusing on social skills, enhancing social support, increasing opportunities for social interaction and addressing deficits in social cognition across a wide range of intervention types and study designs, in their meta-analysis of primarily randomized controlled trials, which are most appropriate in providing a scientifically sound evaluation of intervention effects, Masi et al. (2011) were able to show that there was a slight positive advantage of those interventions that focused on changing maladaptive social cognitions. This result, however, was based on intervention study not only focusing on older adults. Interventions in the social domain often focus both on social relations as a fixed status characteristic of individuals (i.e., network size, loneliness as a disposition over time) but also play out on social behaviours and experiences (i.e., social cognitions that shape behaviour towards one’s social environment). The next section will thus focus on those interventions, which can be subsumed under social behaviour interventions even more explicitly.

3.3.3 Social behaviour

The Active Ageing policy from the WHO (WHO, 2002) refers to participating in the society according to older people's needs, desires and capacities. In this line, when labour market, employment, education, health and social policies and programmes support older people's full participation in socioeconomic, cultural and spiritual activities, according to their basic human rights, capacities, needs and preferences, people will continue to make a productive contribution to society in both paid and unpaid activities as they age.

According to the Active Ageing policy, promoting participation requires:

- Providing education and learning opportunities throughout the life course: Basic education and health literacy, Lifelong learning, etc.
- Recognizing and enabling the active participation of people in economic development activities, formal and informal work and voluntary activities as they age, according to their individual needs, preferences and capacities: Informal work; Voluntary activities
- Encouraging people to participate fully in family community life, as they grow older: Transportation; Leadership (Involve older people in political processes that affect their rights); A society for all ages (including intergenerational encounters), etc.

Social programs targeting social behaviour can be integratively viewed in the context of those programs discussed above on social integration and loneliness in general and as status characteristics because status and behaviour are closely linked when it comes to interventions in this area. Social programs promoting social participation of older individuals can be considered according to the following taxonomy (Raymond et al., 2013): social interactions in individual contexts (a person's home or community-based services), group-based social interactions (e.g., in senior centres or educational classes), collective projects (e.g., in recreational, sports-related or intergenerational settings), and on a more global level socio-political involvement and activism (Raymond et al., 2013).

Reviews of interventions targeting social networks have critically noted some methodological short-comings that make the evaluation of these types of interventions difficult, including small samples, a select focus on subgroups and primarily patient groups rather than the more general population including healthy older adults, to name a few. One shortcoming of this literature is also that many interventions involving social factors evaluate outcomes such as health, well-being and cognitive functioning but do not fully report the impact of the intervention on the social variables themselves.

To date, there is mixed evidence on the success of social network interventions in later life (e.g., Findlay, 2003). Some evidence suggests that educational and social activity group interventions for particular subgroups of adults can be promising to decrease social isolation and loneliness in later life (Cattan et al., 2005). In a recent review of social capital interventions targeting older adults, Coll-Planas, Nyqvist, Umitia, Sola, and Monteserin (2016) review interventions that target both the individual (micro level), the larger neighbourhood (meso level) as well as society and community as a whole (macro level). They also differentiate the target of the interventions, focusing on either structural aspects of social relations and social integration (e.g., number of social ties, frequency of contact) as well as cognitive and subjective aspects (satisfaction with social relationships, social support, sense of belonging). In their systematic review, Coll-Planas et al. (2016) conclude that there is some evidence for partially positive effects of social capital interventions during later life, even though overall, the included 36 randomized controlled trials did not show reliable effects on important late life outcomes such as loneliness, mood and mortality and showed inconsistent results with regard the effects on self-reported health, well-being and quality of life. Some positive effects were found in some studies focusing on select groups of adults. Despite the lack of very clear effects of interventions targeting social integration and participation, in part due to a gap in research systematically studying this in healthy older adults and with methodologically sound studies including large samples and appropriate control group designs, we will briefly review some common types and targets of interventions for social relations involving older adults.

Supporting social participation

In order to support social participation, several strategies and program types are common. Programs involving a focus on art and arts-based activities can be an effective means to increase social inclusion and strengthen social networks among older adults (e.g., Phinney et al., 2012). In addition, university programs that are tailored to seniors are quite popular educational models in the Western world (i.e., often called the University of the Third Age, U3A; cf. Batchelor et al., 2016). Other approaches found to be effective are those that focus on social eating and group-based physical activity programs (for review, see Batchelor et al., 2016).

Interventions that use mobile technology are promising avenues for a number of interventions targeting health in general (Moller et al., 2017) and in particular for healthy ageing (Brose & Ebner-Priemer, 2015). In the social domain, mobile technology can be used to facilitate communication and networking also in later life. There is, for example, an ongoing project in Barcelona called "VINCLES BCN" (http://ajuntament.barcelona.cat/vinclesbcn/en/) awarded by the Bloomberg Foundation using tablet computers to facilitate social networking among older adults. In this project, the focus is both on the existing personal network of the participants but also the neighbourhood peers involved in the same project.

Supporting community participation

One group of older adults who might be in particular need for interventions to support community participation are **older caregivers**, because being a caregiver appears to be related to social isolation and also to a disruption of social networks and employment (e.g., Colombo et al., 2011). Therefore, it is important to provide services to support older carers in their caring roles and thus facilitate and enable community participation and fight social isolation that is due to the caregiving duties. To date, however, there is a scarcity of approaches that directly target older caregivers (Parker et al., 2010; Williams & Owen, 2009). Another approach to supporting community participation is volunteer work and those interventions that focus on recruiting older adults into the volunteering "work" force. Factors that make success of such approaches more likely are, for example, the good collaboration between the organisations involved (Principi et al., 2012; Sellon, 2014). Some best practices for successful recruitment and retention of older volunteer workers include a personal invitation, meaningfulness, social interaction, role flexibility, stipends, support from staff, and recognition (Sellon, 2014). In addition, it is important to incorporate a resource-based perspective, that is one that explicitly focuses on strengths, abilities, and hopes of individuals and communities on the one hand, and also on facilitating factors of the community (Sellon, 2014). Such an approach is also in line with the asset-based approach that considers older people as active agents of their social development (Robertson, 2013). There are a range of programs involving older volunteers in different countries. However, there is limited information on the evaluation of these programs (cf. Batchelor et al., 2016).

Intergenerational programs

Intergenerational programs as another type of interventions on social behaviour are important for at least two reasons: On the one hand, social participation has been shown to be hindered by negative attitudes towards older people and older adults can also gain an improved understanding of the younger generation (Bostrum et al., 2000; Principi et al., 2012, Robertson, 2013). Intergenerational programs can take many forms:

- older individuals help and support younger individuals.
- younger individuals help older individuals to improve certain skills (e.g., computer skills).
- older and younger individuals work together on a joint project.
- shared site programs (Listokin, 2009, Renehan et al., 2010).

A wide range of programs exist that cover academic mentoring, arts activities, computer training, and environment improving activities, and take place in various types of settings (e.g., community centers, schools, homes for seniors). There is some evidence for the benefits of such intergenerational programs, on all levels (i.e., the individual level for both young and older adults, and the community level). From the perspective of the older adult, such programs provide an otherwise possibly unavailable opportunity to share skills and expertise and to remain in connection with the community and neighbourhood. Positive impacts on such diverse outcomes as

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life satisfaction, social engagement, and overall health have been found (e.g., Ellis, 2004; McAvinchey & Gilfoy, 2009; Listokin, 2009; Porter & Seeley, 2008; Purcell & Hatton-Yeo, 2002; Renehan et al., 2010).
There is a strong tradition for such intergenerational volunteering programs in the US, in which older adults become mentors for high school students in disadvantaged public elementary schools (https://www.aarp.org/experience-corps/), where older adults and children enrol in a one-year learning program with the goal to develop an oral history which they present to the community (Creating Community; NYC Department of Ageing, 2010), or where secondary school students provide one-on-one computer training (Trans-IT; Harrison & Mulvehill, 2008). For all of these programs, positive evaluation results have been shown with respect to social variables (i.e., decrease in time spent alone and in feelings of isolation) as well as other psychological variables (i.e., increase in cognitive ability and physical activity; cf. Batchelor et al., 2016). For such programs to work, it seems important that they are participatory in nature, provide enough time for relationships to grow, as well as appropriate training to all involved (i.e., communication training) so that staff, volunteers and participants can effectively collaborate (cf. Batchelor et al., 2016).

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4 Motivational Models for Healthy Ageing

4.1 Lifespan Psychology

To date, the most widely accepted theoretical framework for adulthood development and ageing is the lifespan theoretical framework proposed by Baltes and colleagues (Baltes et al., 1999), in which individual development is described as the interplay between an active agent (i.e., the person) and the environment. Development and ageing are thus not considered to be passively experienced by individuals, but actively shaped and regulated at least to some degree by the individual person. Several guiding principles characterize the lifespan theory and provide the context for the following summary of the model of selective optimization with compensation (SOC Model).

- Development is a **lifelong** process, not restricted to early childhood and adolescence.
- Development is **multidirectional** and **multidimensional**. This means that developmental and ageing trajectories can include maintenance, growth and decline patterns (= multidirectionality) and the shape of the trajectory can differ both within and between different domains of functioning (= multidimensionality).
- Lifespan development involves both **losses and gains** in all phases of life. The gain-loss balance, however, will shift across the lifespan, from gains outweighing losses from childhood through midlife to losses outweighing gains during later adulthood and older age.
- Lifespan development is not fully determined by biological factors but characterized by **plasticity**, which describes the change potential in a person's behaviour, experience and also brain due to, for example, training or after accidents and lesions.
- Lifespan development can only be understood in the **context** of normative historical (i.e., the Fall of the Berlin wall, the Great Depression in the 1920s), normative age-graded (i.e., hormonal changes during puberty) and non-normative person-specific (the premature death of one's child or parent, divorce) influencing factors which interact with one another to shape an individual developmental trajectory.

The lifespan perspective represented a novel view on adulthood and ageing and ended a merely disease- and loss-focused stance on ageing (Levenson & Aldwin, 1994).

4.2 The Model of Selective Optimization with Compensation (SOC Model)

This model is fully rooted in the lifespan theoretical framework that characterizes much of the ageing theories and empirical work of the past decades. It is one model that focuses on the description and understanding on how individuals regulate their own development and adapt to changing resources such as health, social relations, cognition, to name a few key psychological resources. The SOC model posits that optimal lifespan development including successful ageing is best achieved when one manages to achieve a positive balance between developmental gains and developmental losses and to make the most given one's resources, opportunities and constraints (Baltes & Baltes, 1990; Freund, 2008). The model describes three strategies which can be used to achieve this optimal balance of gains and losses:

- **Selection** of goals and preferences describes the choice and specification out of a longer list of possible life goals and opportunities. With selection of a subset of goals, one's developmental path and biography so to speak will be steered into a specific direction. Selection can be loss-based and occur in response to age-related losses and decreases in functioning or self-initiated and interest-based.
- **Optimization** refers to processes of acquiring and improving means to goal attainments (e.g., learning new skills, investing resources such as time and energy).
- **Compensation** focuses on the means for counteracting losses in and blockage of goal-relevant means. Strategies representing compensation include replacing means of goal attainment or drawing upon

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external means for goal achievement (e.g., social support) when previously used strategies and means are no longer available, the person still wants to maintain a given goal rather than disengaging from the goal all together.

From a motivational perspective, SOC strategies can be contextualized within processes of goal setting and goal pursuit on the one hand, and an approach to gains and prevention of loss on the other hand, as schematized in Table 1.

Table 1. Selection, Optimization and Compensation in the Context of an Action-Theoretical Framework

GOAL PROCESS / MOTIVATIONAL ORIENTATION	***GOAL SETTING***	***GOAL PURSUIT***
APPROACHING GAIN	**Elective selection** *= specification of goals, goal commitment, goal system (hierarchy)*	**Optimization** *= resource allocation (time, effort), practice of skills, acquiring new skills*
PREVENTING LOSS	**Loss-based selection** *= reconstruction of goal hierarchy, adaptation of goal standards, search for new goals*	**Compensation** *= substitution of means, use of external help, activation of unused skills/ resources*

To illustrate the SOC strategies, here are some exemplar items from the SOC questionnaire (Freund & Baltes, 2002):

- *Selection – loss-based* (vs. distractor item)
  - TARGET: When things don't go as well as before, I choose one or two important goals.
  - DISTRACTOR: When things don't go as well as before, I still try to keep all my goals.
- *Selection – elective* (vs. distractor item)
  - TARGET: I concentrate all my energy on a few things
  - DISTRACTOR: I divide my energy among many things.
- *Optimization* (vs. distractor item)
  - TARGET: I keep working on what I have planned until I succeed.
  - DISTRACTOR: When I do not succeed right away at what I want to do, I don't try other possibilities for very long.
- *Compensation* (vs. distractor item)
  - TARGET: When things don't go as well as they used to, I keep trying other ways until I can achieve the same result I used to.
  - DISTRACTOR: When things don't go as well as they used to, I accept it.

A central tenet of the SOC model is that successful developmental regulation can be achieved through the flexible implementation of the three proposed strategies, leading to the maintenance of one's functional capacity and well-being. Empirical evidence from both survey studies using self-report measures of the SOC strategies as well as experimental studies and across a wide range of samples differing in age provide support that the three strategies are being employed across the entire adult lifespan into old age and that individuals reporting more use of SOC also report higher well-being (both emotional experience and life satisfaction, as well as with respect to social integration and loneliness; Freund, 2008; Freund & Baltes, 2002; Freund & Baltes, 1998).

4.3 Health-Behaviour Change: The Health Action Process Approach (HAPA)

Given the wide range of changes observed in the general population of older adults, including health-related impairments, it is surprising that there is little research on health behaviour change in older adults (Ziegelmann & Knoll, 2015). Behaviour change interventions that are theory-guided and have empirically shown to be effective are thus needed (Schwarzer et al., 2011).

The Health Action Process Approach (HAPA) is one of several psychological social-cognitive theories of health behaviour change that provides a conceptual framework for describing and understanding how individuals can successfully replace health-compromising behaviours (e.g., sedentary behaviour, social reclusion) with health-enhancing behaviours (e.g., physical activity, social integration) through a process of adoption, initiation and maintenance of health behaviours (Schwarzer, 2008). The main goal of these health-behaviour change theories is to understand how a set of psychological constructs can jointly explain how an individual can be motivated to change an established behavioural pattern in the interest of improved or maintained overall long-term health.

The HAPA model focuses on two distinct phases (motivational phase and volitional phase) and on phase-specific psychological factors explaining or underlying behaviour change (or its failure) in each phase (Figure 3). The motivational phase is also called the pre-intentional phase. It describes the variables that predict that individuals, in fact, form a particular intention about wanting to affect their own health in a particular domain (versus not even getting to the point where that intention is formed). The volitional phase begins right after intention formation and describes those variables that predict the success of setting the implementation into action. A person's perceived self-efficacy is emphasized in each phase as one of the key variables within the HAPA model (Scholz et al., 2005). The model has been applied to a wide range of samples/patient groups and targeting a variety of health behaviours (Schwarzer et al., 2007).

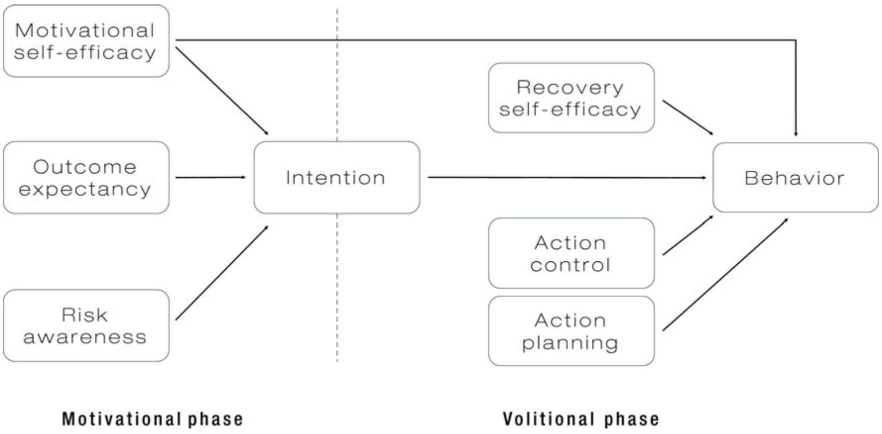

Figure 3 The Health Action Process Approach (HAPA) Model (Bierbauer et al.., 2017; adapted from Schwarzer, 2008).

As opposed to other health-behaviour change models, the HAPA is much more comprehensive and explicitly targets the intention-behaviour gap by separating the two distinct motivational phases and by applying phase-specific predictors and variables. Whereas other models (e.g., Theory of Planned Behavior and PMT; Ajzen, 1991; Maddux & Rogers, 1983) consider behavioural intentions as the proximal predictor of a person's behaviour, the HAPA model acknowledges that despite good intentions, adopting new behaviours can be quite difficult and individuals often fail and do not behave according to their intentions (Sheeran, 2002). The HAPA model thus focuses on mediators of the intention-behaviour gap and has identified distinct factors for each of the two phases.

Table 2 provides an overview of the factors that the HAPA model proposes for the two phases to be important.

Table 2 Overview of HAPA Model Phase-Specific Variables and Exemplary Items

PHASE	VARIABLES PROPOSED TO PREDICT THE INTENTION / THE BEHAVIOR	EXEMPLARY ITEM FOR ASSESSMENT
PHASE I: MOTIVATIONAL PHASE		
	Risk awareness	If I am not regularly physically active, the probability is high that I will have serious health problems
	Positive outcome expectancy	There are more advantages than disadvantages in being physically active on a regular basis
	Motivational self-efficacy	I am confident that I will engage in regular physical activity in the next four weeks, even if it is difficult
PHASE II: VOLITIONAL PHASE		
	Recovery self-efficacy	I am confident that I can be as physically active as I have planned during the next four weeks even as barriers arise.
	Action planning	I have made detailed plans for when and how I will be regularly physically active in the next four weeks
	Action control: (1) Awareness of standards (2) Self-monitoring (3) Self-regulatory effort	(1) During the last 4 weeks, I was always aware of my intended training program. (2) During the last 4 weeks, I constantly monitored whether I was as physically active as I had planned (3) During the last 4 weeks I always tried to be as physically active as I had intended.

During the **motivational phase**, in particular three variables are considered to lead to the intention to act. Of those, *risk awareness* is thought to prepare the stage for a process of contemplation and *positive outcome expectancies* and *self-efficacy* then jointly operate to form the intention (Schwarzer et al., 2011). After forming the intention, a person enters the **volitional phase**, during which the three variables of self-efficacy, action planning about when, where and how the target behaviour will be performed as well as action control contribute to the actual behaviour implementation. As mentioned above, considering the role of self-efficacy not only in forming the intention but also in bridging the intention-behaviour gap (i.e., examining self-efficacy during the volitional phase to predict behaviour) is one of the key advantages of the HAPA model (Schwarzer, 2008). During this second motivational phase, *self-efficacy* concerns the degree of confidence a person has about being able to get back on track after a relapse (Scholz et al., 2005). *Action planning,* shown to predict behaviour over and above behavioural intentions *(*Hagger et al., 2016; Hagger & Luszczynska, 2014), involves the prospective linkage of specific cues from the situational environment with concrete behaviours so that the intention is being put in place (Scholz et al., 2008). *Action control* comprises subfacets of general self-regulation (Carver & Scheier, 1998), such as self-monitoring, awareness of standards, and self-regulatory effort, and has also been shown to be a reliable precursor of subsequent behaviour (Sniehotta et al., 2005).

To date, most of the evidence for the validity of the HAPA model assumptions comes from comparisons between individuals, such that persons with greater self-efficacy and risk awareness as well as more action planning and action control more likely form an intention and carry out the intended behaviour (change) than individuals with lower levels across these motivational and volitional variables (Schwarzer, 2008). The health domains for which such between-person comparisons have been conducted cover a wide range of typical target behaviours in public health campaigns, such as physical activity (Barg et al., 2012; Parschau et al., 2014; Scholz et al., 2008), medication adherence (Greer et al., 2015), breast self-examination, seat belt use, dietary behaviours, and dental flossing (for overview, see Schwarzer, 2008).

5 IT Perspective on Healthy Ageing

5.1 Introduction

Two main aspects have affected the need to develop technological solutions addressed to help older people stay in their own home for as long as possible: ageing of our society and the increasing pressure on health and aged care services.

New technologies have shown promise as effective, accessible, and inexpensive solutions to promote health and wellbeing in global populations. Pedometers, wearable devices that capture step count, can increase activity levels by up to 2000 steps per day (Bravata et al., 2007). In addition, the use of the Internet to communicate information to individuals may allow population health interventions to be delivered, and widely disseminated, at relatively low cost (Bennett & Glasgow, 2009; Enwald & Huotari, 2010; Van den Berg al, 2007; Wanner et al., 2009).

The last decade several research programs and initiatives have been fostered to confront main challenges in promoting active and independent ageing in key domains such as nutrition, physical activity or cognitive and mental status or social interactions. Precisely, in the European contest several initiatives have been generated as the first European Summit on Innovation for Active and Healthy Ageing (Brussels, 2015) where key stakeholders discussed how Europe can transform demographic change into opportunities for economic growth and social development. The event was organized by the European Commission in collaboration with the Active and Assisted Living (AAL) Programme, AGE Platform Europe, the European Connected Health Alliance (ECHAlliance) and Knowledge for Innovation (K4I). The Summit built on the achievements of ongoing EU initiatives:

1. The European Innovation Partnership on Active and Healthy Ageing (EIP-AHA) launched in 2012;
2. “More Years, Better Lives”, the Joint Programming Initiative (JPI) which enhances coordination and collaboration between European and national research programmes related to demographic change;
3. Horizon 2020, the EU Research and Innovation Framework programme, in particular funding under Societal Challenge 1 for innovative ICT solutions for active and healthy ageing;
4. The Active and Assisted Living Programme, where Member States in cooperation with the European Commission fund projects on applied research for innovative ICT-based products, services and systems for ageing well.

5.2 Active Ageing Approaches Based on IT

The four approaches in which IT can enable an Active Ageing come from the literature of Gerontechnology, the interaction between research on various characteristics of ageing and using the possibilities offered by the results of research and development of technology (Micera et al., 2008). This interdisciplinary field is devoted to “the study and design of technology and environments for independent living and quality of life of older adults” (Harrington & Harrington, 2000) for ensuring good health, full social participation, and independent living throughout the entire life span. “Ageing in place” and maintaining independence is very important for older people (Harrington & Harrington, 2000), and this approach can enable older people to stay active and independent (Künemund & Tanschus, 2013). Gerontechnology Five Ways’ approach addresses the technological challenges of ageing in society both for men and women are defined in terms of: 1) prevention, by delaying the onset of diseases, 2) to enhance the performance and opportunities of older citizens in new roles that fit with their ambitions; 3) to help compensate for, or 4) to help care for these types of issues and provide technical support (Fozard et al., 2000). A fifth goal is to encourage more research in this area. This approach is applied to

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various domains of living, including health, housing, personal mobility and transportation, communication and work, as well as leisure, learning and self-fulfilment (Fozard et al., 2000).

5.3 Previous EU-funded Initiatives

In the following section it is analysed a selection of the related EU-funded initiatives. The acronym projects have been categorized using the Five ways' approach, but also each category has been organized by the programme's name that funded each project (e.g. The H2020 "SOCIETAL CHALLENGES—Health, demographic change and well-being", the 7th Framework Programme (FP7), the Competitiveness and Innovation Framework Programme (CIP), and the Ambient Assisted Living (AAL) Joint Programme) which are the main EU funding programmes. It has been consulted three main resources such as: the AAL Joint Programme projects' database, AgeingWell projects database and CORDIS database.

5.3.1 Prevention

Prevention helps us to avoid injuries and slow down physical, mental and social decline (Harrington & Harrington, 2000; Parra et al., 2014). The projects addressed to prevention are promoting aspects as safety in home (e.g. smart living services, fall detection or support in emergency situations indoors), to improve safety mobility outdoors (travel planning, wayfinding, public transport mobility, etc.) physical activity (indoor or outdoor), cognitive and mental stimulation, nutrition (habits, shopping or cooking) or social interaction or participation by means of setting their own goals, monitoring patterns, behaviours or different types of activities and counselling to reduce sedentariness, cognitive decline, malnutrition, depression, isolation, loneliness, etc. These activities are mainly based on the implementation of ICT's systems at home such as: sensors (wearables able to collect and transfer only physio-pathological parameters and not wearables), devices (e.g. Internet enabled or Smart TVs, exer-games based on Wii Fit, Kinect, etc.), performed activities in PC, tablets or smartphones (social networking, Coaches or Avatars, APPs, games and interactives questionnaires focused on the cognitive decline assessment, nutrition, physical activity, etc.) or assistive robots (to support older people in different daily activities).

Some projects combine different domains as physical, cognitive and mental, nutrition and social interaction to promote active ageing and independent life as SAAPHO, DOREMI (Palumbo et al., 2017) or JOIN-IN.

Projects:

AAL Joint Programme:

2PCS (http://www.2pcs.eu)
A2E2 (http://www.aal-europe.eu/projects/a2e2)
AGNES (http://agnes-aal.eu)
AIB (http://www.aib.vtt.fi)
ALIAS (http://www.aal-alias.eu)
AMCO (http://www.ambient-concierge.eu)
AMCOSOP (http://www.amcosop.eu)
BREATHE (http://www.breathe-project.eu)
CaMeLi (http://www.cameli.eu)
CARE (http://www.care-aal.eu)
CARE@HOME (http://www.careathome-project.eu)
CHEFMYSELF (http://www.chefmyself.eu/)
CLOCKWORK (http://www.aal-europe.eu/projects/clockwork/)
COGNIWIN (http://www.cogniwin.eu)
CO-LIVING (http://www.project-coliving.eu)
DIET4ELDERS (http://www.diet4elders.eu/en)
DOSSY (http://www.dossy-aal.com)
ELDERHOP (http://www.elderhop.com)
ELF@HOME (http://www.elfathome.eu/)
EMOTIONAAL (http://www.emotionaal.eu)
ESTOCKINGS (http://www.e-stockings.eu)
FEARLESS (http://www.cogvis.at)

FIT4WORK (http://www.fit4work-aal.eu)
FOOD (http://www.food-aal.eu)
GAMEUP (http://www.gameupproject.eu)
GIVE&TAKE (http://www.givetake.eu)
HAPPY WALKER (http://www.aal-europe.eu/projects/happy-walker)
HEALTHY@WORK (http://www.youpers.ch)
HELICOPTER (http://www.aal-europe.eu/projects/helicopter/)
HEREIAM (http://www.hereiamproject.org)
HOPE (http://www.hope-project.eu)
INSPIRATION (http://www.youpers.ch/en)
IS-ACTIVE (http://www.is-active.eu)
JOIN-IN (http://www.join-in-for-all.eu)
M3W (http://m3w-project.eu/#sthash.iF7jN1BY.dpuf)
MOBECS (http://www.mobecs.eu)
MOBILE.OLD (http://www.mobiledotold.eu)
MOBILESAGE (http://www.mobilesage.eu)
MOTION (http://www.aal-europe.eu/projects/motion/)
MYGUARDIAN (http://www.myguardian-project.eu)
PAMAP (http://www.pamap.org)
SAAPHO (http://www.saapho-aal.eu)
SAFEMOVE (http://www.safemove-project.eu)
SOFTCARE (http://www.softcare-project.eu)
SONOPA (http://www.sonopa.eu)
STAYACTIVE (http://www.stay-active.net)
TRAINUTRI (http://www.trainutri.com)
TRANS.SAFE (http://www.TransSafe.eu)
WELLBEING (http://www.wellbeing-project.eu).

FP6-IST:

DIADEM (http://www.project-diadem.eu/)

FP7:

AISENSE (http://web.itu.edu.tr/hulyayalcin/AISENSE.htm)
CAPSIL (http://www.capsil.org/),
CONFIDENCE (http://www.confidence-eu.org/),
DALI (http://www.ict-dali.eu/dali/)
DOREMI (http://www.doremi-fp7.eu/),
FARSEEING (http://farseeingresearch.eu/)
GIRAFF+ (http://www.giraffplus.eu/)
HERMES (http://www.fp7-hermes.eu/),
ISTOPPFALLS (http://www.istoppfalls.eu/cms/front_content.php)
MOBISERV (http://www.mobiserv.info/)
PERSSILAA (https://perssilaa.com/)
SMILING (http://www.smilingproject.eu/),
WIISEL (http://www.wiisel.eu/)

H2020:

MINDMAP (http://www.mindmap-cities.eu/)
MOsteoDD (http://www.bonevitae.pl/)
MY-AHA (http://myactiveageing.eu/)
PROMISS (http://www.promiss-vu.eu/senior/)
Sense-Cog (http://www.sense-cog.eu/)

CIP-ICT:

CAALYX-MV (http://www.caalyx-mv.eu/project)
DREAMING (http://www.dreaming-project.org/)
Home Sweet Home (http://www.homesweethome-project.be/)
Long Lasting Memories (http://www.longlastingmemories.eu/)
UNCAP (http://www.uncap.eu/)
VitalMind(VM) (http://dcgi.fel.cvut.cz/en/research/vital-mind-vm#vital-mind-vm)

5.3.2 Compensation

Compensation projects are aimed to either reduce the impact of the declined capability or to partially and artificially replace a not available capability (inborn or due to injuries or illnesses) (Harrington & Harrington, 2000; Parra et al., 2014).

When an impairment or disability can no longer be prevented or cured, compensation projects could reduce the impact of the declined capability, or to partially and artificially replace a not available capability, but also are giving support of older people daily activities promoting of time individuals may continue to live independently. The most common health conditions in the projects are chronic diseases as: cardiovascular diseases (stroke), neurodegenerative (e.g., Alzheimer, Parkinson, Dementia, etc.), respiratory diseases (COPD, asthma). But also, projects are addressed to disabled elderly (with hear or visual impairments).

The projects addressed to disabled people give services in: safety in home (navigation systems, support in emergency situations indoors, etc.), mobility safety (localization and mobility services), physical activity (indoor or outdoor), care (medication management, tele-care, support to informal caregivers, and coordination with formal carers), cognition stimulation and support to daily activities. These activities are mainly based on the implementation of ICT's systems such as: sensors (wearables able to collect and transfer only physio-pathological parameters and not wearables), devices (e.g. capacitive sensors, Internet enabled or Smart TVs, exer-games, hearing-glasses, lighting technologies to way-guidance systems), performed activities in PC, tablets or smartphones (navigation systems, videoconferencing, social networks, games, voice controlled assistive care, audio-tagging improve cognition and interactives questionnaires focused on the nutrition, physical activity or cognitive decline diagnosis, assessment, etc.) or assistive robots (to support older people in different daily activities or as a virtual companions) or mobility help (open walkers platforms, personal mobility toolkits for electronic powered wheelchairs and exoskeletons).

Projects:

AAL Joint Programme:

AHEAD (http://www.ahead-project.eu)
ALICE (http://www.alice-project.eu)
ALMA (http://www.aal-europe.eu/projects/alma)
ASSAM (http://www.assam-project.eu)
AXO-SUIT (http://www.aal-europe.eu/projects/axo-suit/)
BEDMOND (http://www.bedmond.eu)
CAPMOUSE (http://www.brusell-dental.com/aal)
COM'ON (http://www.comon.lu)
CONFIDENCE (http://www.salzburgresearch.at/en/projekt/confidence_en)
DOMEO (http://www.aal-domeo.eu)
E-MOSION (http://www.emosion-project.eu)
ESTOCKINGS (http://www.e-stockings.eu)
EXO-LEGS (http://www.exo-legs.org)
GETVIVID (http://www.getvivid.eu/)
GUIDING LIGHT (http://guiding-light.labs.fhv.at/Site_2/GUIDING_LIGHT.html)
HAPPY AGEING (http://www.happyageing.info)
HELICOPTER (http://www.aal-europe.eu/projects/helicopter/)
HERA (http://www.aal-europe.eu/projects/hera)
HMFM (http://www.aal-europe.eu/projects/hear-me-feel-me)
ICITYFORALL (http://www.icityforall.eu)
IMAGO (http://www.aal-imago.eu)
IRONHAND (http://www.ironhand.eu)
IWALKACTIVE (http://www.ihomelab.ch/index.php?id=20)
MOBILESAGE (http://www.mobilesage.eu)
MYGUARDIAN (http://www.myguardian-project.eu)
MYLIFE (http://www.karde.no/MYLIFE_english.html)
NAVMEM (http://www.navmem.eu)
NITICS (http://www.aal-europe.eu/projects/nitics)
OSTEOLINK (http://www.osteolink.org)
REMOTE (http://www.remote-project.eu)
SHIEC (http://www.shiec.eu)
YOUDO (http://www.aal-europe.eu/projects/youdo/)

FP7:
GUIDE (http://www.guide-project.eu)
WALKX (https://cordis.europa.eu/project/rcn/97884_en.html)
CIP-ICT:
DIADEM (http://www.project-diadem.eu/)
ISISEMD (http://www.isisemd.eu/)
ISISEMD (http://www.isisemd.eu/)
NEXES (http://www.nexeshealth.eu/)

5.3.3 Care

Care projects are aimed at giving support or assistance to recover from an incident or to reduce the impact of a chronic condition (Harrington & Harrington, 2000; Parra et al., 2014).

When an impairment or disability can no longer be prevented or cured, these projects are giving answer to older peoples' needs to help them in chronic disease management (tele-monitoring, tele-care, lifestyle monitoring to detect changes in patterns and behaviours and communication with other patients and carers) and in daily activities when they are dependent, but also giving support to caregivers (awareness services, e-learning, networking, etc.). These activities are mainly based on the implementation of ICT's systems such as: sensors (wearables able to collect and transfer only physio-pathological parameters and not wearables), devices (e.g. Internet enabled or Smart TVs, virtual reality, etc.), performed activities in PC, tablets or smartphones (navigation systems, visual stimulation, social networks, videoconferencing, games, voice controlled assistive care, intelligent dashboard systems for multi-stakeholders) or assistive robots (to support older people in different daily activities or as a virtual companions or personal assistants).

Projects:

AAL Joint Programme:
AALUIS (http://www.aaluis.eu)
ACCESS (http://www.aal-europe.eu/projects/access/)
ALADDIN (http://www.aal-europe.eu/projects/alladin)
ALFA (http://www.aal-alfa.eu)
ALIAS (http://www.aal-alias.eu)
AMICA (http://www.aal-europe.eu/projects/amica)
BREATHE (http://www.breathe-project.eu)
CARE4BALANCE (http://www.aal-care4balance.eu)
CCE (http://www.cceproject.eu)
DALIA (http://www.dalia-aal.eu)
ECAALYX (http://www.aal-europe.eu/projects/ecaalyx)
ECH (http://www.WellTogether.eu)
GOLDUI (http://www.goldui.eu)
H@H (http://www.health-at-home.eu)
HELICOPTER (http://www.aal-europe.eu/projects/helicopter/)
HELP (http://www.aal-europe.eu/projects/help)
ICARER (http://icarer-project.azurewebsites.net/)
IS-ACTIVE (http://www.is-active.eu)
KNOTS (http://www.knots-project.eu).
LILY (http://www.aal-europe.eu/projects/lily/)
PIA (www.pia-project.org)
RELAXEDCARE (www.relaxedcare.eu)
REMOTE (http://www.remote-project.eu)
RGS (http://rgs-project.upf.edu)
ROSETTA (http://www.aal-rosetta.eu)
SALIG++ (http://salig.eu/aal-europe/)
STIMULATE (http://www.stimulate-aal.eu)
TOPIC (www.topic-aal.eu)
UNDERSTAID (www.understAID.com)
VICTORYAHOME (http://www.victoryahome.com)
WAYFIS (http://www.wayfis.eu)
WETAKECARE (www.wetakecare.ibv.org/)
H2020:

MARIO (http://www.mario-project.eu/portal/)
SUSTAIN (http://www.sustain-eu.org/)

CIP-ICT:

NEXES (http://www.nexeshealth.eu/)
ISISEMD (http://www.isisemd.eu/)

FP7:

PHS FORESIGHT (http://www.phsforesight.eu/)

5.3.4 Enhancement

Enhancement projects are aimed to create new opportunities, extent existing capabilities and help people gain new capabilities (Harrington & Harrington, 2000; Parra et al., 2014).

In the category of enhancement projects, it has been included those projects aimed to promote social interaction and activation (social volunteering, banking and shop services, intergenerational interactions, etc.), but also based on mentoring and intergenerational sharing and transfer knowledge for older workforce, entertainment and training activities (Self-care management, etc.) to increase well-being and reduce stress. These activities are mainly based on the implementation of ICT's systems such as: sensors (wearables able to collect and transfer only physio-pathological parameters and not wearables), devices (e.g. videoconferencing, Internet enabled or Smart TVs with set-top boxes for remote control unit with gesture recognition, video and audio to capture capabilities, 3D virtual environments, etc.), performed activities in PC, tablets or smartphones (social communities, networking or training platforms, navigation systems, visual stimulation, social networking, games, avatars) or assistive robots (to support older people in different daily activities or as a virtual companions or personal assistants).

Projects:

AAL Joint Programme:

3rD-LIFE (http://www.3rd-life.eu)
ACTGO-GATE (http://www.actgo-gate.eu)
ACTIVE@WORK (http://www.activeatwork.eu)
ALIAS (http://www.aal-alias.eu)
ALICE (www.aal-alice.eu)
ANIMATE (www.animate-aal.eu)
ASSISTANT (http://www.aal-assistant.eu)
AWARE (aware.ibv.org)
BANK4ELDER (http://www.bank4elder.eu)
BREATHE (http://www.breathe-project.eu)
CaMeLi (http://www.cameli.eu)
CARE@HOME (www.careathome-project.eu)
CARERSUPPORT (www.carersupport.eu)
CHEFMYSELF (http://www.chefmyself.eu/)
CO-LIVING (http://www.project-coliving.eu)
COM'ON (www.comon.lu)
CVN (http://www.connectedvitality.eu)
E2C (www.express2connect.org)
EASYREACH (http://www.easyreach-project.eu)
EDLAH (www.edlah.eu)
ELDER-SPACES (www.elderspaces.eu)
ELDERS-UP! (http://www.eldersup-aal.eu)
ENTRANCE (www.entrance.fr)
ExCITE (http://www.excite-project.eu)
EXPACT (www.expact.eu)
FAMCONNECTOR (www.famconnector.mygrandchild.com)
FOSIBLE (http://fosible.eu)
GAMEUP (http://www.gameupproject.eu)
GO-MYLIFE (http://gomylife-project.eu)
HAPPY WALKER (http://www.aal-europe.eu/projects/happy-walker)
HELASCOL (www.helascol.eu)
HEREIAM (www.hereiamproject.org)
HOMEDOTOLD (http://www.homedotold.eu)

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HOPES (www.hopes-project.org)
HOST (www.host-aal.eu)
ICITYFORALL (http://www.icityforall.eu)
INCLUSIONSOCIETY (www.inclusionSociety.com)
INSPIRATION (www.youpers.ch/en)
JOIN-IN (http://www.join-in-for-all.eu)
LETITFLOW (http://www.letitflow-project.com)
LILY (http://www.aal-europe.eu/projects/lily/)
MEDIATE (www.mediate-aal.eu)
NACODEAL (http://www.nacodeal.eu/en)
NOBITS (http://www.aal-europe.eu/projects/nostalgia-bits)
OSTEOLINK (www.osteolink.org)
PAELIFE (www.PaeLife.eu)
PEARL (www.pearl-project.eu)
PEERASSIST (http://cnl.di.uoa.gr/peerassist)
PROME (http://pro-me.eu)
REVOLUTION (www.youpers.ch)
SAAPHO (http://www.saapho-aal.eu)
SAFEMOVE (http://www.safemove-project.eu)
SENIORCHANNEL (http://innovation-labs.com/seniorchannel)
SENIORENGAGE (http://www.seniorengage.eu)
SENIORLUDENS (http://www.seniorludens.eu)
SILVERGAME (www.silvergame.eu)
SI-SCREEN (www.si-screen.eu)
SOCIALIZE (http://www.aal-europe.eu/projects/socialize)
SOMEDALL (http://somedall.vtt.fi)
SONOPA (www.sonopa.eu)
SOPHIA (http://www.sophia-aal.eu)
SPONSOR (http://sponsor-aal.eu)
STIMULATE (http://www.stimulate-aal.eu)
T&TNET (http://ttnet-aal.eu)
TAO (http://www.thirdageonline.eu)
TRAINUTRI (www.trainutri.com)
V2ME (www.v2me.org)
VASSIST (http://vassist.cure.at)
VIRGILIUS (www.virgilius.eu)
WECARE (www.wecare-project.eu)
WETAKECARE(www.wetakecare.ibv.org/)
YOUDO (http://www.aal-europe.eu/projects/youdo/)

FP7

DOREMI (http://www.doremi-fp7.eu)

CIP-ICT:

SOCIABLE (http://www.cognitivetraining.eu/)
T-Seniority (http://tseniority.idieikon.com/)

The listed projects in each category address specific problems in the different technology areas, such as sensor systems, monitoring, tele-health, social networks, etc.; however, there are few projects that have a holistic person centred approach that combines all the domains.

Projects in areas as Care or Compensation were specifically designed to support elderly people in the management of chronic diseases and co-morbidities in the areas of cardiovascular, neurodegenerative (e.g., Parkinson, Alzheimer, Dementia), and respiratory diseases, cardiovascular or metabolic conditions, or neurodegenerative (as Alzheimer or Dementia). Projects in Preventive or Enhancement area were mainly targeted to healthy older people, although there are a few lists of projects addressed to chronic patients which were adding social participation tools and improvement of their skills.

Personal and environmental data collection was used in the development of the projects' monitoring systems, especially in the case of home-based scenarios and less in senior housing or nursing homes.

There are few projects that use virtual coaches acting as friend in a para-social relationship, but also as mentor that helps the elderly end-user to create meaningful relationships in their actual social environment are a powerful method to overcome loneliness and increase the quality of life in the elderly population. The AAL Joint Programme projects A^2E^2 (AAL-2008-1-071) and V2me (AAL-2009-2-107) are exploring virtual coaches and their application in AAL scenarios, including the adoption of user avatars, virtual self-representations that allow the user to be represented in communication scenarios. Other European research projects that focus on social integration of the elderly are e.g. ALICE (AAL-2009-2-091) or WeCare (AAL-2009-2-026) (Braun et al., 2012).

6. The NESTORE Model of Healthy Ageing

6.1 Systematic Description of the NESTORE Model

The NESTORE model is aimed at providing a structured knowledge, built on the expertise of the NESTORE experts (exercise physiologists, nutritionists, psychologists, geriatricians), able to characterize the person in terms of both status and behaviour. In NESTORE **the final user is an older adult which is living by their own (at home or assisted home living), male or female, from 65 to 75 years old, mainly retired or recently retired, with an autonomous life and interested in maintaining or promoting her/his wellbeing and quality of life**.

Based on this user definition, NESTORE describes the person considering a multi-domain model, composed of the different dimensions related to well-being: Physiological status and Physical Activity Behaviour, Nutrition, Cognitive and Mental Status and Social Behaviour.

This section is composed of three subsections, describing the model of the three well-being domains.

Each domain is subdivided in its subdomains; for each subdomain a table containing the variables useful for the characterization and monitoring of the person in that subdomain is provided, following by the synthetic description of the variable meaning; a figure reporting the relationships among the subdomain variables is then reported (solid arrows = direct causal relationship, dashed arrows = indirect causal relationship, dotted arrows = correlation between). After the subdomains description, for each domain, schemes describing the variables relationships within each subdomain and the other subdomains are provided (solid arrows = direct causal relationship, dashed arrows = indirect causal relationship, dotted arrows = correlation between).

The full description of the model for each domain is provided in separated annexes:
Annex 1: Physiological status and Physical Activity Behaviour
Annex 2: Nutrition
Annex 3: Cognitive and Mental Status and Social Behaviour

Each Annex contains:

a) **Description of the Domain Variables useful for the characterization and monitoring of the person**. This part is specifically aimed to support the development of ontology in Task 2.5.

b) **Relationships among the domain variables and variable ranges and/or trends** corresponding to normal ageing status and behaviour. This part is specifically thought for the ontology and to support WP4 in the development of the Decision Support System.

c) **Measurement scenarios of the system variables**. This part provides the functional system requirements from the point of view of the domain experts, in support to WP3 and WP5, for the development of the monitoring system.

d) **Measurement scenarios for variables related to validation.** This part is thought to support the definition of the Virtual Coach Validation Plan to be used in the pilots to assess the impact and the functional effectiveness of the Virtual Coach on the elderly subjects' status and behaviour (Task 2.6).

e) **Scientific references** on which the domain information is based**.**

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6.1.1 Physiological Status and physical activity behaviour

Taking into account the information defined in the previous chapters, the physiological status and physical activity behaviour domain has been organized in four subdomains: 1) **Anthropometric Characteristics**, which contains a detailed description of the main anthropometric variables describing body dimensions and relationship among them; 2) **Cardiovascular System**, which contains a detailed description of the main physiological variables that influence transport of nutrients, oxygen, carbon dioxide, hormones, and blood cells from the lungs to peripheral tissue and vice versa; 3) **Respiratory System**, which contains a detailed description of the main physiological variables related to structure and function of the organs designated to exchange blood gases between ambient air and blood cells; 4) **Musculoskeletal System** , which contains a detailed description of the main physiological variables related to the ability of skeletal muscle to generate force and power. Moreover, this section includes a description of the variables describing the ability of a subject to perform exercise limited from cardiorespiratory system (**Cardiorespiratory Exercise Capacity**) or musculoskeletal system (**Strength-Balance-Flexibility Exercise Capacity**) as well as the usual behaviour of a subject during every-day life (**Physical activity Behaviour**). A description of the main factors related to sleep (**Sleep Quality**) has been also included in this section.

This structure will help NESTORE decision support system in the application of an individualized guidelines and it will improve the understanding about specific effects of the different interventions.

Anthropometric characteristics

Table 3. List of the Anthropometric Characteristics Subdomain Variables

VARIABLE NAME	ACRONYM	TO BE USED IN SYSTEM/PILOT
BODY HEIGHT	BH	System + Pilot
BODY WEIGHT	BW	System + Pilot
BODY MASS INDEX (BMI)	BMI	System + Pilot
FAT MASS	FM	System + Pilot
FAT-FREE MASS	FFM	System + Pilot
HIP CIRCUMFERENCE	HC	System + Pilot
WAIST CIRCUMFERENCE	WC	System + Pilot
WAIST-TO-HEIGHT RATIO	WHtR	System + Pilot
WAIST-TO-HIP RATIO	WHR	System + Pilot

Body height (BH): Standing height of the person, corresponding to the maximum vertical size.

Body weight (BW): Body mass of the person.

Body mass index (BMI): BMI is a weight-for-height index. It is calculated by dividing the subject's weight (kg) by the square of their height (m). Currently, the BMI criteria proposed by WHO are the most widely used. Evidence suggests that the risk of finding oneself at the extremes of the body mass index (either underweight or obese), increases along with age.

Fat mass (FM): Body weight corresponding to fat mass (expressed in Kg and percentage of body weight). Ageing is frequently associated with a gradual increase of fat mass (FM), which has a negative impact on health outcomes, such as morbidity, mortality and quality of life. Elevated fat mass may simultaneously occur in the presence of normal or low fat-free mass (also termed sarcopenia). The double burden of excess FM and low FFM may lead to decreased physical functioning in comparison to those with normal body composition.

Fat-free mass (FFM): FFM, also known as lean body mass, refers to all of the body components except fat. It includes body's water, bone, organs and muscle content. However, when it comes to weight management and body composition, fat-free mass refers primarily to muscle mass.

Hip Circumference (HC): Hip circumference is usually assessed in manual measurements with flexible but non-stretchable tapes at the level of the largest lateral extension of the hips in a horizontal plane. It is considered an indicator of abdominal obesity and it may be a better predictor of risk than the BMI for several diseases, including cardiovascular disease (CVD), cancer, type 2 diabetes, and the Metabolic Syndrome.

Waist Circumference (WC): It is the perimeter of the abdomen, measured at the mid-point between the lower rib and the iliac crest, at a level parallel to the floor. Waist circumference is a better measure of visceral (abdominal) obesity than BMI. Visceral obesity is closely related with comorbidities and with the presence of metabolic syndrome.

Waist-to-height ratio (WHtR): Waist to height ratio is a simple measurement for assessment of lifestyle risk and overweight. Compared to just measuring waist circumference, waist to height ratio is equally fair for short and tall persons. Measuring waist to height ratio is gaining popularity in the scientific society as several studies have found that this is a more valid measurement than BMI. Just measuring waist circumference is inherently biased for people taller or shorter than average population.

Waist-to-hip ratio (WHR): Waist to hip ratio is another simple measurement for assessment of lifestyle risk and overweight (see WHtR).

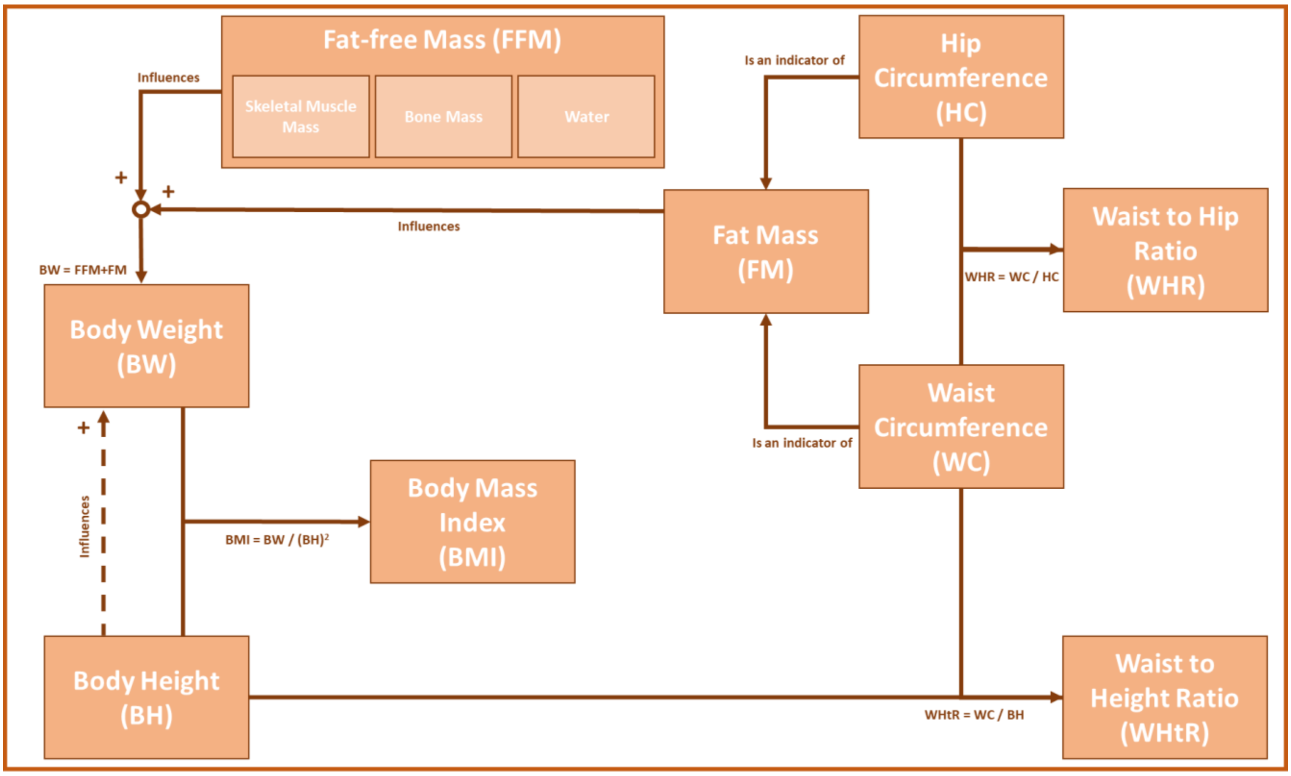


Figure 4 Relationship among variables in the subdomain "Anthropometric Characteristics" (System variables in orange, Pilot variable in Yellow).

Cardiovascular system

Table 4. List of the Cardiovascular System Subdomain Variables

VARIABLE NAME	ACRONYM	TO BE USED IN SYSTEM/PILOT
BLOOD PRESSURE	BP	System + Pilot
CARDIAC OUTPUT	CO	Pilot
HEART RATE	HR	System + Pilot
HEART RATE VARIABILITY	HRV	System + Pilot
STROKE VOLUME	SV	Pilot

Blood Pressure (BP): BP is the pressure of circulating blood on the walls of blood vessels. Blood pressure is usually expressed in terms of the **systolic pressure** (SP) (maximum during one heart beat) over **diastolic pressure** (minimum in between two heart beats). The **mean arterial pressure** (MAP) is the average over a cardiac cycle and is determined by the cardiac output, systemic vascular resistance, and central venous pressure. It can be also derived from systolic and diastolic blood pressure. The **pulse pressure** (PP) is the difference between the measured systolic and diastolic pressures. It results from the fluctuation of the arterial pressure due to the pulsatile nature of the cardiac output.

Cardiac Output (CO): CO is the amount of blood pumped by the heart per minute. In the NESTORE model, CO is composed by the **resting Cardiac Output** (rCO) and the **maximal Cardiac Output** (MCO) that are measured at rest and after a maximal exercise respectively. Despite the cardiac ageing changes that may limit a person’s functional capacity and promote vascular stiffening with consequent increased afterload, the overall resting systolic function of cardiac muscle does not change with healthy ageing.

Heart Rate (HR): HR is the number of times the heart beats per minute. A normal **resting Heart Rate** (rHR) is between 60 and 100 beats per minute (bpm). However, it will vary depending on when it is measured and what you were doing immediately before the reading. For example, it will be higher when a subjects is walking compared to when he/she is sitting or resting. This is because the body needs more energy when it is active. In the NESTORE system, the HR is also described as **Maximal/Peak Heart Rate** (MHR/PHR) when it is related to the maximal HR and **exercise Heart Rate** (eHR) when it is measured during exercise.

Heart Rate Variability (HRV): HRV is the degree of fluctuation in the length of the intervals between either heart beats or the duration of the R-R interval (the time between two successive R waves in a typical electrocardiogram). These temporal fluctuations in heart rate exhibit a marked synchrony with respiration (increasing during inspiration and decreasing during expiration) and are widely believed to reflect changes in cardiac autonomic regulation. HRV has been established as a non-invasive tool to study cardiac autonomic activity and has been proposed as a predictor of increased risk for cardiac mortality.

Stroke Volume (SV): Stroke Volume (SV) is the volume of blood in millilitres ejected from each ventricle due to the contraction of the heart muscle which compresses these ventricles. SV is the difference between end diastolic volume (EDV) and end systolic volume (ESV). Thus, SV is not all the blood contained in the left ventricle; normally, only about two-thirds of the blood in the ventricle is expelled with each beat. It is commonly accepted that, during incremental, upright exercise to maximum, SV increases from rest to exercise and plateaus at 40–50% of VO2max.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 769643

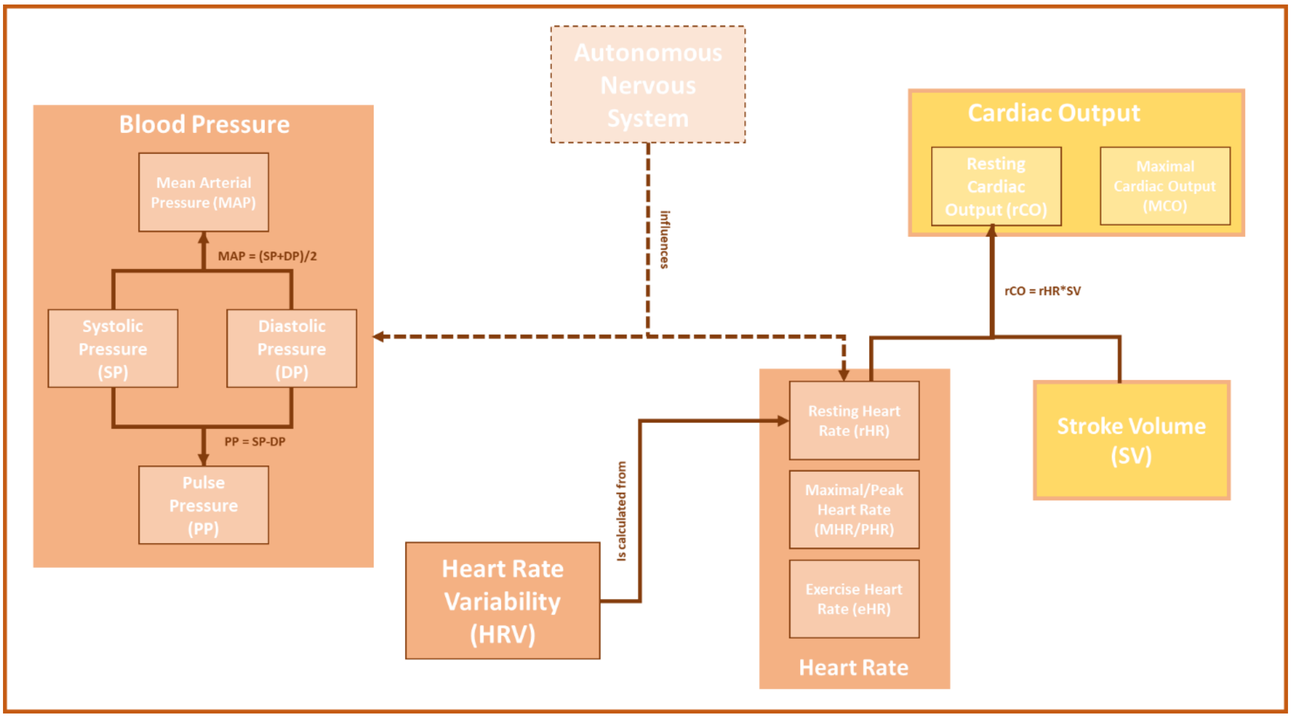


Figure 5 Relationship among variables in the subdomain "Cardiovascular System" (System variables in orange, Pilot variable in Yellow). Please note that "Autonomous Nervous System" is not explicitly considered in the NESTORE model.

Respiratory system

Table .5 List of the Respiratory System Subdomain Variables

VARIABLE NAME	ACRONYM	TO BE USED IN SYSTEM/PILOT
DYNAMIC LUNG VOLUMES	DLV	Pilot
OXYGEN SATURATION	SO_2	System + Pilot
RESPIRATORY MUSCLE PERFORMANCE	RMP	Pilot
BREATH FREQUENCY	BF	System + Pilot
PULMONARY VENTILATION	VE	Pilot
STATIC LUNG VOLUMES	SLV	Pilot

Dynamic Lung Volume (DLV): Lung volumes that depend upon the rate at which air flows out of the lungs are termed DLV. The **Forced Vital Capacity** (FVC) is the volume of gas that can be exhaled as forcefully and rapidly as possible after a maximal inspiration. Normally FVC is equal to Vital Capacity, however in certain pulmonary diseases (characterized by increased airway resistance), FVC is reduced. From the FVC test, we can also determine the **Forced Expiratory Volume in 1 sec** (FEV1), which is the maximum volume of air that can be exhaled in a 1 sec time period. Normally the percentage of the FVC that can be exhaled during 1 sec is around 80% (i.e. FEV1/FVC=80%). **Maximum Voluntary Ventilation** (MVV) is the largest volume of air that can be breathed in and out of the lungs in 1 minute. It will be reduced in pulmonary diseases due to increases in airway resistance or changes in compliance.

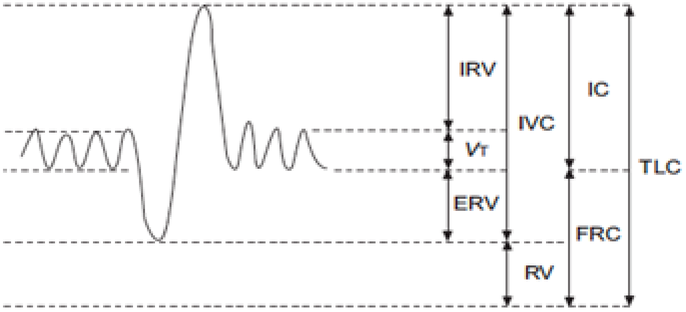
Oxygen Saturation (SO_2): SO_2 is the fraction of oxygen-saturated haemoglobin relative to total haemoglobin (unsaturated + saturated) in the blood. The oxygen concentration of systemic arterial blood depends on several factors, including the partial pressure of inspired oxygen, the adequacy of ventilation and gas exchange, the concentration of haemoglobin and the affinity of the haemoglobin molecule for oxygen.

Respiratory Muscle Performance (RMP): RMP is the performance of the skeletal muscles involved in the respiratory activity. Respiratory muscle performance is impaired concomitantly by the age-related geometric modifications of the rib cage, decreased chest-wall compliance, and increase in functional residual capacity (FRC) resulting from decreased elastic recoil of the lungs. Age-associated alterations in skeletal muscles also affect respiratory muscle function. **Maximal Inspiratory Pressure** (MIP) and **maximal Expiratory Pressure** (MEP) in elderly subjects are correlated strongly and independently with peripheral muscle strength.

Breath Frequency (BF): BF (also known as **Respiratory Rate** (RR)) is the rate at which breathing occurs and it is usually measured in breaths per minute. In the NESTORE model, BF is composed by **resting Breath Frequency** (BF_{rest}) and **exercise Breath Frequency** (eBF). BF_{rest} is measured at rest whilst eBF is measured during exercise. Older adults may have an increased respiratory rate to compensate for the decrease in **Tidal Volume** (TV) that is the normal volume of air displaced between normal inhalation and exhalation. Recent studies report that high respiratory rates (>27 breaths per minute) have been shown to have a high predictive value for serious adverse events, including cardiac arrest in hospital patients; respiratory rates may be more sensitive than pulse or blood pressure in determining critically ill patients.

Pulmonary Ventilation (VE): VE is the amount of gas inhaled or exhaled from a person's lungs in one minute. If both TV and BF are known, pulmonary ventilation can be calculated by multiplying the two values. PV can be measured at rest and is defined as **resting Pulmonary Ventilation** (PV_{rest}) or it can be measured during a maximal exercise and it is defined as **maximal Pulmonary Ventilation** (VE_{max}).

Static Lung Volumes (SLV): SLV measurements provide useful information about the overall lung function that can be fundamental in categorizing and staging pulmonary diseases. **Vital capacity** (VC/IVC) is the amount of air expired or inspired between maximum inspiration and expiration. **Residual volume** (RV) is the volume of air remaining in the lungs after maximal expiration, and, by definition, cannot be measured by classic spirometry but an inert gas (i.e. Helium) is needed. **Functional residual capacity** (FRC) is the amount of air in the lungs at the end-tidal position. **Total lung capacity** (TLC) is the amount of air in the chest after a maximum inspiration. **Inspiratory capacity** (IC) is the volume of gas that can be taken into the lungs in a full inhalation, starting from the resting inspiratory position; equal to the tidal volume plus the inspiratory reserve volume. **Expiratory reserve volume** (ERV) is the additional amount of air that can be expired from the lungs by determined effort after normal expiration. **Inspiratory reserve volume** (IRV) is the maximal amount of additional air that can be drawn into the lungs by determined effort after normal inspiration.



Static lung volumes and capacities based on a volume–time spirogram of an inspiratory vital capacity (IVC). IRV: inspiratory reserve volume; V_T: tidal volume (TV); ERV: expiratory reserve volume; RV: residual volume; IC: inspiratory capacity; FRC: functional residual capacity; TLC: total lung capacity.

Adapted from Wanger et al., 2005

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 769643

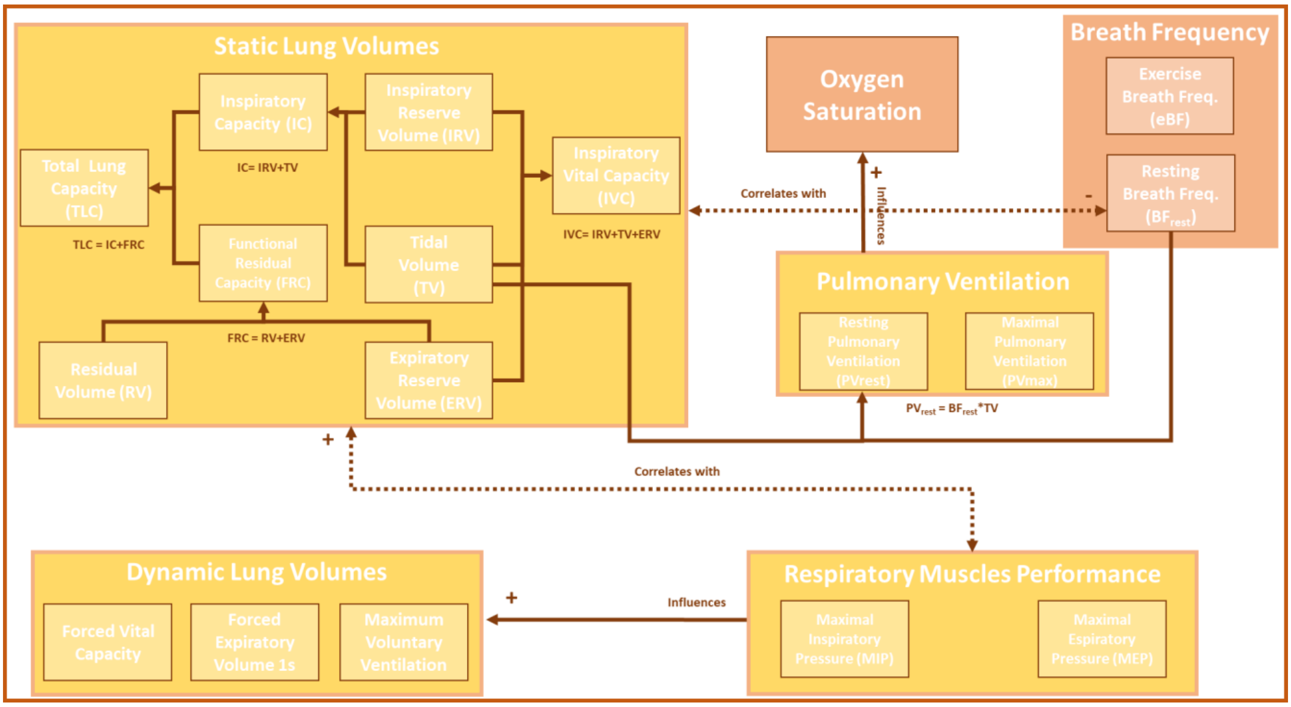


Figure 6 Relationship among variables in the subdomain "Respiratory System" (System variables in Orange, Pilot variable in Yellow).

Musculoskeletal system

Table 6 List of the Musculoskeletal System Subdomain Variables

VARIABLE NAME	ACRONYM	TO BE USED IN SYSTEM/PILOT
MUSCLE CROSS SECTIONAL AREA	CSA	System + Pilot
MUSCLE PHYSIOLOGICAL CROSS SECTIONAL AREA	PCSA	Pilot
MUSCLE MASS	MS	System + Pilot
MUSCLE THICKNESS	MT	Pilot
PENNATION ANGLE	PA	Pilot
RANGE OF MOVEMENT	ROM	System + Pilot

Muscle Cross-Sectional Area (CSA): Anatomical CSA is the area of the cross section of a muscle perpendicular to its longitudinal axis.

Muscle Physiological Cross-Sectional Area (PCSA): PCSA is the area of the cross section of a muscle perpendicular to its fibres, generally at its largest point. This variable is more directly related to muscle strength than CSA.

Muscle Mass (MS): MS is the body weight corresponding to total skeletal muscle mass (expressed in Kg and percentage of body weight). Assuming that the prevalence of sarcopenia will be very low within Nestore user's, the importance of measuring skeletal muscle mass lies in the assessment of body weight loss in obese users, since weight loss has to be at the expense of fat mass but conserving muscle mass, or the assessment of body composition changes across time (i.e. loss of muscle mass across time). Muscle mass is reduced with ageing and the consequences can be extensive because there is an increased susceptibility to falls and fractures, impairment in the ability to thermoregulation, a decrease in basal metabolic rate, as well as an overall loss in the functional ability to perform daily tasks.

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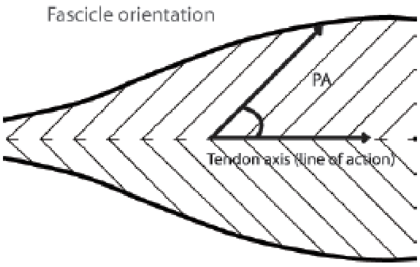
Muscle Thickness (MT): Muscle thickness is the thickness of the muscle.

Pennation Angle (PA): PA is defined as the angle between the orientation of a fascicle and the attached tendon axis. Since fascicles have variable length and arrangement within a muscle, the associated PA differs from fascicle to fascicle. Due to the limited visibility and image resolution, radiological assessments, such as magnetic resonance imaging (MRI) and ultrasonography, yield only an average measurement of PA for an entire muscle. In practice, PA is measured as the acute angle between two intersecting lines representing fascicle orientation and a deep aponeurosis.



Range Of Movement (ROM): ROM is a description of how much movement exists at a joint. Rotation is the typical movement at a joint. This is called "angular" movement. Because the movement is angular, the unit "degree" is used when measuring ROM rather than inches or millimetres. ROM can be measured as either active or passive. Active ROM is created by the person contracting the muscles around that joint. Passive ROM is created by an external force pushing on the body around the joint. Passive ROM is always greater than active ROM. ROM is used to evaluate and classify joints impairments in patients or the efficacy of certain rehabilitation program. It is well recognized that proprioceptive function is crucially important for balance, posture, and motor control.

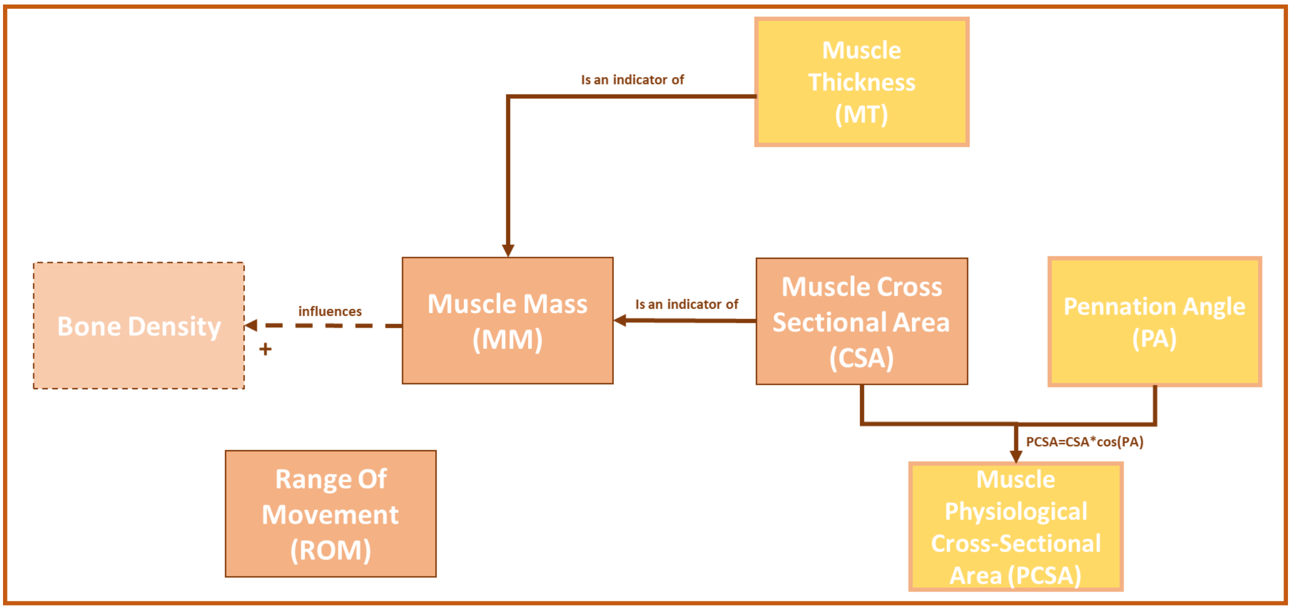


Figure 7 Relationship among variables in the subdomain "Musculoskeletal System" (System variables in Orange, Pilot variable in Yellow). Please note that" bone density" is not explicitly considered in the NESTORE model.

Cardiorespiratory exercise capacity

Table 7. List of the Cardiorespiratory Exercise Capacity Subdomain Variables

VARIABLE NAME	ACRONYM	TO BE USED IN SYSTEM/PILOT
AEROBIC FITNESS	VO_2max	System + Pilot
ANAEROBIC THRESHOLD	AT	System + Pilot
CARDIOVASCULAR FITNESS	CF	Pilot
CARDIAC OUTPUT VS EXERCISE INTENSITY SLOPE (CO-VO2)	$CO\text{-}VO_2$	Pilot
CLINICAL AEROBIC FITNESS	CAerF	System + Pilot
EXERCISE HEART RATE	eHR	System + Pilot
HR RESERVE	HRR	System + Pilot
HABITUAL WALKING SPEED	HWS	System + Pilot
MAXIMAL CARDIAC OUTPUT	COmax	Pilot
MAXIMAL AND PEAK HEART RATE	MHR/PHR	System + Pilot
MAXIMAL PULMONARY VENTILATION	MPV	Pilot
POST-EXERCISE HEART RATE RECOVERY	HRRec	System + Pilot
TARGET HEART RATE	tHR	System + Pilot
VO2 RESERVE	VO_2R	Pilot
VO2 REST	VO_{2rest}	Pilot

Aerobic Fitness (VO_2 max): Maximal oxygen uptake capacity (VO2max) is the highest rate of oxygen consumption that one can attain while performing an exercise test of progressively increasing intensity that requires a large proportion of the total skeletal muscle mass. VO2max is determined by the capacity of the cardiovascular system to deliver oxygen to the working muscles and the capacity of the muscles to extract oxygen from the blood and to utilize it to generate ATP via oxidative metabolism. VO2max is therefore a function of both maximal cardiac output (MCO) and maximal arteriovenous oxygen difference.

Anaerobic Threshold (AT): During incremental exercise, work intensities are reached at which ventilation increases disproportionately with respect to O_2 uptake (VO_2) and lactate accumulates in the blood. The VO_2, at which either or both of these phenomena are observed has been termed ventilator or lactate AT, respectively.

Cardiovascular fitness (CF): CF is the ability of the heart, blood cells and lungs to supply oxygen-rich blood to the working muscle tissues and the ability of the muscles to use oxygen to produce energy for movement.

Clinical Aerobic Fitness (CAerF): It is the clinical correlates to the aerobic fitness. Muscle power and exercise capacity determine the overall CAerF of a subject. Ageing results in an important decrease of CAerF, therefore, older adults often function at the limit of their capacity in order to fulfil the activities of daily living.

Cardiac output vs exercise intensity slope ($CO\text{-}VO_2$): This variable is the slope of oxygen uptake versus exercise intensity curve. Systemic oxygen delivery (cardiac output) increases in proportion to exercising muscle oxygen consumption and is closely coupled to the increase in exercising muscle blood flow (eMBF). The steepness of the slope is a valid measurement of oxygen flow to the exercising tissues.

Exercise Heart rate (eHR): It represents the HR measured during exercise. The potential of eHR to be used as a valid exercise intensity indicator warrants the establishment of the individual relationship between VO_2 and heart rate and the precision of this technique depends on the robustness of the regression line. The precision of the VO_2 over exercise intensity regression is well- described and accepted during treadmill running/walking and cycling. In some cases, VO_2 can be substituted by exercise intensity measured as speed of walking/running or work rate during cycling.

Habitual Walking Speed (HWS): WS is the speed at which a subject tends to walk without any constraint. It is a measure of physical function which is related to musculoskeletal strength and power and is vital for independent life at higher ages. Moreover, walking speed is associated with survival at all ages in both sexes, and is particularly informative for people aged 75 and over. Gait speed is a quick, inexpensive, reliable measure of functional capacity with well-documented predictive value for major health-related outcomes.

Heart Rate Reserve (HRR): HRR is the difference between resting heart rate (rHR) and maximum heart rate (MHR). HRR is used to calculate exercise heart rate at a given percentage training intensity.

Maximal Cardiac Output (COmax): Maximal cardiac output is the highest value of CO reached during an incremental exercise up to exhaustion. It is the most important cardiovascular variable determining maximal aerobic power because the oxygen- enriched blood (carrying about 0.2 L of O2 per litre of blood) must be delivered to the muscle for the mitochondria to use. Endurance training increases the maximal cardiac output and thus the delivery of oxygen to the muscles.

Maximal and Peak Heart Rate (MHR/PHR): MHR is the highest heart rate value that can be achieved by a subject. PHR is the highest value of heart rate reached by a subject during a maximal exercise. PHR is one of the most commonly used values in clinical medicine and physiology. For example, a straight percentage of PHR or a fixed percentage of heart rate reserve is used as a basis for prescribing exercise intensity in both rehabilitation and disease prevention programs. Moreover, in some clinical settings, exercise testing is terminated when subjects reach an arbitrary percentage of their age-predicted maximal heart rate (e.g., 85% of MHR).

Maximal Pulmonary Ventilation (MPV): Pulmonary ventilation is the amount of gas inhaled or exhaled from a person's lungs in one minute. If both tidal volume (TV) and breath frequency (BF) are known, pulmonary ventilation can be calculated by multiplying the two values. Maximal pulmonary ventilation is calculated as the product between maximal TV and maximal BF.

Post Exercise Heart Rate Recovery (HRRec): It is defined as defined as the rate of decline in HR after cessation of the effort. The value for the post-exercise heart rate recovery should be defined as the reduction in the heart rate from the rate at peak exercise to the rate one minute after the cessation of exercise. A delayed decrease in the heart rate during the first minute after graded exercise, which may be a reflection of decreased vagal activity, is a powerful predictor of overall mortality, independent of workload, the presence or absence of myocardial perfusion defects, and changes in heart rate during exercise. In the literature several studies showed that middle-aged and elderly individuals have delayed HR recovery after exercise test, when compared to young individuals and that HRR measures are directly related to the level of aerobic fitness.

Target Heart Rate (tHR): tHR is the heart rate to be reached during a prescribed physical activity.

VO_2 Reserve (VO_2R): VO_2R is the percentage of the difference between resting VO_2 (VO_2rest) and VO_2max. VO_2R is used to calculate exercise VO_2 at a given percentage training intensity.

VO_2 Rest (VO_2rest): It is the amount of oxygen consumed by the body in resting condition.

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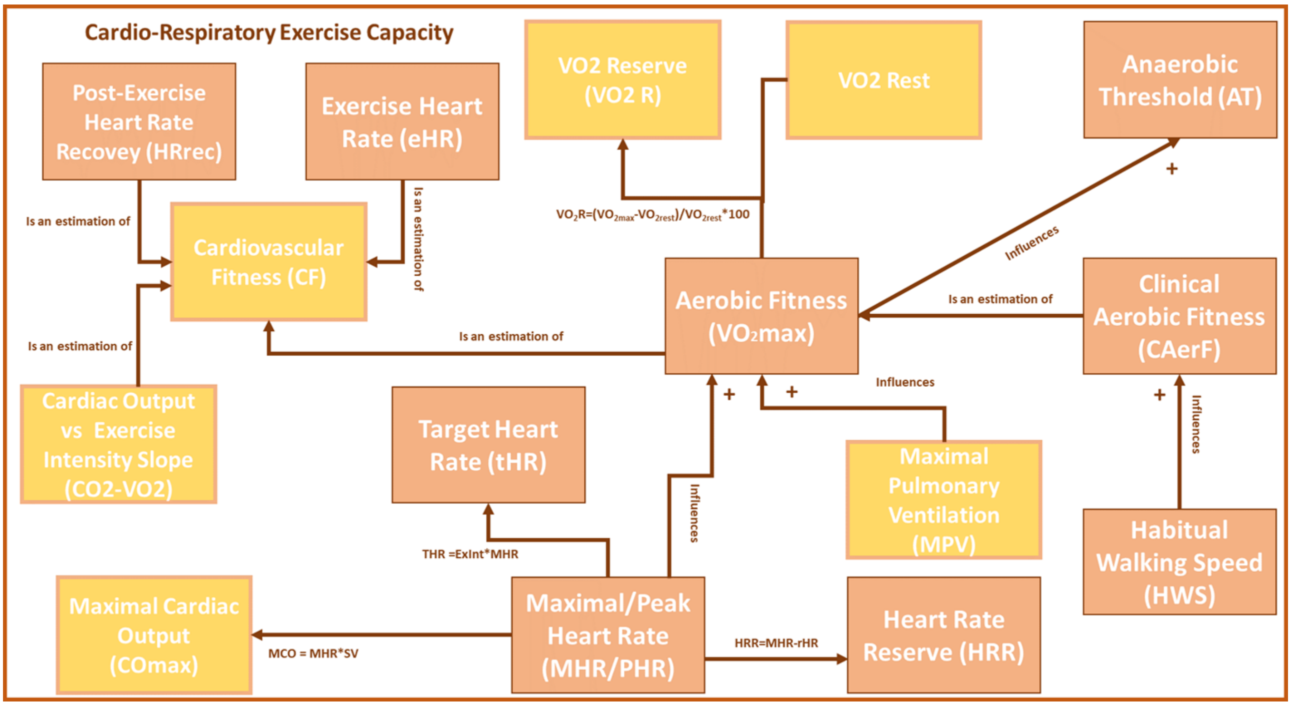

Figure 8 Relationships among variables in the Cardio-Respiratory Exercise Capacity Subdomain. The variables in yellow are those considered for the validation of the System.

Strength-balance-flexibility exercise capacity

VARIABLE NAME	ACRONYM	TO BE USED IN SYSTEM/PILOT
BALANCE		System + Pilot
CLINICAL ANAEROBIC FITNESS	CAnaF	System + Pilot
FLEXIBILITY		System + Pilot
MUSCLE POWER	MP	System + Pilot
MUSCLE STRENGTH	MS	System + Pilot
MOVEMENT SPEED	SoM	System + Pilot

Balance: Balance is the ability to maintain the body's centre of mass (COM) within the limits of the base of support. Balance is achieved by the complex integration and coordination of multiple body systems including the vestibular, visual, auditory, motor, and higher level premotor systems. Weakness in the core stabilizing muscles, altered muscle activation patterns, loss of proprioception, and an inability to control normal postural control can all result in decreased balance in the elderly.

Clinical Anaerobic Fitness (CAnaF): It is the clinical correlate of the anaerobic power**.** Anaerobic power is the amount of energy produced in very short exercise of no more than 10 sec of duration and it is indicative of the phosphagen-splitting mechanism of work production alone. Physical assessment of skeletal muscle power can help predict functional decline, loss of independence, and even frailty. It is well known that the maximum power that can be reached in an exercise of long duration, when an aerobic steady state is attained, is appreciably less than the power output that can be sustained only for a few seconds. Ordinarily, maximum anaerobic power is about three times the steady-state power developed from oxidations.

Flexibility: Flexibility is the ability to move one body segment across another and it depends from the range of motion in a joint or in a group of joints. With ageing, muscle flexibility can demonstrate a marked decline. This decline is influenced by decreases in muscle fibre flexibility and the elasticity of connective tissue. In addition, there is a decline in joint flexibility and stability relating to changes in the joint components of cartilage, ligaments, and tendons. Because flexibility is segment specific, determining the ROM in a joint does not necessarily indicate the level of flexibility in other joints.

Muscle Power (MP): Power is the product of force, generated by the muscle contraction, and velocity of the contraction. It is related to the selective loss of the largest fastest contracting fibres during ageing. Lower limb power has been identified as a significant predictor of functional performance in older adults. Among older adults, a decline in lower extremity muscle power output with advancing years has important implications for independent physical functioning in later life. Compared to traditional measures of muscle performance such as muscle strength (the ability to generate maximal force), impairments in peak lower extremity muscle power are superior predictors of functional tasks involving mobility and ambulation. For these reasons, increased muscle power may represent a more functionally relevant outcome than increased muscle mass or strength for exercise, or rehabilitation programs in older adults.

Muscle Strength (MS): Muscle strength measurements of different body compartments are correlated, so when feasible, grip strength measured in standard conditions with a well-studied model of a handheld dynamometer with reference populations can be a reliable surrogate for more complicated measures of muscle strength in the lower arms or legs. The primary mechanism underlying the decrease in muscle strength with age is a decline in muscle mass and, to a lesser extent, a decrease in muscle strength per unit muscle cross-sectional area (i.e., alterations in neuromuscular junctions, and loss of peripheral motor neurons with selective denervation of type II muscle fibers).

Movement Speed (MoS): MoS is the amount of space covered by a body segment per unit of time. It has been reported that when older adults perform movements toward targets, their movements are characterized by less smoothness and continuity, although performance precision is almost maintained.

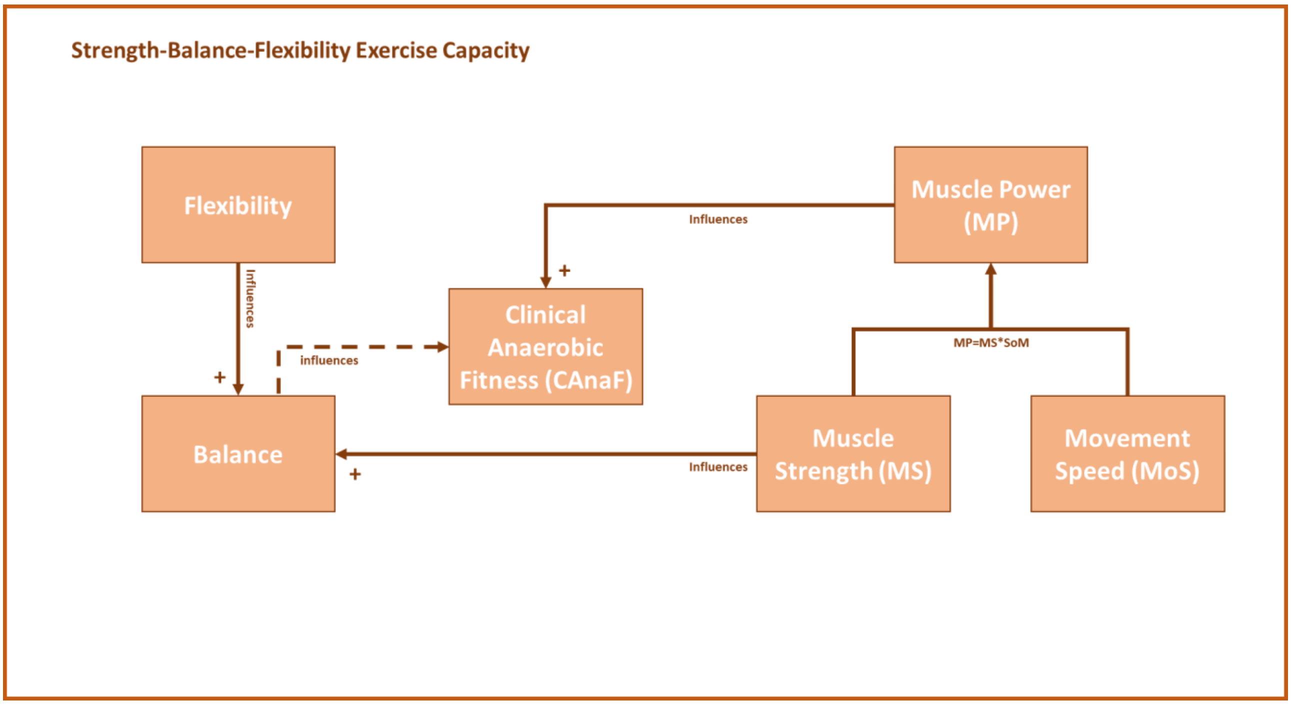

Figure 9 Relationship among variables in the subdomain "Strength-Balance-Flexibility Exercise Capacity" (System variables in Orange, Pilot variable in Yellow).

Physical activity behaviour

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 769643

Table 8. List of the Physical Activity Behaviour Subdomain Variables

VARIABLE NAME	ACRONYM	TO BE USED IN SYSTEM/PILOT
DISTANCE	-	System + Pilot
EXERCISE DURATION	-	System + Pilot
EXERCISE INTENSITY	-	System + Pilot
EXERCISE TYPE	-	System + Pilot
EXERCISE FREQUENCY	-	System + Pilot
FATIGUE ACCUMULATION	-	System + Pilot
GRADE	-	System + Pilot
ACTIVITY ENERGY EXPENDITURE	AEE	System + Pilot
RATE OF PERCEIVED EXERTION	RPE	System + Pilot
SEDENTARINESS	-	System + Pilot
SPEED	-	System + Pilot
STEPS	-	System + Pilot
UPPER LIMBS MOVEMENTS	ULM	System + Pilot

Distance: It is the extent or amount of space covered by a person during movement between two things, points, lines, etc.

Exercise Duration: The exercise duration is the time occurring in between the beginning of the exercise and its conclusion.

Exercise Frequency: This refers to how often a person exercises. After any form of exercise is performed the body completes a process of rebuilding and repairing. So, determining the frequency of exercise is important in order to find a balance that provides just enough stress for the body to adapt and also allows enough rest time for healing.

Exercise Intensity: It can be defined as the amount of effort or work that must be invested in a specific exercise workout. This too requires a good balance to ensure that the intensity is hard enough to overload the body but not so difficult that it results in overtraining, injury or burnout.

Exercise Type: The exercise type is an alphanumeric variable defining a structured program of physical activity categorized into four main classes, namely cardiorespiratory, muscle-strengthening, flexibility and balance.

Fatigue Accumulation: Fatigue is defined as a sense of persistent general tiredness. It is becoming increasingly recognized as a specific geriatric entity since both prevalence and incidence appear to increase with advancing age, and for the majority, fatigue per se exists independently of any specific diagnostic conditions. Task-specific measures of tiredness have been examined in clarification of the theoretical assumption that fatigue may be instrumental in the disablement process. In particular, self-reported tiredness while performing daily activities has been examined, and among nondisabled elderly people, it has been found to be a determinant of subsequent utilization of health and social services, walking limitations, onset of disability, and a reduction in both 10- and 15-year survival.

Grade: is the measurement ground incline during walking and running. It is a determinant of exercise intensity and it is required in some metabolic formulae. Available to estimate energy expenditure of walking and running.

Activity Energy Expenditure (AEE): is the energy consumed by any physical activity beyond the basal expenditure or BMR. It includes any activity that can be done as a free living individual that is not related with the maintenance of vital body functions. Since energy consumed for movement depends on weight, height and age, ranges of AEE are normally relative to BMR.

Rate of perceived exertion (RPE): The RPE is quantitative measure of perceived intensity during physical exercise. Perceived exertion is how hard you feel like your body is working. It is based on the physical sensations a person experiences during physical activity, including increased heart rate, increased respiration or breathing rate, increased sweating, and muscle fatigue. Although this is a subjective measure, a person's exertion rating may provide a fairly good estimate of the actual heart rate during physical activity.

Sedentariness: Sedentariness is a cluster of behaviours adopted in a sitting or lying posture where little energy is being expended. Sedentariness is a risk factor for health independent to inactivity. The definition has been under scrutiny lately, but general consensus indicates that it should be defined by both posture and low energy expenditure (<1.5 Metabolic Equivalent of Task (METs)) during waking hours and includes activities such as watching television, computer use and travel. Sedentariness can be estimated by measuring the **Sedentary Time,** which can be defined as the daily time spent in absence of any physical activity (walking, cycling, etc.).

Speed: is the measurement of body displacement in unit time. It is a determinant of exercise intensity and it is required in some metabolic formulae available to estimate energy expenditure of some modalities of structured exercise.

Steps: Steps are a fundamental unit of human locomotion, and thus the **number of steps** performed during an activity, as well as their **stride**, are a preferred metric for quantifying the physical activity itself.

Upper limbs movements: This variable refers to the amount of upper limbs movements**.** The upper-limb motions are very important for the human daily activities, such as eating, drinking, brushing teeth, combing hair and washing face. Aged individuals are usually characterized by decline in sensorimotor processing as evidenced by slower movement time or reaction time in performing discrete tasks. Consequently, elderly subjects reduce absolute number of movements of upper limbs and increase number of movement adjustments in the approach phase to a task.

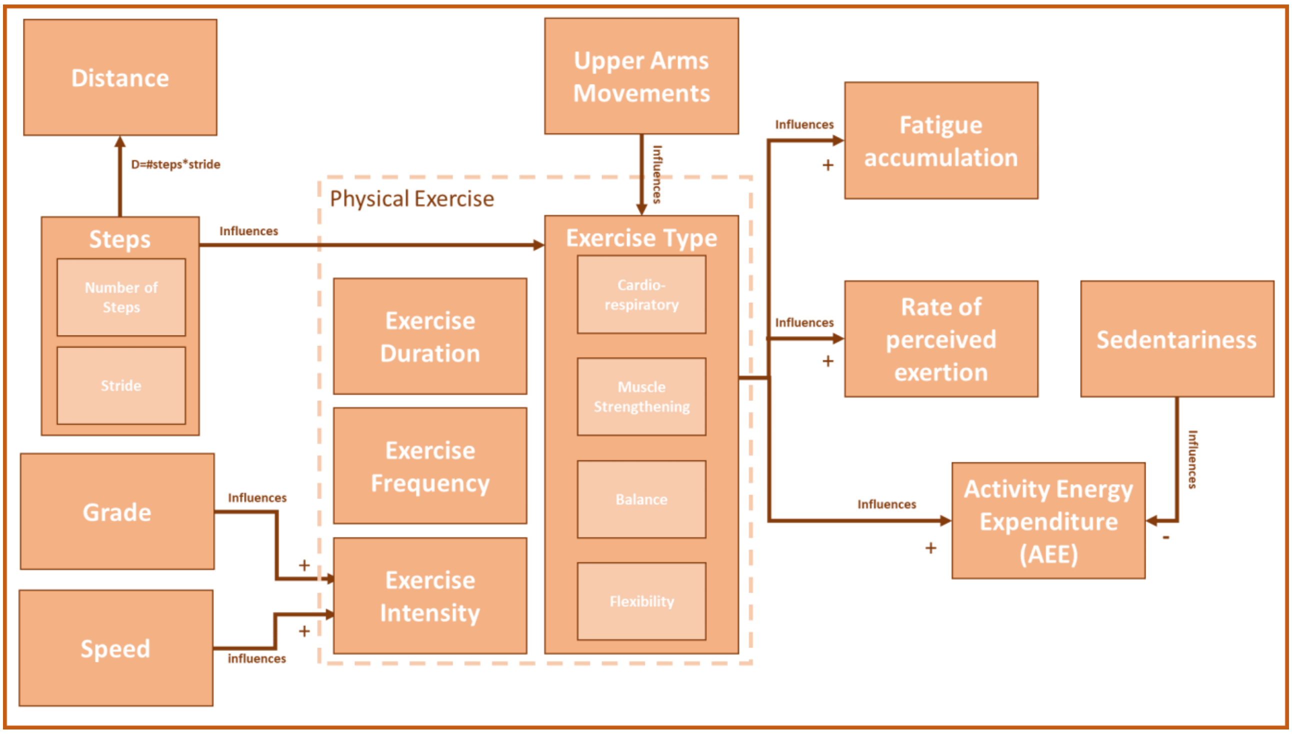

Figure 10 Relationship among variables in the subdomain "Physical Activity Behaviour" (System variables in Orange, Pilot variable in Yellow).

Sleep quality

Table 9. List of the Sleep Quality Subdomain Variables

VARIABLE NAME	ACRONYM	TO BE USED IN SYSTEM/PILOT
PERCEIVED CALM SLEEP	PCS	System + Pilot
SLEEP EFFICIENCY	SE	System + Pilot
TOTAL SLEEP TIME	TST	System + Pilot
SLEEP ONSET	Son	System + Pilot
SLEEP OFFSET	Soff	System + Pilot
TIME IN BED	TB	System + Pilot
AWAKENINGS	-	System + Pilot
SLEEP ONSET LATENCY (SOL)	SOL	System + Pilot
WAKE AFTER SLEEP ONSET	WASO	System + Pilot

Perceived Calm Sleep (PCS): PCS indicates the auto-assessed sleep quality as it is perceived by the subject. Recent studies have investigated the association between sleep quality and the subjective perception of sleep parameters. Among these parameters, calm sleep is a subjective evaluation, after the final awakening in the morning, of the user own physical behaviour (calm or restlessness) during the sleep session.

Sleep Onset (SOn): Sleep Onset is the time at which the subject falls asleep for the first time.

Sleep Offset (SOff): Sleep Offset is the time at which the subject awakes and does not manage to fall asleep again.

Time in Bed (TB): Time in bed is the time spent in bed including the wake periods before the SOn, in between SOn and SOff or after SOff.

Total Sleep Time (TST): TST is the time between sleep session start and sleep session end minus the time classified as awake (i.e. time occurred during nocturnal awakenings). Longer time in bed or sleep times may decrease sleep drive, leading to lower sleep continuity and sleep depth.

Sleep Efficiency (SE): SE is commonly defined as the ratio of **total sleep time (TST)** to **time in bed (TB)**. It plays a central role in the perception of the quality of sleep and, in particular, in insomnia research and practice. SE can be improved replacing the TIB with a combination of sleep onset latency, total sleep time, wake after sleep onset and time attempting to sleep after final awakening.

Awakenings: this variable includes the **number of awakenings (NA)** in between sleep onset and sleep offset and their **duration (AwD)**. It is related to the number of times a subject returns to the wakeful state.

Sleep Onset Latency (SOL): SOL represents the time that it takes to accomplish the transition from full wakefulness to sleep, normally to the lightest of the non-REM sleep stages. SOL could be defined as the elapsed time from the start of the test to the first 30-second epoch scored as sleep.

Wake After Sleep Onset (WASO): Wake after sleep onset is the total duration (minutes) of wake time after SOn and it is calculated as the amount of time elapsed between sleep start and sleep end scored as wake.

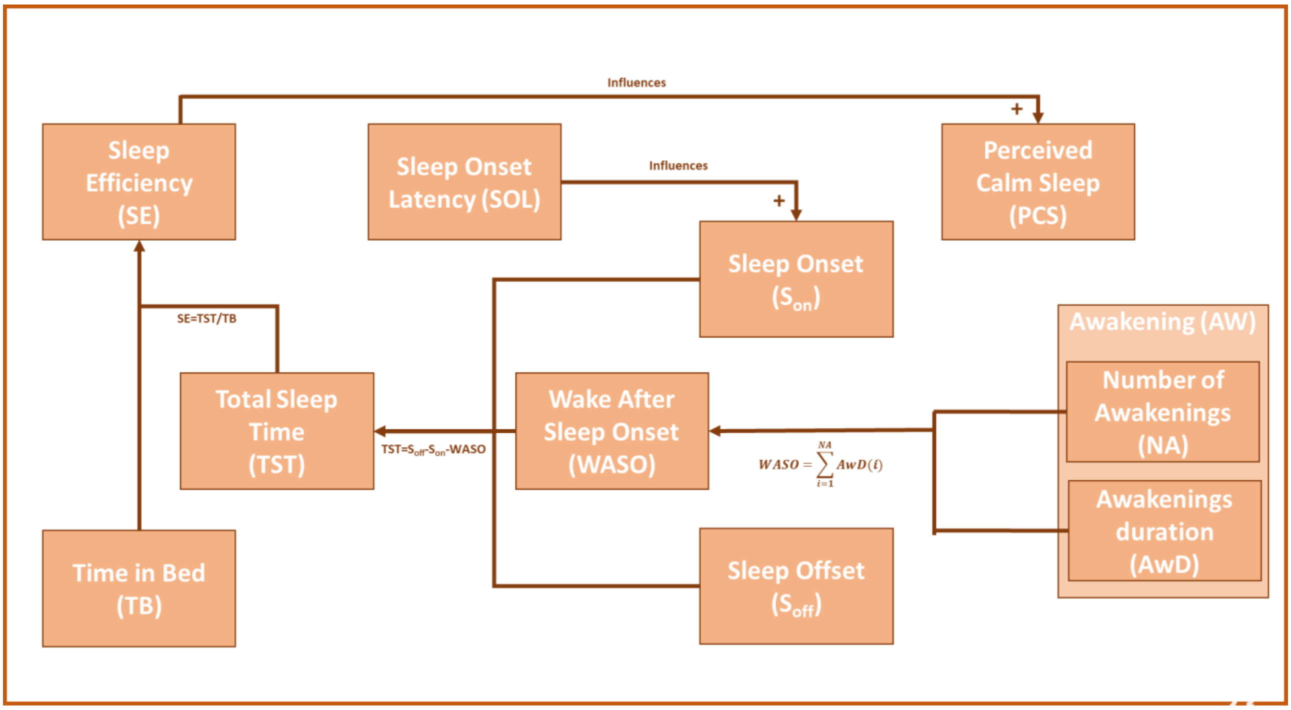

Figure 11 Relationship among variables in the subdomain "Sleep Quality" (System variables in Orange, Pilot variable in Yellow).

Relationships among subdomains

The following figures show the relationships between each subdomain and the other subdomains.

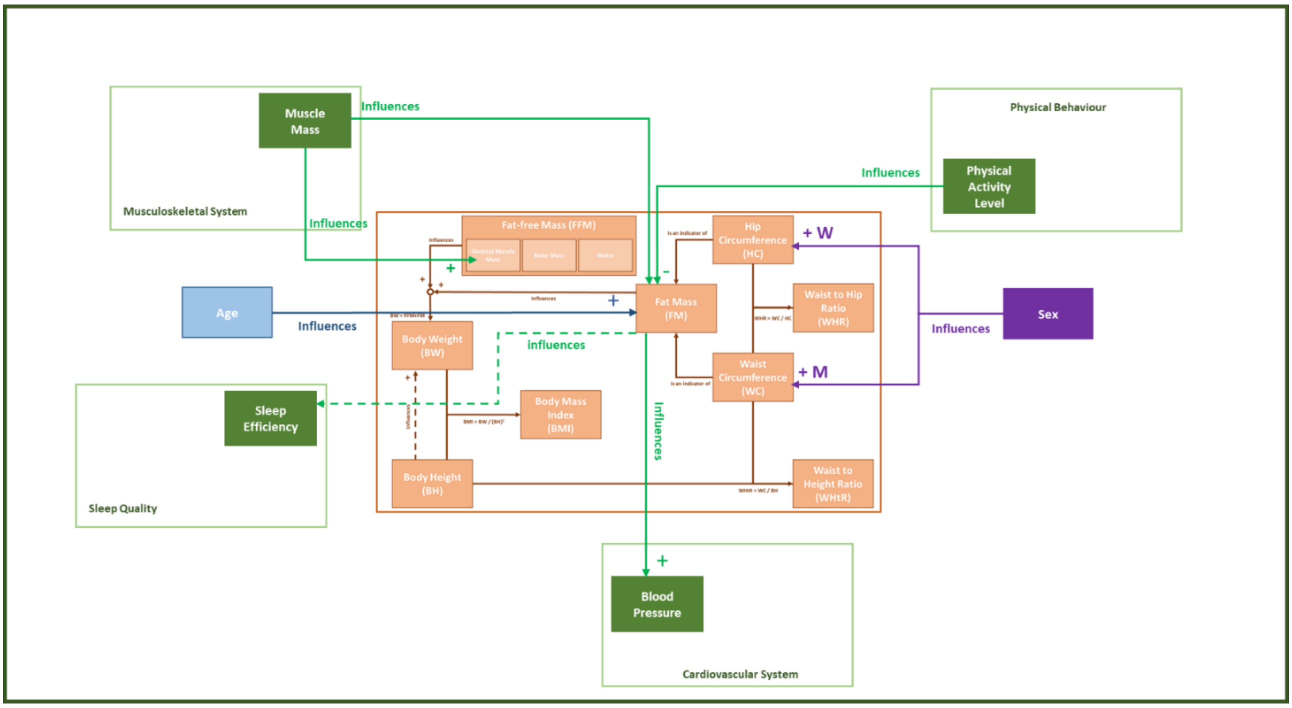

Figure 12 Relationships between the Anthropometric Characteristics subdomain and all the other physiological subdomains.

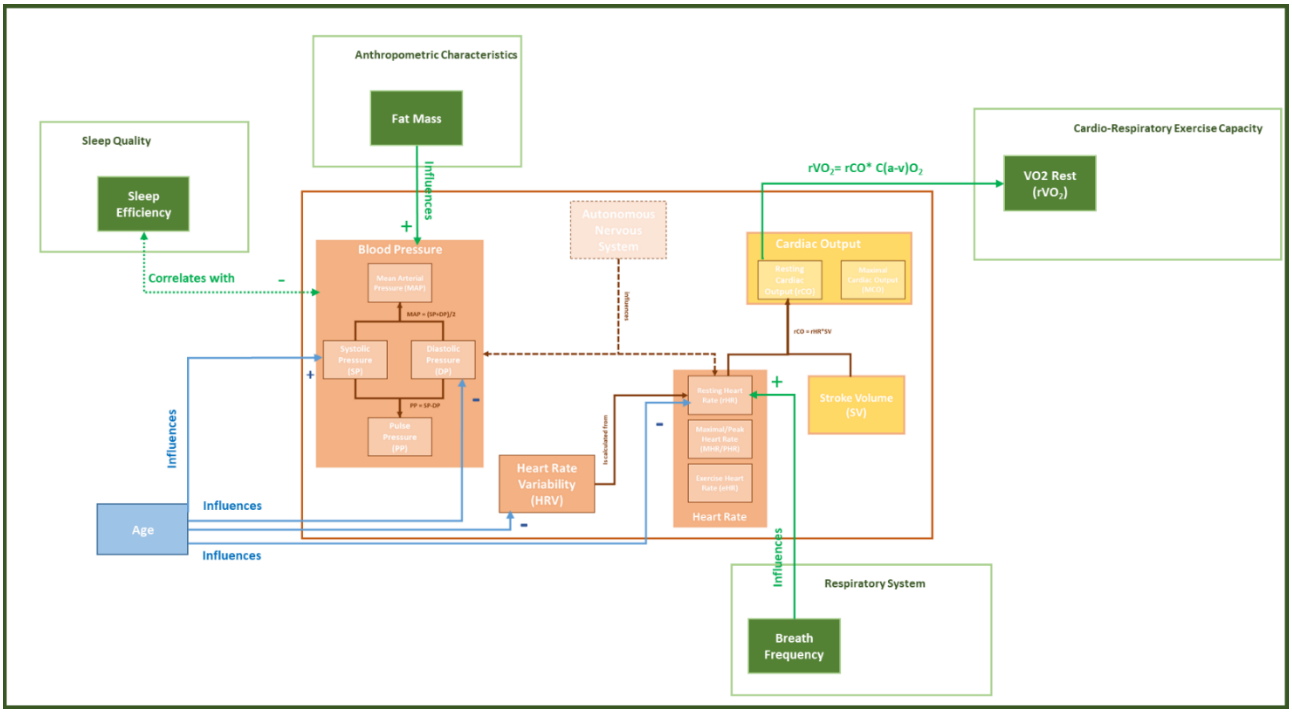

Figure 13 Relationships between the Cardiovascular System subdomain and all the other physiological subdomains.

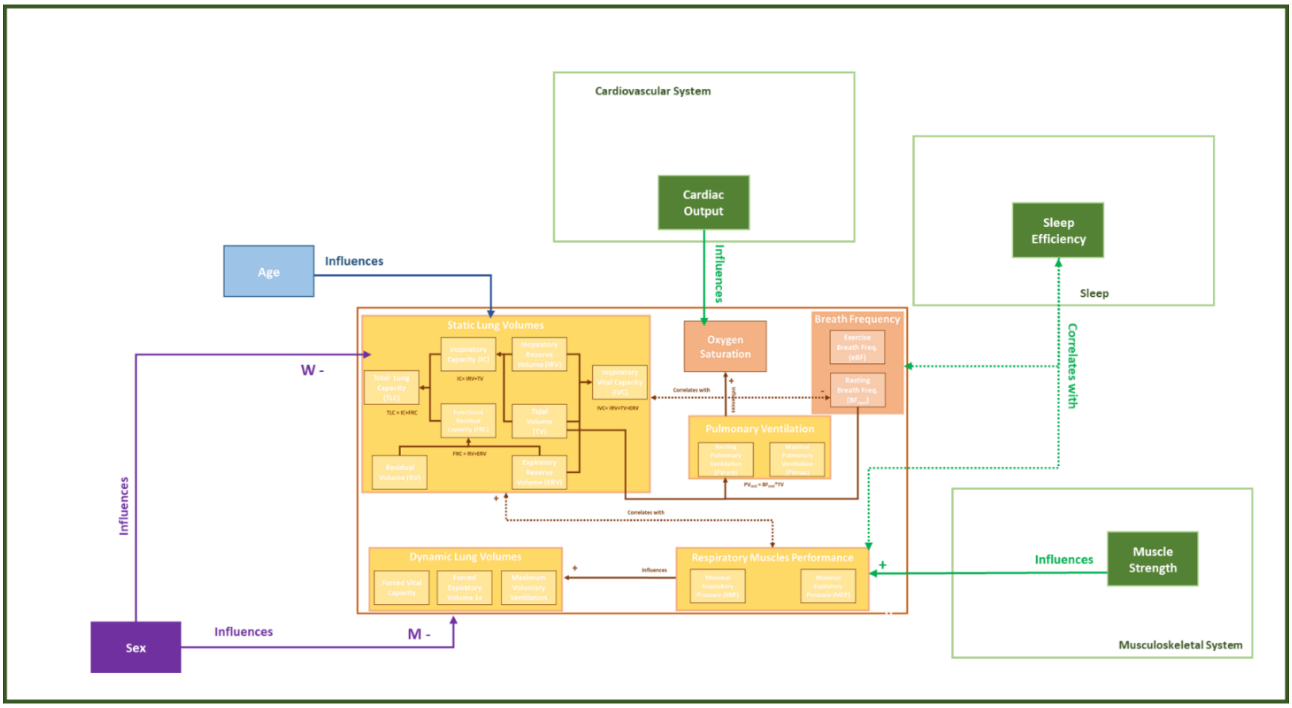

Figure 14 Relationships between the Respiratory System subdomain and all the other physiological subdomains.

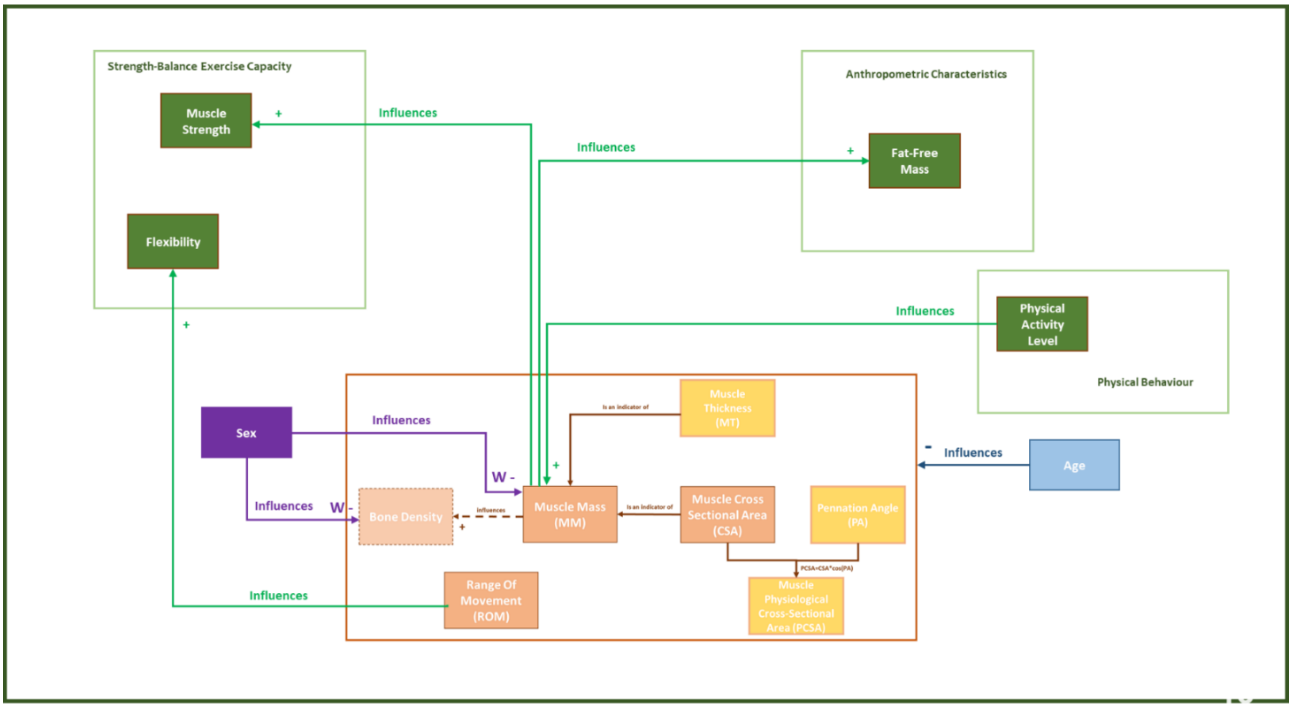

Figure 15 Relationships between the Musculoskeletal System subdomain and all the other physiological subdomains.

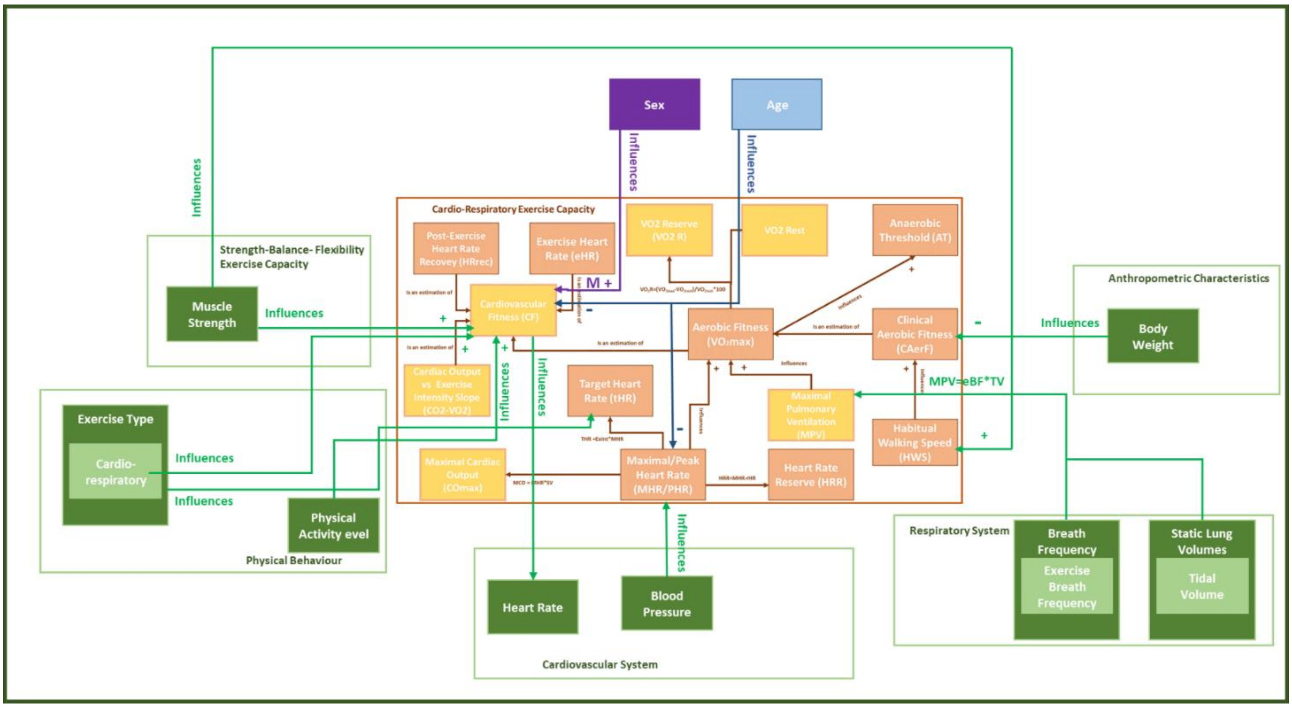

Figure 16 Relationships between the Cardio-Respiratory Exercise Capacity subdomain and all the other physiological subdomains.

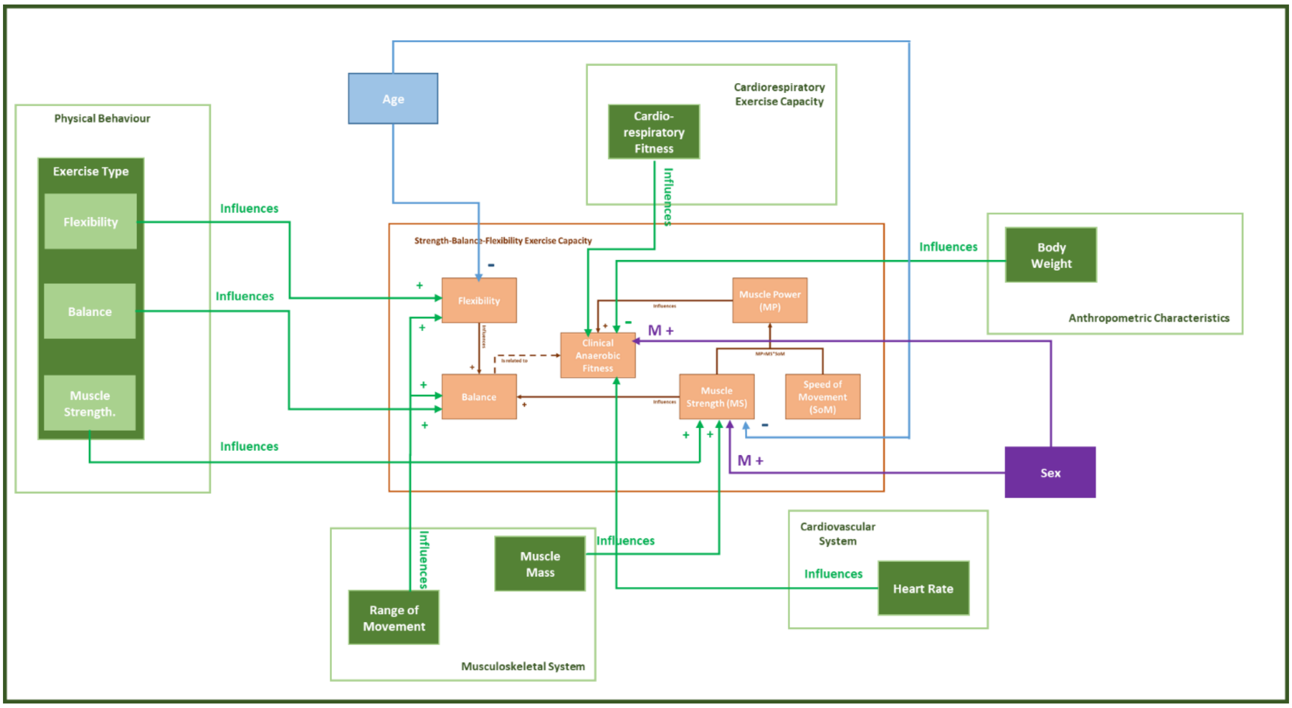

Figure 17 Relationships between the Strength-Balance-Flexibility Exercise Capacity subdomain and all the other physiological subdomains.

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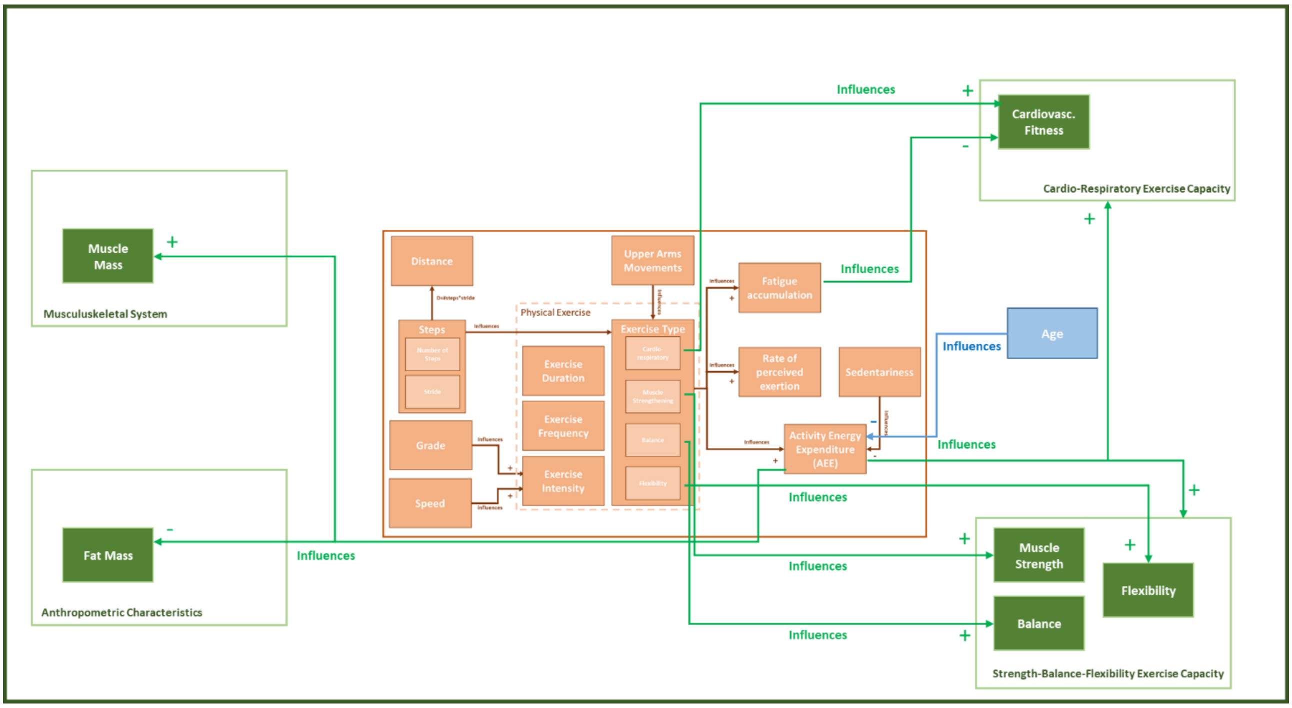

Figure 18 Relationships between the Physical Activity Behaviour subdomain and all the other physiological subdomains.

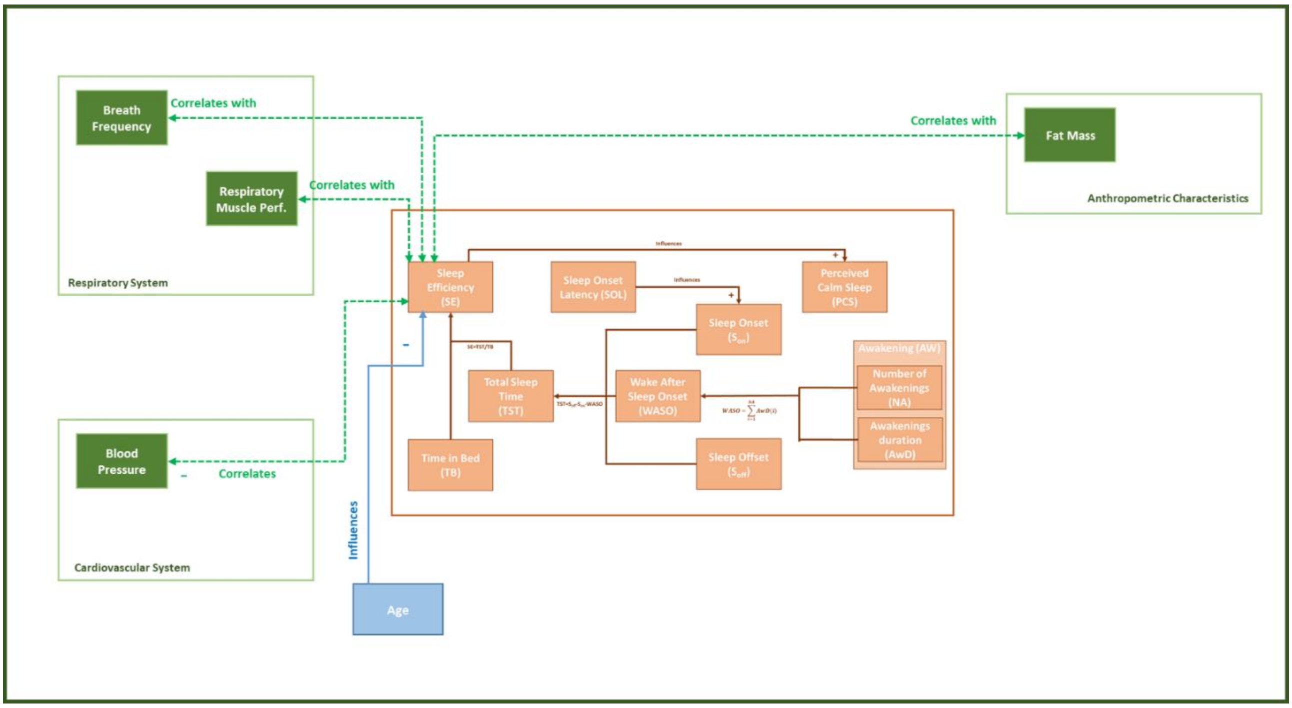

Figure 19 Relationships between the Sleep Quality subdomain and all the other physiological subdomains.

6.1.2 Nutrition

According to the information reported in the previous chapters, the nutritional domain has been organized in four subdomains: 1) **Anthropometric Characteristics** which contains a detailed description of the main anthropometric variables describing body dimensions, body composition and relationship among them; note that this domain is identical to that belonging to the Physiological Status and Physical activity behavior domain; 2) **Blood Parameters** which describes, in detail, 3 crucial parameters (glucose, cholesterol and triglycerides) involved in the nutritional aspect of ageing and the relationships among them 3) **Energy Expenditure** which describes the variables mainly related to the energetics of nutrition 4) **Nutrition Habits** which describes variables directly related to the study of a subject's eating habits.

Anthropometric Characteristics

(Please refer to the previous section 6.1.1)

Blood Parameters

Table 10 List of the Blood Parameters Subdomain Variables

VARIABLE NAME	ACRONYM	TO BE USED IN SYSTEM/PILOT
BLOOD GLUCOSE LEVEL	BGL	System + Pilot
BLOOD TOTAL CHOLESTEROL LEVEL	BTCL	System + Pilot
BLOOD TRIGLYCERIDES LEVEL	BTL	System + Pilot

Blood Glucose Level (BGL): the fasting blood concentration of glucose. Impaired fasting glucose (IFG, also called pre-diabetes) reflect the natural history of progression from normoglycaemia to type 2 diabetes mellitus. Thus, people with IFG have a greater risk of developing type 2 diabetes.

Blood Total Cholesterol Level (BTCL): the fasting blood concentration of total cholesterol which is the sum of Low Density Lipoprotein (LDL)-, High Density Lipoprotein (HDL)- and Very Low Density Lipoprotein (VLDL)-cholesterol. Hypercholesterolemia could be a consequence of a genetic disorder or secondary to dietary habits, obesity, diabetes, drugs.

Blood Triglycerides Level (BTL): the fasting blood concentration of triglycerides which are fatty acid esters of glycerol and represent the main lipid component of dietary fat and fat depots of humans. Hypertriglyceridemia could be a consequence of genetic disorders, but is usually due to the presence of obesity, uncontrolled diabetes or excessive alcohol intake.

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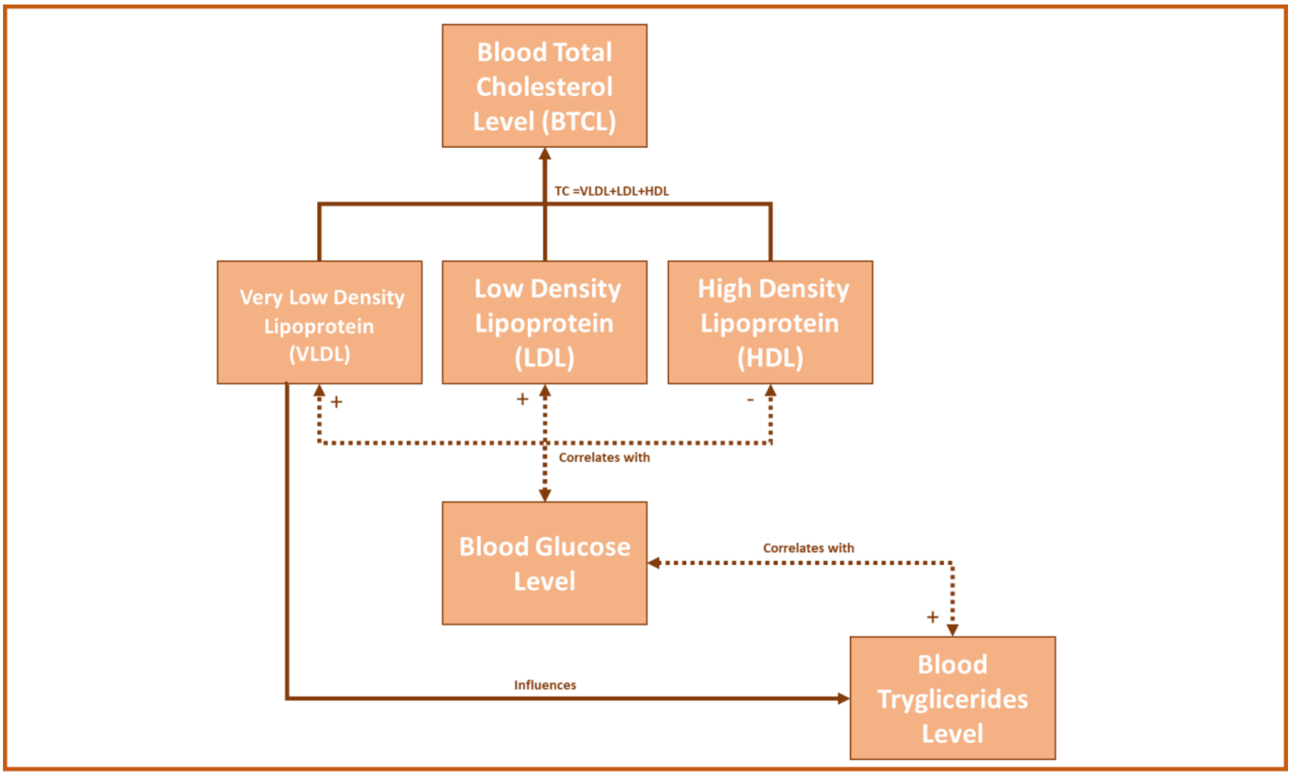

Figure 20 Relationship among variables in the subdomain "Blood Parameters" (System variables in Orange, Pilot variable in Yellow).

Energy Expenditure

Table 11 List of the Energy Expenditure Subdomain Variables

VARIABLE NAME	ACRONYM	TO BE USED IN SYSTEM/PILOT
ACTIVITY ENERGY EXPENDITURE	AEE	System + Pilot
BASAL METABOLIC RATE	BMR	System + Pilot
ENERGY INTAKE	EI	System + Pilot
TOTAL ENERGY EXPENDITURE	TEE	System + Pilot

Activity Energy Expenditure (AEE): the energy consumed by any physical activity beyond the basal expenditure or BMR. It includes any activity that can be done as a free living individual that is not related with the maintenance of vital body functions. Since energy consumed for movement depends on weight, height and age, ranges of AEE are normally relative to BMR.

Basal Metabolic Rate (BMR): the energy consumed by the subject in order to maintain basic metabolic functions. Accounts for 60–70 % of total energy expenditure in most individuals. Therefore, estimating the total contribution of individual BMR to TEE is an important calculation for understanding, developing, and executing weight related interventions. Despite indirect calorimetry is the gold standard, equations have been developed and are routinely used to calculate BMR with nutritional purposes. The purpose of disclosing BMR in NESTORE is to calculate TEE by adding BMR to AEE. Therefore, we propose the use of Harris-Benedict equation (2,3) if TEE cannot be monitored with a device.

Energy Intake (EI): the energy contained in foods consumed by the user. EI is intended to maintain normal function of the organism, supplying the energy that will be lost by the organism. Therefore, EI should match total energy expenditure.

Total Energy Expenditure (TEE): the energy consumed by the subject during 24 hours as the sum of the BMR and AEE. This is, the energy expended by vital body functions together with physical activity of any kind.

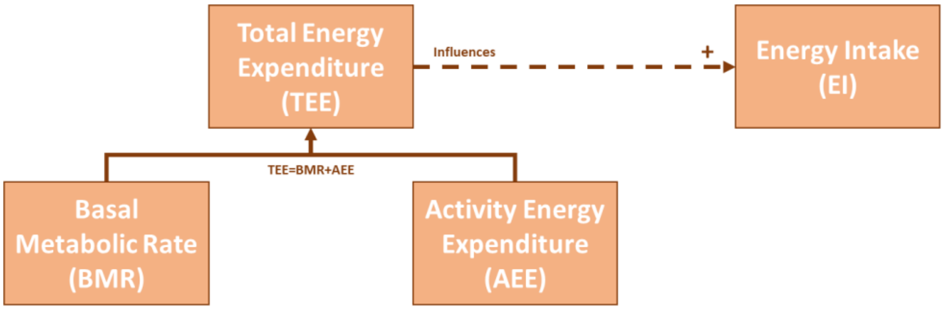

Figure 21 Relationship among variables in the subdomain "Energy Expenditure" (System variables in Orange, Pilot variable in Yellow).

Nutrition Habits

Table 12 List of the Nutrition Habits Subdomain Variables

VARIABLE NAME	ACRONYM	TO BE USED IN SYSTEM/PILOT
DAILY SUPPLEMENT INTAKE	DSI	System + Pilot
FOOD INTAKE	FI	System + Pilot
NUMBER OF MEALS	NoM	System + Pilot
NUTRIENT INTAKE	NI	System + Pilot
PATHOLOGIES	Pat	System + Pilot
REFUSED FOODS	RF	System + Pilot

Daily Supplement Intake (DSI): DIS refers to those nutrients consumed separately from meals and in the form of pills, powder extracts or other formats. Since this supplemental amount of nutrients should be added to that consumed during meals, it should be recorded. The list of nutrients considered in this project that can be consumed as supplements is described in the Annex 2. The effect of the supplement is considered relevant if it is consumed on a daily basis.

Food Intake (FI): this variable will be used to record the nutritional information of the user for setting up the system and for providing feedbacks about dietary advice.
The specific Food Frequency Questionnaire designed for Nestore can be found in the Annex 2. A limited list of food groups has been elaborated in order to use it to translate nutritional information into dietary information that can be easily understood by users with no nutrition skills.

Number of Meals (NoM): the number of meals per day is considered an important factor mainly in weight management diets. It is accepted that increasing the amount of meals has a beneficial impact on the mechanisms of satiety, reduces hunger and therefore meal size and reduces cravings. This variable will be considered only in the case of overweight/obesity.

Nutrient Intake (NI): NI is composed by a limited list of nutrients that have been considered relevant for the target user of the project. This variable will be used to calculate deviations of diet from the recommended values. The nutrients included in this variable are: Water; Vitamins; Minerals; Alcohol; Cholesterol; Fibers; Proteins; Carbohydrates/Sugar; Total Fat (Mono-Unsaturated Fat; Poly-Unsaturated Fat; Saturated Fat); Omega 3 fatty acids. Each nutrient might be considered a single variable

Pathologies (Pat): A limited list of pathologies that are related to special dietary requirements.

Refused Foods (RF): Due to different reasons, a given user might choose to exclude some foods of their diet. This might be due to different reasons, such as allergies, special diets (vegetarian, vegan, ketogenic, weight loss, etc…) or personal preferences among others. The nutritional advice will be conditioned by this variable.

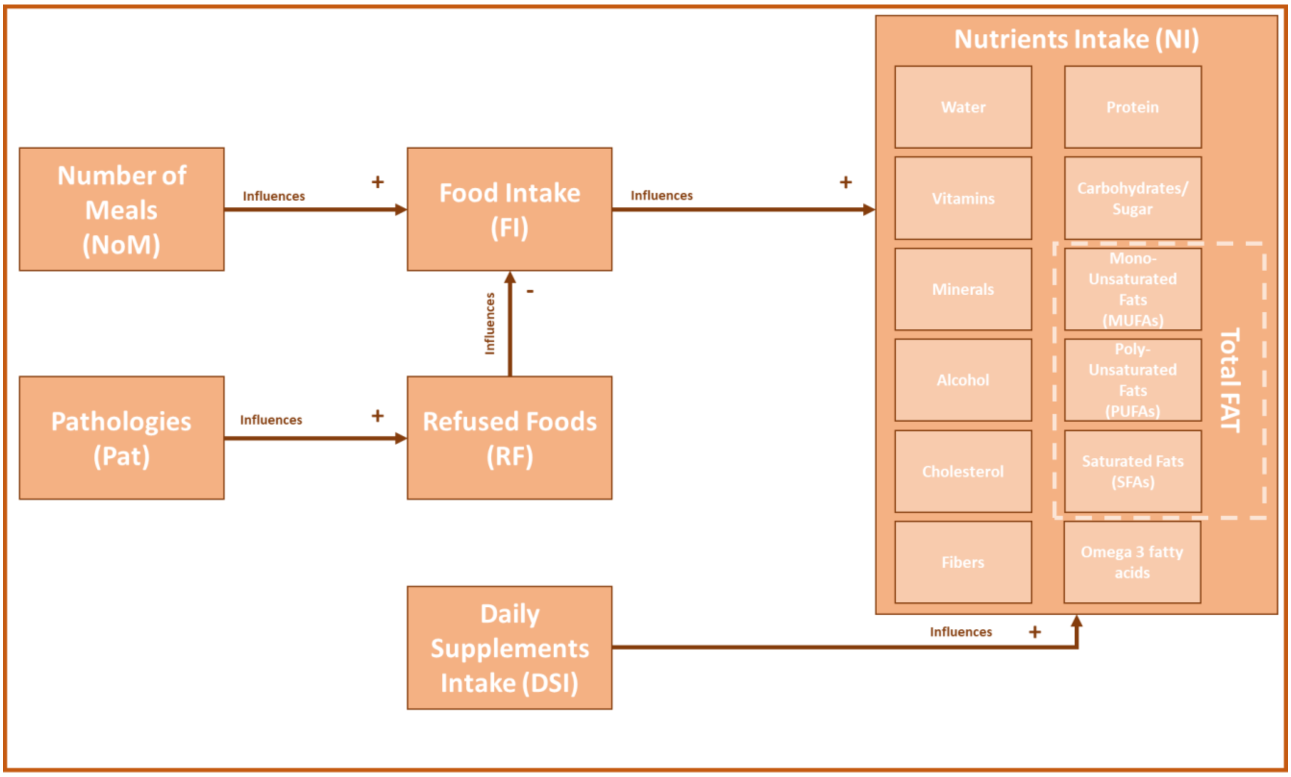

Figure 22 Relationship among variables in the subdomain "Nutrition Habits" (System variables in Orange, Pilot variable in Yellow).

Relationships among subdomains

The following figures show the relationships between each subdomain and the other subdomains.

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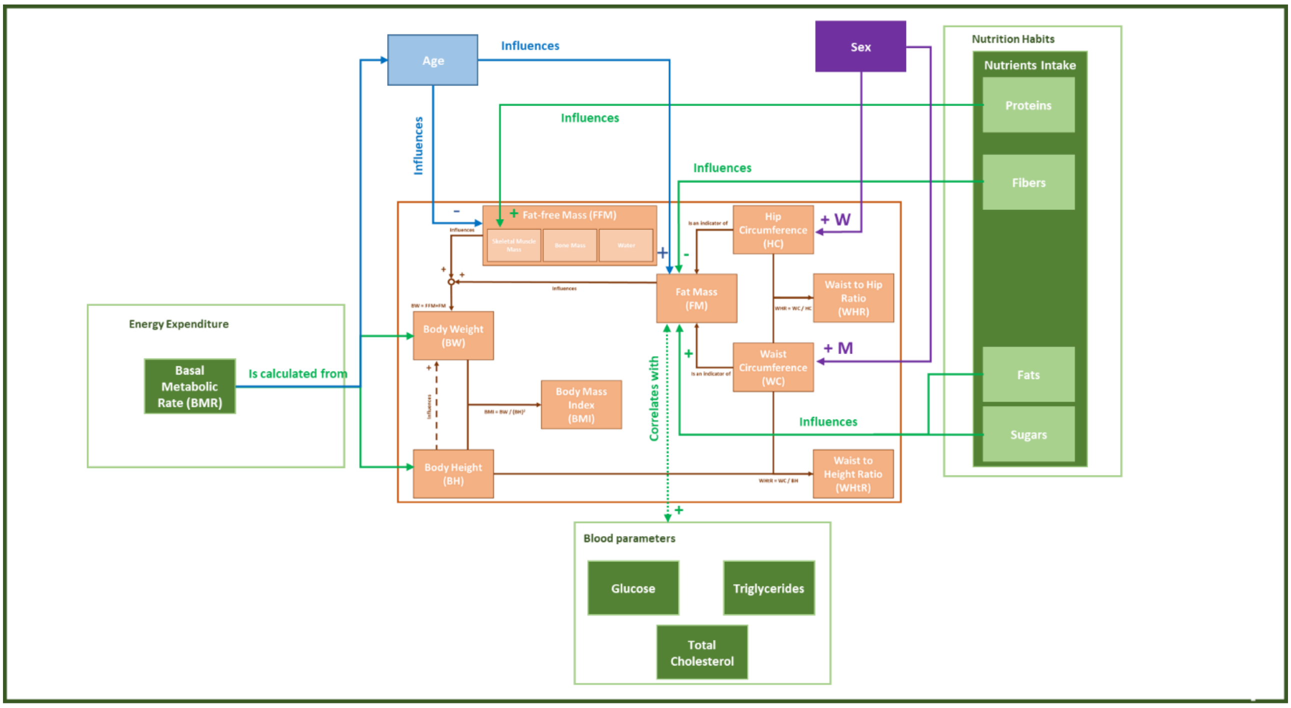

Figure 23 Relationships between the Anthropometric Characteristics subdomain and all the other Nutrition subdomains.

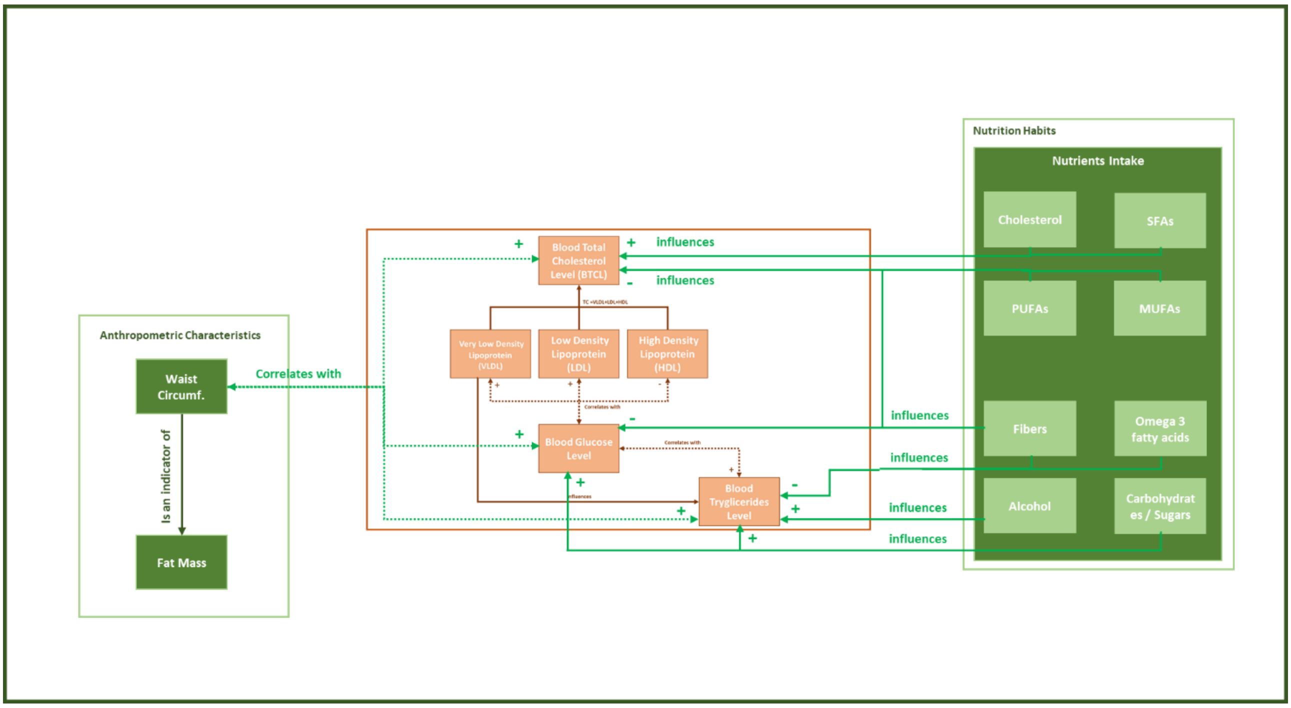

Figure 24 Relationships between the Blood Parameters subdomain and all the other Nutrition subdomains.

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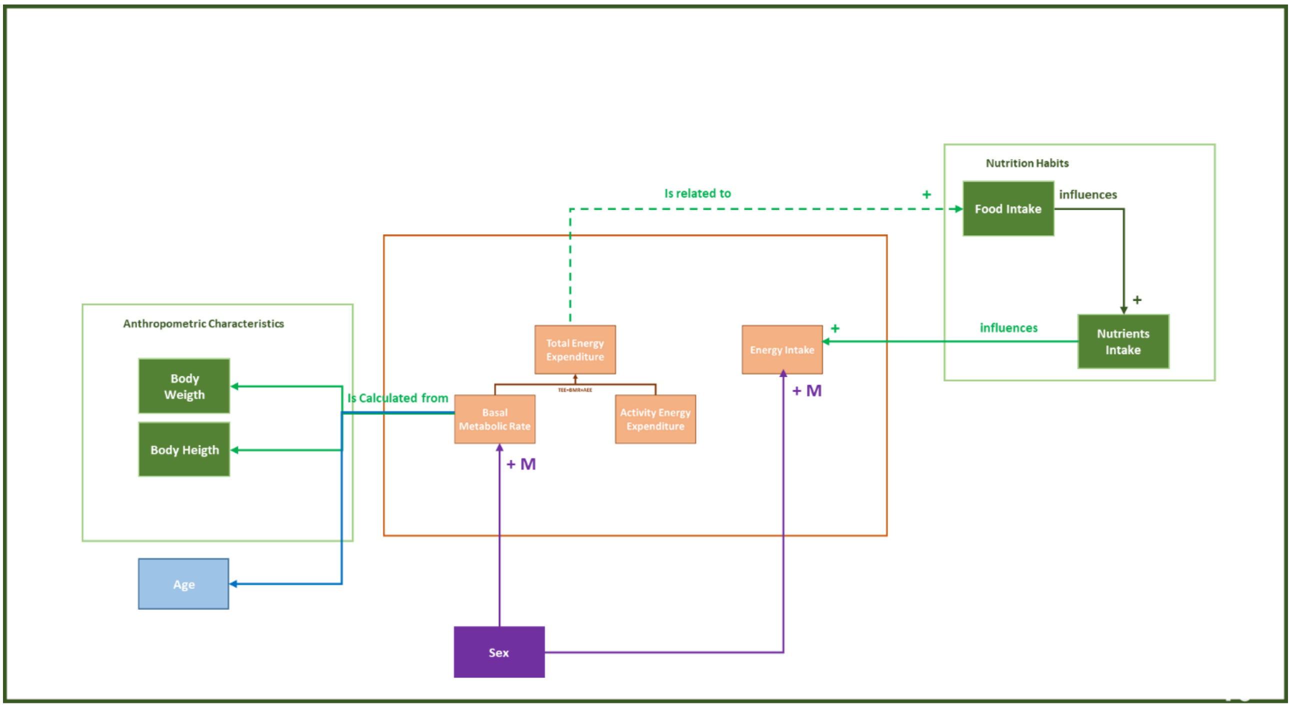

Figure 25 Relationships between the Energy Expenditure subdomain and all the other Nutrition subdomains

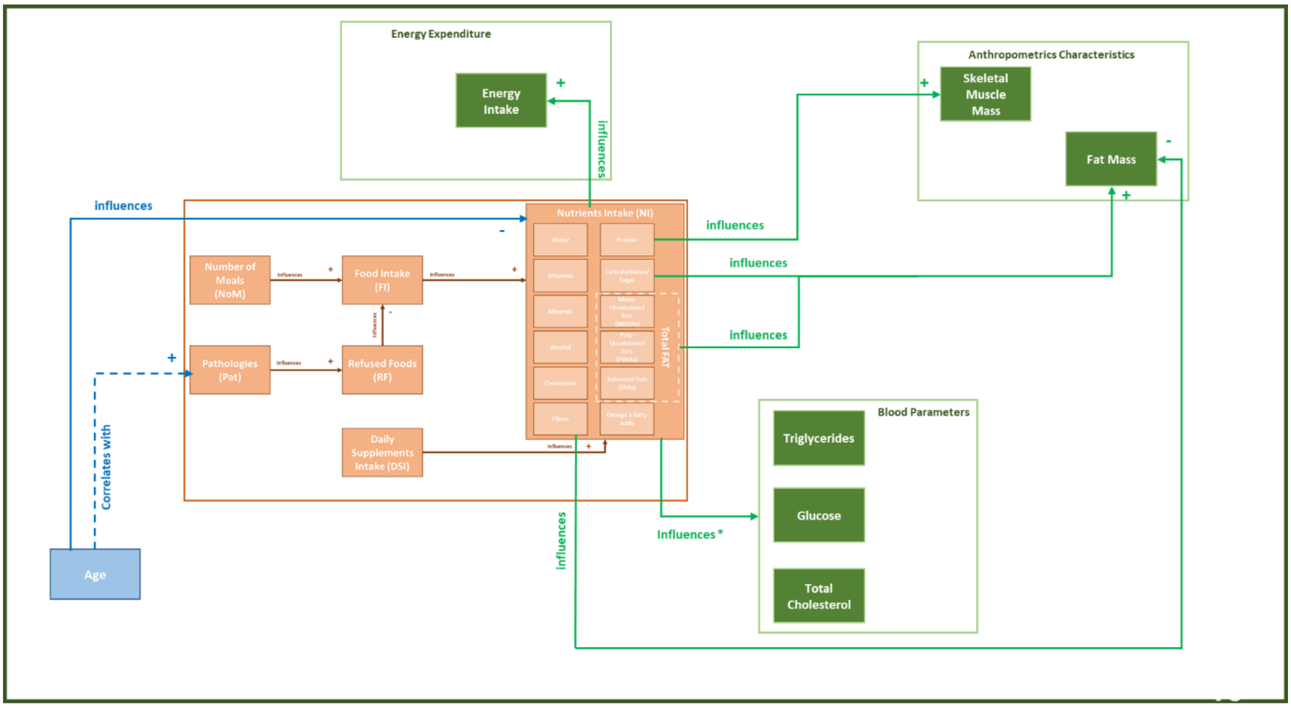

Figure 26 Relationships between the Nutrition Habits subdomain and all the other Nutrition subdomains

6.1.3 Cognitive and mental status and social behaviour

Among the health and well-being domains, Cognitive and Mental Status and Social Behaviour refer to the psychological traits and states related to cognitive, mental, personality-related and social functioning in healthy older adults.

Specifically, it is composed by four subdomains: 1) **Cognitive Status** which describes a range of intelligence domains that define biologically- and experience-/knowledge-driven facets of cognition and intelligence, 2)

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Mental Status, including traits in the area of subjective well-being, self and personality and social integration / feelings of loneliness. The two domains of status or trait variables will allow to describe a dispositional profile of a person's general resources in the cognitive and mental domain. These will be complemented by 3) **Mental Behaviour and States,** which capture the within-person processes mainly in emotional functioning that are observable in daily life on the basis of self-reported experiences and as information extracted from text bodies and speech, and 4) **Social Behaviour** which analyses the social context of the users involved in the studies and in using the NESTORE system. The social behaviour analysis aims at measuring both qualitatively and quantitatively some core variables describing the social behaviour of users in terms of (a) existence of social interactions through self-reported diaries and with sensing devices, (b) the number and duration of such interactions, and (c) possibly, the location of the interactions. The combination of such variables will be used in order to define a social profile of the users and, in turn, to stimulate the users to keep interacting with others.

Cognitive status

Table 13 List of the Cognitive Status Subdomain Variables

VARIABLE NAME	ACRONYM	TO BE USED IN SYSTEM/PILOT
ATTENTION SWITCHING	AS	System + Pilot
EVERYDAY PERFORMANCE	EP	System + Pilot
PROCESSING SPEED	PS	System + Pilot
VERBAL FLUENCY	VF	System + Pilot
VERBAL MEMORY	VM	System + Pilot
WORKING MEMORY	WM	System + Pilot

Attention Switching (AS): AS, the ability to switch attention, is a component of fluid intelligence. It assesses the visual-conceptual as well as visual-motor tracking ability to both hold attention on a simple task and to rapidly shift attention between different mental sets.

Everyday Performance (EP): The EP is the cognitive performance in daily life. Many psychometric tests have been proposed to assess it, nevertheless some were criticized for their low ecological validity. In response, the so-called everyday cognition tests have been developed to assess EP and the so-called far transfer, i.e., transfer to un-trained abilities that go beyond the immediate training domain. There are not many tests measuring everyday cognition available. The Everyday Performance Test (EPT) has been used in one of the largest cognitive training studies that also included a 10-year follow-up and is one of the only tests with well-understood psychometric properties and correlates (Tennstedt & Unverzagt, 2013).

Processing Speed (PS): PS describes the time needed to process information, i.e., to perform a mental task. Processing speed (or just "speed") is considered one of the more basic cognitive functioning domains underlying performance in other cognitive abilities. It is highly correlated with performance in many other cognitive tasks and thus an efficient and representative candidate to represent the more biologically driven overall cognitive ability (i.e., fluid intelligence) of a person.

Verbal Fluency (VF): VF is the ability to produce as many words as possible from a given semantic category (e.g., animals) or according to a phonemic category (e.g., words with S). It is a speeded task but also reflects vocabulary, and is thus a measure of both fluid and crystallized intelligence.

Verbal Memory (VM): VM describes memory for verbal content that is recalled immediately after learning as well as after some longer-term retention interval. It is one of many components of episodic retrospective memory, one of the key subdomains of memory functioning.

Working Memory (WM): WM is a component of short-term memory that encompasses the short-term storage of information in order to process and hold information to make them available for later recall. Working memory is considered to be one of the very basic cognitive components that underlies many other cognitive abilities, similar to processing speed.

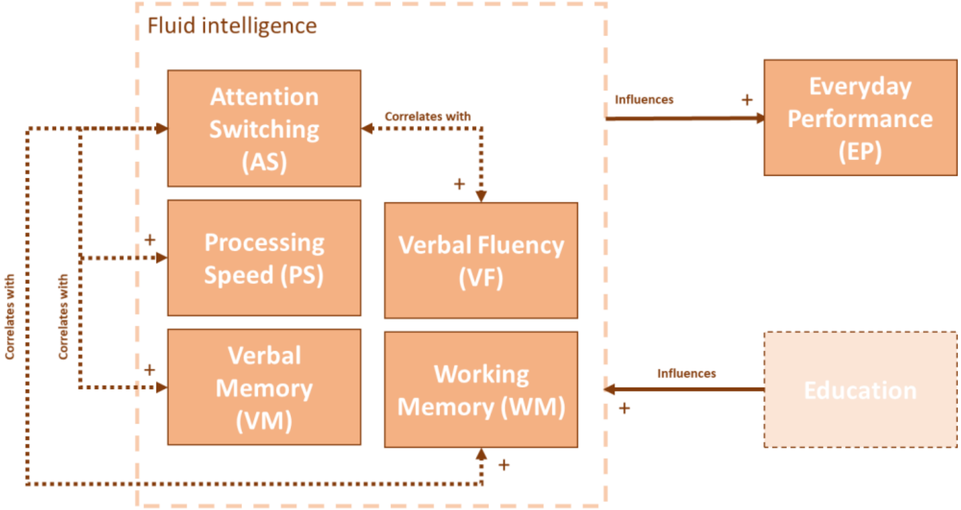

Figure 27 Relationship among variables in the subdomain "Cognitive Status" (System variables in Orange, Pilot variable in Yellow). Please note that the variable "Education" is not explicitly considered in the NESTORE model.

Mental status

Table 14 List of the Mental Status Subdomain Variables

VARIABLE NAME	ACRONYM	TO BE USED IN SYSTEM/PILOT
PERSONALITY	Per	System + Pilot
SOCIAL NETWORK / SOCIAL INTEGRATION	SNI	System + Pilot
SUBJECTIVE WELL BEING	SWB	System + Pilot

Personality (Per): Personality is a key dimension to describe the stable characteristics of a person along 5 dimensions, the so-called **Big Five**. These dimensions are associated with the social dimension (i.e., **extraversion**, **agreeableness**), the emotional dimension (i.e., **neuroticism**), the cognitive dimension (i.e., **conscientiousness**) and in general the attitude of a person to experiences in life (i.e., **openness to experiences**). Other sub facets of personality are **control beliefs** and **self-efficacy**. Control beliefs capture the degree and locus of control a person perceives to have over the positive and negative things occurring in his/her life. It involves both the perception of being able to master life in general and (on the negative side) the degree of perceived external constraints from the environment. Self-efficacy is personal judgement of one's capacity to carry out certain actions in the future / when facing future situations. All these personality components represent a meaningful variable to describe and understand differences between individuals in how they function in daily life and how good or limited they profit from interventions regarding their health behaviours.

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Social Network / Social Integration (SNI): Social relations are a key ingredient to well-being and health at all ages. They undergo characteristic changes across the adult lifespan, with the number of emotionally very close social network members remaining rather stable over the years, and the number of less close network members decreasing over the adult lifespan. Social relations can be assessed in terms of **quantity** (network size, frequency of contact), and **quality** (satisfaction with social relations in general and with individual relationship types in particular, e.g., with spouse, children, friends; social support). In a related vein, **loneliness** is an evaluative aspect to social relations that is often also used as a social well-being indicator. In addition, **social support** (received and provided) is an important quality characteristic of social relations, and in the NESTORE context, companionship/social distress as well as health-related social control could be important social network markers to be assessed at least at baseline/post-test and at intermediate time-points.

Subjective Well-Being (SWB): Subjective Well-Being is a multidimensional construct. In a common theoretical model, SWB consists of a cognitive component, the evaluation of how satisfied individuals are with their lives in general (**Life Satisfaction**) and with particular aspects of it (health, social relations, finances, etc.). The **emotional component** of SWB is conceptualized in two parts, capturing the **positive and negative affective** (PA and NA) states a person typically experiences. SWB is a key indicator of successful ageing, and as such a typical outcome measure to assess how well individuals are doing in their lives in general. In ageing studies it is further typical to screen individuals for depressive symptoms (depressive symptoms can be related to cognitive impairments).

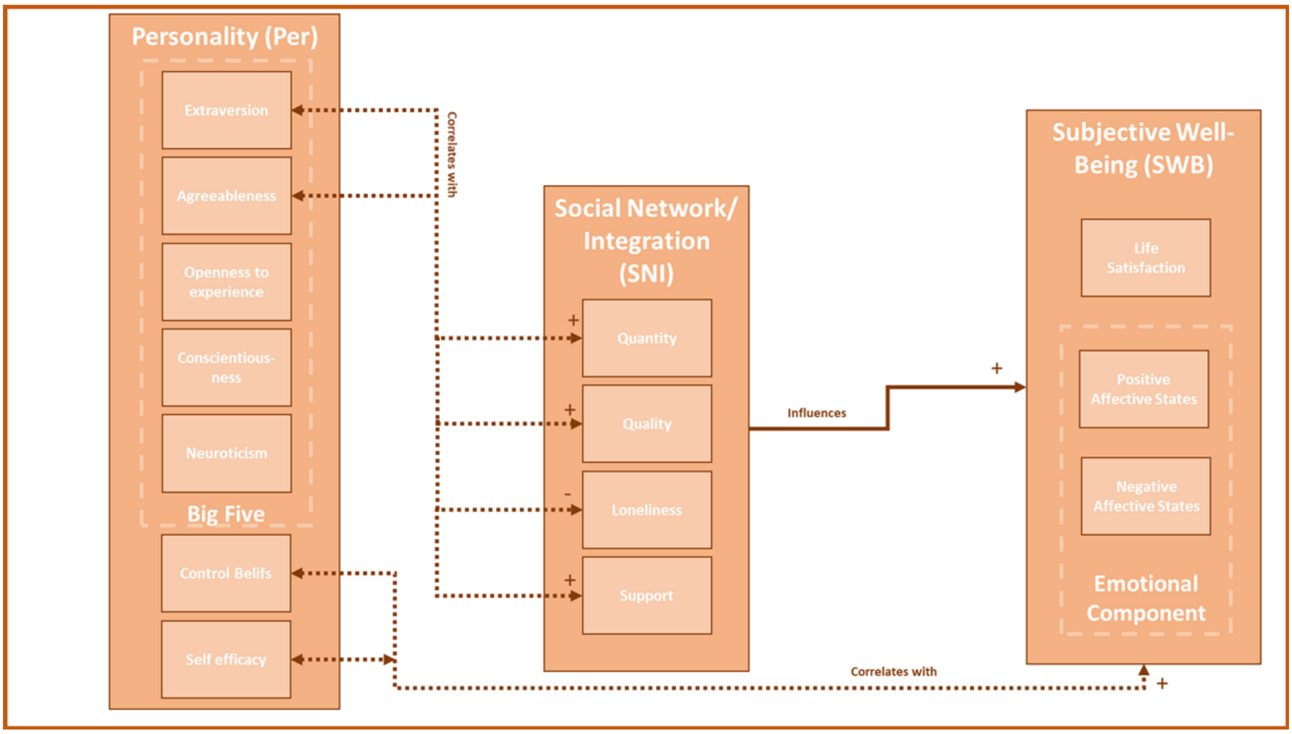

Figure 28 Relationship among variables in the subdomain "Mental Status" (System variables in Orange, Pilot variable in Yellow).

Mental behaviour and states

Table 15 List of the Mental behaviour and states Subdomain Variables

VARIABLE NAME	ACRONYM	TO BE USED IN SYSTEM/PILOT
ACUTE STRESS	AS	System + Pilot
DIMENSIONAL EMOTIONS		System + Pilot
DISCRETE EMOTIONS		System + Pilot

SENTIMENT VALENCE DETECTION	SVD	System + Pilot

Acute Stress (AS): AS indicates the presence of stress. High levels of stress are a significant determinant of well-being and it would be meaningful and well suited to capture prevalence of acute stress from any suitable deliberate or incidental textual data generated by users during interactions with the NESTORE coach and the social platform of the NESTORE system. In NESTORE the level of stress will be assessed by Acute Stress Detection (ASD) which is the ability to measure whether a piece of textual / free-form (written) content contains words and expressions that are indicative of acute stress being experienced by the creator of the content.

Dimensional Emotions: Dimensional models of emotion attempt to conceptualize human emotions by defining where they lie in two or three dimensions. Most dimensional models incorporate valence and arousal or intensity dimensions. Dimensional models of emotion suggest that a common and interconnected neurophysiological system is responsible for all affective states. Dimensional emotions in NESTORE will be assessed using both a self-report tool (DimER) and sensing devices (DimED). **Dimensional Emotions Detection (DimED)** measures the valence and arousal / intensity of an emotion or rather a variety of affective states on a circumplex model expressed in a piece of textual / free-form (written) content. This would be meaningful and well suited to capture affective state variables from any suitable deliberate or incidental textual data generated by users during interactions with the NESTORE coach and the social platform of the NESTORE system. **Dimensional Emotions self-Report (DimER)** is a self-report aimed at assessing the Subjective Well-Being (SWB) status of a patient. SWB is a multidimensional construct, in a common theoretical model, it consists of a cognitive component, the evaluation of how satisfied individuals are with their lives in general (satisfaction with life) and with particular aspects of it (health, social relations, finances, etc.). The emotional component of SWB is conceptualized in two parts, capturing the positive and negative affective (PA and NA) states a person typically experiences. ASR is a key indicator of successful ageing, and as such a typical outcome measure to assess how well individuals are doing in their lives in general.

Discrete Emotions: This variable is related to the intensity (or arousal) of an emotion, from a range of discrete 'basic emotions'. Discrete emotions in NESTORE will be assessed using both a self-report tool (DER) and sensing devices (DED). **Discrete Emotions Detection (DED)** represents the ability of discerning and measuring the intensity (or arousal) of an emotion expressed in a piece of textual / free-form (written) content. This would be meaningful and well suited to capture emotion variables from any suitable deliberate or incidental textual data generated by users during interactions with the NESTORE coach and the social platform of the NESTORE system. **Discrete Emotions self-Report (DER)** represents the ability to detect and measure the intensity (or arousal) of an emotion, from a range of discrete 'basic emotions' referring to the subject directly by means of a self-report.

Sentiment Valence Detection (SD): SD is the ability to measure whether a piece of textual / free-form (written) content contains words and expressions that are 'broadly' (depending on the measurement tool) perceived as positive or negative. This is distinct to the previous variable, where instead of two (or more dimensions) on a circumplex model of affect, only one valence dimension is considered – i.e. positive / negative.

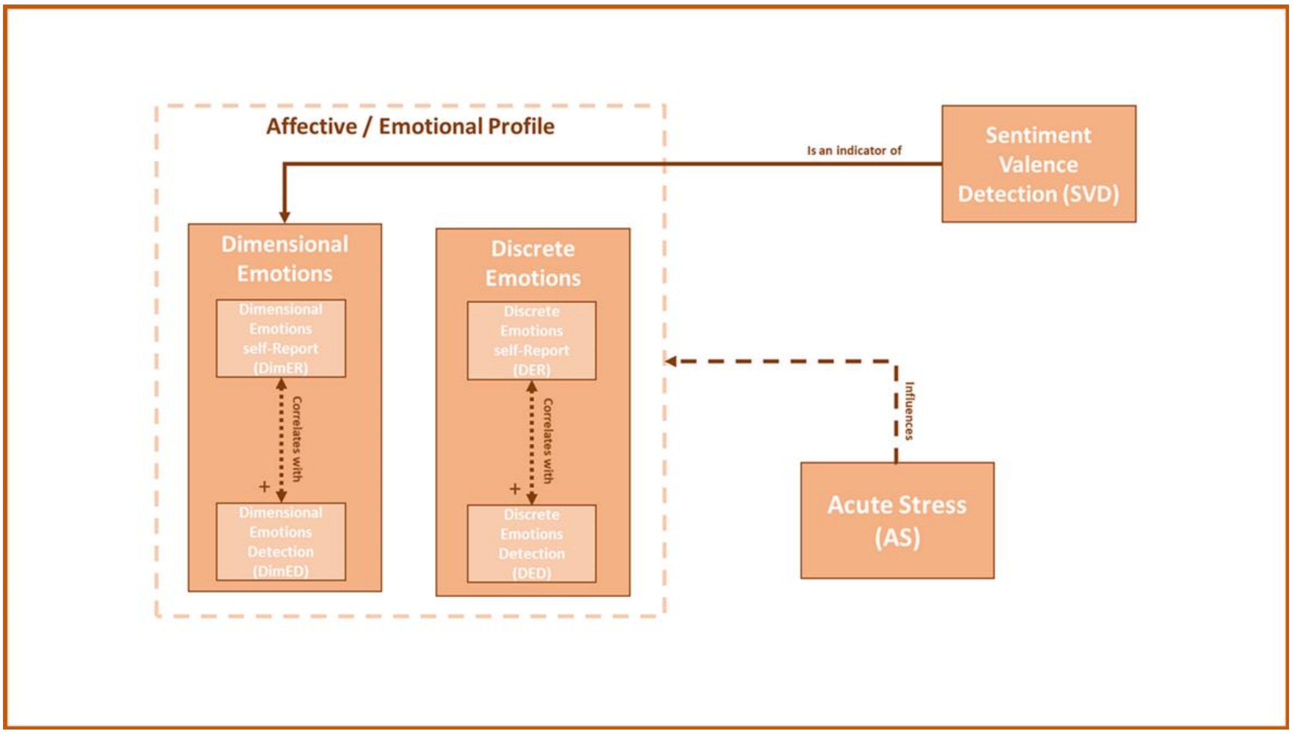

Figure 29 Relationship among variables in the subdomain "Mental Behaviour and States" (System variables in Orange, Pilot variable in Yellow).

Social behaviour

Table 16 List of the Social Behaviour Subdomain Variables

VARIABLE NAME	ACRONYM	TO BE USED IN SYSTEM/PILOT
INTERACTION DURATION	ID	System + Pilot
INTERACTION FUNCTION	IF	System + Pilot
INTERACTION LOCATIONS	IL	System + Pilot
SOCIAL INTERACTION SELF-REPORT	SIR	System + Pilot
SOCIAL INTERACTION DETECTION	SID	System + Pilot
TOTAL NUMBER OF INTERACTIONS	TNI	System + Pilot

Interaction Duration (ID): The IDD is the sum of the durations of all the interactions for a user. IDD can be measured by considering the duration of the interactions detected with sensing devices (SID) and interactions detected with self-report tools (SIR). Similarly, to the TNI variable, also IDD can be computed with different time-scales, e.g. by considering short-term interactions (e.g. 24 hours) or long-term interactions (e.g. weeks or months). As a result, it will be possible to measure the IDD variable for every user hourly, daily, weekly or with other temporal scales. The duration of the social interactions allows revealing two interesting behaviours of the users:

1. A quantitative assessment of the total time a user spends interacting with other users
2. The temporal features of the user's interactions. More specifically, the IDD variable of user X reveals that he/she typically, has long-lasting interactions (e.g. hours) during the week-end while he/she is engaged in short interactions (e.g. minutes) during the working days.

Interaction Function (IF): This variable describes the function related to the social interaction (e.g. practical help and support, keeping company, consolation / emotional support, etc.)

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Interaction Locations (IL): Being able to assign a location to the interactions happening indoor. According to the nature of the pilot site (co-housing, private homes etc.), it could be possible to detect the location of the interactions so that to reveal where interactions are more frequent and/or longer lasting and when such locations become active. Detecting the location of the interactions is another useful variable to assign the notion of context to the interactions and tailor coaching input.

Social Interaction Detection (SID): SID is a variable assessing the existence of social interactions of a subject with other subjects that join the experimentations. The SID variable detects *if* and *when* a user had an interaction with another user, such variable is measured by using sensing devices. According to the kind of "sensing" technology used in the NESTORE project, it will be possible to recognize when two users are in proximity, namely when two subjects lay within a distant range. The proximity (proxemics) among users is a good marker for recognizing the interactions. In an intuitive way, the more two users stay in contact along the time, the more they express the explicit intent of interacting. The sensing technology used will influence the accuracy of the SID variable.

Social Interaction self-Report (SIR): The SIR variable is a subjective report aimed at assessing the quantity and quality of social interactions of the subject in any given moment of being prompted. Social relations are a key ingredient to well-being and health at all ages. They undergo characteristic changes across the adult lifespan, with the number of emotionally very close social network members remaining rather stable over the years, and the number of less close network members decreasing over the adult lifespan. Social relations can be assessed in terms of quantity (network size, frequency of contact) and quality (satisfaction with social relations in general and with individual relationship types in particular, e.g., with spouse, children, friends; social support). In the social behaviour domain, self-reported interactions can refer to the number and type of social interaction a person has in a particular situation.

Total Number of Interactions (TNI): This variable counts the total number of interactions of a subject with other individuals in its social network. It can be measured by considering the interactions detected with sensing devices (SID) and interactions detected with self-report tools (SIR). The TNI can be computed with different time-scales, e.g. by considering short-term interactions (e.g. 24 hours) or long-term interactions (e.g. weeks or months). As a result, it will be possible to measure the TNI for every user hourly, daily, weekly or with other temporal scales. The amount of the interactions is a valuable indicator of the social activity of a user.

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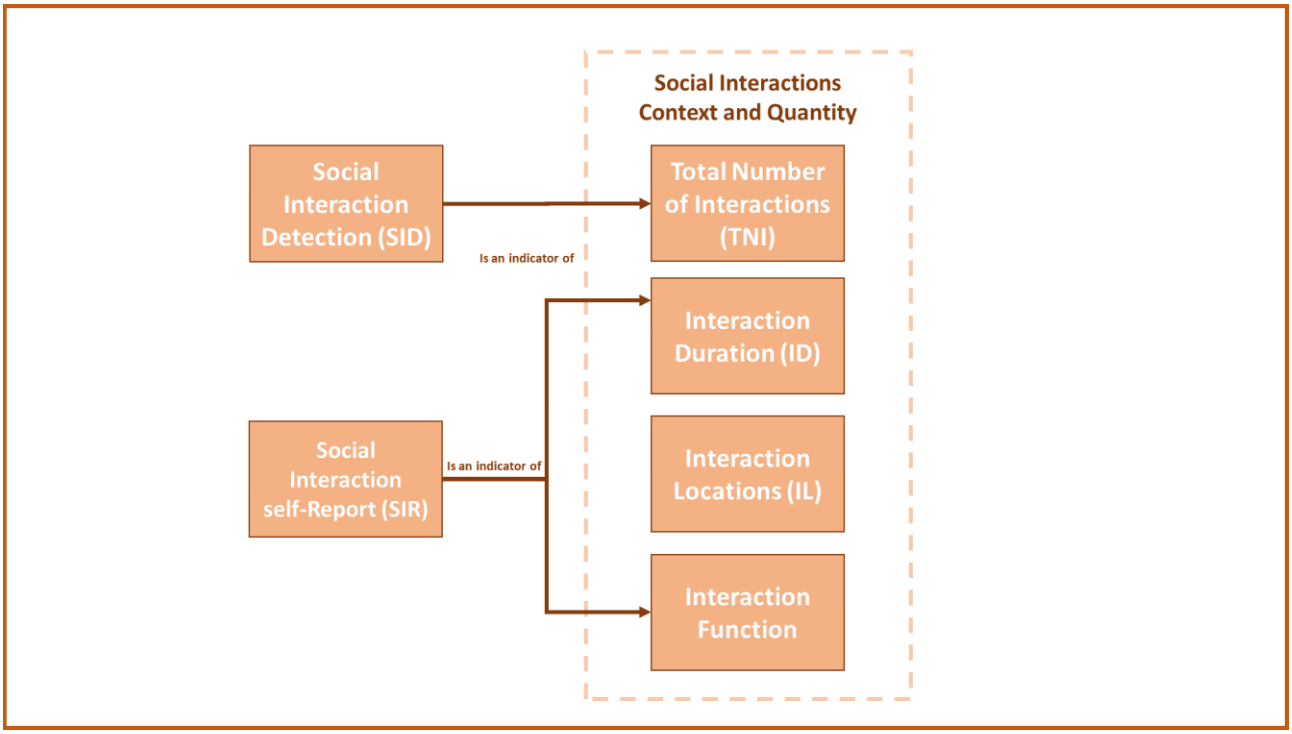

Figure 30 Relationship among variables in the subdomain "Social Behaviour"

Relationships among subdomains

The following figures show the relationships between each subdomain and the other subdomains.

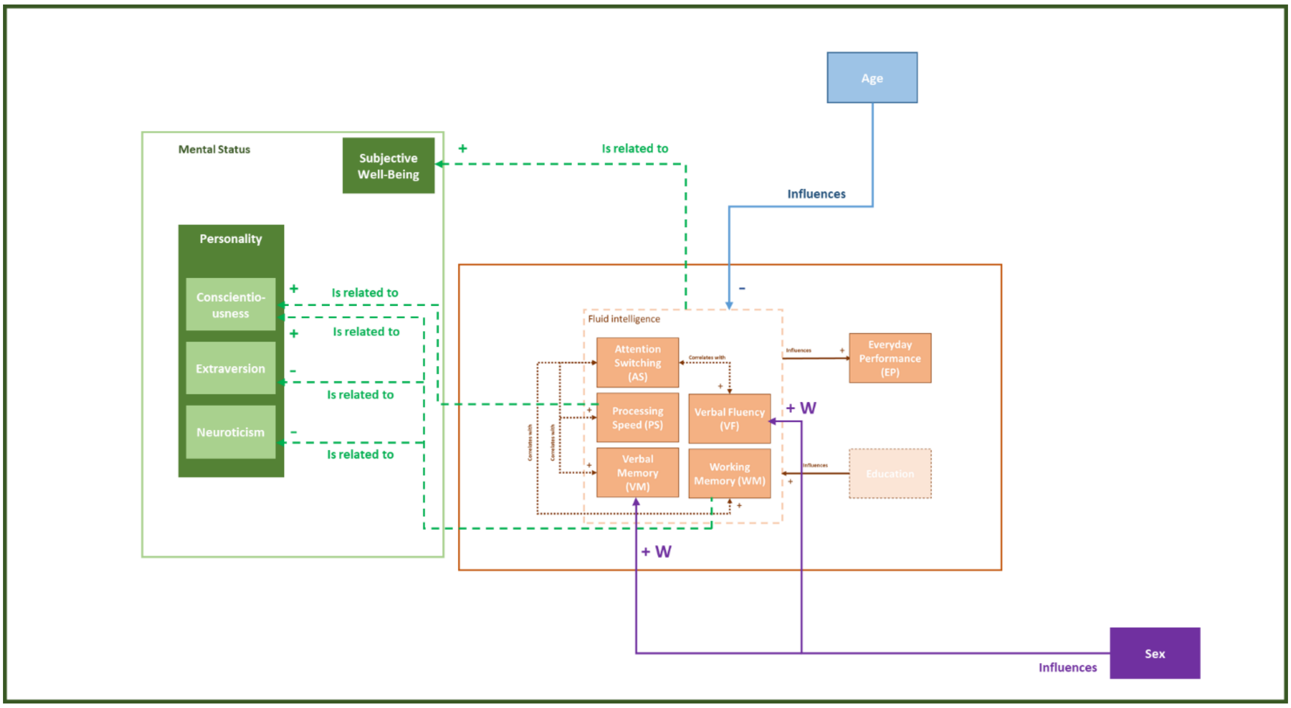

Figure 31 Relationships between the Cognitive Status subdomain and all the other Cognitive/Mental/Social subdomains

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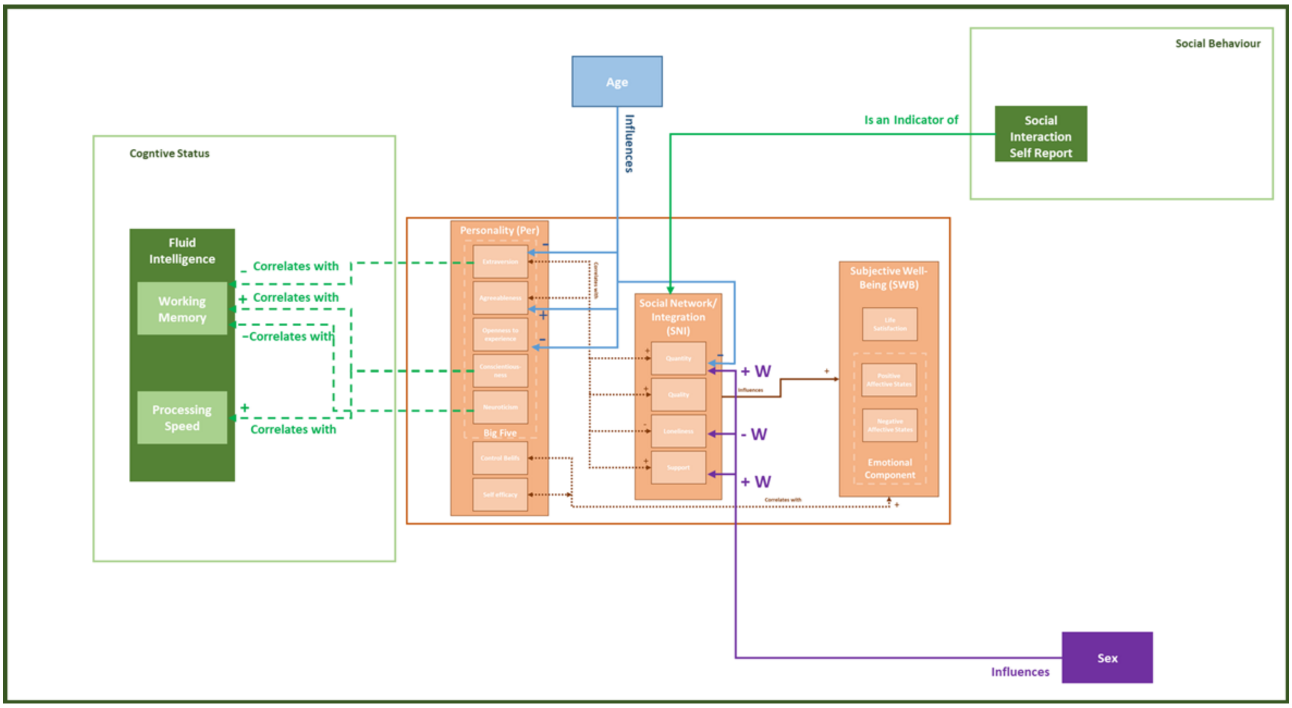

Figure 32 Relationships between the Mental Status subdomain and all the other Cognitive/Mental/Social subdomains

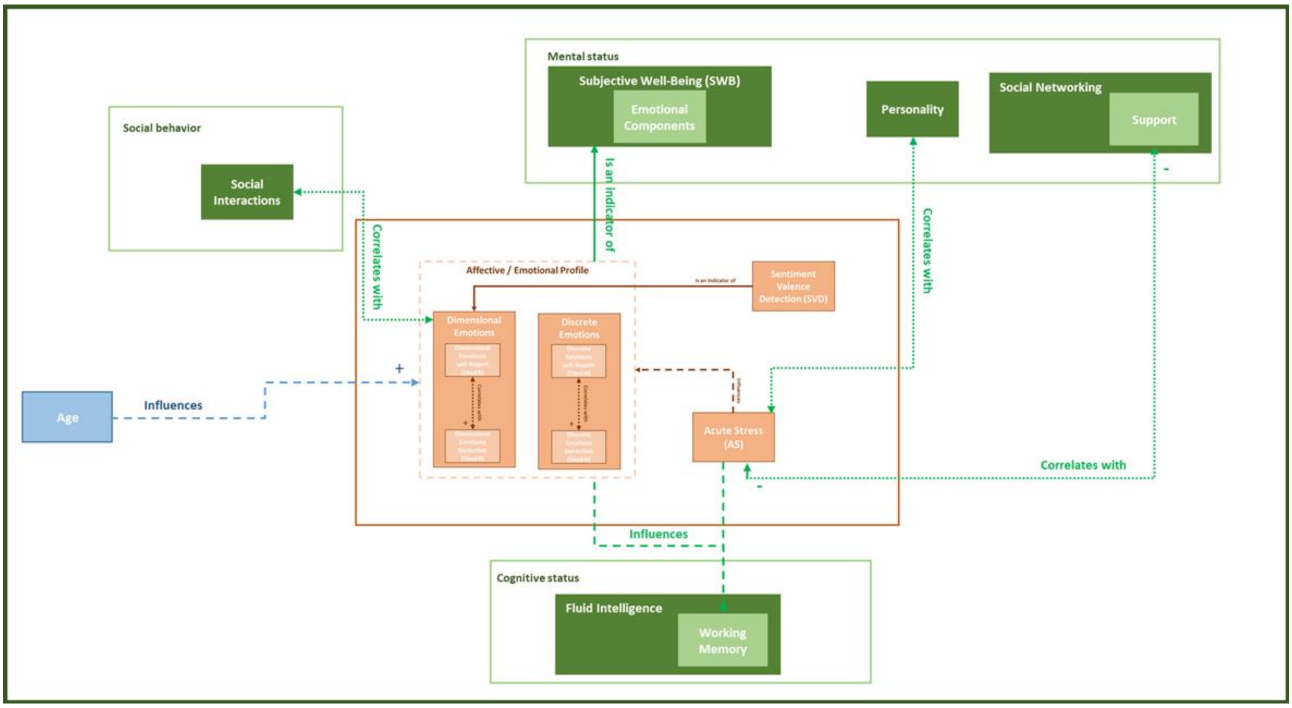

Figure 33 Relationships between the Mental Behaviour and States subdomain and all the other Cognitive/Mental/Social subdomains

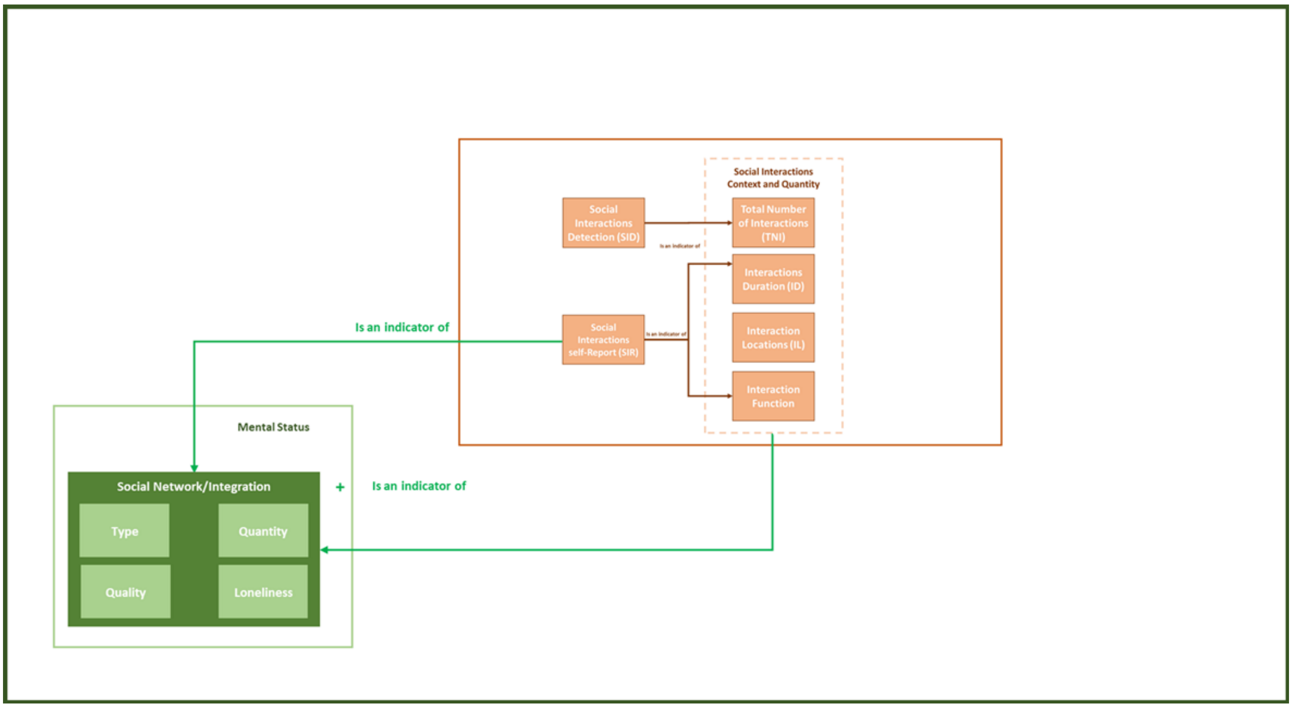

Figure 34 Relationships between the Social Behaviour subdomain and all the other Cognitive/Mental/Social subdomains

6.2 SOC and HAPA in NESTORE

6.2.1 SOC in NESTORE

As outlined above in Chapter 4, the SOC Model, (Baltes & Baltes, 1993) is a theoretical meta-model that describes three core strategies developing and ageing individuals can employ in order to deal with changes in the resources they possess (both person-level resources such as health, cognition, social belonging as well as changes in their environment such as availability of peers and close confidants). The strategies proposed, if employed, have shown to relate to better psychological adjustment.

Beyond the domain-general level, domain-specific adaptations of the general strategies have been employed in the past, such as work- and family-related selection, optimization and compensation (e.g., Baltes & Heydens-Gahir, 2003; Wiese et al., 2000). In such more specific applications, participants have been asked to rate their life-management strategies with respect not to life in general but with regard to their work or their family. In NESTORE, the goal is to cover a wide range of key domains for successful ageing, such as physical activity, nutrition and on the psychological side, emotional well-being, cognition and social relations (with other psychological factors being included to describe the sample along their dispositional psychological profile across self and personality, cognitive functioning, subjective well-being and social relations and support).

For NESTORE, one could go either the general or the domain-specific path. Given the length of the SOC questionnaire, which is the standard assessment tool (Freund & Baltes, 2002), it seems rather unpractical to apply these questions to all domains in the long format, even for the baseline status assessment. There is a shorter version available that has been used in daily life micro longitudinal studies (Knecht & Freund, 2017) and one possibility will be to use the domain-general SOC assessment at baseline and an abbreviated version of the domain-specific items during the micro longitudinal monitoring phase. This could be done at weekly or other intermediate time intervals (rather than daily) and would provide a glimpse into the implementation and use of these developmental regulatory strategies for the NESTORE domains during the daily life of healthy older adults pursuing particular health-related goals.

6.2.2 HAPA in NESTORE

Similar considerations are appropriate and necessary with regard to the HAPA model. It has been used in the past with regard to specific health behaviours and in the context of specific health-behaviour change interventions (e.g., Schwarzer, 2008). For this model, it is important to phrase it in domain-specific terms, so within NESTORE a challenge will be to use sufficiently brief scales that enable the assessment of the HAPA components such as self-efficacy and planning with regard to those goal domains an individual selects to pursue (e.g., nutrition and physical activity during one week, cognition and social relations during another). For this model, items have been used in very brief formats, in studies that tracked health-behaviour change processes in a longitudinal context and on the within-person level (Bierbauer et al., 2017), so in order to meet usability requirements in the form of short assessment scales that can be applied in short-term study designs are available. In further developing the nature and functionality of the NESTORE coach and in determining the user perspectives during the planned participatory approach, the exact implementation of SOC and HAPA, beyond the purely scientific needs, will have to be outlined in detail in order to meet one of the challenges of the NESTORE coach in obtaining maximum information with minimal intervention. This topic will be specifically addressed in the deliverable 5.1

7 Unique Features of NESTORE Approach

7.1 Building on a Novel Framework of What Constitutes Healthy Ageing

The core of the NESTORE approach is to consider healthy older adults on the basis of the healthy ageing as functional capacity definition put forth by the World Health Organization (Beard et al., 2016; WHO, 2015). Functional capacity is defined as those characteristics of individuals, as a result of intrinsic features and their interplay with the environmental context, which enable individuals to pursue their personal goals (i.e., those things in life that are of highest importance to them). It is further conceptualized as a process (rather than a status quo) during which individuals develop and maintain the functional ability that facilitates psychological and physical well-being during later life.

As such, this definition of healthy ageing acknowledges on the one hand that many of the older adults typically in the focus of interventions are healthy in the sense of not being demented (Wagster et al., 2012), but at the same time it is rather unlikely that individuals in their sixth and seventh or higher decade of life suffer of no diagnosed health challenge (Salive, 2013). This new definition does not neglect morbidity in age, but puts forth a more holistic perspective of older persons and of quality of life and the many opportunities for later life developmental regulation, at least during the so-called Third Age (i.e., until about age 80/85 years, when many domains do show significant decreases and impaired compensatory opportunities).

Given the NESTORE approach of developing a personalized coaching system that allows to value individual goals of older adults between the ages of 65 and 75 and focus on a wide range of domains that are important for quality of life in the latter phases of the human lifespan, using a participatory approach that again ensures acknowledgement of what the target group values, matches very well on the new global healthy ageing framework and the Global Strategy and Action report (WHO, 2016).

7.2 A Holistic Multi-Domain Approach

The NESTORE framework and system go beyond a single domain of functioning, but encompass a holistic approach that targets physical, nutritional, psychological, social, and cognitive domains. In addition to following a user-centred approach and one that includes a personalized decision support system, based on monitoring typical experiences and behaviours of individuals and relating these profiles to their personal goals, the NESTORE system also fits well into theoretical and empirical lifespan psychological findings in the motivation domain. Research has shown that older adults very well manage to construct a personal goal system that is functional and of little inter-goal conflict (Riediger et al., 2005), and incorporates a well-known health-behaviour change approach (Schwarzer, 2008)

7.3 A Within-Person Perspective Implemented with Innovative Ambulatory Assessment ICT Solutions

Developing a holistic coaching intervention with personalization option and for the broader population of healthy older adults is, as described above, one of the innovative features of the NESTORE approach. The implementation through an intelligent ICT solution involving mobile sensing approaches within an interdisciplinary context is another added value. Within psychology, including the psychology of ageing, ambulatory assessment approaches that enable both researchers and practitioners alike to examine ageing from a process-focused within-person perspective, have recently been identified for their untapped value in not only describing experiences and behaviour but also in implementing and evaluating health- and quality of life-oriented interventions (Brose & Ebner-Priemer, 2015). For instance, using a monitoring and tracking system that is developed under strict acknowledgement of the needs and goals identified with the targeted end users (i.e., in a participatory fashion) and with the goal to be as minimally disruptive as possible while rendering the maximum needed information to be able to feed into the decision support system of the NESTORE coach, provides an effective and innovative way for intervening in the interest of healthy ageing for any given person (e.g., Brose & Ebner-Priemer, 2015), a strategy that has been used already in clinical contexts (Trull & Ebner-Priemer, 2013), but that provides novel opportunities in the digital health era and including late life health and well-being (Moller et al., 2017; Yardley, Choudhury, Patrick, & Michie, 2016).

There are numerous issues and important considerations both from a conceptual and an assessment perspective, in terms of how all NESTORE variables proposed in Work Package 2 will be implemented (e.g., at what frequency, through which modality, etc.), especially so that maximum information is collected with minimal intervention. In this regard, innovative approaches as outlined in Mehl and Conner (2012) need to be considered when measuring the variables of interest, and when applying approaches ranging from experience sampling methods, diary methods, physiological measures, and other self-report and non-self-report tools that allow for repeated, real-time measurement in natural settings. The real-life approach that focuses on multimodal assessments of experiences, activities, performance and behaviour in a micro-longitudinal design provides very rich process information at the level of single individuals (which, of course, can also be aggregated to the population level to understand interindividual differences in the intraindividual dynamics), and has been shown to render useful and unique insights into physiological processes such as blood pressure (Burr, Dolan, O'Brien, O'Brien & McCormack, 2008), physical and psychological symptoms (Moore, Depp, Wetherell, & Lenze, 2016), everyday activities (Hoppmann et al., 2007), sleep patterns (van Hees et al., 2015) and cognitive functioning in daily life (Riediger & Rauers, 2014), and can and should be integrated with more classical long-term longitudinal approaches to study development and ageing (Röcke & Brose, 2013). To date, many health behaviour change theories have mainly been tested and evaluated at the intraindividual (i.e., within-person level) but only on the between-person level. It is known, however, that differences between individuals (i.e., persons with greater self-efficacy also tend to be more physically active if they intend to be) do not necessarily translate into variations within individuals (i.e., during times of greater perceived self-efficacy, people tend to be more successful in executing their plans to be more physically active; Molenaar, 2004). Initial tests of the HAPA model on the within-person level indicate that key tenets of the theory hold, but a systematic investigation and replication also in older adults is much needed to further corroborate theory building in the health behaviour change domain (Bierbauer et al., 2017; Scholz et al., 2009).

Overall, the NESTORE project is unique in its combination of the new WHO definition of health and ageing, using novel technologies, a user-centred participatory approach, being theory-guided (SOC and HAPA) and using novel methods put forth to describe, explain and intervene on healthy ageing processes in both psychological and health domains, following the ongoing discussion on the role of big data and digital health in different age groups, including later life illness and health (for a recent discussion in the context of dementia research, with many challenges that also apply in healthy ageing approaches, see Ienca et al., 2018).

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ANNEX 1
Physiological Status and Physical Activity Behaviour

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Short Abstract

This annex contains a detailed description of the model of the Physiological status and Physical Activity Behaviour. Based on the information reported in the previous chapters, the physiological status has been organized in four subdomains: 1) **Anthropometric Characteristics**, which contains a detailed description of the main anthropometric variables describing body dimensions and relationship among them; 2) **Cardiovascular System**, which contains a detailed description of the main physiological variables that influence transport of nutrients, oxygen, carbon dioxide, hormones, and blood cells from the lungs to peripheral tissue and vice versa; 3) **Respiratory System**, which contains a detailed description of the main physiological variables related to structure and function of the organs designated to exchange blood gases between ambient air and blood cells; 4) **Musculoskeletal System** , which contains a detailed description of the main physiological variables related to the ability of skeletal muscle to generate force and power. Moreover, this Annex includes a description of the variables describing the ability of a subject to perform exercise limited from cardiorespiratory system (**Cardiorespiratory Exercise Capacity**) or musculoskeletal system (**Strength-Balance-Flexibility Exercise Capacity**) as well as the usual behaviour of a subject during every-day life (**Physical activity Behaviour**). A description of the main factors related to sleep (**Sleep Quality**) has been also included in this chapter.
This structure will help NESTORE Decision Support System in the application of an individualized guidelines and it will improve the understanding about specific effects of the different interventions.

The document is composed of four subsections, describing:

- **Variables useful for the characterization and monitoring of the physiological status of the person along with his/her physical activity behaviour**: for each subdomain a table containing the related variables is provided, followed by a short description of the variable meaning. Each variable is classified with respect to its foreseen use in NESTORE (System=variable to be used in the system, Pilot=variable to be used during the system validation in Pilots), its importance (necessary, important), the factors negatively affecting the variable itself.

This part is specifically thought to support the development of ontology in Task 2.5 and also for profiling activities and, consequently, for personalization purposes (WP4 and WP5).

- **Relationships among the domain variables and variable ranges and/or trends corresponding to normal aging status and behaviour**: for each subdomain a scheme describing the relationships among the variable domains is provided (solid arrows = direct causal relationship, dashed arrows = indirect causal relationship, dotted arrows = correlation between); if a variable can be directly calculated from others, the formula is provided; variables foreseen as system variables are in orange, variables foreseen only in Pilots are in yellow. Moreover, for each domain a table containing the normality range and/or the normal trend physiologically occurred during aging, is provided for each system variable, if known. The consequences of out of range values (or trends) are also reported.

This part is specifically thought for the ontology and to support WP4 in the development of the Decision Support System.

- **Measurement scenarios of the system variables**: for each subdomain, the principal information describing how the variables should be measured by the system are reported in a dedicated table. Specifically, the table includes: measurement conditions (frequency, location, duration, etc.), measurements units, formulas to derive the variable value from other variables, measurement devices, gold standard measurements.

This part provides the functional system requirements from the point of view of the domain experts, in support to WP3 and WP5, for the development of the monitoring system.

- **Measurement scenarios for variables related to validation:** for each subdomain, some suggestions on how to measure the variables during pilots are provided.

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This part is thought to support the definition of Virtual Coach Validation Plan to be used in the pilots to assess the impact and the functional effectiveness of the Virtual Coach on the elderly subjects' status and behaviour (Task 2.6)

Key Words

Physiological status, Physical Activity Behaviour, Anthropometric Characteristics, Cardiovascular System, Respiratory System, Musculoskeletal System, Cardiorespiratory Exercise Capacity, Strength-Flexibility-Balance Exercise Capacity, Physical Activity Behaviour, Sleep Quality

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1. Description of the subdomains and related variables

1.1 Anthropometric characteristics

Table 1. List of variables of the Anthropometric Characteristics subdomain.

VARIABLE NAME	ACRONYM	TO BE USED IN SYSTEM/PILOT	PRIORITY	AFFECTED BY
BODY HEIGHT	BH	System + Pilot	Necessary	-
BODY WEIGHT	BW	System + Pilot	Necessary	Undernutrition, overnutrition, sedentary lifestyle, genetics, socioeconomic factors, drugs.
BODY MASS INDEX (BMI)	BMI	System + Pilot	Necessary	Undernutrition, overnutrition, sedentary lifestyle, genetics, socioeconomic factors, drugs.
FAT MASS	FM	System + Pilot	Necessary	Dietary habits, sedentary lifestyle, genetics, socioeconomic factors.
FAT-FREE MASS	FFM	System + Pilot	Necessary	Dietary habits, sarcopenia, sedentary life, socioeconomic factors.
HIP CIRCUMFERENCE	HC	System + Pilot	Necessary	Dietary habits, sedentary life, genetics, socioeconomic factors.
WAIST CIRCUMFERENCE	WC	System + Pilot	Necessary	Dietary habits, sedentary lifestyle, genetics, socioeconomic factors.
WAIST-TO-HEIGHT RATIO	WHtR	System + Pilot	Necessary	Dietary habits, sedentary lifestyle, genetics, socioeconomic factors.
WAIST-TO-HIP RATIO	WHR	System + Pilot	Necessary	Dietary habits, sedentary lifestyle, genetics, socioeconomic factors.

Body height (BH): Standing height of the person, corresponding to the maximum vertical size. Ref: Perissinotto et al., 2002

Body weight (BW): Body mass of the person. Ref: Buffa et al., 2011; Guo et al., 1999, Harms et al., 2011; Hughes et al.2002

Body mass index (BMI): BMI is a weight-for-height index. It is calculated by dividing the subject's weight (kg) by the square of their height (m). Currently, the BMI criteria proposed by WHO are the most widely used. Evidence suggests that the risk of finding oneself at the extremes of the body mass index (either underweight or obese), increases along with age. Ref: Buffa et al., 2011; Babiarczyk et al., 2012

Fat mass (FM): Body weight corresponding to fat mass (expressed in Kg and percentage of body weight). Aging is frequently associated with a gradual increase of fat mass (FM), which has a negative impact on health outcomes, such as morbidity, mortality and quality of life. Elevated fat mass may simultaneously occur in the presence of normal or low fat-free mass (also termed sarcopenia). The double burden of excess FM and low FFM may lead to decreased physical functioning in comparison to those with normal body composition. Ref: Buffa et al., 2011; Harms et al., 2011; Kyle et al., 2001; Zamora et al., 2017

Fat-free mass (FFM): FFM, also known as lean body mass, refers to all of the body components except fat. It includes body's water, bone, organs and muscle content. However, when it comes to weight management and body composition, fat-free mass refers primarily to muscle mass. Ref: Buffa et al., 2011; Fuller et al., 1996; Harms et al., 2011; Kyle et al., 2001; Zamora et al., 2017

Hip Circumference (HC): Hip circumference is usually assessed in manual measurements with flexible but non-stretchable tapes at the level of the largest lateral extension of the hips in a horizontal plane. It is considered an

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indicator of abdominal obesity and it may be better predictors of risk than the BMI for several diseases, including cardiovascular disease (CVD), cancer, type 2 diabetes, and the Metabolic Syndrome. Ref: Buffa et al., 2011; Kyle et al., 2001; WHO, 2011.

Waist Circumference (WC): It is the perimeter of the abdomen, measured at the mid-point between the lower rib and the iliac crest, at a level parallel to the floor. Waist circumference is a better measure of visceral (abdominal) obesity than BMI. Visceral obesity is closely related with comorbidities and with the presence of metabolic syndrome. Ref: Ma et al.,2013; Klein et al., 2007; WHO, 2011.

Waist-to-height ratio (WHtR): Waist to height ratio is a simple measurement for assessment of lifestyle risk and overweight. Compared to just measuring waist circumference, waist to height ratio is equally fair for short and tall persons. Measuring waist to height ratio is gaining popularity in the scientific society as several studies have found that this is a more valid measurement than BMI. Just measuring waist circumference is inherently biased for people taller or shorter than average population. Ref: Buffa et al., 2011; Kyle et al., 2001; Swainson et al., 2017.

Waist-to-hip ratio (WHR): Waist to hip ratio is another simple measurement for assessment of lifestyle risk and overweight (see previous WHtR)

1.2 Cardiovascular System

Table 2 List of variables of the Cardiovascular System subdomain.

VARIABLE NAME	ACRONYM	TO BE USED IN SYSTEM/PILOT	PRIORITY	AFFECTED BY
BLOOD PRESSURE	BP	System + Pilot	Necessary	Smoking, cardiovascular diseases, diet
CARDIAC OUTPUT	CO	Pilot	-	Smoking, cardiovascular diseases, anxiety, stress
HEART RATE	HR	System + Pilot	Necessary	Smoking, cardiovascular diseases, anxiety, stress
HEART RATE VARIABILITY	HRV	System + Pilot	Necessary	Smoking, cardiovascular diseases, anxiety, stress
STROKE VOLUME	SV	Pilot	-	Smoking, cardiovascular diseases, anxiety, stress

Blood Pressure (BP): BP is the pressure of circulating blood on the walls of blood vessels. Blood pressure is usually expressed in terms of the **systolic pressure** (SP) (maximum during one heart beat) over **diastolic pressure** (minimum in between two heart beats). The **mean arterial pressure** (MAP) is the average over a cardiac cycle and is determined by the cardiac output, systemic vascular resistance, and central venous pressure. It can be also derived from systolic and diastolic blood pressure. The **pulse pressure** (PP) is the difference between the measured systolic and diastolic pressures. It results from the fluctuation of the arterial pressure resulting from the pulsatile nature of the cardiac output. Ref: Alghatrif et al., 2017; Lakatta, 1995.

Cardiac Output (CO): CO is the amount of blood pumped by the heart per minute. In the NESTORE model, CO is composed by the **resting Cardiac Output** (rCO) and the **maximal Cardiac Output** (MCO) that are measured at rest and after a maximal exercise respectively. Despite the cardiac aging changes that may limit a person's functional capacity and promote vascular stiffening with consequent increased afterload, the overall resting systolic function of cardiac muscle does not change with healthy aging. Ref: Fleg et al., 2012; Fellahi et al., 2009; Lakatta, 1995.

Heart Rate (HR): HR is the number of times the heart beats per minute. A normal **resting Heart Rate** (rHR) is between 60 and 100 beats per minute (bpm). However, it will vary depending on when it is measured and what you were doing immediately before the reading. For example, it will be higher when a subjects is walking compared to when he/she is sitting or resting. This is because the body needs more energy when it is active. In the NESTORE system, the HR is also described as **Maximal/Peak Heart Rate** (MHR/PHR) when it is related to the

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maximal HR and **exercise Heart Rate** (eHR) when it is measured during exercise. Ref: Ferrari et al., 2004; Lakatta, 1995.

Heart Rate Variability (HRV): HRV is the degree of fluctuation in the length of the intervals between either heart beats or the duration of the R-R interval (the time between two successive R waves in a typical electrocardiogram). These temporal fluctuations in heart rate exhibit a marked synchrony with respiration (increasing during inspiration and decreasing during expiration) and are widely believed to reflect changes in cardiac autonomic regulation. HRV is usually composed by the following components: HF (0.15–0.40 Hz), expression of vagal activity; LF (0.04–0.15 Hz), expression of sympathetic and vagal activity as well as baroreflex sensitivity; LF/HF ratio, proposed as balance between sympathetic and parasympathetic activities; VLF (0.0033–0.04 Hz), expression of sympathetic activity and parasympathetic activity but also influenced by thermoregulation and renin–angiotensin system; ULF (<0.0033 Hz), marker of circadian and neuroendocrine rhythms. RV has been established as a non-invasive tool to study cardiac autonomic activity and has been proposed as a predictor of increased risk for cardiac mortality. Ref: Voss et al., 2015; Billman et al., 2015; Zulfiqar et al., 2010; Tsuji et al., 1994.

Stroke Volume (SV): Stroke Volume (SV) is the volume of blood in millilitres ejected from each ventricle due to the contraction of the heart muscle which compresses these ventricles. SV is the difference between end diastolic volume (EDV) and end systolic volume (ESV). Thus, SV is not all the blood contained in the left ventricle; normally, only about two-thirds of the blood in the ventricle is expelled with each beat. It is commonly accepted that, during incremental, upright exercise to maximum, SV increases from rest to exercise and plateaus at 40–50% of VO2max. Ref: Vella et al., 2005.

1.3 Respiratory System

Table 3 List of variables of the Respiratory System subdomain.

VARIABLE NAME	ACRONYM	TO BE USED IN SYSTEM/PILOT	PRIORITY	AFFECTED BY
DYNAMIC LUNG VOLUMES	DLV	Pilot	-	Smoking, pulmonary diseases
OXYGEN SATURATION	SO_2	System + Pilot	Important	Smoking, pulmonary disease, cardiovascular disease, anemia, CO poisoning
RESPIRATORY MUSCLE PERFORMANCE	RMP	Pilot	-	Smoking, pulmonary diseases
BREATH FREQUENCY	BF	System + Pilot	Optional	Smoking, pulmonary diseases
PULMONARY VENTILATION	VE	Pilot	Optional	Smoking, pulmonary diseases
STATIC LUNG VOLUMES	SLV	Pilot	-	Smoking, pulmonary diseases

Dynamic Lung Volume (DLV): Lung volumes that depend upon the rate at which air flows out of the lungs are termed DLV. The **Forced Vital Capacity** (FVC) is the volume of gas that can be exhaled as forcefully and rapidly as possible after a maximal inspiration. Normally FVC is equal to Vital Capacity, however in certain pulmonary diseases (characterized by increased airway resistance), FVC is reduced. From the FVC test, we can also determine the **Forced Expiratory Volume in 1 sec** (FEV1), which is the maximum volume of air that can be exhaled in a 1 sec time period. Normally the percentage of the FVC that can be exhaled during 1 sec is around 80% (i.e. FEV1/FVC=80%). **Maximum Voluntary Ventilation** (MVV) is the largest volume of air that can be breathed in and out of the lungs in 1 minute. It will be reduced in pulmonary diseases due to increases in airway resistance or changes in compliance. Ref: Jessen et al., 2005; Neder et al., 1999.

Oxygen Saturation (SO_2): SO_2 is the fraction of oxygen-saturated haemoglobin relative to total haemoglobin (unsaturated + saturated) in the blood. The oxygen concentration of systemic arterial blood depends on several

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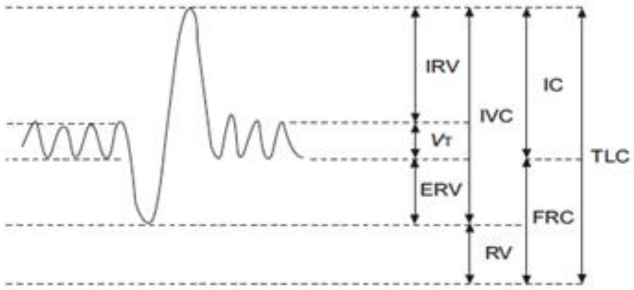
factors, including the partial pressure of inspired oxygen, the adequacy of ventilation and gas exchange, the concentration of haemoglobin and the affinity of the haemoglobin molecule for oxygen. Ref: Collins et al., 2015
Respiratory Muscle Performance (RMP): RMP is the performance of the skeletal muscles involved in the respiratory activity. Respiratory muscle performance is impaired concomitantly by the age-related geometric modifications of the rib cage, decreased chest-wall compliance, and increase in functional residual capacity (FRC) resulting from decreased elastic recoil of the lungs. Age-associated alterations in skeletal muscles also affect respiratory muscle function. **Maximal Inspiratory Pressure** (MIP) and **maximal Expiratory Pressure** (MEP) in elderly subjects are correlated strongly and independently with peripheral muscle strength. Ref: Jessen et al., 2005.
Breath Frequency (BF): BF (also known as **Respiratory Rate** (RR)) is the rate at which breathing occurs and it is usually measured in breaths per minute. In the NESTORE model, BF is composed by **resting Breath Frequency** (BF_{rest}) and **exercise Breath Frequency** (eBF). BF_{rest} is measured at rest whilst eBF is measured during exercise. Older adults may have an increased respiratory rate to compensate for the decrease in Tidal Volume (TV) that is the normal volume of air displaced between normal inhalation and exhalation. Recent studies report that high respiratory rates (>27 breaths per minute) have been shown to have a high predictive value for serious adverse events, including cardiac arrest in hospital patients, respiratory rates may be more sensitive than pulse or blood pressure in determining critically ill patients. Ref: Jessen et al., 2005; Neder et al., 1999; Chester et al., 2011; Williams et al., 2009.
Pulmonary Ventilation (VE): VE is the amount of gas inhaled or exhaled from a person's lungs in one minute. If both TV and BF are known, pulmonary ventilation can be calculated by multiplying the two values. PV can be measured at rest and is defined as **resting Pulmonary Ventilation** (PV_{rest}) or it can be measured during a maximal exercise and it is defined as **maximal Pulmonary Ventilation** (VE_{max}). Ref: Jessen et al., 2005; Neder et al., 1999.
Static Lung Volumes (SLV): SLV measurements provide useful information about the overall lung function that can be fundamental in categorizing and staging pulmonary diseases. **Vital capacity** (VC/IVC) is the amount of air expired or inspired between maximum inspiration and expiration. **Residual volume** (RV) is the volume of air remaining in the lungs after maximal expiration, and, by definition, cannot be measured by classic spirometry but an inert gas (i.e. Helium) is needed. **Functional residual capacity** (FRC) is the amount of air in the lungs at the end-tidal position. **Total lung capacity** (TLC) is the amount of air in the chest after a maximum inspiration. **Inspiratory capacity** (IC) is the volume of gas that can be taken into the lungs in a full inhalation, starting from the resting inspiratory position; equal to the tidal volume plus the inspiratory reserve volume. **Expiratory reserve volume** (ERV) is the additional amount of air that can be expired from the lungs by determined effort after normal expiration. **Inspiratory reserve volume** (IRV) is the maximal amount of additional air that can be drawn into the lungs by determined effort after normal inspiration. Ref: Jessen et al., 2005; Wanger et al., 2005.



Static lung volumes and capacities based on a volume-time spirogram of an inspiratory vital capacity (IVC). IRV: inspiratory reserve volume; V_T: tidal volume (TV); ERV: expiratory reserve volume; RV: residual volume; IC: inspiratory capacity; FRC: functional residual capacity; TLC: total lung capacity.

Adapted from Wanger et al., 2005

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1.4 Musculoskeletal System

Table 4 List of variables of the Musculoskeletal System subdomain.

VARIABLE NAME	ACRONYM	TO BE USED IN SYSTEM/PILOT	PRIORITY	AFFECTED BY
MUSCLE CROSS SECTIONAL AREA	CSA	System + Pilot	Important	Sarcopenia
MUSCLE PHYSIOLOGICAL CROSS SECTIONAL AREA	PCSA	Pilot	-	Sarcopenia
MUSCLE MASS	MS	System + Pilot	Important	Sarcopenia
MUSCLE THICKNESS	MT	Pilot	-	Sarcopenia
PENNATION ANGLE	PA	Pilot	-	Sarcopenia
RANGE OF MOVEMENT	ROM	System + Pilot	Necessary	Arthrosis, Arthritis, Orthopedic surgery

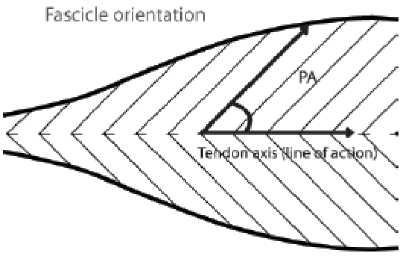
Muscle Cross-Sectional Area (CSA): Anatomical CSA is the area of the cross section of a muscle perpendicular to its longitudinal axis. Ref: Harms et al., 2011; Kyle et al., 2001; Jubrias et al., 1997; Hakkinen et al., 1991; Vandervoort, 2002; Cruz-Jentof et al., 2010.

Muscle Physiological Cross-Sectional Area (PCSA): PCSA is the area of the cross section of a muscle perpendicular to its fibres, generally at its largest point. This variable is more directly related to muscle strength than CSA. Ref: Narici et al., 1992.

Muscle Mass (MS): MS is the body weight corresponding to total skeletal muscle mass (expressed in Kg and percentage of body weight). Assuming that the prevalence of sarcopenia will be very low within Nestore user's, the importance of measuring skeletal muscle mass lies in the assessment of body weight loss in obese users, since weight loss has to be at the expense of fat mass but conserving muscle mass, or the assessment of body composition changes across time (i.e. loss of muscle mass across time). Muscle mass is reduced with aging and the consequences can be extensive because there is an increased susceptibility to falls and fractures, impairment in the ability to thermoregulate, a decrease in basal metabolic rate, as well as an overall loss in the functional ability to perform daily tasks. Ref: Harms et al., 2011; Kyle et al., 2001; Lee et al., 2000; Cohn et al., 1980; Kalyani et al., 2014.

Muscle Thickness (MT): Muscle thickness is the thickness of the muscle. Ref: Fukunga et al., 2001; Narici et al., 2003.

Pennation Angle (PA): PA is defined as the angle between the orientation of a fascicle and the attached tendon axis. Since fascicles have variable length and arrangement within a muscle, the associated PA differs from fascicle to fascicle. In practice, PA is measured as the acute angle between two intersecting lines representing fascicle orientation and a deep aponeurosis. Ref: Kubo et al., 2003; Narici et al., 2003.



Range Of Movement (ROM): ROM is a description of how much movement exists at a joint. Rotation is the typical movement at a joint. This is called “angular” movement. Because the movement is angular, the unit “degree” is used when measuring ROM rather than inches or millimetres. ROM can be measured as either active or passive. Active ROM is created by the person contracting the muscles around that joint. Passive ROM is created by an external force pushing on the body around the joint. Passive ROM is always greater than active ROM. ROM is used to evaluate and classify joints impairments in patients or the efficacy of certain rehabilitation program. It is well recognized that proprioceptive function is crucially important for balance, posture, and motor control. Ref: Hamilton, 2011.

1.5 Cardiorespiratory Exercise Capacity

Table 5 List of variables of the Cardiorespiratory Exercise Capacity subdomain.

VARIABLE NAME	ACRONYM	TO BE USED IN SYSTEM/PILOT	PRIORITY	AFFECTED BY
AEROBIC FITNESS	VO_2max	System + Pilot	Necessary	Smoking, Cardiovascular diseases, Pulmonary disease, Deconditioning, Anemia, Sarcopenia
ANAEROBIC THRESHOLD	AT	System + Pilot	Important	Smoking, Cardiovascular diseases, Pulmonary disease, Deconditioning, Anemia, Sarcopenia
CARDIOVASCULAR FITNESS	CF	Pilot	-	Smoking, Cardiovascular diseases, Pulmonary disease, Deconditioning, Anemia, Sarcopenia
CARDIAC OUTPUT VS EXERCISE INTENSITY SLOPE (CO-VO$_2$)	CO-VO_2	Pilot	-	Smoking, Cardiovascular diseases, Pulmonary disease, Deconditioning, Anemia, Sarcopenia
CLINICAL AEROBIC FITNESS	CAerF	System + Pilot	Necessary	Smoking, Cardiovascular diseases, Pulmonary disease, Deconditioning, Anemia, Sarcopenia
EXERCISE HEART RATE	eHR	System + Pilot	Necessary	Smoking, Cardiovascular diseases, Anxiety, Stress
HR RESERVE	HRR	System + Pilot	Necessary	Smoking, Cardiovascular diseases, Pulmonary disease, Deconditioning, Anemia, Sarcopenia
HABITUAL WALKING SPEED	HWS	System + Pilot	Necessary	Smoking, Cardiovascular diseases
MAXIMAL CARDIAC OUTPUT	COmax	Pilot	-	Smoking, Cardiovascular diseases, Anxiety, Stress
MAXIMAL AND PEAK HEART RATE	MHR/PHR	System + Pilot	Necessary	Smoking, Cardiovascular diseases, Anxiety, Stress
MAXIMAL PULMONARY VENTILATION	MPV	Pilot	-	Smoking, Pulmonary diseases

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POST-EXERCISE HEART RATE RECOVERY	HRRec	System + Pilot	Necessary	Smoking, Cardiovascular diseases, Pulmonary disease, Deconditioning, Anemia, Sarcopenia
TARGET HEART RATE	tHR	System + Pilot	Necessary	Smoking, cardiovascular diseases, anxiety, stress
VO_2 RESERVE	VO_2R	Pilot	-	Smoking, Cardiovascular diseases, Pulmonary disease, Deconditioning, Anemia, Sarcopenia
VO_2 REST	VO_{2rest}	Pilot	-	Smoking, Cardiovascular diseases, Pulmonary disease, Deconditioning, Anemia, Sarcopenia

Aerobic Fitness (VO_2 max): Maximal oxygen uptake capacity (VO2max) is the highest rate of oxygen consumption that one can attain while performing an exercise test of progressively increasing intensity that requires a large proportion of the total skeletal muscle mass. VO2max is determined by the capacity of the cardiovascular system to deliver oxygen to the working muscles and the capacity of the muscles to extract oxygen from the blood and to utilize it to generate ATP via oxidative metabolism. VO2max is therefore a function of both maximal cardiac output (MCO) and maximal arteriovenous oxygen difference. Ref: Lakatta, 1995; Golding, et al., 1986.

Anaerobic Threshold (AT): During incremental exercise, work intensities are reached at which ventilation increases disproportionately with respect to O_2 uptake (VO_2) and lactate accumulates in the blood. The VO_2, at which either or both of these phenomena are observed has been termed ventilator or lactate AT, respectively. Ref: Posner et al., 1987; Thomas et al., 1985.

Cardiovascular fitness (CF): CF is the ability of the heart, blood cells and lungs to supply oxygen-rich blood to the working muscle tissues and the ability of the muscles to use oxygen to produce energy for movement.

Clinical Aerobic Fitness (CAerF): It is the clinical correlate of the Aerobic fitness. Muscle power and exercise capacity determine the overall CAerF of a subject. Aging results in an important decrease of CAerF, therefore, older adults often function at the limit of their capacity in order to fulfil the activities of daily living. Ref: Lipkin et al. ,1986; Troosters et al., 1999; Salbach et al., 2015.

Cardiac output vs exercise intensity slope (CO-VO_2): This variable is the slope of oxygen uptake versus exercise intensity curve. Systemic oxygen delivery (cardiac output) increases in proportion to exercising muscle oxygen consumption and is closely coupled to the increase in exercising muscle blood flow (eMBF) (Mortensen et al. 2008; Calbet et al. 2015). The steepness of the slope is a valid measurement of oxygen flow to the exercising tissues. Ref: Lakatta et al., 1995; Adami et al., 2014.

Exercise Heart rate (eHR): It represents the HR measured during exercise. The potential of eHR to be used as a valid exercise intensity indicator warrants the establishment of the individual relationship between VO_2 and heart rate and the precision of this technique depends on the robustness of the regression line. The precision of the VO_2 over exercise intensity regression is well- described and accepted during treadmill running/walking and cycling. In some cases, VO_2 can be substituted by exercise intensity measured as speed of walking/running or work rate during cycling. Ref: Lakatta et al., 1995; Fairbarn et al., 1994.

Habitual Walking Speed (HWS): WS is the speed at which a subject tends to walk without any constraint. It is a measure of physical function which is related to musculoskeletal strength and power and is vital for independent life at higher ages. Moreover, walking speed is associated with survival at all ages in both sexes, and is particularly informative for people aged 75 and over. Gait speed is a quick, inexpensive, reliable measure of functional capacity with well-documented predictive value for major health-related outcomes. Ref: Minetti et al., 2002; Studenski et al., 2011; Weber et al., 2016.

Heart Rate Reserve (HRR): HRR is the difference between resting heart rate (rHR) and maximum heart rate (MHR). HRR is used to calculate exercise heart rate at a given percentage training intensity. Ref: Lakatta, 1995.

Maximal Cardiac Output (COmax): Maximal cardiac output is the highest value of CO reached during an incremental exercise up to exhaustion. It is the most important cardiovascular variable determining maximal aerobic power because the oxygen- enriched blood (carrying about 0.2 L of O2 per liter of blood) must be delivered to the muscle for the mitochondria to use. Endurance training increases the maximal cardiac output and thus the delivery of oxygen to the muscles. Ref: Lakatta, 1995.

Maximal and Peak Heart Rate (MHR/PHR): MHR is the highest heart rate value that can be achieved by a subject. PHR is the highest value of heart rate reached by a subject during a maximal exercise. PHR is one of the most commonly used values in clinical medicine and physiology. For example, a straight percentage of PHR or a fixed percentage of heart rate reserve is used as a basis for prescribing exercise intensity in both rehabilitation and disease prevention programs. Moreover, in some clinical settings, exercise testing is terminated when subjects reach an arbitrary percentage of their age-predicted maximal heart rate (e.g., 85% of MHR). Ref: Lakatta, 1995; Ferrari et al, 2003; Tanaka et al., 2001.

Maximal Pulmonary Ventilation (MPV): Pulmonary ventilation is the amount of gas inhaled or exhaled from a person's lungs in one minute. If both tidal volume (TV) and breath frequency (BF) are known, pulmonary ventilation can be calculated by multiplying the two values. Maximal pulmonary ventilation is calculated as the product between maximal TV and maximal BF. Ref: McClaran et al., 1995.

Post Exercise Heart Rate Recovery (HRRec): It is defined as defined as the rate of decline in HR after cessation of the effort. The value for the post-exercise heart rate recovery should be defined as the reduction in the heart rate from the rate at peak exercise to the rate one minute after the cessation of exercise. A delayed decrease in the heart rate during the first minute after graded exercise, which may be a reflection of decreased vagal activity, is a powerful predictor of overall mortality, independent of workload, the presence or absence of myocardial perfusion defects, and changes in heart rate during exercise. In the literature several studies showed that middle-aged and elderly individuals have delayed HR recovery after exercise test, when compared to young individuals and that HRR measures are directly related to the level of aerobic fitness. Ref: Cole et al., 1999; Deschenes et al., 2006; Darr et al., 1988.

Target Heart Rate (tHR): tHR is the heart rate to be reached during a prescribed physical activity. Ref: Ferrari et al., 2003; Lakatta, 1995.

VO_2 Reserve (VO_2R): VO_2R is the percentage of the difference between resting VO_2 (VO_2rest) and VO_2max. VO_2R is used to calculate exercise VO_2 at a given percentage training intensity. Ref: Lakatta, 1995.

VO_2 Rest (VO_2rest): It is the amount of oxygen consumed by the body in resting condition. Ref: Lakatta, 1995.

1.6 Strength-Balance-Flexibility Exercise Capacity

Table 6 List of variables of the Strength-Balance-Flexibility Exercise Capacity subdomain.

VARIABLE NAME	ACRONYM	TO BE USED IN SYSTEM/PILOT	PRIORITY	AFFECTED BY
BALANCE		System + Pilot	Important	Arthrosis, Arthritis, Tendinitis, Orthopedic surgery
CLINICAL ANAEROBIC FITNESS	CAnaF	System + Pilot	Necessary	Deconditioning, Sarcopenia
FLEXIBILITY		System + Pilot	Important	Arthrosis, Arthritis, Tendinitis, Orthopedic surgery
MUSCLE POWER	MP	System + Pilot	Necessary	Sarcopenia
MUSCLE STRENGTH	MS	System + Pilot	Necessary	Sarcopenia
MOVEMENT SPEED	SoM	System + Pilot	Important	Neuromuscular Diseases

Balance: Balance is the ability to maintain the body's centre of mass (COM) within the limits of the base of support. Balance is achieved by the complex integration and coordination of multiple body systems including the vestibular, visual, auditory, motor, and higher level premotor systems. Weakness in the core stabilizing muscles, altered muscle activation patterns, loss of proprioception, and an inability to control normal postural control can all result in decreased balance in the elderly. Ref: Galloza et al., 2017; Mancini et al., 2010; Bloem et al., 2003; Nnodim et al., 2015.

Clinical Anaerobic Fitness (CAnaF): It is the clinical correlate of the anaerobic power. Anaerobic power is the amount of energy produced in very short exercise of no more than 10 sec of duration and it is indicative of the phosphagen-splitting mechanism of work production alone. Physical assessment of skeletal muscle power can help predict functional decline, loss of independence, and even frailty. It is well known that the maximum power that can be reached in an exercise of long duration, when an aerobic steady state is attained, is appreciably less than the power output that can be sustained only for a few seconds. Ordinarily, maximum anaerobic power is about three times the steady-state power developed from oxidations. Ref: Rikli et al., 1999; Jones et al., 2002.

Flexibility: Flexibility is the ability to move one body segment across another and it depends from the range of motion in a joint or in a group of joints. With aging muscle flexibility can demonstrate a marked decline. This decline is influenced by decreases in muscle fibre flexibility and the elasticity of connective tissue. In addition, there is a decline in joint flexibility and stability relating to changes in the joint components of cartilage, ligaments, and tendons. Because flexibility is segment specific, determining the ROM in a joint does not necessarily indicate the level of flexibility in other joints. Ref: Stathokostas et al., 2012; Gehlsen et al., 1990.

Muscle Power (MP): Power is the product of force, generated by the muscle contraction, and velocity of the contraction. It is related to the selective loss of the largest fastest contracting fibres during aging. Lower limb power has been identified as a significant predictor of functional performance in older adults. Among older adults, a decline in lower extremity muscle power output with advancing years has important implications for independent physical functioning in later life. compared to traditional measures of muscle performance such as muscle strength (the ability to generate maximal force), impairments in peak lower extremity muscle power are superior predictors of functional tasks involving mobility and ambulation. For these reasons, increased muscle power may represent a more functionally relevant outcome than increased muscle mass or strength for exercise, or rehabilitation programs in older adults. Ref: Harms et al., 2011; Frontera et al., 2000; Mosole et al., 2014; McKinnona et al., 2017; Reid et al., 2014.

Muscle Strength (MS): Muscle strength measurements of different body compartments are correlated, so when feasible, grip strength measured in standard conditions with a well-studied model of a handheld dynamometer with reference populations can be a reliable surrogate for more complicated measures of muscle strength in the lower arms or legs. The primary mechanism underlying the decrease in muscle strength with age is a decline in muscle mass and, to a lesser extent, a decrease in muscle strength per unit muscle cross-sectional area (i.e., alterations in neuromuscular junctions, and loss of peripheral motor neurons with selective denervation of type II muscle fibers). Ref: Frontera et al., 2000; Cruz-Jentoft et al., 2010.

Movement Speed (MoS): MoS is the amount of space covered by a body segment per unit of time. It has been reported that when older adults perform movements toward targets, their movements are characterized by less smoothness and continuity, although performance precision is almost maintained. Ref: Morgan et al., 1994

1.7 Physical Activity Behaviour

Table 7 List of variables of the Physical Activity Behaviour subdomain.

VARIABLE NAME	ACRONYM	TO BE USED IN SYSTEM/PILOT	PRIORITY	AFFECTED BY
DISTANCE		System + Pilot	Necessary	Smoking, cardiovascular diseases, Respiratory disease, metabolic disease

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EXERCISE DURATION		System + Pilot	Important	Smoking, cardiovascular diseases, Respiratory disease, metabolic disease
EXERCISE INTENSITY		System + Pilot	Important	Smoking, cardiovascular diseases, Respiratory disease, metabolic disease
EXERCISE TYPE		System + Pilot	Important	Smoking, cardiovascular diseases, Respiratory disease, metabolic disease
EXERCISE FREQUENCY		System + Pilot	Important	Smoking, cardiovascular diseases, Respiratory disease, metabolic disease
FATIGUE ACCUMULATION		System + Pilot	Important	Smoking, cardiovascular diseases, Respiratory disease, metabolic disease
GRADE		System + Pilot	Necessary	-
ACTIVITY ENERGY EXPENDITURE	AEE	System + Pilot	Necessary	Sedentary lifestyle, disabilities
RATE OF PERCEIVED EXERTION	RPE	System + Pilot	Important	Smoking, cardiovascular diseases, Respiratory disease, metabolic disease
SEDENTARINESS		System + Pilot	Necessary	Smoking, cardiovascular diseases, Respiratory disease, metabolic disease
SPEED		System + Pilot	Necessary	-
STEPS		System + Pilot	Necessary	Smoking, cardiovascular diseases, Respiratory disease, metabolic disease
UPPER LIMBS MOVEMENTS	ULM	System + Pilot	Important	

Distance: It is the extent or amount of space covered by a person during movement between two things, points, lines, etc.

Exercise Duration: The exercise duration is the time occurring in between the beginning of the exercise and its conclusion.

Exercise Frequency: This refers to how often one person exercises. After any form of exercise is performed the body completes a process of rebuilding and repairing. So, determining the frequency of exercise is important in order to find a balance that provides just enough stress for the body to adapt and also allows enough rest time for healing.

Exercise Intensity: It is defined as the amount of effort or work that must be invested in a specific exercise workout. This too requires a good balance to ensure that the intensity is hard enough to overload the body but not so difficult that it results in overtraining, injury or burnout.

Exercise Type: The exercise type is an alphanumeric variable defining a structured program of physical activity categorized into four main classes, namely **cardiorespiratory**, **muscle-strengthening**, **flexibility** and **balance**.

Fatigue Accumulation: Fatigue is defined as a sense of persistent general tiredness. It is becoming increasingly recognized as a specific geriatric entity since both prevalence and incidence appear to increase with advancing age, and for the majority, fatigue per se exists independently of any specific diagnostic conditions. Task-specific measures of tiredness have been examined in clarification of the theoretical assumption that fatigue may be instrumental in the disablement process. In particular, self-reported tiredness while performing daily activities has been examined, and among nondisabled elderly people, it has been found to be a determinant of subsequent utilization of health and social services, walking limitations, onset of disability, and a reduction in both 10- and 15-year survival. Ref: Kentta et al., 1998.

Grade: is the measurement ground incline during walking and running. It is a determinant of exercise intensity and it is required in some metabolic formulae. Available to estimate energy expenditure of walking and running. **Activity Energy Expenditure (AEE):** the energy consumed by any physical activity beyond the basal expenditure or BMR. It includes any activity that can be done as a free living individual that is not related with the maintenance of vital body functions. Since energy consumed for movement depends on weight, height and age, ranges of AEE are normally relative to BMR. Ref: Bastone et al., 2015; Taylor et al., 2014.

Rate of perceived exertion (RPE): The RPE is quantitative measure of perceived intensity during physical exercise. Perceived exertion is how hard you feel like your body is working. It is based on the physical sensations a person experiences during physical activity, including increased heart rate, increased respiration or breathing rate, increased sweating, and muscle fatigue. Although this is a subjective measure, a person's exertion rating may provide a fairly good estimate of the actual heart rate during physical activity. Ref: Borg et al., 1982.

Sedentariness: Sedentariness is a cluster of behaviours adopted in a sitting or lying posture where little energy is being expended. Sedentariness is a risk factor for health independent to inactivity. The definition has been under scrutiny lately, but general consensus indicates that it should be defined by both posture and low energy expenditure (<1.5 Metabolic Equivalent of Task (METS)) during waking hours and includes activities such as watching television, computer use and travel. Sedentariness can be estimated by measuring the **Sedentary Time** which can be defined as the daily time spent in absence of any physical activity (walking, cycling, etc.). Ref: Harvey et al., 2013; Katzmarzyk et al., 2009.

Speed: is the measurement of body displacement in unit time. It is a determinant of exercise intensity and it is required in some metabolic formulae available to estimate energy expenditure of some modalities of structured exercise.

Steps: Steps are a fundamental unit of human locomotion, and thus the **number of steps** performed during an activity, as well as their **stride**, are a preferred metric for quantifying the physical activity itself. Ref: Bassett et al., 2017.

Upper limbs movements: This variable refers to the amount of upper limbs movements**.** The upper-limb motions are very important for the human daily activities, such as eating, drinking, brushing teeth, combing hair and washing face. Aged individuals are usually characterized by decline in sensorimotor processing as evidenced by slower movement time or reaction time in performing discrete tasks. As a consequence, elderly subjects reduce absolute number of movements of upper limbs and increase number of movement adjustments in the approach phase to a task

1.8 Sleep Quality

Table 8 List of variables of the Sleep Quality subdomain.

VARIABLE NAME	ACRONYM	TO BE USED IN SYSTEM/PILOT	PRIORITY	AFFECTED BY
PERCEIVED CALM SLEEP	PCS	System + Pilot	Necessary	Stress, Insomnia, Metabolic syndrome
SLEEP EFFICIENCY	SE	System + Pilot	Necessary	Calm/restless level at bed time, Insomnia, Pharmaceutical drugs
TOTAL SLEEP TIME	TST	System + Pilot	Necessary	Calm/restless level at bed time, Insomnia, Pharmaceutical drugs
SLEEP ONSET	S_{on}	System + Pilot	Necessary	Calm/restless level at bed time, Insomnia, Pharmaceutical drugs
SLEEP OFFSET	S_{off}	System + Pilot	Necessary	Calm/restless level at bed time, Insomnia, Pharmaceutical drugs
TIME IN BED	TIB	System Pilot	Necessary	Calm/restless level at bed time, Insomnia, Pharmaceutical drugs
AWAKENINGS		System + Pilot	Necessary	Stress levels during the day and at bedtime; Insomnia.

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SLEEP ONSET LATENCY (SOL)	SOL	System + Pilot	Optional	Insomnia
WAKE AFTER SLEEP ONSET	WASO	System + Pilot	Optional	Insomnia, sleep disorders and medical treatment

Perceived Calm Sleep (PCS): PCS indicates the auto-assessed sleep quality as it is perceived by the subject. Recent studies have investigated the association between sleep quality and the subjective perception of sleep parameters. Among these parameters, calm sleep is a subjective evaluation, after the final awakening in the morning, of the user own physical behaviour (calm or restlessness) during the sleep session. Ref: Harvey et al., 2008; Akerstedt et al., 1994; Barsocchi et al., 2016; Jennings et al., 2007; Choudhary et al., 2009; Sherwood et al., 2011. Grap et al., 2011; Hanne et al., 2013

Total Sleep Time (TST): TST is the time between sleep session start and sleep session end minus the time classified as awake (i.e. time occurred during nocturnal awakenings). Longer time in bed or sleep times may decrease sleep drive, leading to lower sleep continuity and sleep depth.

Sleep Onset (SOn): Sleep Onset is the time at which the subject falls asleep for the first time.

Sleep Offset (SOff): Sleep Offset is the time at which the subject awakes and does not manage to fall asleep again.

Time in Bed (TB): Time in bed is the time spent in bed including the wake periods before the SOn, in between SOn and SOff or after SOff.

Sleep Efficiency (SE): SE is commonly defined as the ratio of **total sleep time (TST)** to **time in bed (TB)**. It plays a central role in the perception of the quality of sleep and, in particular, in insomnia research and practice. Reed et al. claimed that a more accurate definition of SE is needed in the particular case of insomnia care. SE can be improved replacing the TIB with a combination of sleep onset latency, total sleep time, wake after sleep onset and time attempting to sleep after final awakening. Ref: Wilckens et al., 2014; Bastien et al., 2003; Susneri et al., 2009; Auger et al., 2013; Khalighi et al., 2016; Pressman et al., 1988; Andreeva et al., 2017; Grandner et al., 2015; Kahlhöfer et al., 2016; Ferranti et al., 2016; Fung et al., 2013; Patel et al., 2008; Simonds et al., 2012; D'Ambrosio et al., 2014; Nagai et al., 2010; Kerkhofs et al., 2012; Backhaus et al., 2002; Reed et al., 2016; Morin et al., 1989.

Awakenings: this variable includes the **number of awakenings (NA)** in between sleep onset and sleep offset and their **duration (AwD)**. It is related to the number of times a subject return to the wakeful state. Ref: Harvey et al., 2008; Barsocchi et al., 2016; Kecklund et al., 1997; Bastien et al., 2003; Webb et al., 1976; Goelema et al., 2017; Hanne et al., 2013; Nam et al., 2017; Smith et al., 2008.

Sleep Onset Latency (SOL): SOL represents the time that it takes to accomplish the transition from full wakefulness to sleep, normally to the lightest of the non-REM sleep stages. Authors in [4] define SOL as the elapsed time from the start of the test to the first 30-second epoch scored as sleep. Ref: Harvey et al., 2008; Kecklund et al., 2003; Goelema et al., 2017; Mitler et al., 2005; Togeiro et al., 2005; Shahid et al., 2011; El Ghoch et al., 2016; Tan et al., 2016.

Wake After Sleep Onset (WASO): Wake after sleep onset is the total duration (minutes) of wake time after SOn and it is calculated as the amount of time elapsed between sleep start and sleep end scored as wake. Ref: Goelema et al., 2017; Ancoli-Israel et al., 2010; Cooper et al., 2015; Kaplan et al., 2012; Wilckens et al., 2014; Sunseri et al., 2009; Blackwell et al., 2008; Sirvan et al., 2016; Spriggs et al., 2014; Moraes et al., 2013; Mokhlesi et al., 2015; Corbalan-Tutau et al., 2012.

2. Variables Relationships and ranges

2.1 Anthropometric characteristics

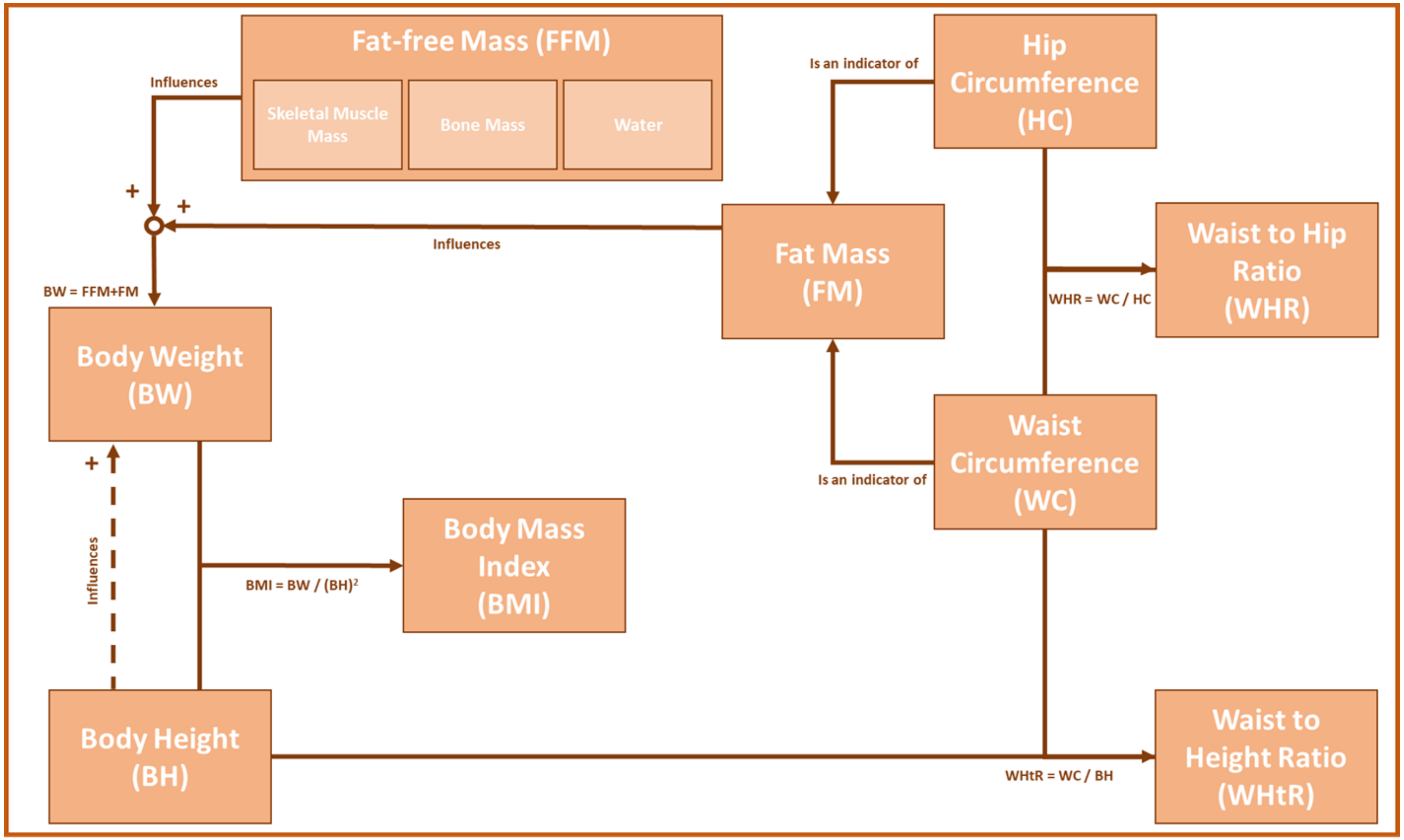

Figure 1 Relationships among variables in the Anthropometric Characteristics Subdomain

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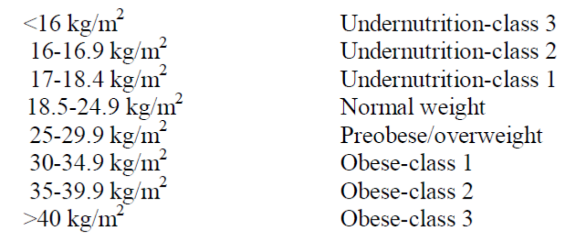
VARIABLE NAME	NORMALITY RANGES AND TRENDS	OUT OF RANGES
BODY WEIGHT	Normality ranges are provided by BMI. Taller people present higher body weight. Proportionality is assessed by body mass index	Please refer to BMI
BODY HEIGHT	Men are usually taller than women and a significant decrease with age in both sexes is usually observed. Older men are about 3% shorter than younger men, while women have an age-related reduction in height of 4%. Both sexes show a similar mean decrement per year (0.3 cm/year).	Loss of height is caused by a thinning of the vertebrae, compression of the vertebral discs, development of kyphosis or the effects of osteoporosis. Please refer also to BMI
BODY MASS INDEX	Tendency to an increase of BMI from 40 to 66 years of age in both men (average annual rate: BMI, 0.11 kg/m2/year) and women (BMI, 0.22 kg/m2/year). After age 70, BMI decreases significantly in both sexes, and there was a gender difference in the trend, as females decreased more than males. Normality: from 18 to 24.9 Kg/m^2	BMI ranges as established by WHO (1997):  <16 kg/m^2 Undernutrition-class 3 16-16.9 kg/m^2 Undernutrition-class 2 17-18.4 kg/m^2 Undernutrition-class 1 18.5-24.9 kg/m^2 Normal weight 25-29.9 kg/m^2 Preobese/overweight 30-34.9 kg/m^2 Obese-class 1 35-39.9 kg/m^2 Obese-class 2 >40 kg/m^2 Obese-class 3
FAT MASS	Fat mass increases progressively during adulthood. In the 7th decade, FM increases similarly in both sexes (7.5%). Ageing is typically associated with an increase of the visceral fat component. Men show a centripetalization and internalization of fat. Women are characterized by a peripheral distribution of fat (less visceral adiposity). The subcutaneous fat component, which increases until the 7th decade, tends to decrease thereafter. Moreover, distribution of subcutaneous fat (peripheral in women, central in men) changes so that males and females appear to be more similar for triceps, subscapular and suprailiac skinfolds at advanced ages. Normality:	Males: ≥ 25%, Women: ≥ 30% (reduction of sexual dimorphism)

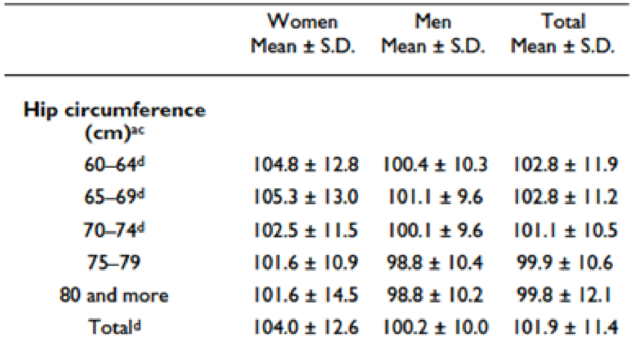
Males: < 25%
Women: < 30%

FAT-FREE MASS

The age-related FFM loss is smaller in active than sedentary individuals. There is no general consensus on the magnitude and mean rate of the FFM decrease. As reviewed by some authors, FFM decreases by around 15% between the third and eighth decade, with a rate of decrease of about 6.3% per decade and the percentage reduction can reach 30%. According to longitudinal studies, after 60 years of age FFM decreases in men (2.0% per decade) but not in women. Studies of body composition at the molecular level show that the reduction of total body protein is particularly evident after 65 years and can be estimated at 5% overall. Studies at the atomic level show that total body potassium decreases at a rate of 7.20+/1.00 mg/kg per year in women and 9.16+/0.96 mg/kg per year in men.

Males: Skeletal Muscle Mass < 37% (Sarcopenia)
Women: Skeletal Muscle Mass < 27.6% (Sarcopenia)

HIP CIRCUMFERENCE



	Women Mean ± S.D.	Men Mean ± S.D.	Total Mean ± S.D.
Hip circumference (cm)[ac]			
60–64[d]	104.8 ± 12.8	100.4 ± 10.3	102.8 ± 11.9
65–69[d]	105.3 ± 13.0	101.1 ± 9.6	102.8 ± 11.2
70–74[d]	102.5 ± 11.5	100.1 ± 9.6	101.1 ± 10.5
75–79	101.6 ± 10.9	98.8 ± 10.4	99.9 ± 10.6
80 and more	101.6 ± 14.5	98.8 ± 10.2	99.8 ± 12.1
Total[d]	104.0 ± 12.6	100.2 ± 10.0	101.9 ± 11.4

WAIST CIRCUMFERENCE

Normality:
Males < 94 cm

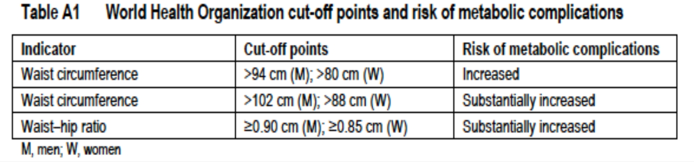
	Women< 80 cm	
WAIST TO HEIGHT RATIO	WHtR could differ among age groups because whole-body fat distribution and waist circumference changes considerably with age and because height differs among generations.	It has been proposed that cut-point values of 0.5 and 0.6 can identify individuals who are at increased health risk and substantial health risk, respectively. Some papers report WHtR cut-points 0.55 (men) and 0.58 (women) in participants over 60 years.
WAIST TO HIP RATIO	Normality: Males < 0.90 Women < 0.85	A WHR >= 0.90 for men and 0.85 for women is related to a substantial increase of risks of metabolic complications.

Table A1 World Health Organization cut-off points and risk of metabolic complications

Indicator	Cut-off points	Risk of metabolic complications
Waist circumference	>94 cm (M); >80 cm (W)	Increased
Waist circumference	>102 cm (M); >88 cm (W)	Substantially increased
Waist–hip ratio	≥0.90 cm (M); ≥0.85 cm (W)	Substantially increased

M, men; W, women

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2.2 Cardiovascular System

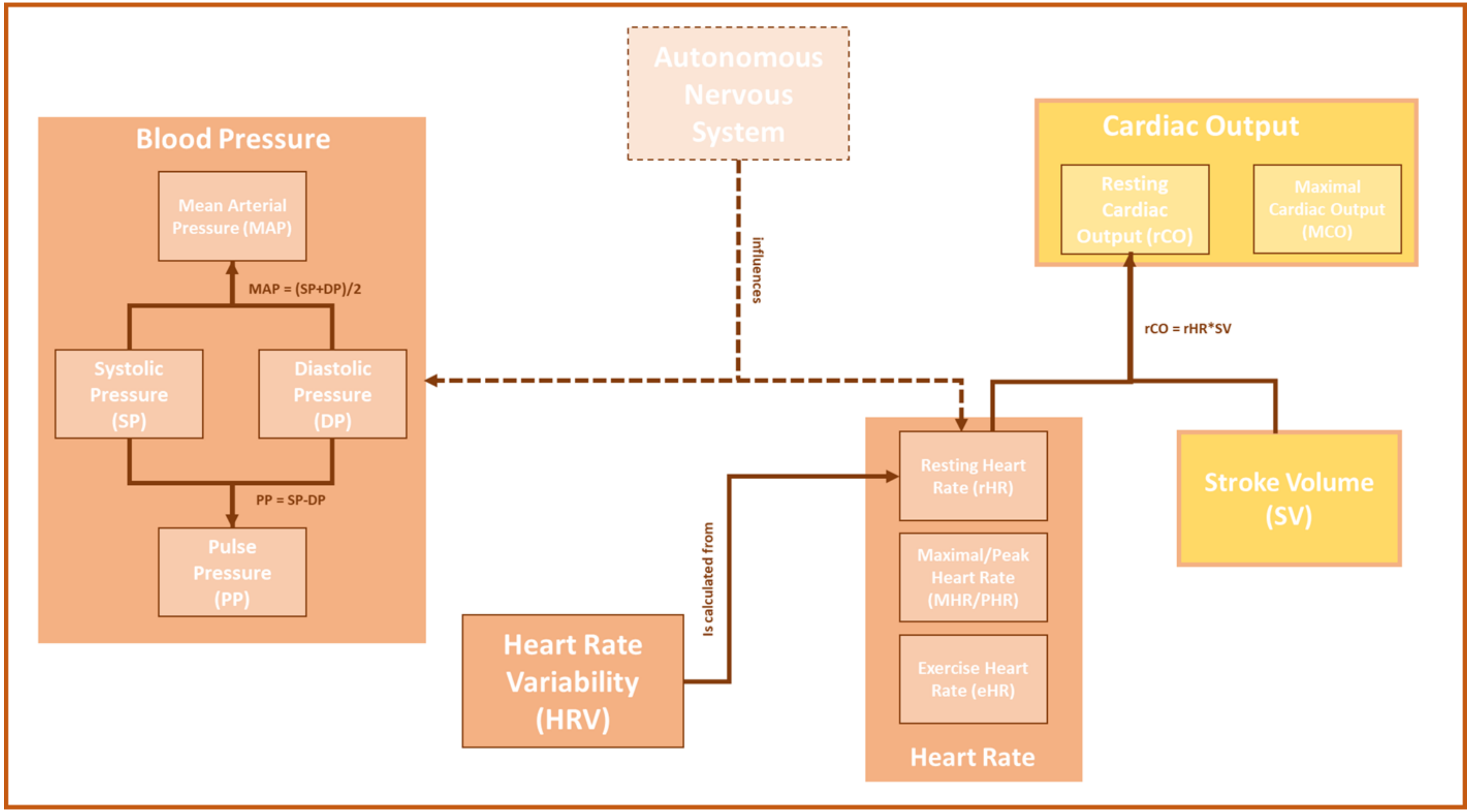

Figure 2 Relationships among variables in the Cardiovascular System Subdomain. The variable "Autonomous Nervous System" is surrounded by dotted line since it is not considered neither in the NESTORE system nor in the pilots. The variables in yellow are those considered for the validation of the System.

VARIABLE NAME	NORMALITY RANGES AND TRENDS	OUT OF RANGES
BLOOD PRESSURE	Data obtained during the Framingham Heart Study, which followed patients for 30 years, agreed that systolic blood pressure (SBP) shows a continuous increase between the ages of 30 and 84 years or over. Diastolic blood pressure (DBP), however, has a varying pattern with ageing, increasing until the fifth decade and slowly decreasing from the age of 60 to at least 84 years of age. This leads to a steep rise in pulse pressure (PP) with ageing. Normality: SBP < 140 mmHg DBP < 90 mmHg	SBP⩾140 mm Hg or DBP⩾90 mm Hg) (Hypertension)
HEART RATE	Studies of a large number of rigorously screened, healthy individuals, however, indicate that in the sitting position, heart rate decreases with age in both males and females. Normality: At rest 60-100 BPM	HR< 60 BPM (bradycardia) HR > 100 BPM (tachycardia)
HEART RATE VARIABILITY	Lower heart rate variability generally indicates an increased biological age (older). Higher heart rate variability is correlated with increased fitness, health, and youthfulness. Predominance of sympathetic tone over parasympathetic tone in males and vice versa in females have been reported. Furthermore, it has been reported that autonomic activities diminish with age in both genders and that gender-related variation in parasympathetic regulation decreases after the age of 50 years. Normality: Age 60-69: rMSSD = 20±10 ms; pNN50=4±6%; SDNN=114±33 ms; SDANN=106±34 ms; Age 70-79: rMSSD=19±7 ms; pNN50=3±3%; SDNN=116±29 ms; SDANN=107±30 ms; rMSSD = Root mean square of successive differences between N-N intervals. pNN50 = Mean number of times per hour in which the change in consecutive normal sinus (NN) intervals exceeds 50 milliseconds SDNN = Standard deviation of all N-N intervals (from the entire recording).	n.a.

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SDANN = Standard Deviation of the Averages of NN (Normal Sinus to Normal Sinus) Intervals in All 5-Minute Segments of a 24-Hour Recording

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2.3 Respiratory System

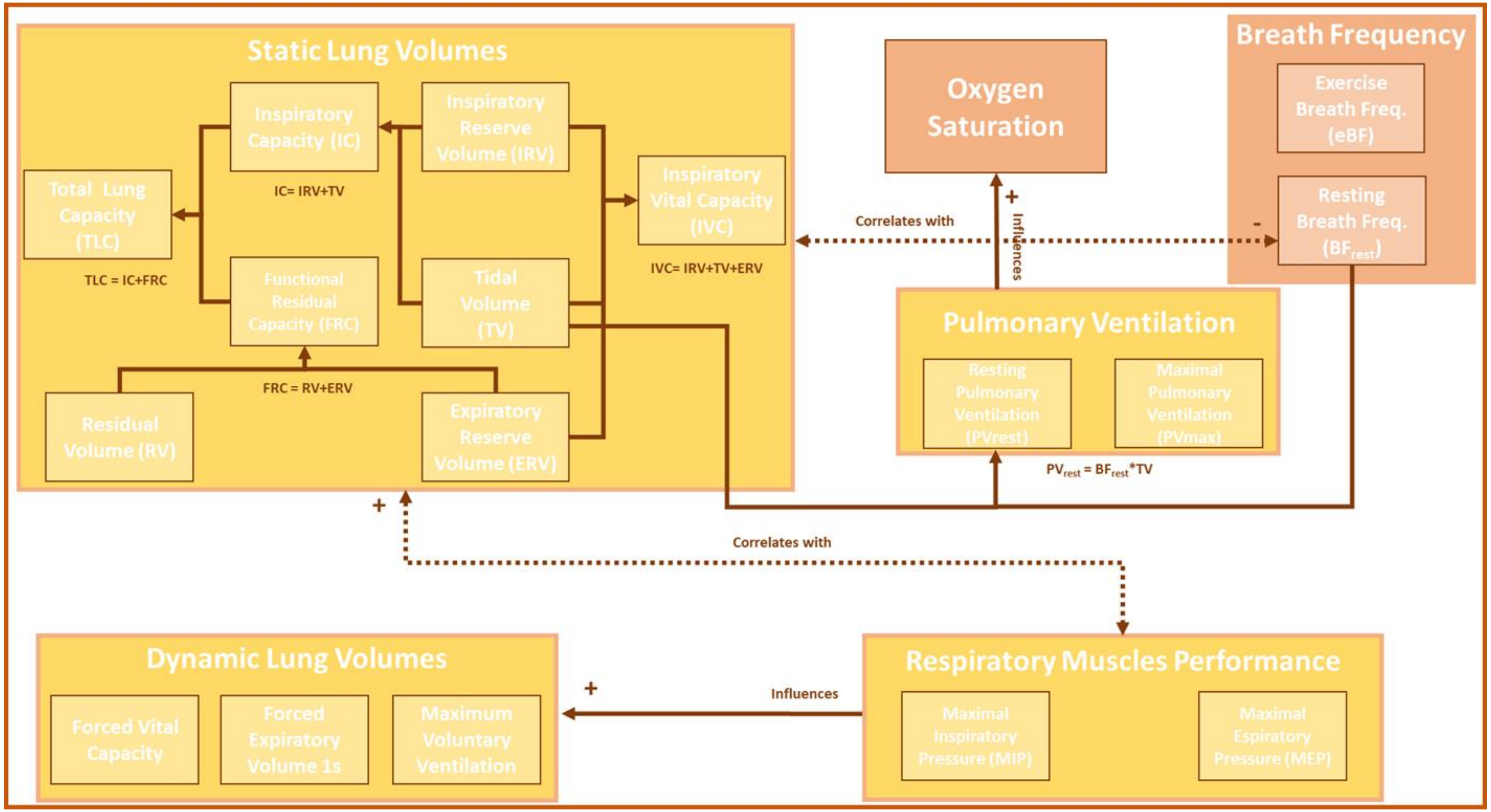

Figure 3 Relationships among variables in the Respiratory System Subdomain. The variables in yellow are those considered for the validation of the System.

VARIABLE NAME	NORMALITY RANGES AND TRENDS	OUT OF RANGES
OXYGEN SATURATION	Normality: 96% - 100%. (In healthy individuals breathing room air at sea level)	<80% (disturbances of lung function or hypoxia)
BREATH FREQUENCY	Since minute ventilations are similar in the young and old, older adults may have an increased respiratory rate to compensate for the decrease in tidal volume. Normality: 12- 18 breaths per minute (older adults living independently) 16 to 25 breaths per minute (older adults in long term-care)	BF <10: Bradypnea BF >20: Tachypnea Recent studies report that high respiratory rates (**>27 breaths per minute**) have been shown to have a high predictive value for cardiac arrest in hospital patients.

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2.4 Musculoskeletal System

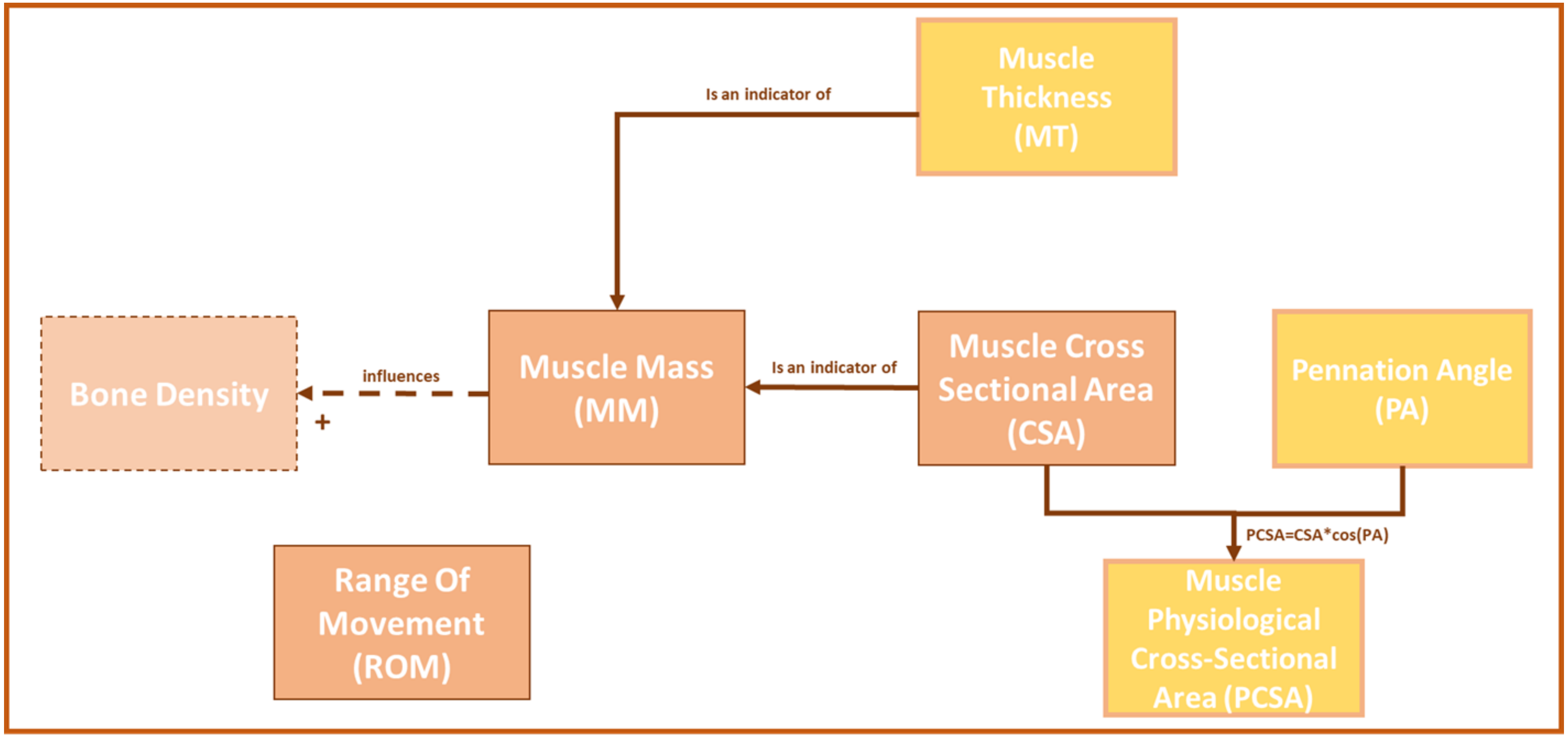

Figure 4 Relationships among variables in the Musculoskeletal System Subdomain. The variable "Bone Density" is surrounded by dotted line since it is not considered neither in the NESTORE system nor in the pilots. The variables in yellow are those considered for the validation of the System.

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VARIABLE NAME	NORMALITY RANGES AND TRENDS	OUT OF RANGES
MUSCLE CROSS SECTIONAL AREA	CSA peaks at the age of approximately 30 years and then gradually declines. The suggested loss of muscle mass, as reflected by reductions in total CSA is on the magnitude of 0.5%–0.8% per year when investigated in cross-sectional studies of older adults. These declines are more pronounced in women than in men.	**Hypotrophy**: There is about 20–40% decrease in muscle mass by the age of 70 **Atrophy**: There is about >40% decrease in muscle mass by the age of 70 years
MUSCLE MASS	Muscle mass peaks at the age of approximately 30 years and then gradually declines. There is about 20–40% decrease in muscle mass by the age of 70 years. These declines are more pronounced in women than in men. Normal SMI (Muscle Mass/(Body Height)^2): Men: >= 10.76 kg/m^2 Women: >= 6.76 kg/m^2	Moderate Sarcopenia: Men: 8.51 - 10.75 kg/m^2 Women: 5.76 - 6.75 kg/m^2 Severe Sarcopenia: Men: <= 8.50 kg/m^2 Women: <= 5.75 kg/m^2
RANGE OF MOVEMENT	It has been demonstrated that ROM measures depend on the number of degrees of freedom of the joint, the initial position, the direction of the movement, and diurnal variation.	Light: ROM reduced from 15% to 29% Moderate: ROM reduced from 30% to 50 % Severe: ROM reduced >50%

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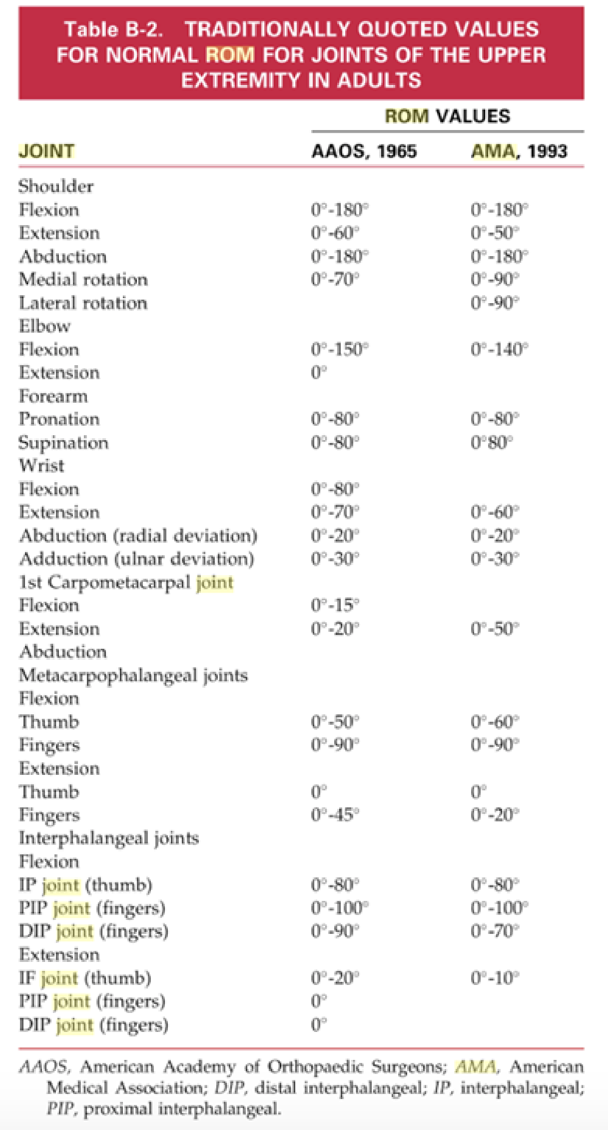

Table B-2. TRADITIONALLY QUOTED VALUES FOR NORMAL ROM FOR JOINTS OF THE UPPER EXTREMITY IN ADULTS

	ROM VALUES	
JOINT	**AAOS, 1965**	**AMA, 1993**
Shoulder		
Flexion	0°-180°	0°-180°
Extension	0°-60°	0°-50°
Abduction	0°-180°	0°-180°
Medial rotation	0°-70°	0°-90°
Lateral rotation		0°-90°
Elbow		
Flexion	0°-150°	0°-140°
Extension	0°	
Forearm		
Pronation	0°-80°	0°-80°
Supination	0°-80°	0°80°
Wrist		
Flexion	0°-80°	
Extension	0°-70°	0°-60°
Abduction (radial deviation)	0°-20°	0°-20°
Adduction (ulnar deviation)	0°-30°	0°-30°
1st Carpometacarpal joint		
Flexion	0°-15°	
Extension	0°-20°	0°-50°
Abduction		
Metacarpophalangeal joints		
Flexion		
Thumb	0°-50°	0°-60°
Fingers	0°-90°	0°-90°
Extension		
Thumb	0°	0°
Fingers	0°-45°	0°-20°
Interphalangeal joints		
Flexion		
IP joint (thumb)	0°-80°	0°-80°
PIP joint (fingers)	0°-100°	0°-100°
DIP joint (fingers)	0°-90°	0°-70°
Extension		
IF joint (thumb)	0°-20°	0°-10°
PIP joint (fingers)	0°	
DIP joint (fingers)	0°	

AAOS, American Academy of Orthopaedic Surgeons; *AMA*, American Medical Association; *DIP*, distal interphalangeal; *IP*, interphalangeal; *PIP*, proximal interphalangeal.

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2.5 Cardio-Respiratory Exercise Capacity

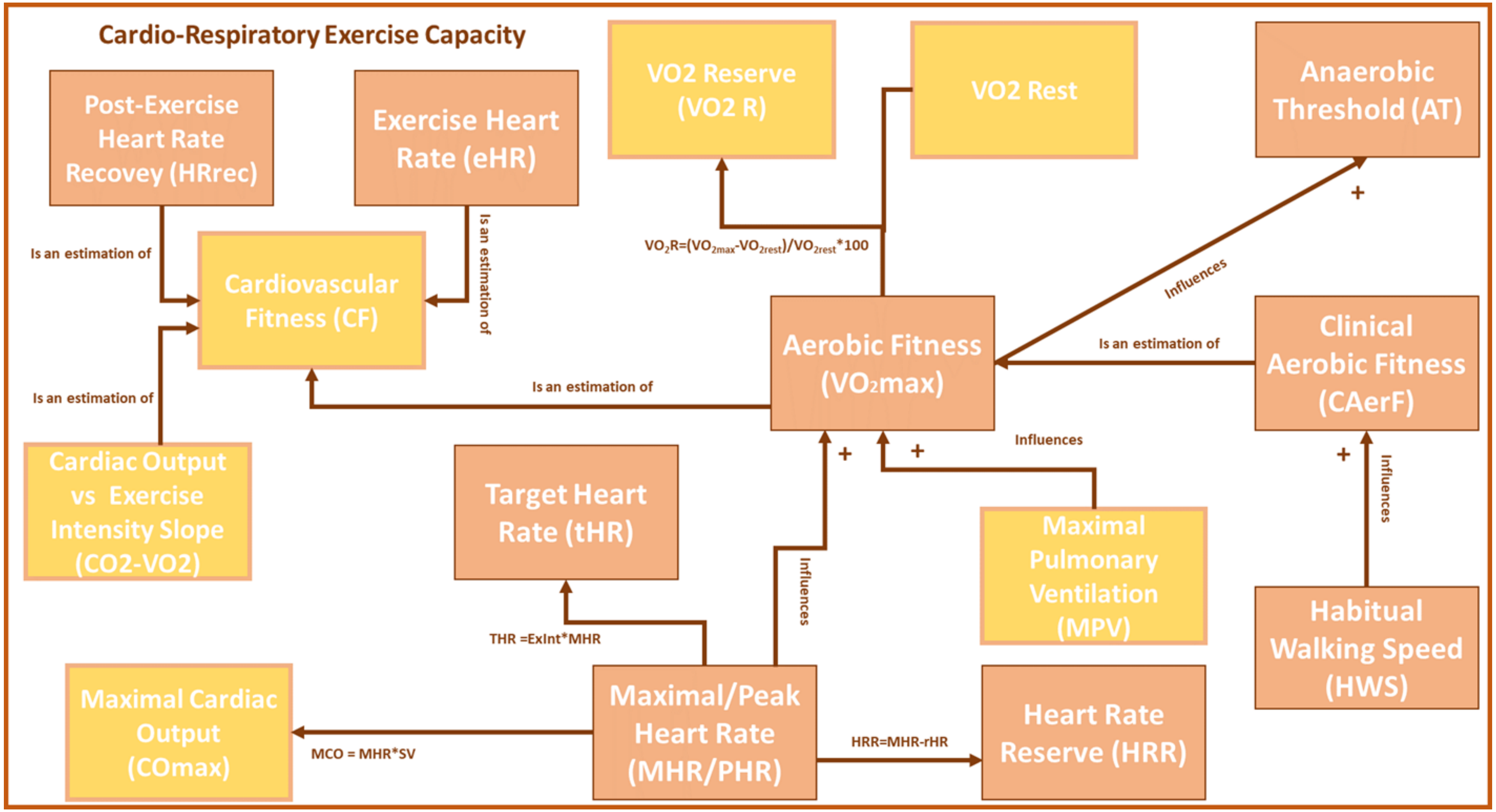
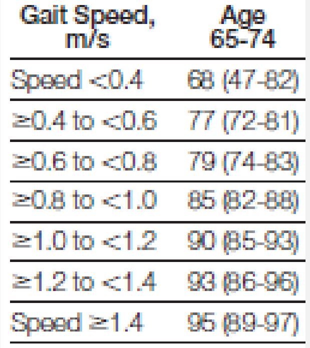


Figure 5 Relationships among variables in the Cardio-Respiratory Exercise Capacity Subdomain. The variables in yellow are those considered for the validation of the System.

<table>
<tr><th>VARIABLE NAME</th><th>NORMALITY RANGES AND TRENDS</th><th>OUT OF RANGES</th></tr>
<tr><td>AEROBIC FITNESS</td><td>
<i>Maximal oxygen uptake norms for men (ml/kg/min)</i>
<table>
<tr><th><i>rating</i></th><th>Age (years)</th></tr>
<tr><td></td><td>65+</td></tr>
<tr><td><i>excellent</i></td><td>> 37</td></tr>
<tr><td><i>good</i></td><td>33-37</td></tr>
<tr><td><i>above average</i></td><td>29-32</td></tr>
<tr><td><i>average</i></td><td>26-28</td></tr>
<tr><td><i>below average</i></td><td>22-25</td></tr>
<tr><td><i>poor</i></td><td>20-21</td></tr>
<tr><td><i>very poor</i></td><td>< 20</td></tr>
</table>
<i>Maximal oxygen uptake norms for women (ml/kg/min)</i>
<table>
<tr><th><i>rating</i></th><th>Age (years)</th></tr>
<tr><td></td><td>65+</td></tr>
<tr><td><i>excellent</i></td><td>> 32</td></tr>
<tr><td><i>good</i></td><td>28-32</td></tr>
<tr><td><i>above average</i></td><td>25-27</td></tr>
<tr><td><i>average</i></td><td>22-24</td></tr>
<tr><td><i>below average</i></td><td>19-21</td></tr>
<tr><td><i>poor</i></td><td>17-18</td></tr>
<tr><td><i>very poor</i></td><td>< 17</td></tr>
</table>
<p>Men and women in their 60s and 70s can adapt to endurance exercise training with an increase in $VO2_{max}$. If the training stimulus is sufficiently intense, frequent, and prolonged, the magnitude of the increase in $VO2_{max}$ in previously sedentary older people is similar in relative magnitude (- 20%-30%) to that in young people.</p>
</td><td>VO2 max values lower than 18 ml/kg/min (in men) and 15 ml/kg/min (in women) - very challenged to autonomously complete activities of daily living.</td></tr>
<tr><td>ANAEROBIC THRESHOLD</td><td><p>Anaerobic threshold (AT) varied negatively with age in both males and females. Both VO2max and AT decline with age, but AT declines more slowly. It has been reported that VO2max declines at a rate of 20.61 ml*min-1*yr-1 (0.0206 l/min), whereas VO2 corresponding to AT declines at a rate of 4.98 ml*min-1*yr-1 (0.0049 l/min).</p><p>Normality:
60-80% of VO2max</p></td><td>Unfit: lower than 50% VO2max</td></tr>
</table>

<table>
<tr><td>CARDIOVASCULAR FITNESS</td><td>Please refer to: Exercise Heart Rate; Post-Exercise Heart Rate Recovery; Cardiac Output vs Exercise Intensity Slope; Aerobic Fitness</td><td></td></tr>
<tr><td>CLINICAL AEROBIC FITNESS</td><td>Across five studies, the median 6MWT distance for each age decade in men (M) and women (W) was:
Normality:
60-70 years: Males: average:491m,
Women: average:440m;
70-79 years: Males: average: 400m,
Women: 350m.</td><td>The value may be less for patients with chronic obstructive pulmonary or interstitial lung disease as well as chronic heart failure and peripheral artery disease patients.</td></tr>
<tr><td>EXERCISE HEART RATE</td><td>n.a.</td><td>n.a.</td></tr>
<tr><td>HR RESERVE</td><td>n.a.</td><td>n.a.</td></tr>
<tr><td>HABITUAL WALKING SPEED</td><td>Several researches have shown that walking speed declines with age and that men outperform women at all ages.

Men – age 60-69 – Gait Speed 126.6 to 141.2 cm/sec
Men – age 70-79 – Gait Speed 121.0 to 132.2 cm/sec

Women – age 60-69 – Gait Speed 118.3 to 130.0 cm/sec
Women – age 70-79 – Gait Speed 107.2 to 119.2 cm/sec</td><td>
<table>
<tr><th>Gait Speed, m/s</th><th>Age 65-74</th></tr>
<tr><td>Speed <0.4</td><td>68 (47-82)</td></tr>
<tr><td>≥0.4 to <0.6</td><td>77 (72-81)</td></tr>
<tr><td>≥0.6 to <0.8</td><td>79 (74-83)</td></tr>
<tr><td>≥0.8 to <1.0</td><td>85 (82-88)</td></tr>
<tr><td>≥1.0 to <1.2</td><td>90 (85-93)</td></tr>
<tr><td>≥1.2 to <1.4</td><td>93 (86-96)</td></tr>
<tr><td>Speed ≥1.4</td><td>95 (89-97)</td></tr>
</table>
5-years Survival rate (%)</td></tr>
</table>

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MAXIMAL AND PEAK HEART RATE	The MHR and PHR reduce linearly with age. Moreover, gender and habitual physical activity do not appear to influence intrinsic heart rate in humans. Men – age 60-69 – MHR 158 to 165 beats/min Men – age 70-79 – MHR 151 to 158 beats/min Women – age 60-69 – MHR 155 to 162 beats/min Women – age 70-79 – MHR 147 to 154 beats/min	n.a.
POST-EXERCISE HEART RATE RECOVERY	It depends from type, duration and intensity of exercise. However, if we consider a person exercising for three minutes at moderate intensity, we should expect these values: Ratings for Men, Based on Age Excellent 59-81 Good 87-92 Above Average 94-102 Average 104-110 Below Average 114-118 Poor 121-126 Very Poor 130-151 Ratings for Women, Based on Age Excellent 70-92 Good 96-101 Above Average 104-111 Average 116-121 Below Average 123-126 Poor 128-133 Very Poor 135-155	n.a.
TARGET HEART RATE	Light intense activities – 25 – 50% of MHR moderately intense activities – 50 - 69% of MHR, vigorous physical activities - 70% - 89% of MHR. severe intensity activities - above 90% of MHR.	n.a.

2.6 Strength-Flexibility-Balance Exercise Capacity

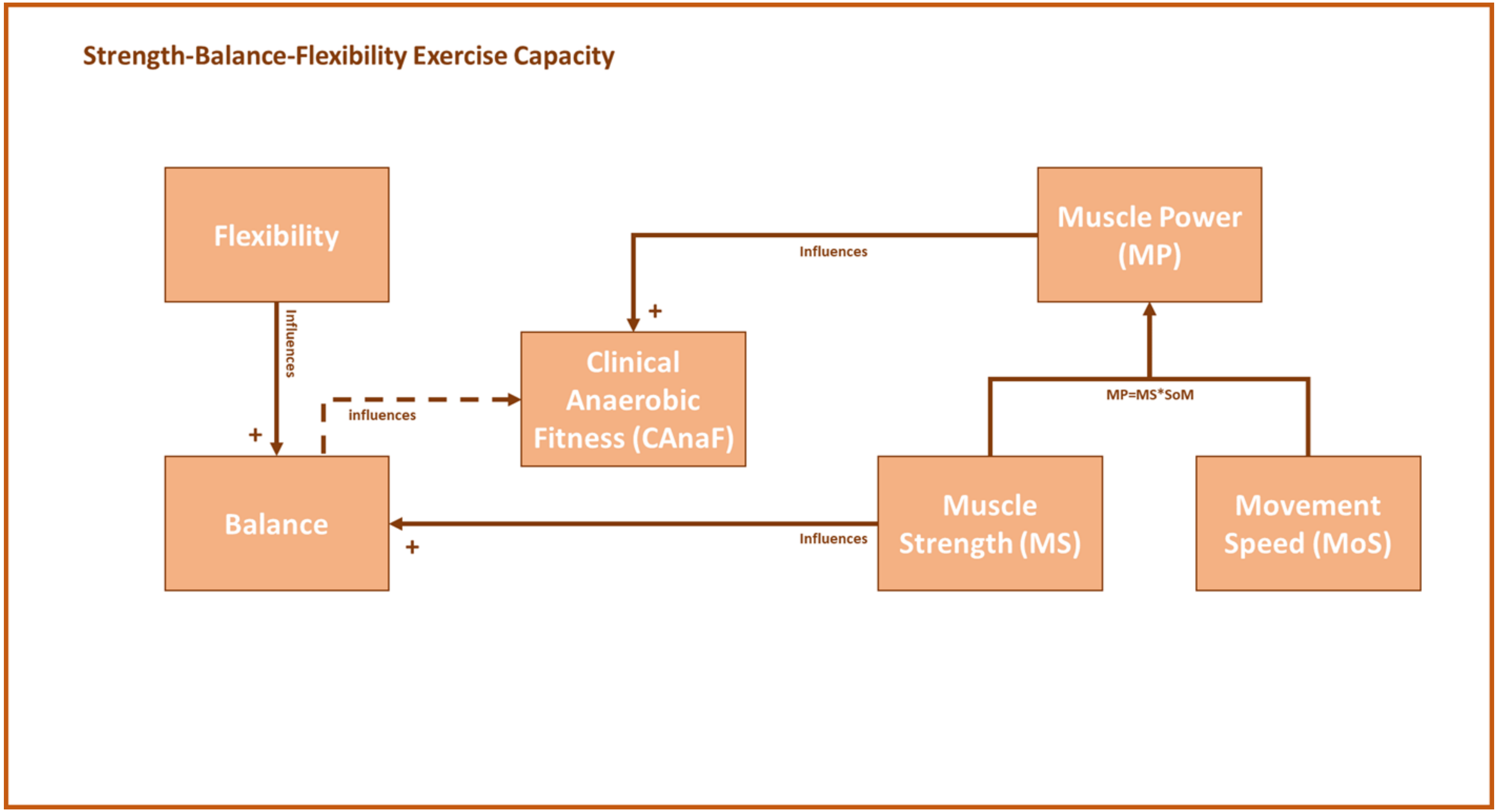

Figure 6 Relationships among variables in the Strength-Balance-Flexibility Exercise Capacity Subdomain.

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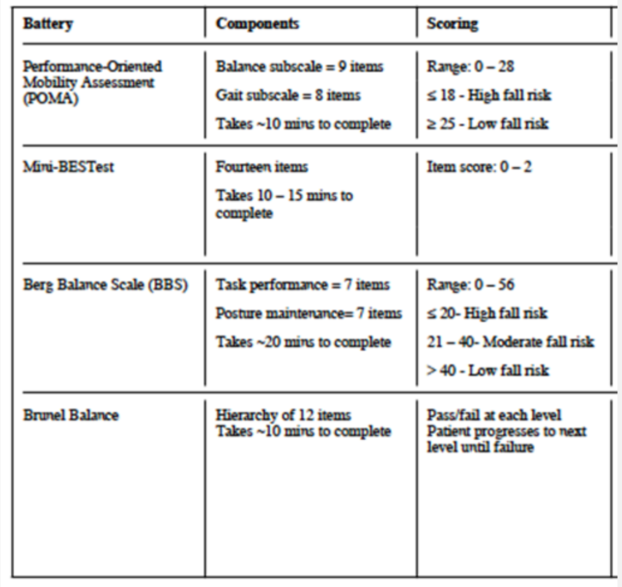
<table>
<tr><th>VARIABLE NAME</th><th>NORMALITY RANGES AND TRENDS</th><th>OUT OF RANGES</th></tr>
<tr><td>BALANCE</td><td>
With advancing age, the postural control mechanism becomes less efficient because of changes in its individual components.



<table>
<tr><th>Battery</th><th>Components</th><th>Scoring</th></tr>
<tr><td>Performance-Oriented Mobility Assessment (POMA)</td><td>Balance subscale = 9 items
Gait subscale = 8 items
Takes ~10 mins to complete</td><td>Range: 0 – 28
≤ 18 - High fall risk
≥ 25 - Low fall risk</td></tr>
<tr><td>Mini-BESTest</td><td>Fourteen items
Takes 10 – 15 mins to complete</td><td>Item score: 0 – 2</td></tr>
<tr><td>Berg Balance Scale (BBS)</td><td>Task performance = 7 items
Posture maintenance= 7 items
Takes ~20 mins to complete</td><td>Range: 0 – 56
≤ 20- High fall risk
21 – 40- Moderate fall risk
> 40 - Low fall risk</td></tr>
<tr><td>Brunel Balance</td><td>Hierarchy of 12 items
Takes ~10 mins to complete</td><td>Pass/fail at each level
Patient progresses to next level until failure</td></tr>
</table>
</td><td>POMA <= 18 -> High Fall Risk
BBS <=20 High Fall Risk</td></tr>
<tr><td>CLINICAL ANAEROBIC FITNESS</td><td>
There appears to be remarkably similar patterns of age-related declines in anaerobic power, which cluster around the 6–8% range across numerous heterogeneous studies and range in duration of testing evaluation from 10–100 s.

Normality ranges for chair stands:
Men – age 65-69 – # stands 12-18
Men – age 70-74– # stands 12-17
Men – age 75-79– # stands 11-17

Women – age 65-69 – # stands 12-17
Women – age 70-74 – # stands 11-16
Women – age 75-79 – # stands 10-15
</td><td>n.a.</td></tr>
</table>

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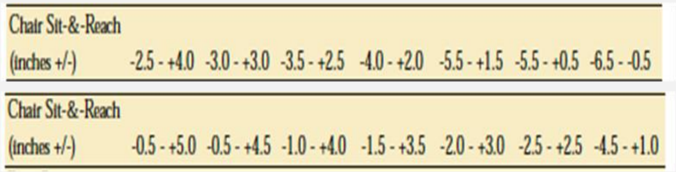
FLEXIBILITY

It has been postulated that by 70 years of age, flexibility and joint ROM declines are significant for hip (20%–30%), spine (20%–30%), and ankle (30%–40%), especially in women. Without active intervention, literature reports a loss of flexibility (measured by the sit-and-reach test) of 15% per decade.



Chair Sit-&-Reach (inches +/-)	-2.5 - +4.0	-3.0 - +3.0	-3.5 - +2.5	-4.0 - +2.0	-5.5 - +1.5	-5.5 - +0.5	-6.5 - -0.5

Chair Sit-&-Reach (inches +/-)	-0.5 - +5.0	-0.5 - +4.5	-1.0 - +4.0	-1.5 - +3.5	-2.0 - +3.0	-2.5 - +2.5	-4.5 - +1.0

A flexibility value below the threshold of normality ranges may be a cause of falls in the elderly.

MUSCLE POWER

The well-described decline in skeletal muscle size that occurs with aging, and changes in the properties of remaining muscle fibers, contributes to reduced muscle power in older adults. Dynamic muscular power declines at a much faster rate than static or isometric strength in healthy aging men. Dynamic muscular power declines similarly in the upper and lower body with advancing age.

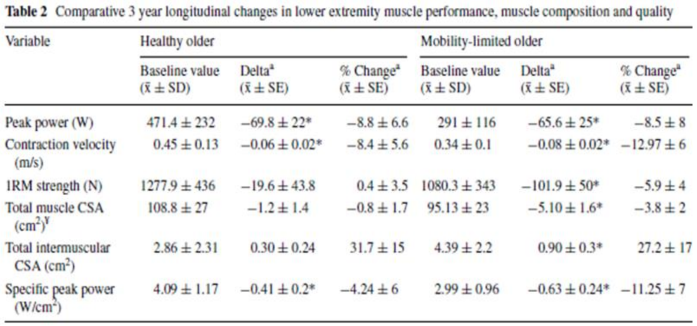


Table 2 Comparative 3 year longitudinal changes in lower extremity muscle performance, muscle composition and quality

Variable	Healthy older			Mobility-limited older		
	Baseline value ($\bar{x}$ ± SD)	Delta^{a} ($\bar{x}$ ± SE)	% Change^{a} ($\bar{x}$ ± SE)	Baseline value ($\bar{x}$ ± SD)	Delta^{a} ($\bar{x}$ ± SE)	% Change^{a} ($\bar{x}$ ± SE)
Peak power (W)	471.4 ± 232	−69.8 ± 22*	−8.8 ± 6.6	291 ± 116	−65.6 ± 25*	−8.5 ± 8
Contraction velocity (m/s)	0.45 ± 0.13	−0.06 ± 0.02*	−8.4 ± 5.6	0.34 ± 0.1	−0.08 ± 0.02*	−12.97 ± 6
1RM strength (N)	1277.9 ± 436	−19.6 ± 43.8	0.4 ± 3.5	1080.3 ± 343	−101.9 ± 50*	−5.9 ± 4
Total muscle CSA (cm^{2})^{Y}	108.8 ± 27	−1.2 ± 1.4	−0.8 ± 1.7	95.13 ± 23	−5.10 ± 1.6*	−3.8 ± 2
Total intermuscular CSA (cm^{2})	2.86 ± 2.31	0.30 ± 0.24	31.7 ± 15	4.39 ± 2.2	0.90 ± 0.3*	27.2 ± 17
Specific peak power (W/cm^{2})	4.09 ± 1.17	−0.41 ± 0.2*	−4.24 ± 6	2.99 ± 0.96	−0.63 ± 0.24*	−11.25 ± 7

n.a.

MUSCLE STRENGTH

Between the ages of 30 and 80, humans lose an average of 30% to 40% of their muscle strength (around 40% in the leg and back muscles and 30% in the arm muscles). A loss in isometric strength with aging appears to occur sooner and at a faster rate in the lower body than in the upper body.

Low handgrip strength is a clinical marker of poor mobility and a better predictor of clinical outcomes than low muscle mass. Moreover, there is also a linear relationship between baseline handgrip strength and incident disability for activities of daily living (ADL).

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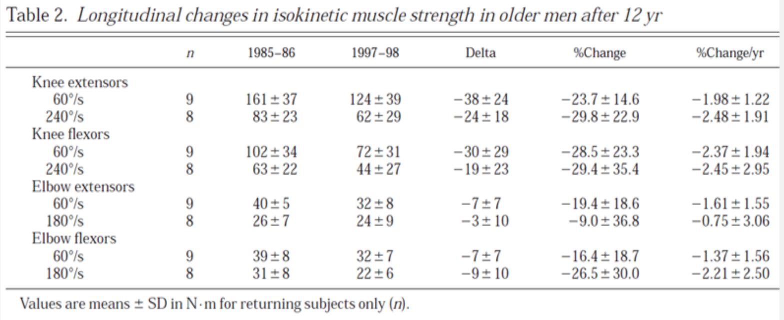

Table 2. *Longitudinal changes in isokinetic muscle strength in older men after 12 yr*

	n	1985–86	1997–98	Delta	%Change	%Change/yr
Knee extensors						
60°/s	9	161 ± 37	124 ± 39	−38 ± 24	−23.7 ± 14.6	−1.98 ± 1.22
240°/s	8	83 ± 23	62 ± 29	−24 ± 18	−29.8 ± 22.9	−2.48 ± 1.91
Knee flexors						
60°/s	9	102 ± 34	72 ± 31	−30 ± 29	−28.5 ± 23.3	−2.37 ± 1.94
240°/s	8	63 ± 22	44 ± 27	−19 ± 23	−29.4 ± 35.4	−2.45 ± 2.95
Elbow extensors						
60°/s	9	40 ± 5	32 ± 8	−7 ± 7	−19.4 ± 18.6	−1.61 ± 1.55
180°/s	8	26 ± 7	24 ± 9	−3 ± 10	−9.0 ± 36.8	−0.75 ± 3.06
Elbow flexors						
60°/s	9	39 ± 8	32 ± 7	−7 ± 7	−16.4 ± 18.7	−1.37 ± 1.56
180°/s	8	31 ± 8	22 ± 6	−9 ± 10	−26.5 ± 30.0	−2.21 ± 2.50

Values are means ± SD in N·m for returning subjects only (*n*).

SPEED OF MOVEMENT	n.a.	n.a.

2.7 Physical Activity Behaviour

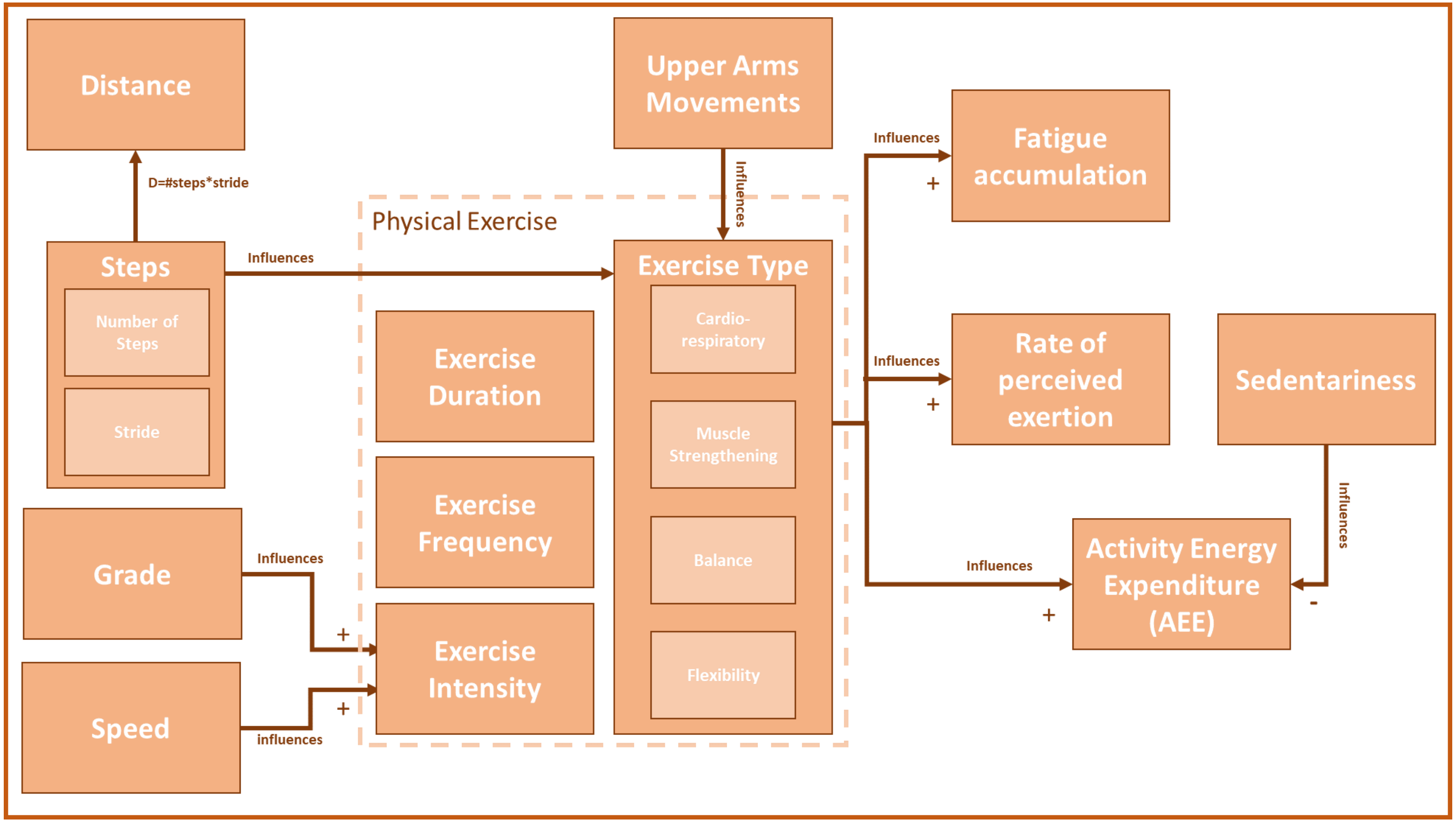

Figure 7 Relationships among variables in the Physical Behaviour Subdomain.

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VARIABLE NAME	NORMALITY RANGES AND TRENDS	OUT OF RANGES
DISTANCE	Please refer to steps	Please refer to steps
EXERCISE DURATION	n.a.	n.a.
EXERCISE FREQUENCY	n.a.	n.a.
EXERCISE INTENSITY	Light intense activities – 25 – 50% of MHR or VO2max moderately intense activities – 50 - 69% MHR or VO2max vigorous physical activities - 70% - 89% of MHR or VO2max severe intensity activities - above 90% MHR or VO2max	n.a.
EXERCISE TYPE	n.a.	n.a.
FATIGUE ACCUMULATION	Using Total Quality of Recovery (TQR) scale:  TQR 6 7 Very, very poor recovery 8 9 Very poor recovery 10 11 Poor recovery 12 13 Reasonable recovery 14 15 Good recovery 16 17 Very good recovery 18 19 20 Very, very good recovery	n.a.
GRADE	n.a.	n.a.
ACTIVITY ENERGY EXPENDITURE	AEE > 3.5 METS per exercise session Overall physical activity able to guarantee >4200 kJ/week	AEE that is below 3.5 METS (light activities) or a total amount of activity that is below around 4200 kJ/week (equivalent to more

<table>
<tr><td></td><td></td><td>than 3 h of brisk walking per week) is unlikely to produce health-related changes in adults.</td></tr>
<tr><td>RATE OF PERCEIVED EXERTION</td><td>Practitioners generally agree that perceived exertion ratings between 12 to 14 on the Borg Scale suggests that physical activity is being performed at a moderate level of intensity.

<table>
<tr><th colspan="2">RPE</th></tr>
<tr><td>6</td><td></td></tr>
<tr><td>7</td><td>Very, very light</td></tr>
<tr><td>8</td><td></td></tr>
<tr><td>9</td><td>Very light</td></tr>
<tr><td>10</td><td></td></tr>
<tr><td>11</td><td>Fairly light</td></tr>
<tr><td>12</td><td></td></tr>
<tr><td>13</td><td>Somewhat hard</td></tr>
<tr><td>14</td><td></td></tr>
<tr><td>15</td><td>Hard</td></tr>
<tr><td>16</td><td></td></tr>
<tr><td>17</td><td>Very hard</td></tr>
<tr><td>18</td><td></td></tr>
<tr><td>19</td><td></td></tr>
<tr><td>20</td><td>Very, very hard</td></tr>
</table>
A high correlation exists between a person's perceived exertion rating times 10 and the actual heart rate during physical activity; so a person's exertion rating may provide a fairly good estimate of the actual heart rate during activity (Borg, 1998).</td><td>n.a.</td></tr>
</table>

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SEDENTARINESS

The number of hours spent sitting per day were used to classify participants as sedentary (4 hours or more/day), moderately sedentary (2–4 hours/day), or least sedentary (<2 hours/day).

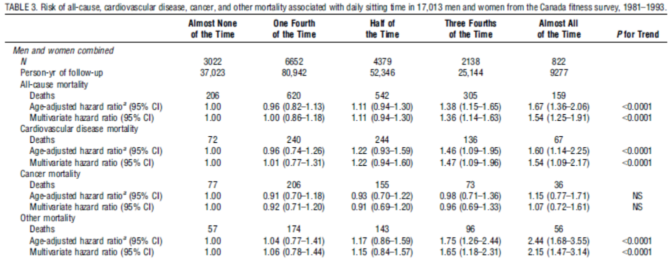

TABLE 3. Risk of all-cause, cardiovascular disease, cancer, and other mortality associated with daily sitting time in 17,013 men and women from the Canada fitness survey, 1981–1993.

	Almost None of the Time	One Fourth of the Time	Half of the Time	Three Fourths of the Time	Almost All of the Time	*P* for Trend
Men and women combined						
N	3022	6652	4379	2138	822	
Person-yr of follow-up	37,023	80,942	52,346	25,144	9277	
All-cause mortality						
Deaths	206	620	542	305	159	
Age-adjusted hazard ratio^a (95% CI)	1.00	0.96 (0.82–1.13)	1.11 (0.94–1.30)	1.38 (1.15–1.65)	1.67 (1.36–2.06)	<0.0001
Multivariate hazard ratio (95% CI)	1.00	1.00 (0.86–1.18)	1.11 (0.94–1.30)	1.36 (1.14–1.63)	1.54 (1.25–1.91)	<0.0001
Cardiovascular disease mortality						
Deaths	72	240	244	136	67	
Age-adjusted hazard ratio^a (95% CI)	1.00	0.96 (0.74–1.26)	1.22 (0.93–1.59)	1.46 (1.09–1.95)	1.60 (1.14–2.25)	<0.0001
Multivariate hazard ratio (95% CI)	1.00	1.01 (0.77–1.31)	1.22 (0.94–1.60)	1.47 (1.09–1.96)	1.54 (1.09–2.17)	<0.0001
Cancer mortality						
Deaths	77	206	155	73	36	
Age-adjusted hazard ratio^a (95% CI)	1.00	0.91 (0.70–1.18)	0.93 (0.70–1.22)	0.98 (0.71–1.36)	1.15 (0.77–1.71)	NS
Multivariate hazard ratio (95% CI)	1.00	0.92 (0.71–1.20)	0.91 (0.69–1.20)	0.96 (0.69–1.33)	1.07 (0.72–1.61)	NS
Other mortality						
Deaths	57	174	143	96	56	
Age-adjusted hazard ratio^a (95% CI)	1.00	1.04 (0.77–1.41)	1.17 (0.86–1.59)	1.75 (1.26–2.44)	2.44 (1.68–3.55)	<0.0001
Multivariate hazard ratio (95% CI)	1.00	1.06 (0.78–1.44)	1.15 (0.84–1.57)	1.65 (1.18–2.31)	2.15 (1.47–3.14)	<0.0001

The amount of daily sitting time is positively associated with mortality rates from all causes, cardiovascular disease, and other causes but not from cancer in the combined sample of men and women.

SPEED

n.a.

n.a.

STEPS

Healthy older adults - 6,000-8,500 steps/day

Step-defined physical activity ranged from 2,000- 9,000 steps/day, was (generally) lower for women than men, appeared to decrease over reported age groups, and was lower for those defined as overweight/obese compared to normal weight samples.

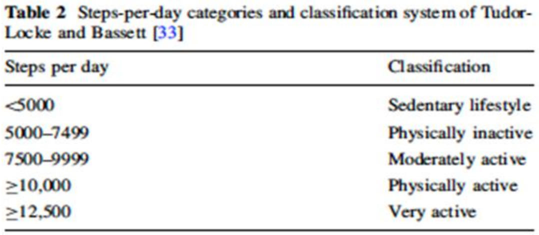

Table 2 Steps-per-day categories and classification system of Tudor-Locke and Bassett [33]

Steps per day	Classification
<5000	Sedentary lifestyle
5000–7499	Physically inactive
7500–9999	Moderately active
≥10,000	Physically active
≥12,500	Very active

UPPER LIMBS MOVEMENTS

n.a.

n.a.

2.8 Sleep Quality

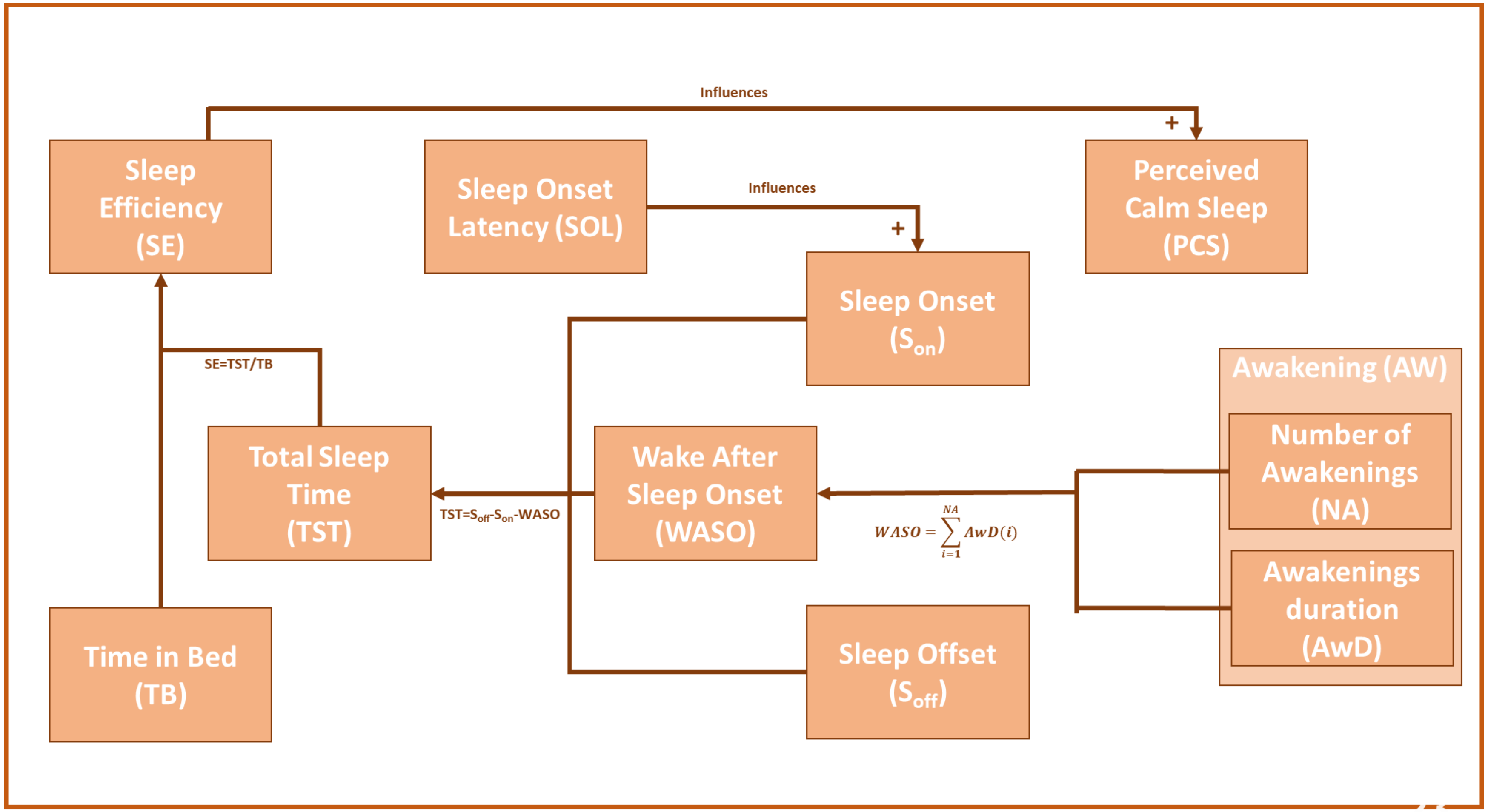

Figure 8 Relationships among variables in the Sleep Quality Subdomain.

VARIABLE NAME	NORMALITY RANGES AND TRENDS	OUT OF RANGES
AWAKENINGS	-Age/Sex-dependent ranges: authors report that the negative effect of the number of awakenings is softened by increased ages. Furthermore, it is showed a positive effect for number of awakenings during the night, but this positive effect was found only for males.	-Status-dependent ranges: authors report how anorexia and bulimia led to disturbed sleep maintenance, comprising sleep efficiency, increased intermittent wake time, and an increased amount of sleep stage 1.
PERCEIVED CALM SLEEP	- Normality ranges: according to Kalorinska sleep diary, from 1-very poor sleep to 5-very good sleep	-Status-dependent ranges: patient movement, especially restlessness and agitation in the critically ill, may result from a variety of physiologic (e.g., hypoxemia, ischemia, inadequate pain control) and psychologic conditions (e.g., anxiety, fear, disorientation)
SLEEP EFFICIENCY	According to the Pittsburgh Sleep Quality Index, **sleep efficiency is considered normal 85% or more**.	n.a.
TOTAL SLEEP TIME	- Normality ranges: on average, a person sleeps about seven hours per night around the age of 40, and about six and a half hours a night between the ages of 55 and 60. A healthy 80-year-old will usually sleep about six hours a night. - Age/Sex-dependent ranges: older adults have significantly shorter TST	n.a.
SLEEP ONSET	n.a.	n.a.
SLEEP OFFSET	n.a.	n.a.
TIME IN BED	n.a.	n.a.
SLEEP ONSET LATENCY (SOL)	Normality ranges: up to 30 minutes [5]	Status-dependent ranges: In patients with anorexia nervosa, total sleep time and sleep onset latency appears to be

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	- Age/Sex-dependent ranges: sleep onset latency can naturally be lower, particularly in older people.	reduced. This sleep disturbance seems to be influenced by the duration and severity of malnutrition, and appears to normalize with weight restoration [7].
WAKE AFTER SLEEP ONSET	- Normality ranges: the average person is asleep at least 90% of the sleep period (from sleep onset to the final awakening). In other words, WASO should comprise less than 10% of the sleep period [9]. - Age/Sex-dependent ranges: [1] reports a negative effect of WASO on PSQ being greater for females. For each extra hour of WASO, women report on average a PSQ score lower than males. WASO should be lower in young subjects than in old subjects. [5]	n.a.

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2.9 Relationships among subdomains

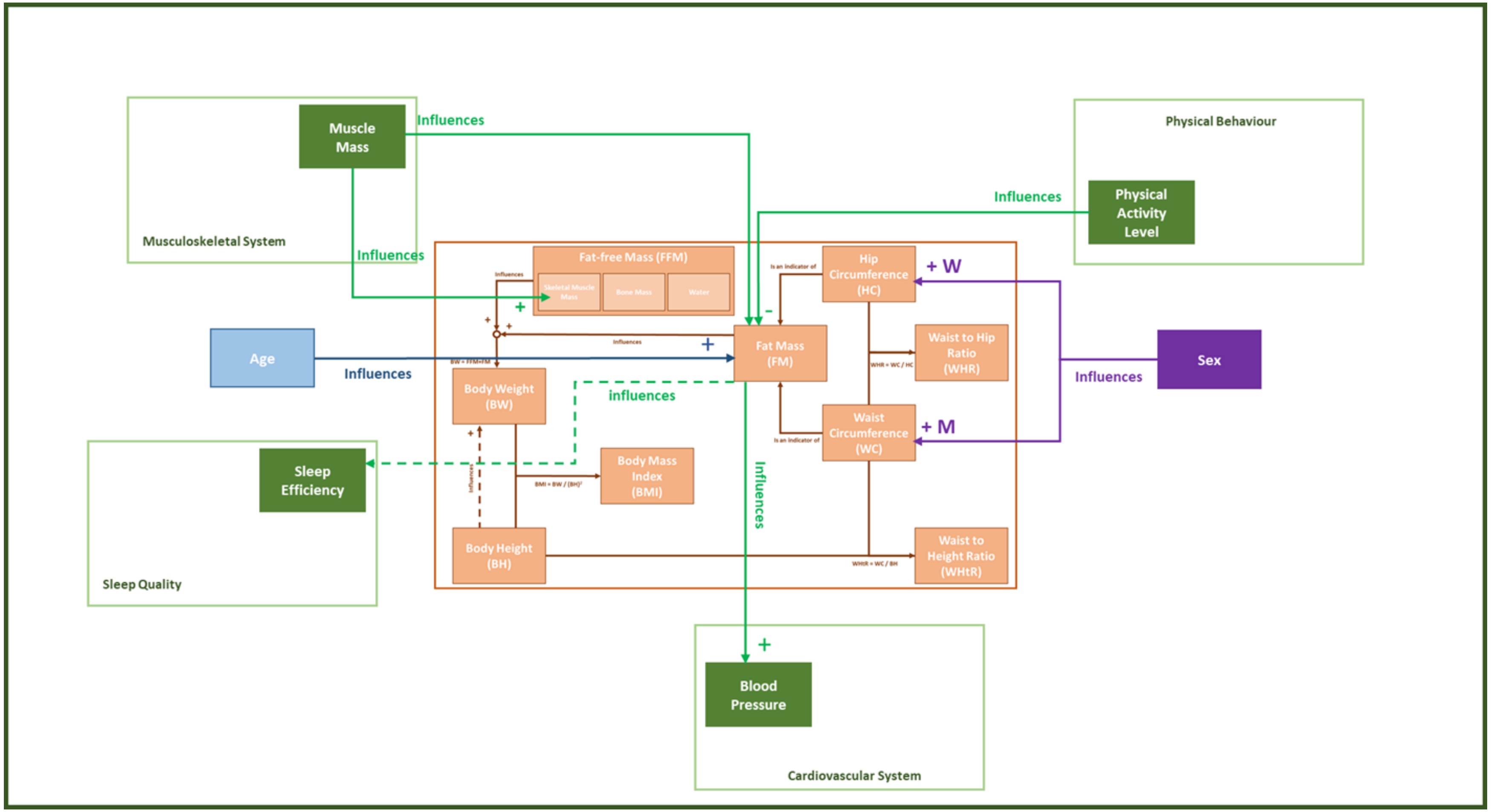

Figure 9 Relationships among the Anthropometric Characteristics subdomain and all the other physiological subdomains

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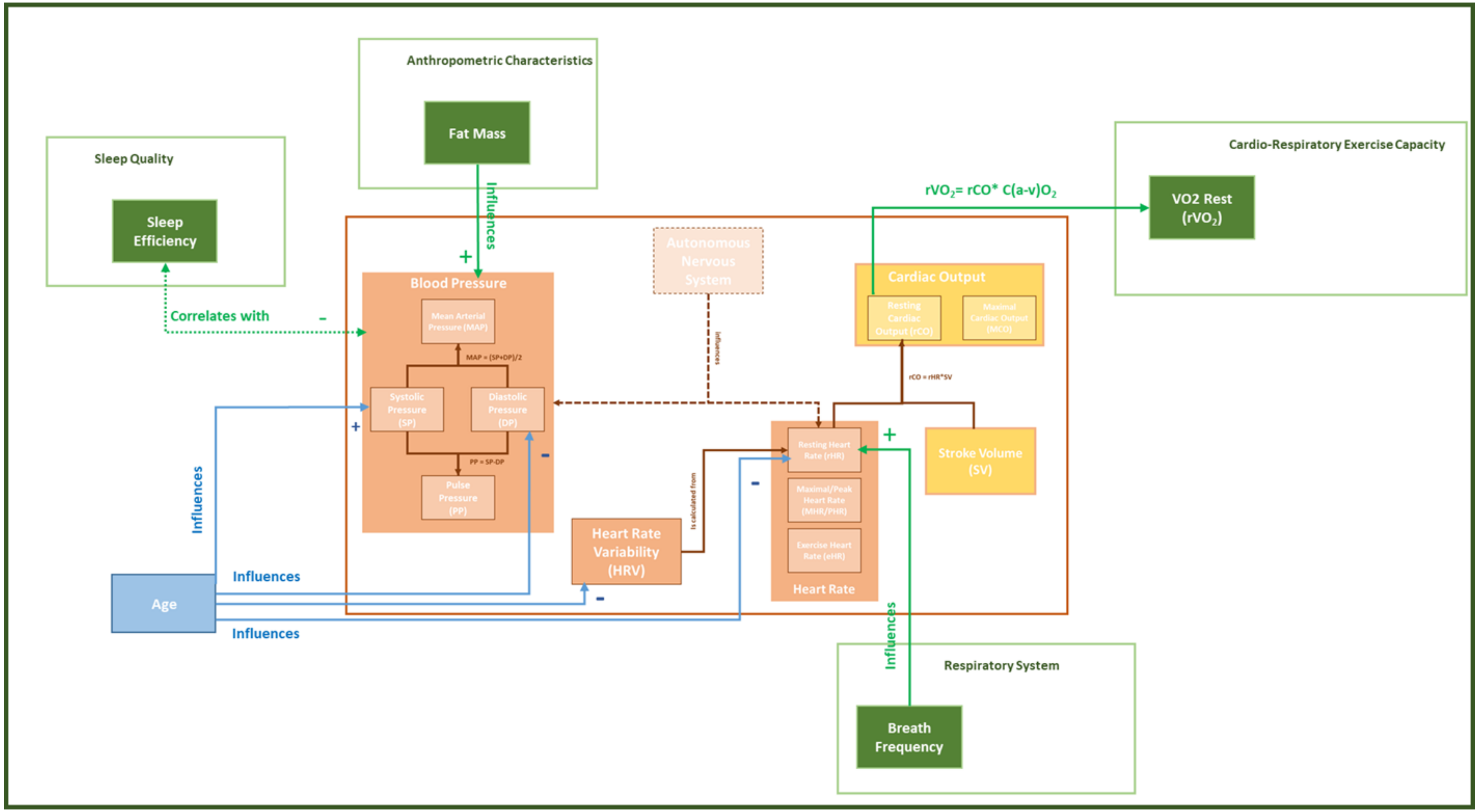

Figure 10 Relationships among the Cardiovascular System subdomain and all the other physiological subdomains.

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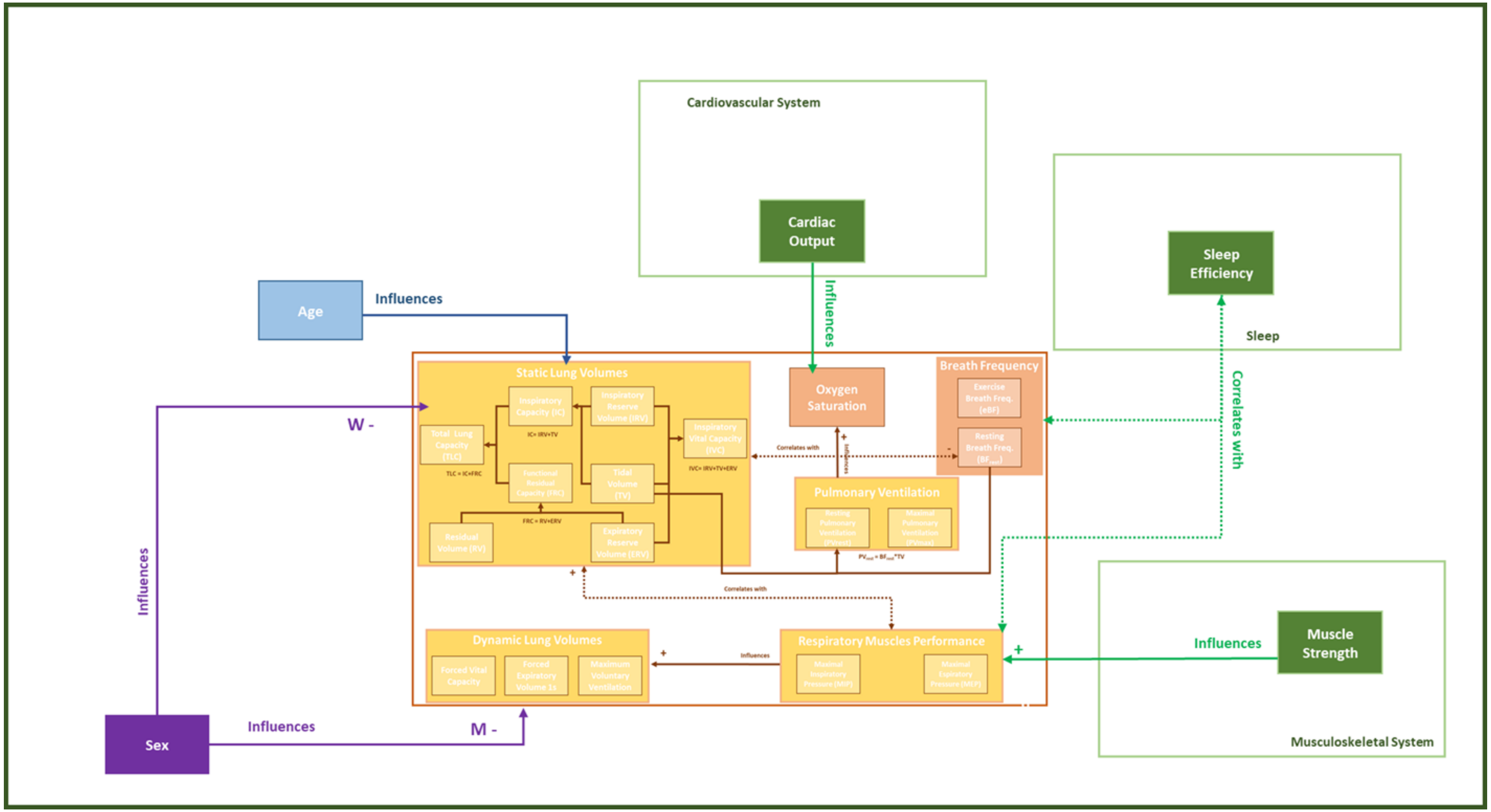

Figure 11 Relationships among the Respiratory System subdomain and all the other physiological subdomains.

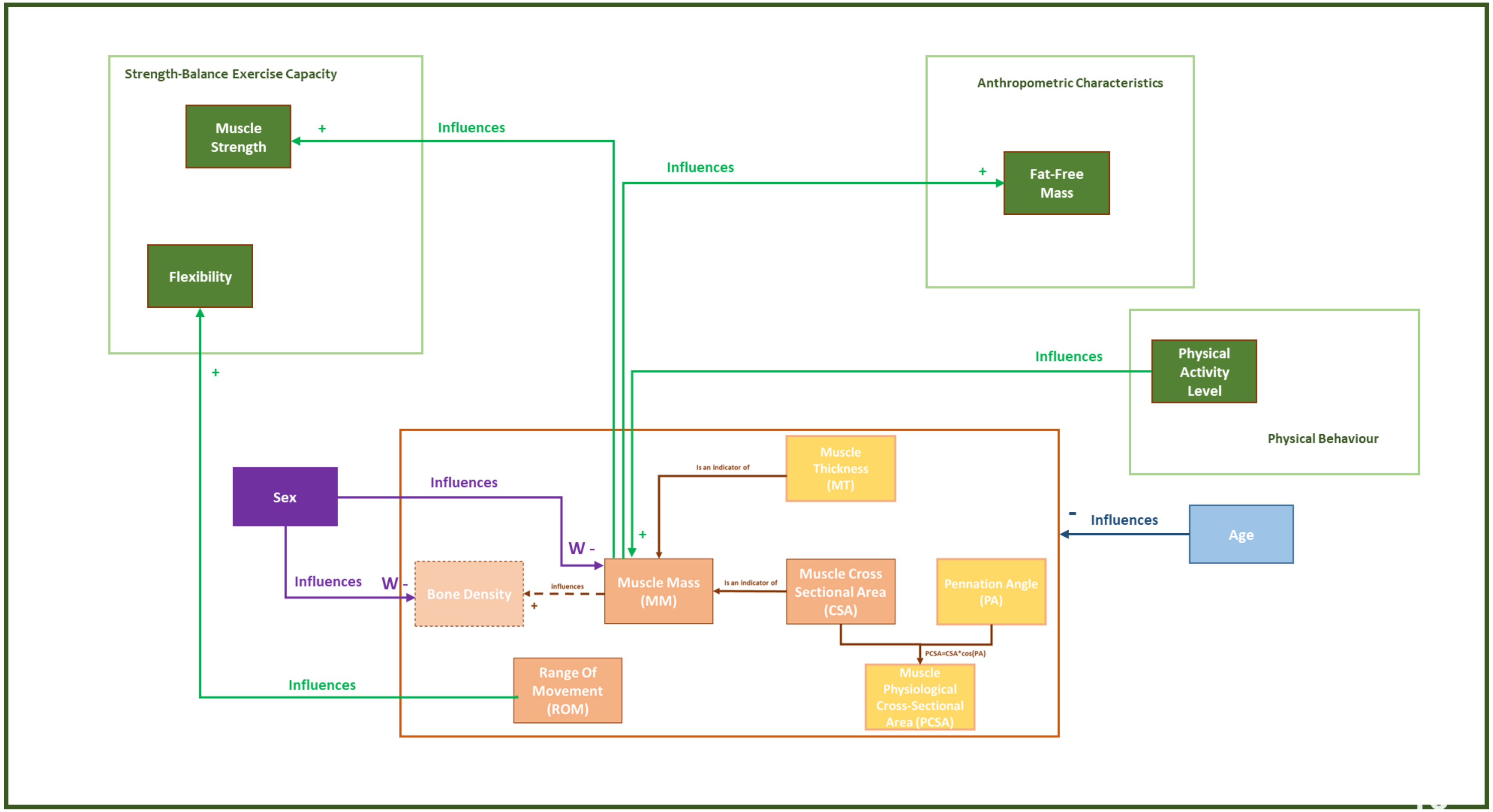

Figure 12 Relationships among the Musculoskeletal System subdomain and all the other physiological subdomains.

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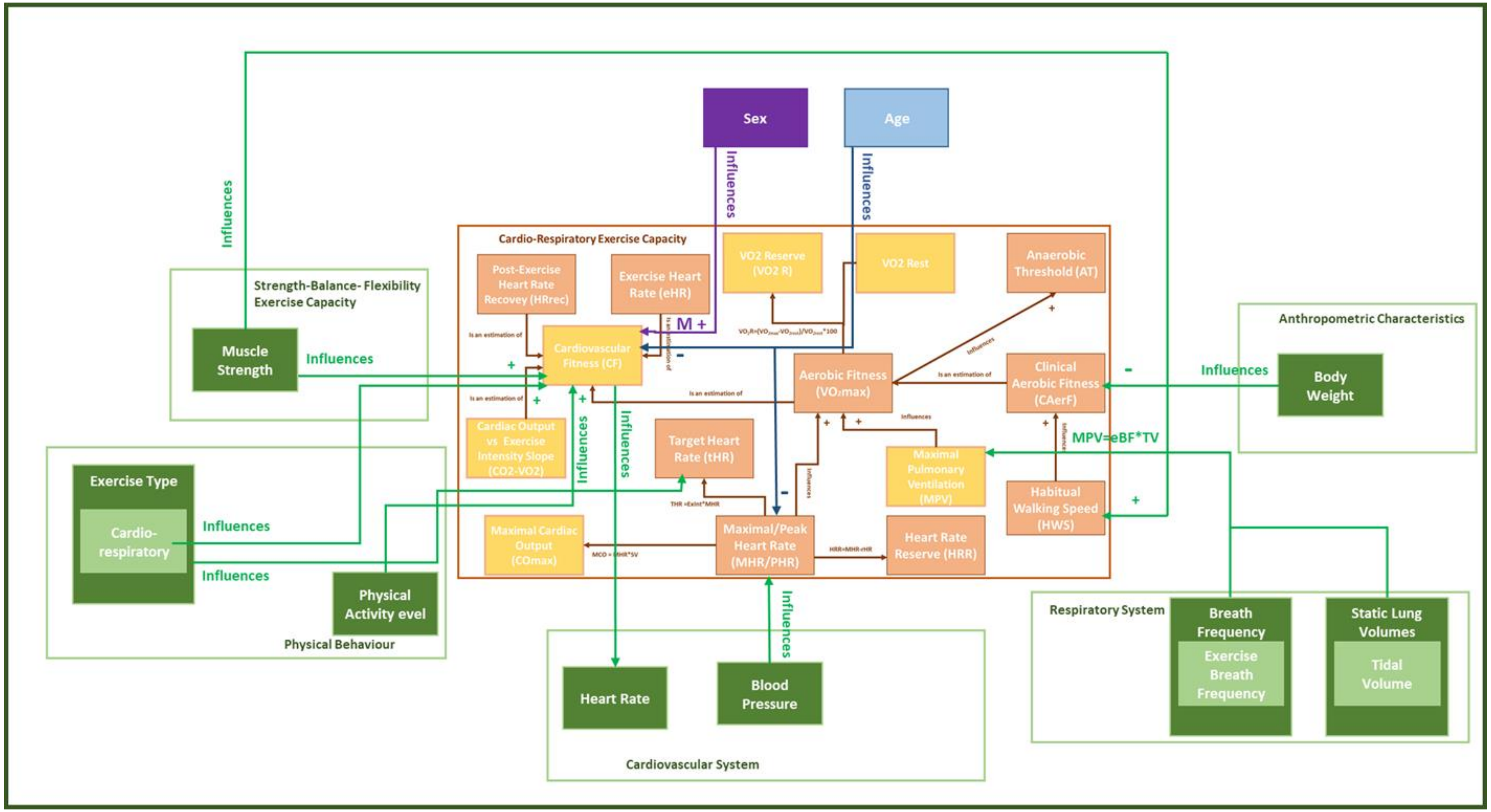

Figure 13 Relationships among the Cardiorespiratory Exercise Capacity subdomain and all the other physiological subdomains.

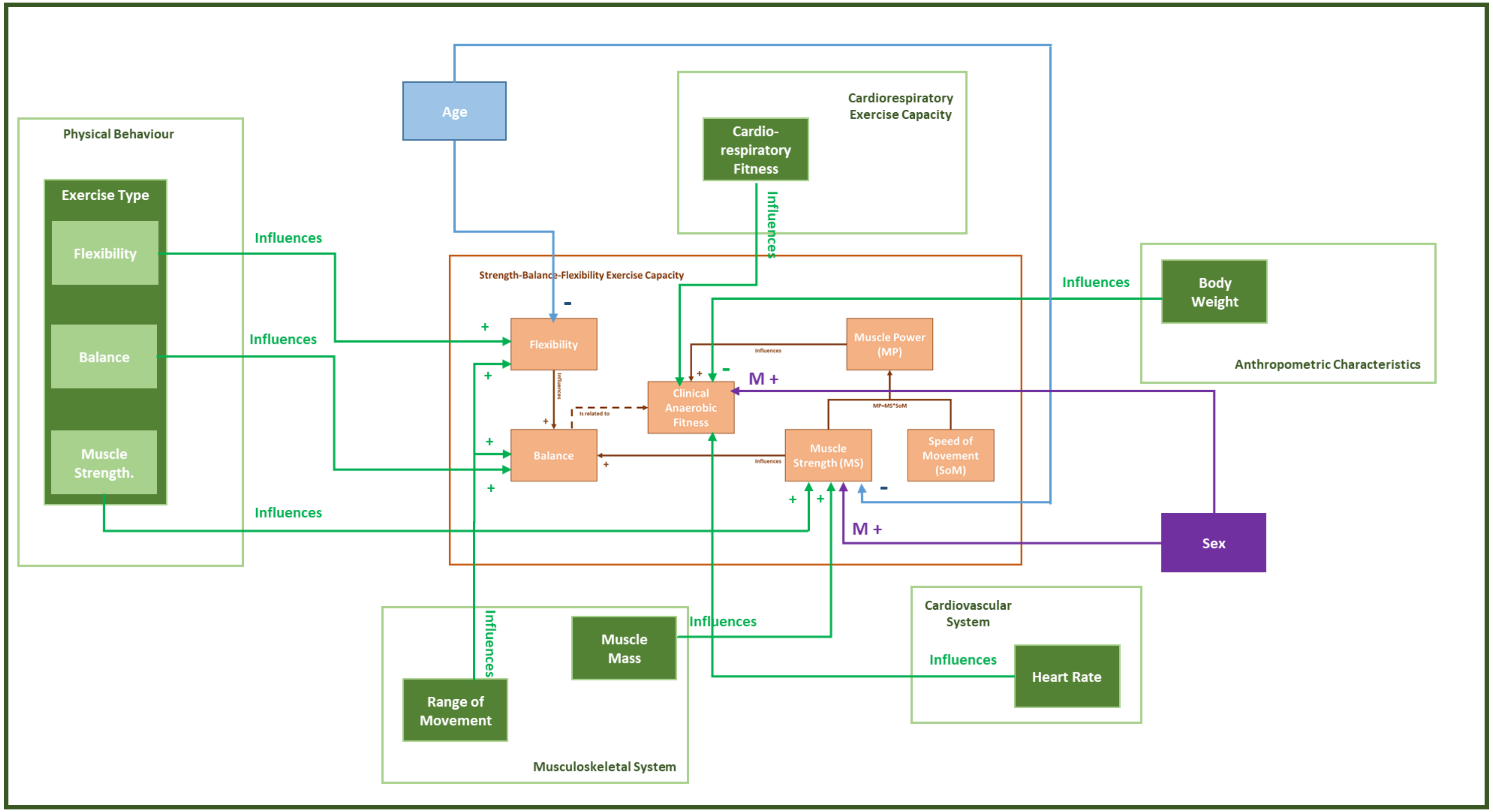

Figure 14 Relationships among the Strength-Flexibility-Balance subdomain and all the other physiological subdomains.

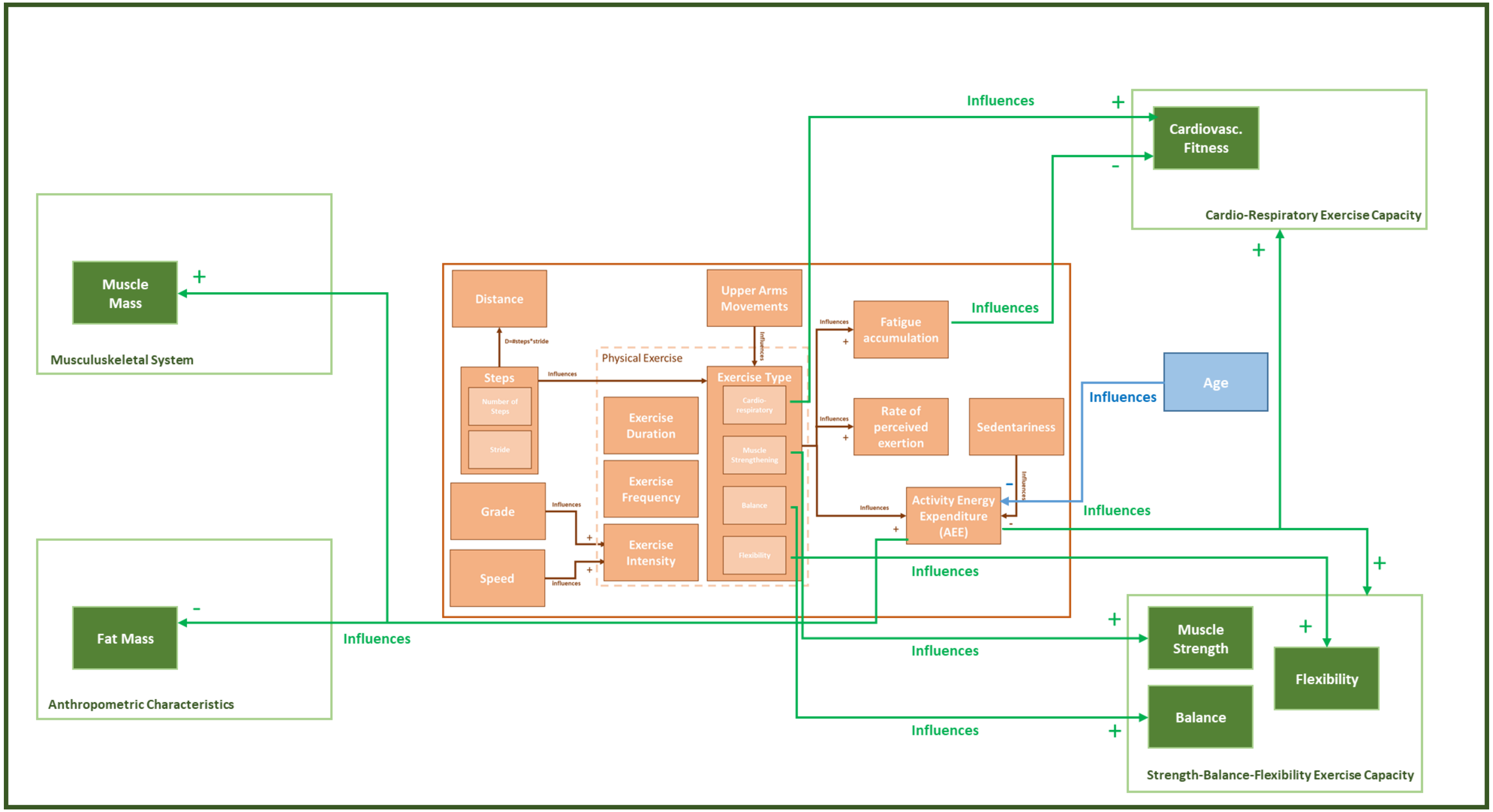

Figure 15 Relationships among the Physical Activity Behaviour subdomain and all the other physiological subdomains.

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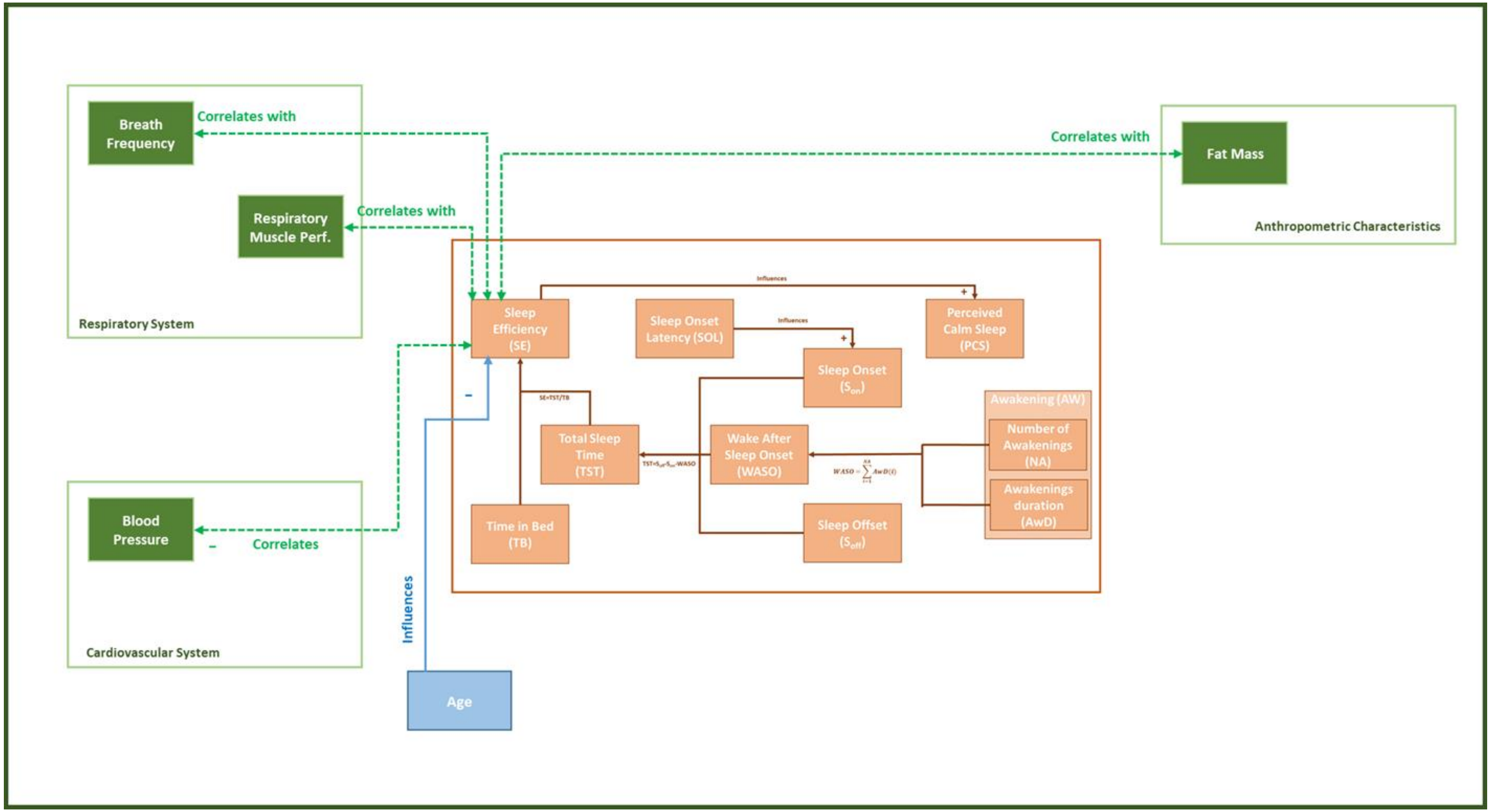

Figure 16 Relationships among the Sleep Quality subdomain and all the other physiological subdomains.

3. Measurement scenarios of the system variables

3.1 Anthropometric characteristics

VARIABLE	MEASUREMENT SCENARIO	UNITS	FORMULA	MEASUREMENT DEVICE	GOLD STANDARD MEASUREMENT
BODY WEIGHT	**Where**: at home (or health professional's office) **When**: morning after waking up (in fasting conditions) **Frequency**: at the initial point and every 15/30 days **Measurement precision**: ±0.5 Kg **Specific requirements (for the user)**: undressed and standing; empty bladder	kg	n.a.	Weighing scale Sensitized carpet Direct inquiry to the user	Weighing scale
BODY HEIGHT	**Where**: at home (or pharmacy, GP…) **Frequency**: at the initial point and at least once every four weeks **Duration of measurement**: seconds **Sampling frequency**: once **Measurement precision**: ±0.5 cm **Specific requirements (for the user)**: standing straight up, without shoes and with the back of the head, scapula, buttocks and heels resting against a wall and the heels touching each other. The measurement should be taken after a deep breath.	m or cm	n.a.	Measuring tape or height rod (by direct inquiry to the user) Sensitized wall or mirror Questionnaire	Stadiometer
BODY MASS INDEX	**Frequency:** at the initial point and every 15/30 days	kg/m^2	$BMI=BW/BH^2$	Derived Measure	Derived Measure
FAT MASS	**Where**: at home (or doctor's office, pharmacy, nutritionist's office, fitness centres…) **When**: in the morning after waking up (in fasting conditions) **Body Position:** In the case of skinfold thickness measurement, four districts (triceps, subscapular, suprailiac, thigh) could be taken by means of a calibrated caliper and averaged. **Frequency**: at the initial point and every 15/30 days Duration of measurement: seconds	kg or %	FM (kg) = – 11.938 + 1.606 *BMI – 8.511*Gender	Bio-impedance analysis (BIA) Skinfolds thickness Sensors for Skinfolds	Dual energy X-ray absorptiometry (DEXA)

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	Measurement precision: ±0.5 kg or ±1% (BIA) – 0.2 mm (Skinfold Thickness) **Specific requirements (for the user)**: Not to drink alcoholic beverages during the 24 hours prior to the measurement				
FAT-FREE MASS	**Where**: at home (or doctor's office, pharmacy, nutritionist's office, fitness centres…) **When**: in the morning after waking up (in fasting conditions) **Frequency**: at the initial point and every 15/30 days **Duration of measurement**: seconds **Measurement precision**: 0.5 kg or ±1% **Specific requirements (for the user)**: Not to drink alcoholic beverages during the 24 hours prior to the measurement.	kg or %	FFM (kg) = +14.966 + 0.588 *BMI + 18.694*Gender + 0.137*WC – 0.138*Age	Bio-impedance analysis (BIA) Derived by Equations	Dual energy X-ray absorptiometry (DEXA)
HIP CIRCUMFERENCE	**Where**: free living. **When**: early in the morning. **Body Position:** around the widest portion of the buttocks and the subject should stand with arms at the sides, feet positioned close together, and weight evenly distributed across the feet. **Frequency**: at the initial point and every 15/30 days. **Measurement precision**: ± 1 cm **Specific requirements (for the user)**: stay relax and take a few deep, natural breaths before the actual measurement.	cm		Stretch resistant tape (3D) body surface scanners	Measuring tape
WAIST CIRCUMFERENCE	**Where**: free living **When**: early in the morning **Frequency**: at the initial point and every 15/30 days **Measurement precision**: ± 1 cm	cm		Stretch resistant tape (3D) body surface scanners	Stretch resistant tape
WAIST-TO-HEIGHT RATIO	**Where**: free living **When**: early in the morning **Frequency**: at the initial point and every 15/30 days **Measurement precision**: ± 1 cm	unitless	WHtR=WC/BH	Derived measure	Derived measure

WAIST-TO-HIP RATIO	**Where**: free living **When**: early in the morning **Frequency**: at the initial point and every 15/30 days **Measurement precision**: ± 1 cm	unitless	WHR=WC/HP	Derived measure	Derived measure

3.2 Cardiovascular System

VARIABLE	MEASUREMENT SCENARIO	UNITS	FORMULA	MEASUREMENT DEVICE	GOLD STANDARD MEASUREMENT
BLOOD PRESSURE	**Where**: quiet, light controlled room. Body position: left arm **Frequency**: once a week (repeated twice) Measurement precision: ±10 mmHg **Specific requirements (for the user)**: seated for a minimum of 10 min prior to the measurement	mmHg		Automated system (inflating cuff)	Sphygmomanometer, photo-plethysmography
HEART RATE	**Where**: at home, quiet room. **When**: in the morning. **Body position**: chest or wrist **Frequency**: once a week (repeated twice) Measurement precision: ±2 bpm **Specific requirements (for the user)**: seated; avoid measuring heart rate after a poor night's sleep or right after strenuous exercise.	bpm (min^{-1})		HR monitor	ECG
HEART RATE VARIABILITY	**Where**: at home, quiet room. **When**: in the morning or same day time at each repetition **Frequency**: once a week **Specific requirements (for the user)**: sitting position; still; normal breathing; subjects should avoid caffeine, smoking and eating in the two hours before the measurement.	ms, ms2, %	HRV is assessed analyzing the variation in the beat-to-beat interval and can be described by different parameters extracted from the HR signal.	Indirect measure (calculated from HR)	Indirect measure (calculated from HR)

3.3 Respiratory System

VARIABLE	MEASUREMENT SCENARIO	UNITS	FORMULA	MEASUREMENT DEVICE	GOLD STANDARD MEASUREMENT
OXYGEN SATURATION	**Body position**: finger, earlobe, toe **Frequency**: once every two weeks **Measurement precision**: ± 2%	%		Pulse oximetry	Blood gas analysis
RESTING BREATH FREQUENCY	**Where**: calm setting **When**: early morning **Body position**: chest **Frequency**: once every 2 weeks **Measurement precision**: 3 bpm **Specific requirements (for the user)**: sitting motionless;	Breath/min		Chest Sensor	Spirometer

3.4 Musculoskeletal System

VARIABLE	MEASUREMENT SCENARIO	UNITS	FORMULA	MEASUREMENT DEVICE	GOLD STANDARD MEASUREMENT
MUSCLE CSA	**Where**: on a flat mat **Body position**: right thigh **Frequency**: once a month Measurement precision: ± 0.5 kg **Specific requirements** (for the user): lying supine	cm^2	muscle CSA = $\pi[r – (SFT/2)]^2$; where r is the radius of the whole thigh and SFT is the subcutaneous fat thickness (SFT) measured at the same location.	derived from equations	MRI
MUSCLE MASS	**Body position**: mid-upper arm and calf **Frequency**: once a month	Kg or kg/m^2	$MM=BH*(0.0553*CTG^2+0.0987*FG^2+0.0331*CCG^2)-2445$ Where BH is the body height in cm; CTG is corrected tigh girth (in cm); FG is uncorrected forearm girth (in cm); CCG is corrected calf girth (in cm)	BIA or derived from equations	MRI, CT, DEXA, BIA

RANGE OF MOVEMENT	**Body position**: back, neck, shoulder, elbow, forearm, hip, knee and ankle joints **Frequency**: Once a month Measurement precision: ± 2 ° **Specific requirements (for the user)**: Stabilize the stationary portion of the body	degree or rad		Inertial sensors, low-cost video-recordings (e.g. Kinect)	Electro-goniometer, three-dimensional motion analysis system (e.g. VICON)

3.5 Cardiorespiratory Exercise Capacity

VARIABLE	MEASUREMENT SCENARIO	UNITS	FORMULA	MEASUREMENT DEVICE	GOLD STANDARD MEASUREMENT
AEROBIC FITNESS (VO2 MAX)	**Frequency**: once a month	l/min, ml/(kg*min)	Equations		Metabolic cart
ANAEROBIC THRESHOLD	**Frequency**: once a month	l/min, ml/(kg*min), mM	AT can be a function of anthropometric parameters. AT (ml/min) = (-206) sex + (8.10) height + (6.8) weight + (-4.98) age + (-125.74). Sex is coded 1 for males and 2 for females.		Metabolic cart or blood lactate analyser
BALANCE	**Body position**: leg, arm and torso **Frequency**: once a month Measurement precision: ± 1 s; ± 1 cm Specific requirements (for the user):	s, cm, scale		Functional balance tests, inertial sensors	Posturography
CLINICAL AEROBIC FITNESS	**Where**: long, flat, straight, enclosed path with a hard surface. A 3o m hallway is required. **Frequency**: once a month **Specific requirements (for the user)**: A starting line, which marks the beginning and end of each	m		Functional test (6MWT)	VO_2 max by Metabolic cart

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	60-m lap, should be marked on the floor using brightly coloured tape				
EXERCISE HEART RATE	**Where**: gym, outdoor **When**: during physical activity **Body position**: chest, wrist **Frequency**: once a month	ml*kg-1*b-1		HR band chest and inertial sensors	Metabolic cart and HR from ECG signal
HABITUAL WALKING SPEED	**Frequency**: at least once a month **Measurement precision:** ± 0.1 m/s	m/s		Inertial sensors /video tracking	Video track Analysis / photoelectric cells
HEART RATE RESERVE	**Where**: gym, lab **Body position**: chest wrist **Frequency**: at least once a month Measurement precision: see rHR	Beats/min,	HRR = MHR - rHR	HR monitor	ECG
MAXIMAL AND PEAK HEART RATE	**Where**: gym, lab **Body position**: chest wrist **Frequency**: at least once a month **Measurement precision:** see rHR	Beats/min, %MHR	MHR= 208.7 − 0.73 × age (men) MHR= 208.1 − 0.77 × age (women) or MHR =220 – age	HR monitor	ECG
POST-EXERCISE HEART RATE RECOVERY	**Where**: gym, outdoor **When**: at the same time of day **Body position**: chest, wrist **Frequency**: once a month Measurement precision: see rHR **Specific requirements (for the user)**: Subjects should complete a 15/20 minutes exercise session of submaximal (50%–60% of peak VO2) intensity	sec		HR chest band	ECG
TARGET HEART RATE	**Where**: gym, outdoor **When**: during the physical activity **Body position**: chest, wrist **Frequency**: every exercise session Measurement precision: see rHR	Beats/min, %MHR	THR = Exercise Intensity * MHR	HR monitor	ECG

3.6 Strength-Flexibility-Balance Exercise Capacity

VARIABLE	MEASUREMENT SCENARIO	UNITS	FORMULA	MEASUREMENT DEVICE	GOLD STANDARD MEASUREMENT
BALANCE	**Body position**: leg, arm and torso **Frequency**: once a month **Measurement precision**: ± 1 s; ± 1 cm	s, cm, scale		Functional balance tests, inertial sensors	Posturography
CLINICAL ANAEROBIC FITNESS	**Where**: Stairs/Chair **Frequency**: once a month	W, W/kg		functional tests (Margaria and 30s Chair-rise tests)	
FLEXIBILITY	**Frequency**: once a month **Measurement precision:** ± 1 cm	cm, rad, degree		Functional tests (Sit-and-reach test, back scratch)	
MUSCLE POWER	**Where**: gym **Body position**: upper and lower limbs **Frequency:** at least once every 2 weeks **Measurement precision:** ± 2 W **Specific requirements (for the user):** specific gym equipment	W, W/kg		Inertial sensors (e.g. GykoRepower, Beast, etc.)	Isokinetic dynamometer (e.g. Biodex)
MUSCLE STRENGTH	**Body position**: upper and lower body segments **Frequency**: at least once every 2 weeks Measurement precision: ± 1 kg **Specific requirements (for the user)**: specific type of contraction (isometric, concentric or eccentric)	Kg, N, N*m		sensitized objects	- One-repetition maximum (1-RM) - Load cells /force transducer (static strength) -Specific ergometers (dynamic strength)

3.7 Physical Activity Behaviour

VARIABLE	MEASUREMENT SCENARIO	UNITS	FORMULA	MEASUREMENT DEVICE	GOLD STANDARD MEASUREMENT
DISTANCE	**Frequency**: every day	m		Inertial sensors	Video recording
EXERCISE DURATION	**Frequency**: every day	sec		Inertial sensors	Video recording

EXERCISE INTENSITY	**Where**: Gym, outdoor **When**: every day **Body position**: Chest, wrist		Herat Rate Monitoring System	ECG
EXERCISE TYPE	**Frequency**: every day	n.a.	Inertial sensors	Video recording
EXERCISE FREQUENCY	**Where**: Gym, outdoor **When**: every week		Inertial sensors	
FATIGUE ACCUMULATION	**When**: 12h and 24h after exercise **Frequency**: every exercise session	n.a.	Questionnaire (TQR scale)	
GRADE	**Where**: Outdoor, Gym **When**: During Exercise Activity		Inertial sensors	
ACTIVITY ENERGY EXPENDITURE	**Frequency**: once a week	METS, Kcal	Questionnaire (PAL-PAR-q)	Pedometers and accelerometers
RATE OF PERCEIVED EXERTION	**When**: after an exercise session	n.a.	Questionnaire (BORG scale)	
SEDENTARINESS	**Frequency**: once a week	sec, min	Questionnaire (PAL-PAR-q)	Accelerometers
SPEED	**Where**: Outdoor, Gym **When**: During Exercise Activity	m/s	Inertial sensors	
STEPS	**Frequency**: every day Measurement precision: ± 100 steps	# number of steps, stride (m)	Pedometer	Pedometer
UPPER LIMBS MOVEMENTS	**Body position**: upper limbs **Frequency**: every day	# number of movements	Inertial sensors	Video recording

3.8 Sleep Quality

VARIABLE	MEASUREMENT SCENARIO	UNITS	FORMULA	MEASUREMENT DEVICE	GOLD STANDARD MEASUREMENT
PERCEIVED CALM SLEEP	**Where**: at home **Frequency**: once a day **Sampling Frequency**: between 1Hz and 30Hz	Integer 1 to 5		Smart wristband Actigraphy	Pittsburgh Sleep Quality (PSQ) and/or Karolinska Sleep Diary (KSD)

SLEEP EFFICIENCY	**Where**: at home **When**: during bedtime **Frequency**: once a day	dimensionless	SE = TST/TIB	Derived	
TOTAL SLEEP TIME	**Where**: at home **When**: during bedtime **Frequency**: once a day **Sampling Frequency**: between 1Hz and 0.1Hz	min		Actigraphy based solution (i.e. SenseWear armband, JawBone UP, ActiwatchAw-64)	Polysomnography instrumentation
SLEEP ONSET	**Where**: at home **When**: during bedtime **Frequency**: once a day **Sampling Frequency**: between 1Hz and 0.1Hz	min		Actigraphy based solution (i.e. SenseWear armband, JawBone UP, ActiwatchAw-64)	Polysomnography instrumentation
SLEEP OFFSET	**Where**: at home **When**: during bedtime **Frequency**: once a day **Sampling Frequency**: between 1Hz and 0.1Hz	min		Actigraphy based solution (i.e. SenseWear armband, JawBone UP, ActiwatchAw-64)	Polysomnography instrumentation
TIME IN BED	**Where**: at home **When**: during bedtime **Frequency**: once a day **Sampling Frequency**: between 1Hz and 0.1Hz	min		Actigraphy based solution (i.e. SenseWear armband, JawBone UP, ActiwatchAw-64)	Polysomnography instrumentation
AWAKENINGS	**Where**: at home **When**: during bedtime **Frequency**: once a day **Sampling Frequency**: between 1Hz and 0.1Hz	# number of awakenings, duration (min)		Smart wristband Actigraphy	Pittsburgh Sleep Quality Index (PSQI) [2].
SLEEP ONSET LATENCY	**Where**: at home **When**: during bedtime **Frequency**: once a day **Sampling Frequency**: between 1Hz and 100Hz	min		Smart wristband Actigraphy	- EEG / Polysomnography - Actigraphy - Richards–Campbell Sleep Questionnaire (RCSQ)
WAKE AFTER SLEEP ONSET	**Where**: at home **When**: during bedtime **Frequency**: once a day **Sampling Frequency**: between 1Hz and 30Hz	min	$\boldsymbol{WASO} = \sum_{i=1}^{NA} \boldsymbol{AwD}(i)$	Actigraphy-based methods	Polysomnography instrumentation

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4. Measurement scenarios for variables related to validation

4.1 Anthropometric characteristics

BODY WEIGHT

MEASUREMENT SCENARIO (PILOTS)

Subjects should remove outerwear, shoes and socks. Measurements should be performed in the morning at the same day time every 15 days. Subjects should be fasted overnight and should empty their bladder before taking the measurement.

The measurements should be done at least once every two weeks. Each measurement should be repeated twice.

BODY HEIGHT

MEASUREMENT SCENARIO (PILOTS)

Height should be taken at head level to the nearest centimetre with the subject standing barefoot, with feet together. The measurements should be done at least once every four weeks. Each measurement should be repeated twice

BODY MASS INDEX

MEASUREMENT SCENARIO (PILOTS)

The value should be calculated every time there is a change in body weight or body height.

FAT MASS

MEASUREMENT SCENARIO (PILOTS)

The deuterium oxide dilution technique is a reference technique for the evaluation of body composition. It is innocuous, non-invasive, simple, reproducible, and can be used directly in fieldwork but it is also expensive and impractical for use in the clinic. Therefore, the results obtained by deuterium oxide dilution are considered to be the “gold standard” for the study of the validity of other less expensive methods like Bioelectrical Impedance Analysis (BIA). BIA is based on the fact that lean tissue contains a high level of water and electrolytes so it acts as an electrical conductor, and fat acts as an insulator. Subjects should lie supine with their hands at their sides and with their legs abducted to 45°. The skin surfaces on the dorsum of the right foot and hand should be cleaned with ethanol before the procedure. Electrodes should be attached to the dorsal surfaces of the foot over the distal portion of the second metatarsal, and on the hand over the distal portion of the second metacarpal. Sensing electrodes will be attached to the anterior ankle between the tibial and fibular malleoli and to the posterior wrist between the styloid processes of the radius and ulna. All BIA measurements should be taken during temperatures ranging from 24°C to 34°C. The measurements should be done at least once every four weeks. Each measurement should be repeated twice.

FAT-FREE MASS

MEASUREMENT SCENARIO (PILOTS)

See Fat Mass.

HIP CIRCUMFERENCE

MEASUREMENT SCENARIO (PILOTS)

The measurement should be taken around the widest portion of the buttocks. The tape should be snug around the body, but not pulled so tight that it is constricting. The protocol also recommends the use of a stretch-resistant tape that provides a constant 100 g of tension through the use of a

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special indicator buckle; use of this type of tape reduces differences in tightness. The measurements should be made with the tape held snugly, but not constricting, and at a level parallel to the floor. The protocol recommends that the subject stands with arms at the sides, feet positioned close together, and weight evenly distributed across the feet. Moreover, it is recommended the subject stay relax and take a few deep, natural breaths before the actual measurement is made, to minimize the inward pull of the abdominal contents during the hip measurement.

The measurements should be done at least once every four weeks. Each measurement should be repeated twice.

WAIST CIRCUMFERENCE

MEASUREMENT SCENARIO (PILOTS)

The Subject should first locate the upper hip bone by placing his/her hands around the waist, squeezing slightly, and then moving the fingers downward until you feel the top curve of your hips. Afterwards, the subjects should lace a tape measure around his/her bare stomach just above the upper hip bone. Make sure the measuring tape is parallel to the floor (slanting can falsely increase your measurement). Also ensure that the tape measure is snug to the body, but not so tight that it compresses the skin. Exhale while measuring and relax your abdomen — sucking in is not allowed!

WAIST TO HEIGHT RATIO

MEASUREMENT SCENARIO (PILOTS)

The measurements should be done at least once every four weeks. Each measurement should be repeated twice.

WAIST TO HIP RATIO

MEASUREMENT SCENARIO (PILOTS)

The measurements should be done at least once every four weeks. Each measurement should be repeated twice.

4.2 Cardiovascular System

BLOOD PRESSURE

MEASUREMENT SCENARIO (PILOTS)

Blood pressure measurements should be performed in seated position, in a quiet, light controlled room with an ambient temperature of between 19–21 °C. To record systolic blood pressure (SBP), diastolic blood pressure (DBP), and mean arterial pressure (MAP), a cuff should be placed on the left arm or the middle finger. Participants should remain in a seated position for a minimum 10 min to stabilize blood pressure. During this time, the cuff should be inflated and deflated rapidly with a minimum of 3 min among each measurement.

The measurements should be done at least once every one week. Each measurement should be repeated twice.

RESTING CARDIAC OUTPUT

MEASUREMENT SCENARIO (PILOTS)

Echo images or trans-thoracic bio-impedance signal should be obtained at rest in all subjects. Recorded echo imaging should last between 45 and 60 seconds and include biplane LV end-diastolic volume (LVEDV), end-systolic volume, and calculated stroke volume (SV). As for bio-impedance, two sensors including gel pads should be carefully placed on each side of the thorax along the midaxillary line, and the two remaining sensors will be placed on each side of the neck just above the clavicle. An alternating current of 1.5 mA (85 kHz) will be applied, and the signal will be the first derivative of the thoracic impedance (dZ/dt). Bio impedance values will be updated every 15 heart beats. The

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left ventricular ejection time (LVET) will be directly measured. Left ventricular stroke volume will be calculated using the formula:SV=VEPT*dZmax/Z0*LVET, where VEPT will be calculated from patient's data (weight, height, age, gender), Zmax represents the amplitude of the systolic wave of the bio-impedance signal and Z0 the base impedance.

RESTING HEART RATE

MEASUREMENT SCENARIO (PILOTS)

HR varies throughout the day depending on whether you're eating, sleeping, experiencing stress, engaging in physical activity, or relaxing and reading a book.

The best time to measure resting heart rate is a few minutes after waking up in the morning. Indeed, the body is least stressed first thing in the morning and will give a more accurate reading. Additionally, early morning measurements will reduce the effects of any stress associated with measuring your heart rate and waiting for results. The subject should sit motionless in a calm setting, do not talk and strive for "normal conditions." (e.g. avoid measuring heart rate after a poor night's sleep or right after strenuous exercise). The measurements should be recorded for several minutes and the mean value should be calculated as final value.

The measurements should be done at least once every one week. Each measurement should be repeated twice.

HEART RATE VARIABILITY

MEASUREMENT SCENARIO (PILOTS)

HRV should be measured at the same day time since it is known to have circadian rhythm due to changing of ANS balance (morning/evening). Before the measurement, subjects should avoid caffeine, smoking and eating in the last two hours. During the measurement, subjects should maintain comfortable sitting position, they cannot move or talk, they have to stay awake and breath normally, without control the breathing intentionally.

The measurements should be done at least once every one week.

STROKE VOLUME

MEASUREMENT SCENARIO (PILOTS)

Echo images or trans-thoracic bio-impedance signal should be obtained at rest in all subjects. Recorded echo imaging should last between 45 and 60 seconds and include biplane LV end-diastolic volume (LVEDV), end-systolic volume, and calculated stroke volume (SV). As for bio-impedance, two sensors including gel pads should be carefully placed on each side of the thorax along the midaxillary line, and the two remaining sensors will be placed on each side of the neck just above the clavicle. An alternating current of 1.5 mA (85 kHz) will be applied, and the signal will be the first derivative of the thoracic impedance (dZ/dt). Bio impedance values will be updated every 15 heart beats. The left ventricular ejection time (LVET) will be directly measured. Left ventricular stroke volume will be calculated using the formula: SV=VEPT*dZmax/Z0*LVET, where VEPT will be calculated from patient's data (weight, height, age, gender), Zmax represents the amplitude of the systolic wave of the bio-impedance signal and Z0 the base impedance.

4.3 Respiratory System

DYNAMIC LUNG VOLUMES

MEASUREMENT SCENARIO (PILOTS)

Spirometry requires a voluntary manoeuvre in which a seated patient inhales maximally from tidal respiration to total lung capacity and then rapidly exhales to the fullest extent until no further volume is exhaled at residual volume. The manoeuvre should be performed in a forceful manner to generate a forced vital capacity (FVC). The amount of air expired in the first second (FEV1) is the

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most widely used parameter to measure the mechanical properties of the lungs. In normal persons, the FEV1 accounts for the greatest part of the exhaled volume from a spirometric manoeuvre and reflects mechanical properties of the large and the medium-sized airways. In a normal flow-volume loop, the FEV1occurs at about 75% to 85% of the FVC. This parameter is reduced in obstructive and restrictive disorders. In obstructive diseases, FEV1 is reduced disproportionately to the FVC, reducing the FEV1/FVC ratio below the lower limit of normal and indicates airflow limitation. In restrictive disorders, the FEV1, FVC, and total lung capacity are all reduced, and the FEV1/FVC ratio is normal or even elevated.

OXYGEN SATURATION

MEASUREMENT SCENARIO (PILOTS)

Non-invasive pulse oximetry has been in widespread use since the 1970s and offers the clear advantages of no discomfort, immediate results and availability of continuous monitoring. A pulse oximeter measures SpO2 based on the absorption of light by pulsating arterial blood at two specific wavelengths that correspond to the absorption peaks of oxygenated and deoxygenated haemoglobin. Although less accurate than SaO2, the typical difference of <2% is usually of no clinical significance. The probe is placed on the patient's finger, earlobe or toe, with the finger usually the most convenient. An important caveat is that pulse oximeter measurements can be less reliable in instances where the patient has poor peripheral perfusion either acutely or chronically; however, most devices are equipped with a detector for pulse signal strength to guide reliability of measurements. Additional factors which can affect reliability of oximetry include skin pigmentation, nail varnish and the presence of methaemoglobin or carboxyhaemoglobin. Pulse oximeters have been found to be generally reliable when oxygen saturation is >88% but less so when the saturation is lower.

The measurements should be done at least once every two weeks. Each measurement should be repeated twice.

RESPIRATORY MUSCLE PERFORMANCE

MEASUREMENT SCENARIO (PILOTS)

The overall strength of respiratory muscles can be measured noninvasively by recording MIP and MEP or by measuring SNIP. These measurements can be performed easily at bedside. Inspiratory pressures are measured at FRC or at RV. Expiratory pressures usually are measured at TLC. The learning effect for MIP, MEP, and SNIP measurements is important, with significant increases over at least five consecutive manoeuvres. Values greater than or equal to 80 cm H2O (in men) or 70 cm H2O (in women) for MIP or greater than or equal to 70 cm H2O in men and 60 cm H2O in women for SNIP exclude clinically relevant respiratory muscle weakness

RESTING BREATH FREQUENCY

MEASUREMENT SCENARIO (PILOTS)

The best time to measure rBF is a few minutes after waking up in the morning. Indeed, the body is least stressed first thing in the morning and will give a more accurate reading. Additionally, early morning measurements will reduce the effects of any stress associated with measuring your heart rate and waiting for results. The subject should sit motionless in a calm setting, do not talk and strive for "normal conditions." The measurements should be done at least once every two weeks. Each measurement should be repeated twice.

RESTING PULMONARY VENTILATION

MEASUREMENT SCENARIO (PILOTS)

VErest should be measured when the subject is sit motionless in a calm setting, do not talk and strive for "normal conditions." The measurements should be recorded for several minutes and the mean value should be calculated as final value. It should be done at least once every two weeks. Each measurement should be repeated twice.

STATIC LUNG VOLUMES

MEASUREMENT SCENARIO (PILOTS)

At first subjects exhaled under normal breathing conditions down to the residual volume (RV), followed by inspiratory vital capacity (IVC) and expiratory vital capacity manoeuvre (EVC).

The application of conventional quality control standards to objective assessment of pulmonary function in older subjects may prove difficult because of mood alterations, fatigability, lack of cooperation, or cognitive impairment.

4.4 Musculoskeletal System

MUSCLE CROSS SECTIONAL AREA

MEASUREMENT SCENARIO (PILOTS)

All anthropometric measurements should be performed on the right thigh, with the participants lying supine on a flat mat. Thigh circumference (Thighcircum) should be measured mid-distance between the anterior superior iliac spine and superior border of the patella in triplicate using a standard inflexible measuring tape. Subcutaneous fat thickness (SFT) should be measured in triplicate at the same location using a skinfold caliper. Knowing that circumference is equal to πr where π is 3.14, the radius (r) of the whole thigh is equal to Thighcircum/2. To estimate the radius of the whole muscle CSA (muscle CSAanthro), SFT should be subtracted from the radius of the whole thigh.

Thus, muscle CSAanthro can be calculated using the following equation:

CSA = π [r – (SFT/2)]2.

The same procedure should be applied to the mid arm.

The measurements should be done at least once every four weeks. Each measurement should be repeated twice.

MUSCLE PHYSIOLOGICAL CROSS SECTIONAL AREA

MEASUREMENT SCENARIO (PILOTS)

Please refer to CSA

MUSCLE MASS

MEASUREMENT SCENARIO (PILOTS)

Bio impedance analysis (BIA) estimates the volume of fat and lean body mass. The test itself is inexpensive, easy to use, readily reproducible and appropriate for both ambulatory and bedridden patients. BIA measurement techniques, used under standard conditions, have been found to correlate well with MRI predictions. Prediction equations should respect individual characteristics (ethnicity, sex, etc.) and reference values established for adult white men and women, including older subjects.

SMM (kg) = ((Ht2 /R50 * 0.401) + (sex * 3.825) + (age * -0.071)) + 5.102

The measurements should be done at least once every four weeks. Each measurement should be repeated twice.

Magnetic Resonance Imaging (MRI) could be useful to measure muscle mass, together to other muscle properties (fat infiltration, CSA, PCSA). Its use is suggested at the beginning and the end of the pilot period.

MUSCLE THICKNESS

MEASUREMENT SCENARIO (PILOTS)

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Before the measurements, the position at the middle of the limb (lower and upper) should be detected by bone references, and it should be marked on the skin using a pen marker. During the measurements, the subject lay in supine position. Tissue thickness is measured in the subcutaneous fat and the muscle group using the ultrasound probe.

The measurements should be done at least once every four weeks. Each measurement should be repeated twice.

PENNATION ANGLE

MEASUREMENT SCENARIO (PILOTS)

The subject should lay on an examination table with legs and arms relaxed. Resting pennation angle (PA) will be measured by real-time

ultrasound. The probe should be positioned perpendicular to the dermal surface and oriented along the median longitudinal plane of the muscle. The PA is measured as the angle of insertion of muscle fibre fascicles into the deep aponeurosis. The accuracy of the ultrasound method in measuring the architectural features of the human muscle has been previously tested against direct anatomic measurement on a cadaver and found to be in good agreement: in the central region of the muscle, PA differed by an average of 1.5°.

The measurements should be done at least once every four weeks. Each measurement should be repeated twice.

RANGE OF MOVEMENT

MEASUREMENT SCENARIO (PILOTS)

For each joint (back, neck, shoulder, elbow, forearm, hip, knee, ankle) the maximum possible range of motion in degrees should be evaluated by a goniometer. Range of Joint Motion Evaluation Chart. For each joint (back, neck, shoulder, elbow, forearm, hip, knee, ankle) the existing limitation of motion should be indicated by showing the maximum possible range of motion in degrees. A complete description of any abnormalities should be reported in a narrative summary. A traditional goniometer is a protractor with extending arms. To use a goniometer: (1) Align the fulcrum of the device with the fulcrum or the joint to be measured; (2) Align the stationary arm of the device with the limb being measured; (3) Hold the arms of the goniometer in place while the joint is moved through its range of motion. The degree between the endpoints represents the entire range-of-motion.

The measurements should be done at least once every four weeks. Each measurement should be repeated twice.

4.5 Cardio-Respiratory Exercise Capacity

AEROBIC FITNESS (VO$_2$ MAX)

MEASUREMENT SCENARIO (PILOTS)

VO2max is usually measured during incremental graded exercises and it is believed to exist only when VO2 fails to increase with an increase in work load during a graded exercise test. However, relatively low incidences ranging from 25 to 47% have been reported and secondary criteria to validate VO2max measurements have been established. These include age-predicted maximum heart rate (HRmax), respiratory exchange ratio (RER) higher than 1.1-1.15, and blood lactate concentration higher than 8 mM.

ANAEROBIC THRESHOLD

MEASUREMENT SCENARIO (PILOTS)

A treadmill or a cycle ergometer should be used for the test. After 1 min of rest, exercise is initiated by 2 min of unloaded cycling or a warm up walking speed and subsequent uniform increases in work rate or speed every minute until exhaustion or inability to move the pedals. The workload or speed increments should be designed so that a subject would reach exhaustion within 10 min of incremental work. Ventilation and gas exchange variables should be recorded breath by breath using a metabolic cart. The ventilator threshold should be highlighted by: 1) a systematic increase in the ventilator equivalent for O2 without an increase in the ventilator equivalent for CO2; and 2) a systematic increase in the end tidal O2 partial pressure without a decrease in end-tidal CO2 partial pressure. If blood lactate concentration is used as variable for determining AT, the exercise should consist of at least 3min of duration steps and blood lactate should be collected at the end of each step.

Measurements should be performed at least once per month.

CLINICAL AEROBIC FITNESS

MEASUREMENT SCENARIO (PILOTS)

The 6 minutes walking test (6MWT) should be performed along a long, flat, straight, enclosed path with a hard surface that is seldom travelled. The walking course must be 30 m in length. A 100-ft hallway is, therefore, required. The length of the corridor should be marked every 3 m. The turnaround points should be marked with a cone (such as an orange traffic cone). A starting line, which marks the beginning and end of each 60-m lap, should be marked on the floor using brightly coloured tape. Standardized phrases for encouragement should be used during the test.

The test should be repeated every month.

CARDIAC OUTPUT VS EXERCISE INTENSITY SLOPE

MEASUREMENT SCENARIO (PILOTS)

A treadmill or a cycle ergometer should be used for the test. After 1 min of rest, exercise is initiated by 2 min of unloaded cycling or a warm up walking speed and subsequent uniform increases in work rate or speed every minute until exhaustion or inability to move the pedals. The workload or speed increments should be designed so that a subject would reach exhaustion within 10 min of incremental work. Ventilation and gas exchange variables should be recorded breath by breath using a metabolic cart. Cardiac output should be estimated by transthoracic bioimpedence.

Measurements should be performed at least once per month.

EXERCISE HEART RATE

MEASUREMENT SCENARIO (PILOTS)

Each subject should perform at least two six min bouts at a constant velocity. The running velocity of the subjects or the work rate should be kept constant. The starting running velocity/work rate should be selected according to subjects' usual habits. Each subsequent bout intensity should be determined in relation to exercise capacity of the subject. The recovery time between bouts should allow that heart rate is less than 5 b*min-1 different from the value observed before the beginning of the previous bout. The HR for each bout should be calculated as the mean value of the last 30 sec.

Through all testing expired gases will be collected and VO2 be averaged in 20 s intervals. Heart rate will be recorded continuously and averaged over 20 s intervals.

For each velocity/work rate, mean heart rate and mean VO2 over the last minute of the bout will be used for drawing a linear relationship between these two variables. A zero velocity VO2 (mean 1 min value recorded before the start of the sub maximal test) and hear rate (mean 1 min value recorded before the start of the sub maximal test) could be included in the regression lines.

Measurements should be performed at least once per month.

HEART RATE RESERVE

MEASUREMENT SCENARIO (PILOTS)

Please refer to HR and MHR

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HABITUAL WALKING SPEED

MEASUREMENT SCENARIO (PILOTS)

Gait speed should be calculated using distance in meters and time in seconds. The instructions should request the subject to walk at usual pace starting from a standing position. The walking distance should be 4 m. The average speed is calculated as meters divided by time.
The measurements should be done at least once every four weeks. Each measurement should be repeated twice.

MAXIMAL CARDIAC OUTPUT

MEASUREMENT SCENARIO (PILOTS)

Echo images or trans-thoracic bio-impedance signal should be obtained at end of an incremental exercise. After a warm-up period of 6 to 10 min, each subject can run, walk or cycle at a comfortable but brisk speed. The treadmill grade or the brake resistance increases every 2 min until volitional exhaustion. At the end of each stage, the subjects could be asked to rate their perception of effort using a Borg category scale. Peak CO is defined as the highest value recorded during the test. Recorded echo imaging or bio-impedance values should represent the mean values of the last 30 seconds.
The measurements should be done at least once every four week.

MAXIMAL AND PEAK HEART RATE

MEASUREMENT SCENARIO (PILOTS)

Maximal heart rate should be determined by a continuous, incremental treadmill protocol: after a warm-up period of 6 to 10 min, each subject can run, walk or cycle at a comfortable but brisk speed. The treadmill grade or the brake resistance increases every 2 min until volitional exhaustion. At the end of each stage, the subjects could be asked to rate their perception of effort using a Borg category scale. Peak heart rate is defined as the highest value recorded during the test.
The measurements should be done at least once every four weeks. Each measurement should be repeated twice.

MAXIMAL PULMONARY VENTILATION

MEASUREMENT SCENARIO (PILOTS)

Maximal VE should be determined by a continuous, incremental treadmill protocol: after a warm-up period of 6 to 10 min, each subject can run, walk or cycle at a comfortable but brisk speed. The treadmill grade or the brake resistance increases every 2 min until volitional exhaustion. At the end of each stage, the subjects could be asked to rate their perception of effort using a Borg category scale. Peak ventilation is defined as the highest value recorded during the test.
The measurements should be done at least once every four weeks.

POST-EXERCISE HEART RATE RECOVERY

MEASUREMENT SCENARIO (PILOTS)

Subjects should complete a 15/20 minutes exercise session of submaximal (50%–60% of peak VO2) intensity. To control for circadian variability, all submaximal exercise sessions should be conducted at the same time of day. At the end of the exercise bout, the subject should remain seated on a chair for a 15-min passive recovery period. HR recovery data should be averaged on a minute-by-minute basis for all the 15min period.
HR recovery should be evaluated as the amount of HR change from the mean HR obtained during the last minute exercise and the mean HR between the first and the second minute of recovery.
The test should be repeated every month.

TARGET HEART RATE

MEASUREMENT SCENARIO (PILOTS)

The measurements should be done during all the activities. The HR should be recorded beat by beats. Please refer to Maximal Heart Rate for specifics.

VO₂ RESERVE

MEASUREMENT SCENARIO (PILOTS)

Please refer to VO2rest and VO2max

VO₂ REST

MEASUREMENT SCENARIO (PILOTS)

The subject should sit motionless in a calm setting, do not talk and strive for “normal conditions.” The measurements should be recorded for several minutes and the mean value should be calculated as final value. The measurements should be done at least once every one week. Each measurement should be repeated twice.

4.6 Strength-Balance-Flexibility Exercise Capacity

BALANCE

MEASUREMENT SCENARIO (PILOTS)

Static posturography is not really static but aims to quantify postural sway while a subject stands as still as possible. Postural sway is usually quantified by characterizing displacements of the centre of foot pressure from a force plate.

In contrast to static posturography, dynamic posturography involves the use of external balance perturbations or changing surface and/or visual conditions. Postural perturbations usually are usually made with a movable, computerized support surface so that induces disequilibrium is induced by sudden horizontal translations or rotations (Bloem, Visser, Allum 2003).

The measurements should be done at least once every four weeks. Each measurement should be repeated twice.

CLINICAL ANAEROBIC FITNESS

MEASUREMENT SCENARIO (PILOTS)

MARGARIA TEST: A short-term anaerobic test or power test in which the subject stands 2 m from a staircase and then sprints at top speed up the staircase, taking two steps at a time, each step being 175 mm high. Pressure pads on the eighth and twelfth step act as switches recording time taken to run between the pads. It is assumed that all the external work of the subject is used to raise the centre of mass of the body, and that this rise is the same as the vertical distance between the eighth and twelfth step. The power output (P) of the subject is calculated as follows:

$$P = (W \times 9.8 \times D)/t$$

where W is the body weight of the subject in kilograms: 9.8 is the normal acceleration due to gravity in ms^{-2}; D is the vertical height in metres between the eighth and twelfth steps: and t is the time taken from the first pressure pad to the second pad.

30SEC CHAIR-RISE: Lower-body muscle power is assessed by measuring the number of stands from an armless chair of standard height (45 cm) performed in 30 seconds. The test begins when the participant is in seated position with a neutral spine and feet flat on the floor. The participant is instructed to rise to a full stand and return to the original seated position as quickly as possible. The chair rises begin with the participant’s arms crossed at the wrist and held against the chest. The participant is verbally cued using the command “1, 2, 3, GO,” and a stopwatch is started simultaneously with the “GO” cue. Participants should be instructed to move at a maximal speed

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until they either feel the need to stop or the 30-second time limit is reached. The measurements should be repeated twice and a five-minute recovery among them should be guaranteed.

Average power (W) = − 504.845 + 10.793 body weight (kg) + 21.603 stands in 20s
Peak power (W) = − 715.218 + 13.915 body weight (kg) + 33.425 stands in 20s

FLEXIBILITY

MEASUREMENT SCENARIO (PILOTS)

The SIT-AND-REACH TEST has the purpose to assess lower body flexibility, which is important for good posture, for normal gait patterns and for various mobility tasks, such as getting in and out of a bathtub or car. From a sitting position at front of chair, with leg extended and hands reaching toward toes, the number of inches (cm) (+ or -) between extended fingers and tip of toe.

The BACK SCRATCH TEST has the purpose to assess upper body (shoulder) flexibility, which is important in tasks such as combing one's hair, putting on overhead garments and reaching for a seat belt. With one hand reaching over the shoulder and one up the middle of the back, the number of inches (cm) between extended middle fingers (+ or -).

The measurements should be done at least once every four weeks. Each measurement should be repeated twice.

MUSCLE POWER

MEASUREMENT SCENARIO (PILOTS)

Upper and lower limb should be tested. Participants will be positioned on the isokinetic dynamometer in accordance to manufacturer guidelines. They then will perform three maximal, voluntary contractions (e.g. knee extension/flexion), through a specific range of motion, at a fixed angular velocity. Dynamometer's torque and angular velocity will be sampled and power (W) will be calculated as the product of the torque (N*m) and angular velocity (rad*s-1).

The measurements should be done at least once every two weeks. Each measurement should be repeated twice.

MUSCLE STRENGTH

MEASUREMENT SCENARIO (PILOTS)

One-Repetition maximum (1-RM): the maximum amount of weight that can be lifted while maintaining an acceptable movement technique. Determination of 1RM proceeds over subsequent trials in which the amount of weight to be lifted is increased stepwise until the subject fails to produce a full-range movement. As the procedure requires multiple repetitions, an adequate period or resting among each contraction should be performed.

Static strength: it is the maximal force which can be generated by an isometric muscle contraction (the muscle is activated, but instead of being allowed to lengthen or shorten, it is held at a constant length). The force generated during an isometric contraction is wholly dependent on the length of the muscle while contracting. Thus, is should be determined at fixed angles within the range of motion of the body segment investigated

Dynamic strength: It can be generated by concentric and eccentric muscle contractions. The first one is generated when a muscle is activated and it begins to shorten. The second one is generated when the external force on the muscle is greater than the force that the muscle can generate. Thus even though the muscle may be fully activated, it is forced to lengthen due to the high external load.

Strength can be measured isometrically or isokinetically, the latter being a closer reflection of muscle function in everyday activity. Isometric strength testing of maximal voluntary contractions can be measured with relatively simple custom-made equipment. It is usually measured as the force

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applied to the ankle, with the subject seated in an adjustable straight-back chair, the lower leg unsupported and the knee flexed to 90°. Modern, commercial isokinetic dynamometers allow both isometric and isokinetic measurements of strength as concentric torque at various angular velocities.
The measurements should be done at least once every two weeks. Each measurement should be repeated twice.

SPEED OF MOVEMENT

MEASUREMENT SCENARIO (PILOTS)
Upper and lower limb should be tested. The measurements should be done at least once every two weeks. Each measurement should be repeated twice.

4.7 Physical Activity Behaviour

DISTANCE

MEASUREMENT SCENARIO (PILOTS)
It should be measured everyday across the 24h or at least during the daytime.

EXERCISE DURATION

MEASUREMENT SCENARIO (PILOTS)
It should be measured when an exercise session starts. HR could be used as indirect marker, if necessary

EXERCISE FREQUENCY

MEASUREMENT SCENARIO (PILOTS)
It should be measured across a week

EXERCISE INTENSITY

MEASUREMENT SCENARIO (PILOTS)
It should be measured when an exercise session starts. Please pay attention that it can change within the same exercise session

EXERCISE TYPE

MEASUREMENT SCENARIO (PILOTS)
This is just a list of exercise types

FATIGUE ACCUMULATION

MEASUREMENT SCENARIO (PILOTS)
It should be measured after 24h from the last exercise session.

GRADE

MEASUREMENT SCENARIO (PILOTS)
This variable should be measured each time a subject performs an exercise activity involving walking or running or cycling.

ACTIVITY ENERGY EXPENDITURE

MEASUREMENT SCENARIO (PILOTS)
The measurements should be done every day and it should refer to at least four consecutive days

RATE OF PERCEIVED EXERTION

MEASUREMENT SCENARIO (PILOTS)

Using a questionnaire (BORG scale), the subject should evaluate all sensations and feelings of physical stress, effort, and fatigue. He/she should not concern himself with any one factor such as leg pain or shortness of breath, but try to focus on his total feeling of exertion.

The measurements should be done during and immediately after an exercise session.

SEDENTARINESS

MEASUREMENT SCENARIO (PILOTS)

It should be measured everyday across the 24h or at least during the daytime. It should not take into account the time in bed during the night

SPEED

MEASUREMENT SCENARIO (PILOTS)

This variable should be measured each time a subject performs exercise activity

STEPS

MEASUREMENT SCENARIO (PILOTS)

They should be measured everyday across the 24h or at least during the daytime.

UPPER LIMBS MOVEMENTS

MEASUREMENT SCENARIO (PILOTS)

They should be measured everyday across the 24h or at least during the daytime.

4.8 Sleep Quality

AWAKENINGS

MEASUREMENT SCENARIO (PILOTS)

Once a day: the sleep maintenance variable can be evaluated once a day, in the morning, after a sleep session by analysing sleep data stream. The data stream may be recorded using a sampling frequency ranged between 1Hz to 0.1 Hz.

The data coming from devices (actigraph/unobtrusive devices) are recorded on the cloud.

The detection of the number of awakenings during the night state is achieved by periodically running (after each night) analytic tools able to detect the awakenings of each user.

The results of this analytic tool can be further analysed so that to measure other variables and correlated to the diary entries.

Once a day: participants are instructed to annotate on a diary the time of their sleep awakenings when occurs. Furthermore, they should annotate, once in the morning, the time when they are gone to sleep. This task can be done in awake condition.

This diary can be used as baseline to validate the system’s outputs.

PERCEIVED CALM SLEEP

MEASUREMENT SCENARIO (PILOTS)

Once a day: the detection of the calm/restless during the night state is achieved by periodically running (after each night) analytic tools able to detect the state for every user. The Calm Sleep variable can be evaluated once a day, in the morning, after a sleep session by analysing sleep data stream. In order to efficiently detect Restless during the night through the analysis of accelerations due to patient movements, and/ or forces applied by the body to the mattress, and/ or continuously monitor heart rate without disturbing the patient through BCG, the data stream may be recorded using a sampling frequency ranged between 1Hz and 30Hz. This range depends on the different

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technologies utilized. The Calm Sleep variable detection needs precise measurements. The body position has a strong influence on the detection process. However, considering the domain (and sub-domain) of this variable, any requirements in terms of body position and condition can be applied.

The results of this analytic tool can be further analysed so that to measure other variables and correlated to the diary entries.

Once a day: participants are instructed to fill subjective sleep diary for a limited baseline period to train the analytics modules.

SLEEP EFFICIENCY

MEASUREMENT SCENARIO (PILOTS)

Once a day: participants should be equipped with Polysomnography system. Moreover, users should be equipped with sleep detection device [2] in order to validate analytic tools using polysomnography outputs as ground truth. Otherwise, the analytic tools developed can be validated using public repository of sleep recordings [5]. The working frequency of the PSG system is ranged from 1Hz and 500Hz. The polysomnography instrumentation can be considered a precision instrument and it have to record all the sleep session

SLEEP ONSET

MEASUREMENT SCENARIO (PILOTS)

Please refer to Sleep Efficiency

SLEEP ONSET LATENCY

MEASUREMENT SCENARIO (PILOTS)

Once a day: participants can be equipped with Electroencephalography monitoring instrumentation for a limited time, in order to improve the accuracy of the actigraph/unobtrusive based system. The EEG technology can be considered a precision instrument, and its working frequency is ranged from 1Hz to 100Hz.

Once a day: For a qualitative analysis, also the Richards–Campbell Sleep Questionnaire (RCSQ) scale can be used. The scale evaluates perceptions of depth of sleep, sleep onset latency, number of awakenings, time spent awake, and overall sleep quality.

If the baseline phase is not achievable due to the obtrusiveness of polisomnography, an explorative data analysis approach will be used (by means of segmentation and clustering of data most probably related to sleep onset time).

SLEEP OFFSET

MEASUREMENT SCENARIO (PILOTS)

Please refer to Sleep Efficiency

TIME IN BED

MEASUREMENT SCENARIO (PILOTS)

Please refer to Sleep Efficiency

TOTAL SLEEP TIME

MEASUREMENT SCENARIO (PILOTS)

Please refer to Sleep Efficiency

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WAKE AFTER SLEEP ONSET

MEASUREMENT SCENARIO (PILOTS)

Once a day: participants are instructed to fill subjective sleep diary [4 for a limited baseline period to train the analytics modules.

Participants beds are equipped with measuring devices. Furthermore, they should be equipped with actigraphy-based (or equivalent sleep monitoring) systems and instructed to fill sleep diary) in order to validate the analytic tools' output. Furthermore, these outputs can be evaluate also applied to public sleep session repository.

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ANNEX 2
Nutrition

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2018.03.01	Josep del Bas	EURECAT	Domain Expert
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2018.04.06	Giuseppe Andreoni	POLIMI	Scientific Coordinator

Short Abstract

This annex describes in detail the model of the Nutritional domain.
Based on the information reported in the previous chapters, the nutritional domain has been organized in four subdomains: 1) **Anthropometric Characteristics** which contains a detailed description of the main anthropometric variables describing body dimensions, body composition and relationship among them; 2) **Blood Parameters** which describes, in detail, 3 crucial parameters (glucose, cholesterol and triglycerides) involved in the nutritional aspect of aging and the relationships among them 3) **Energy Expenditure** which describes the variables mainly related to the energetics of nutrition 4) **Nutrition Habits** which describes variables directly related to the study of a subject's eating habits.

The document is composed of four subsections, describing:

- **Variables useful for the characterization and monitoring of the physiological status of the person along with his/her physical activity behaviour**: for each subdomain a table containing the related variables is provided, followed by a short description of the variable meaning. Each variable is classified with respect to its foreseen use in NESTORE (System=variable to be used in the system, Pilot=variable to be used during the system validation in Pilots), its importance (necessary, important), the factors negatively affecting the variable itself.

This part is specifically thought to support the development of ontology in Task 2.5 and also for profiling activities and, consequently, for personalization purposes (WP4 and WP5).

- **Relationships among the domain variables and variable ranges and/or trends corresponding to normal aging status and behaviour**: for each subdomain a scheme describing the relationships among the variable domains is provided (solid arrows = direct causal relationship, dashed arrows = indirect causal relationship, dotted arrows = correlation between); if a variable can be directly calculated from others, the formula is provided; variables foreseen as system variables are in orange, variables foreseen only in Pilots are in yellow. Moreover, for each domain a table containing the normality range and/or the normal trend physiologically occurred during aging, is provided for each system variable, if known. The consequences of out of range values (or trends) are also reported.

This part is specifically thought for the ontology and to support WP4 in the development of the Decision Support System.

- **Measurement scenarios of the system variables**: for each subdomain, the principal information describing how the variables should be measured by the system are reported in a dedicated table. Specifically, the table includes: measurement conditions (frequency, location, duration, etc.), measurements units, formulas to derive the variable value from other variables, measurement devices, gold standard measurements.

This part provides the functional system requirements from the point of view of the domain experts, in support to WP3 and WP5, for the development of the monitoring system.

- **Measurement scenarios for variables related to validation:** for each subdomain, some suggestions on how to measure the variables during pilots are provided.

This part is thought to support the definition of Virtual Coach Validation Plan to be used in the pilots to assess the impact and the functional effectiveness of the Virtual Coach on the elderly subjects’ status and behaviour (Task 2.6)

Key Words

Nutrition, Anthropometric Characteristics, Blood Parameters, Energy Expenditure, Nutrition Habits

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1. Description of the subdomains and related variables

1.1 Anthropometric characteristics

Table 1. List of variables of the Anthropometric Characteristics subdomain.

VARIABLE NAME	ACRONYM	TO BE USED IN SYSTEM/PILOT	PRIORITY	AFFECTED BY
BODY HEIGHT	BH	System + Pilot	Necessary	-
BODY WEIGHT	BW	System + Pilot	Necessary	Undernutrition, overnutrition, sedentary lifestyle, genetics, socioeconomic factors, drugs.
BODY MASS INDEX (BMI)	BMI	System + Pilot	Necessary	Undernutrition, overnutrition, sedentary lifestyle, genetics, socioeconomic factors, drugs.
FAT MASS	FM	System + Pilot	Necessary	Dietary habits, sedentary lifestyle, genetics, socioeconomic factors.
FAT-FREE MASS	FFM	System + Pilot	Necessary	Dietary habits, sarcopenia, sedentary life, socioeconomic factors.
HIP CIRCUMFERENCE	HC	System + Pilot	Necessary	Dietary habits, sedentary life, genetics, socioeconomic factors.
WAIST CIRCUMFERENCE	WC	System + Pilot	Necessary	Dietary habits, sedentary lifestyle, genetics, socioeconomic factors.
WAIST-TO-HEIGHT RATIO	WHtR	System + Pilot	Necessary	Dietary habits, sedentary lifestyle, genetics, socioeconomic factors.
WAIST-TO-HIP RATIO	WHR	System + Pilot	Necessary	Dietary habits, sedentary lifestyle, genetics, socioeconomic factors.

Body height (BH): Standing height of the person, corresponding to the maximum vertical size. Ref: Perissinotto et al., 2002

Body weight (BW): Body mass of the person. Ref: Buffa et al., 2011; Guo et al., 1999, Harms et al., 2011; Hughes et al.2002

Body mass index (BMI): BMI is a weight-for-height index. It is calculated by dividing the subject's weight (kg) by the square of their height (m). Currently, the BMI criteria proposed by WHO are the most widely used. Evidence suggests that the risk of finding oneself at the extremes of the body mass index (either underweight or obese), increases along with age. Ref: Buffa et al., 2011; Babiarczyk et al., 2012

Fat mass (FM): Body weight corresponding to fat mass (expressed in Kg and percentage of body weight). Aging is frequently associated with a gradual increase of fat mass (FM), which has a negative impact on health outcomes, such as morbidity, mortality and quality of life. Elevated fat mass may simultaneously occur in the presence of normal or low fat-free mass (also termed sarcopenia). The double burden of excess FM and low FFM may lead to decreased physical functioning in comparison to those with normal body composition. Ref: Buffa et al., 2011; Harms et al., 2011; Kyle et al., 2001; Zamora et al., 2017

Fat-free mass (FFM): FFM, also known as lean body mass, refers to all of the body components except fat. It includes body's water, bone, organs and muscle content. However, when it comes to weight management and

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body composition, fat-free mass refers primarily to muscle mass. Ref: Buffa et al., 2011; Fuller et al., 1996; Harms et al., 2011; Kyle et al., 2001; Zamora et al., 2017

Hip Circumference (HC): Hip circumference is usually assessed in manual measurements with flexible but non-stretchable tapes at the level of the largest lateral extension of the hips in a horizontal plane. It is considered an indicator of abdominal obesity and it may be better predictors of risk than the BMI for several diseases, including cardiovascular disease (CVD), cancer, type 2 diabetes, and the Metabolic Syndrome. Ref: Buffa et al., 2011; Kyle et al., 2001; WHO, 2011.

Waist Circumference (WC): It is the perimeter of the abdomen, measured at the mid-point between the lower rib and the iliac crest, at a level parallel to the floor. Waist circumference is a better measure of visceral (abdominal) obesity than BMI. Visceral obesity is closely related with comorbidities and with the presence of metabolic syndrome. Ref: Ma et al.,2013; Klein et al., 2007; WHO, 2011.

Waist-to-height ratio (WHtR): Waist to height ratio is a simple measurement for assessment of lifestyle risk and overweight. Compared to just measuring waist circumference, waist to height ratio is equally fair for short and tall persons. Measuring waist to height ratio is gaining popularity in the scientific society as several studies have found that this is a more valid measurement than BMI. Just measuring waist circumference is inherently biased for people taller or shorter than average population. Ref: Buffa et al., 2011; Kyle et al., 2001; Swainson et al., 2017.

Waist-to-hip ratio (WHR): Waist to hip ratio is another simple measurement for assessment of lifestyle risk and overweight (see previous WHtR)

1.2 Blood Parameters

Table 2 List of variables of the Blood Parameters subdomain.

VARIABLE NAME	ACRONYM	TO BE USED IN SYSTEM/PILOT	PRIORITY	AFFECTED BY
BLOOD GLUCOSE LEVEL	BGL	System + Pilot	Optional	Dietary habits, sedentary lifestyle, genetics, obesity, drugs.
BLOOD TOTAL CHOLESTEROL LEVEL	BTCL	System + Pilot	Optional	Dietary habits, sedentary lifestyle, genetics, obesity, diabetes, drugs
BLOOD TRIGLYCERIDES LEVEL	BTL	System + Pilot	Optional	Dietary habits, sedentary lifestyle, genetics, obesity, diabetes, drugs

Blood Glucose Level (BGL): the fasting blood concentration of glucose. Impaired fasting glucose (IFG, also called pre-diabetes) reflect the natural history of progression from normoglycaemia to type 2 diabetes mellitus. Thus, people with IFG have a greater risk of developing type 2 diabetes. Ref: Cho et al., 2013; Rydén et al., 2013; Garber et al., 2016; Pistrosch et al., 2011; Ryan et al., 2016.

Blood Total Cholesterol Level (BTCL): the fasting blood concentration of total cholesterol which is the sum of Low Density Lipoprotein (LDL)-, High Density Lipoprotein (HDL)- and Very Low Density Lipoprotein (VLDL)-cholesterol. Hypercholesterolemia could be a consequence of a genetic disorder or secondary to dietary habits, obesity, diabetes, drugs. Ref: Catapano et al., 2016; Jellinger et al., 2012; Gonzalez-Campoy et al., 2013.

Blood Triglycerides Level (BTL): the fasting blood concentration of triglycerides which are fatty acid esters of glycerol and represent the main lipid component of dietary fat and fat depots of humans.

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Hypertriglyceridemia could be a consequence of genetic disorders, but is usually due to the presence of obesity, uncontrolled diabetes or excessive alcohol intake. Ref: Catapano et al., 2016; Jellinger et al., 2012; Gonzalez-Campoy et al., 2013.

1.3 Energy Expenditure

Table 3 List of variables of the Energy Expenditure subdomain.

VARIABLE NAME	ACRONYM	TO BE USED IN SYSTEM/PILOT	PRIORITY	AFFECTED BY
ACTIVITY ENERGY EXPENDITURE	AEE	System + Pilot	Important	Sedentary lifestyle, disabilities
BASAL METABOLIC RATE	BMR	System + Pilot	Important	Basal Metabolic Rate
ENERGY INTAKE	EI	System + Pilot	Necessary	Dietary habits, socioeconomic factors, drugs, disabilities, age-associated sensory loss and neuro-endocrine alterations
TOTAL ENERGY EXPENDITURE	TEE	System + Pilot	Necessary	-

Activity Energy Expenditure (AEE): the energy consumed by any physical activity beyond the basal expenditure or BMR. It includes any activity that can be done as a free living individual that is not related with the maintenance of vital body functions. Since energy consumed for movement depends on weight, height and age, ranges of AEE are normally relative to BMR. Ref: Manini, 2010; Manini et al., 2006; Joint, F. A. O., 2001; Neilson et al., 2008; Hills et al., 2014; Dillon et al., 2016; Khan et al., 2016.

Basal Metabolic Rate (BMR): the energy consumed by the subject in order to maintain basic metabolic functions. Accounts for 60–70 % of total energy expenditure in most individuals. Therefore, estimating the total contribution of individual BMR to TEE is an important calculation for understanding, developing, and executing weight related interventions. Despite indirect calorimetry is the gold standard, equations have been developed and are routinely used to calculate BMR with nutritional purposes. The purpose of disclosing BMR in NESTORE is to calculate TEE by adding BMR to AEE. Therefore, we propose the use of Harris-Benedict equation (2,3) if TEE cannot be monitored with a device. Ref: Manini, 2010; Lührmann et al., 2004; Sabounchi et al., 2013; Joint, F.A.O., 2001; EFSA, 2013; Johannsen et al., 2010; Sazonoy et al., 2014; Heiermann et al., 2011.

Energy Intake (EI): the energy contained in foods consumed by the user. EI is intended to maintain normal function of the organism, supplying the energy that will be lost by the organism. Therefore, EI should match total energy expenditure. Ref: Manini, 2010; Joint, F.A.O., 2001; Hills et al., 2014; EFSA, 2013.

Total Energy Expenditure (TEE): the energy consumed by the subject during 24 hours as the sum of the BMR and AEE. This is, the energy expended by vital body functions together with physical activity of any kind. Ref: Manini, 2010; Joint, F.A.O., 2001; EFSA, 2013; Johannsen et al., 2010; Sazonov et al., 2014; Hills et al., 2014; Khan et al., 2016; Van Remoortel et al., 2012; Schrack et al., 2014; Chowdhury et al., 2017; Garatachea et al., 2010;

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1.4 Nutrition Habits

Table 4 List of variables of the Nutrition Habits subdomain.

VARIABLE NAME	ACRONYM	USED IN SYSTEM/PILOT	PRIORITY	AFFECTED BY
DAILY SUPPLEMENTS INTAKE	DSI	System + Pilot	Important	Malnutrition, Socioeconomic factors
FOOD INTAKE	FI	System + Pilot	Necessary	Dietary habits, socioeconomic factors
NUMBER OF MEALS	NoM	System + Pilot	Important	Dietary habits, socioeconomic factors
NUTRIENT INTAKE	NI	System + Pilot	Important	Dietary habits, socioeconomic factors
PATHOLOGIES	Pat	System + Pilot	Important	
REFUSED FOODS	RF	System + Pilot	Important	Dietary habits, gastrointestinal disorders, pathologies, allergies

Daily Supplements Intake (DSI): DIS refers to those nutrients consumed separately from meals and in the form of pills, powder extracts or other formats. Since this supplemental amount of nutrients should be added to that consumed during meals, it should be recorded. The list of nutrients considered in this project that can be consumed as supplements is presented below in the "Ranges" Section. The effect of the supplement is considered relevant if it is consumed on a daily basis.

Food Intake (FI): this variable will be used to record the nutritional information of the user for setting up the system and for providing feedbacks about dietary advice. The specific Food Frequency Questionnaire designed for Nestore has been enclosed at the end of this document. A limited list of food groups has been elaborated in order to use it to translate nutritional information into dietary information that can be easily understood by users with no nutrition skills.

Number of Meals (NoM): the number of meals per day is considered an important factor mainly in weight management diets. It is accepted that increasing the amount of meals has a beneficial impact on the mechanisms of satiety, reduces hunger and therefore meal size and reduces cravings. This variable will be considered only in the case of overweight/obesity.

Nutrient Intake (NI): NI is composed by a limited list of nutrients that have been considered relevant for the target user of the project. This variable will be used to calculate deviations of diet from the recommended values. The nutrients included in this variable are: **Water; Vitamins; Minerals; Alcohol; Cholesterol; Fibers; Proteins; Carbohydrates/Sugar; Total Fat (Mono-Unsaturated Fat; Poly-Unsaturated Fat; Saturated Fat); Omega 3 fatty acids**. Each nutrient might be considered a single variable. Ref: Shim et al., 2014

Pathologies (Pat): A limited list of pathologies that are related to special dietary requirements. Ref: Franklin et al., 2013; Kithas et al., 2010; Vestergaard et al., 2009; Won Bae et al., 2014; Ciudin et al., 2017; Wolters et al., 2004; Schiller et al., 2009; Gandell et al., 2013.

Refused Foods (RF): Due to different reasons, a given user might choose to exclude some foods of their diet. This might be due to different reasons, such as allergies, special diets (vegetarian, vegan, ketogenic, weight loss, etc…) or personal preferences among others. The nutritional advice will be conditioned by this variable.

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2. Variables Relationships and ranges

2.1 Anthropometric characteristics

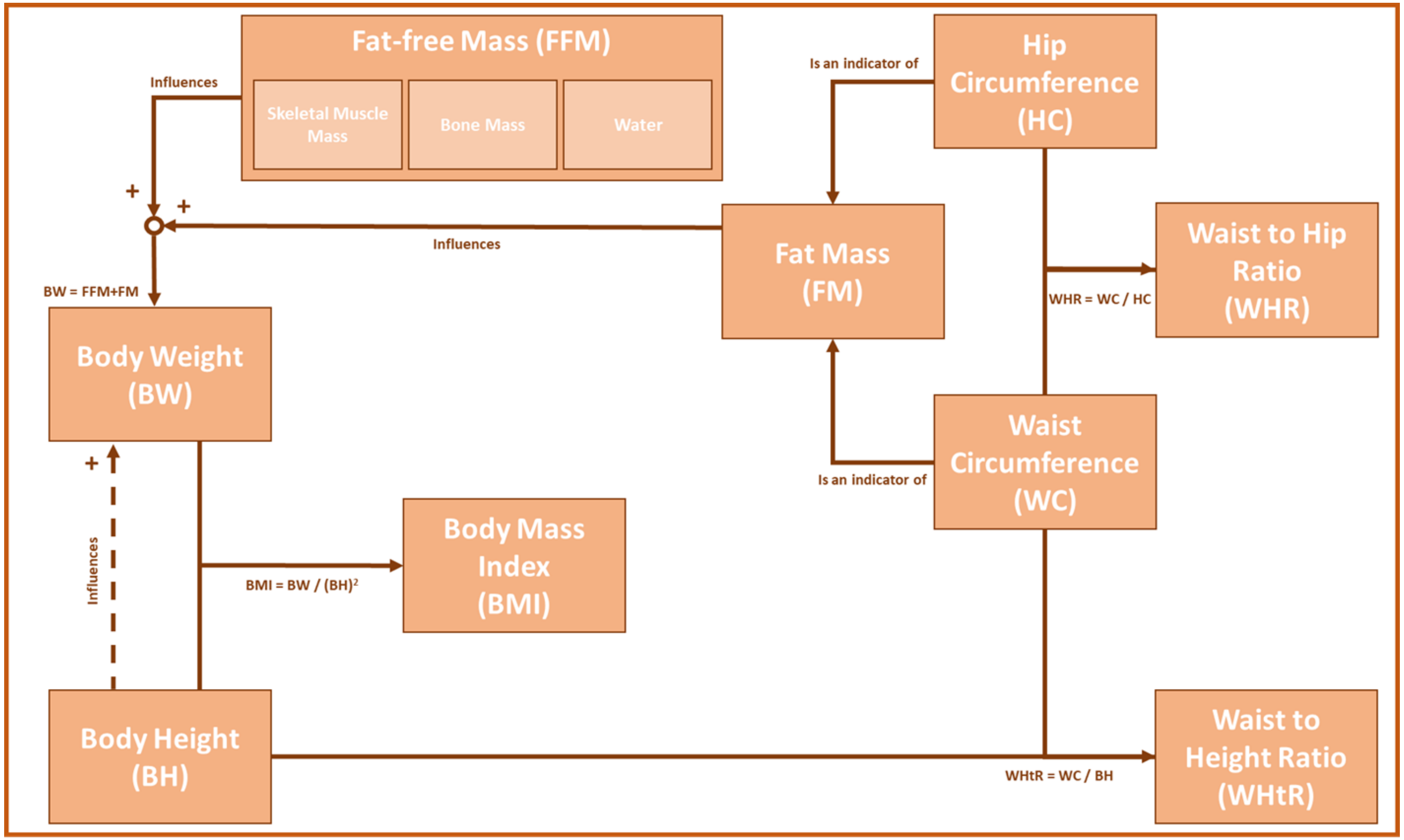

Figure 1 Relationships among variables in the Anthropometric Characteristics Subdomain

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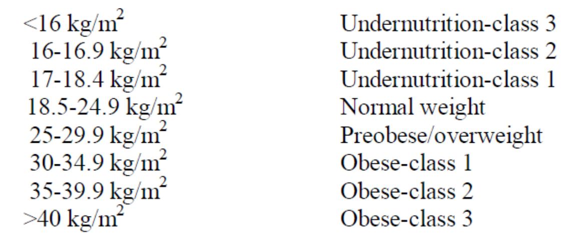
VARIABLE NAME	NORMALITY RANGES AND TRENDS	OUT OF RANGES
BODY WEIGHT	Normality ranges are provided by BMI. Taller people present higher body weight. Proportionality is assessed by body mass index	Please refer to BMI
BODY HEIGHT	Men are usually taller than women and a significant decrease with age in both sexes is usually observed. Older men are about 3% shorter than younger men, while women have an age-related reduction in height of 4%. Both sexes show a similar mean decrement per year (0.3 cm/year).	Loss of height is caused by a thinning of the vertebrae, compression of the vertebral discs, development of kyphosis or the effects of osteoporosis. Please refer also to BMI
BODY MASS INDEX	Tendency to an increase of BMI from 40 to 66 years of age in both men (average annual rate: BMI, 0.11 kg/m2/year) and women (BMI, 0.22 kg/m2/year). After age 70, BMI decreases significantly in both sexes, and there was a gender difference in the trend, as females decreased more than males. Normality: from 18 to 24.9 Kg/m^2	BMI ranges as established by WHO (1997):  <16 kg/m^2 Undernutrition-class 3 16-16.9 kg/m^2 Undernutrition-class 2 17-18.4 kg/m^2 Undernutrition-class 1 18.5-24.9 kg/m^2 Normal weight 25-29.9 kg/m^2 Preobese/overweight 30-34.9 kg/m^2 Obese-class 1 35-39.9 kg/m^2 Obese-class 2 >40 kg/m^2 Obese-class 3
FAT MASS	Fat mass increases progressively during adulthood. In the 7th decade, FM increases similarly in both sexes (7.5%). Ageing is typically associated with an increase of the visceral fat component. Men show a centripetalization and internalization of fat. Women are characterized by a peripheral distribution of fat (less visceral adiposity). The subcutaneous fat component, which increases until the 7th decade, tends to decrease thereafter. Moreover, distribution of subcutaneous fat (peripheral in women, central in men) changes so that males and females appear to be more similar for triceps, subscapular and suprailiac skinfolds at advanced ages. Normality:	Males: ≥ 25%, Women: ≥ 30% (reduction of sexual dimorphism)

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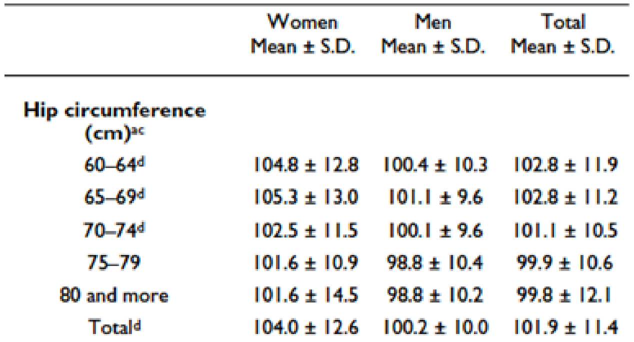
Males: < 25%
Women: < 30%

FAT-FREE MASS

The age-related FFM loss is smaller in active than sedentary individuals. There is no general consensus on the magnitude and mean rate of the FFM decrease. As reviewed by some authors, FFM decreases by around 15% between the third and eighth decade, with a rate of decrease of about 6.3% per decade and the percentage reduction can reach 30%. According to longitudinal studies, after 60 years of age FFM decreases in men (2.0% per decade) but not in women. Studies of body composition at the molecular level show that the reduction of total body protein is particularly evident after 65 years and can be estimated at 5% overall. Studies at the atomic level show that total body potassium decreases at a rate of 7.20+/1.00 mg/kg per year in women and 9.16+/0.96 mg/kg per year in men.

Males: Skeletal Muscle Mass < 37% (Sarcopenia)
Women: Skeletal Muscle Mass < 27.6% (Sarcopenia)

HIP CIRCUMFERENCE



	Women Mean ± S.D.	Men Mean ± S.D.	Total Mean ± S.D.
Hip circumference (cm)[ac]			
60–64[d]	104.8 ± 12.8	100.4 ± 10.3	102.8 ± 11.9
65–69[d]	105.3 ± 13.0	101.1 ± 9.6	102.8 ± 11.2
70–74[d]	102.5 ± 11.5	100.1 ± 9.6	101.1 ± 10.5
75–79	101.6 ± 10.9	98.8 ± 10.4	99.9 ± 10.6
80 and more	101.6 ± 14.5	98.8 ± 10.2	99.8 ± 12.1
Total[d]	104.0 ± 12.6	100.2 ± 10.0	101.9 ± 11.4

WAIST CIRCUMFERENCE

Normality:
Males < 94 cm

Women< 80 cm

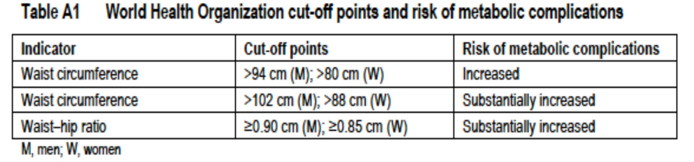


Table A1 World Health Organization cut-off points and risk of metabolic complications

Indicator	Cut-off points	Risk of metabolic complications
Waist circumference	>94 cm (M); >80 cm (W)	Increased
Waist circumference	>102 cm (M); >88 cm (W)	Substantially increased
Waist–hip ratio	≥0.90 cm (M); ≥0.85 cm (W)	Substantially increased

M, men; W, women

WAIST TO HEIGHT RATIO

WHtR could differ among age groups because whole-body fat distribution and waist circumference changes considerably with age and because height differs among generations.

It has been proposed that cut-point values of 0.5 and 0.6 can identify individuals who are at increased health risk and substantial health risk, respectively. Some papers report WHtR cut-points 0.55 (men) and 0.58 (women) in participants over 60 years.

WAIST TO HIP RATIO

Normality:
Males < 0.90
Women < 0.85

A WHR >= 0.90 for men and 0.85 for women is related to a substantial increase of risks of metabolic complications.

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2.2 Blood Parameters

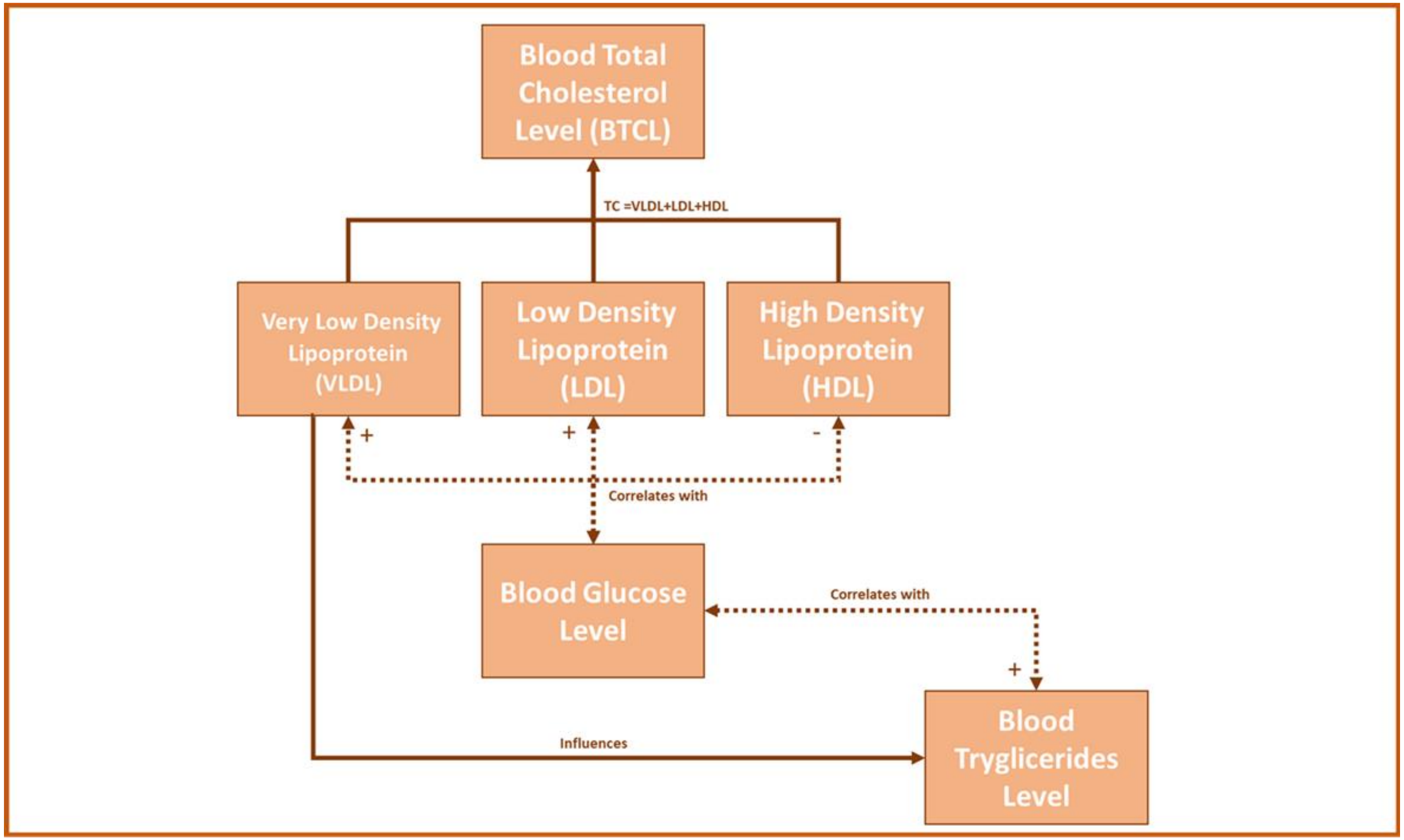

Figure 2 Relationships among variables in the Blood Parameters Subdomain.

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VARIABLE NAME	NORMALITY RANGES AND TRENDS	OUT OF RANGES
BLOOD PRESSURE	70-110 mg/dL (3.9-6.1 mmol/L)	110-125 mg/dL (6.1-6.9 mmol/L): impaired fasting glucose ≥ 126 mg/dL (7 mmol/L): diabetes
BLOOD TOTAL CHOLESTEROL LEVEL	< 200 mg/dL (5.2 mmol/L)	≥ 240 mg/dL (6.2 mmol/L): cardiovascular disease.
BLOOD TRIGLYCERIDES LEVEL	< 150 mg/dL (1.7 mmol/L)	150-880 mg/dL (1.7-10 mmol/L): mild to moderate hypertriglyceridemia. > 880 mg/dL (10 mmol/L): severe hypertriglyceridemia.

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2.3 Energy Expenditure

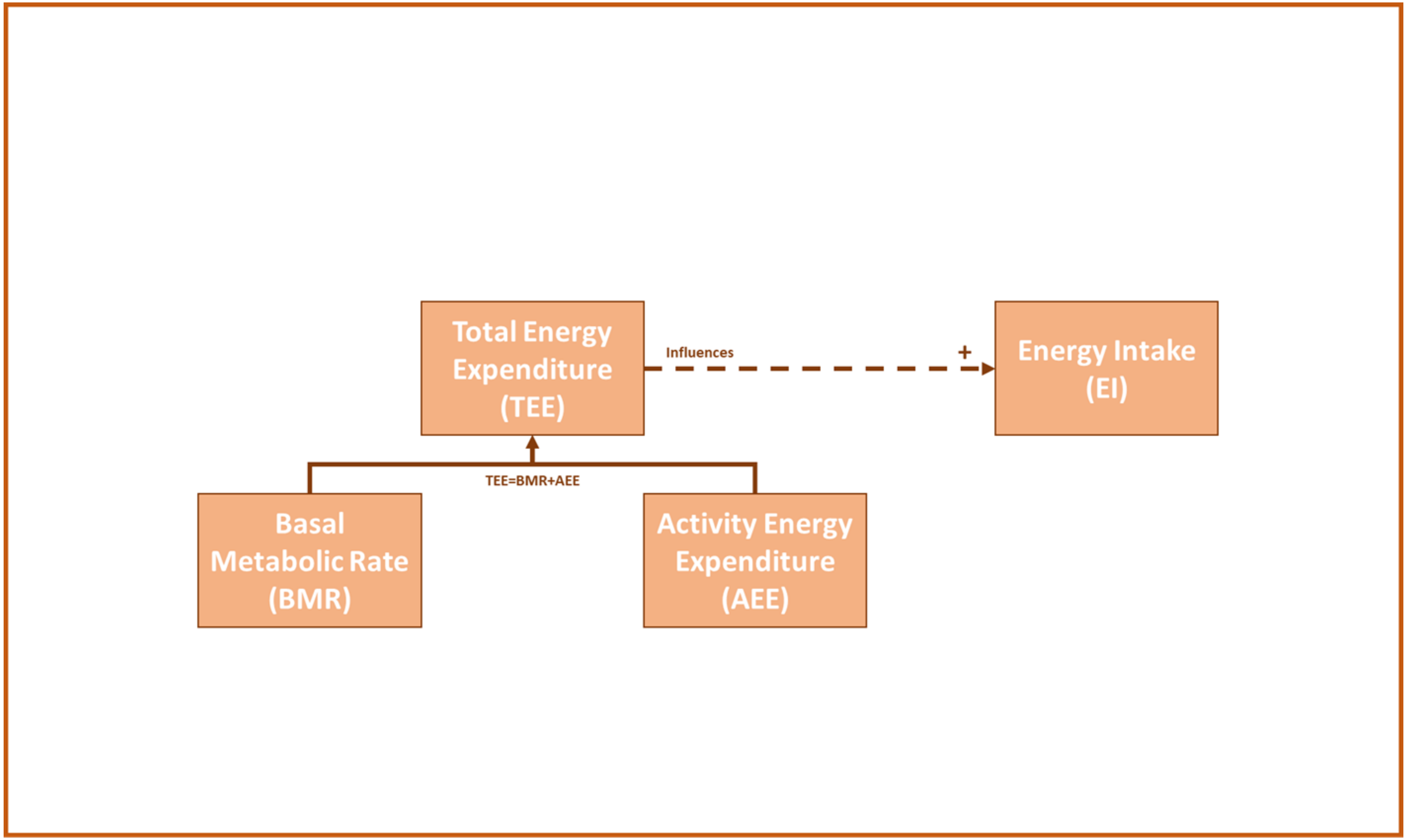

Figure 3 Relationships among variables in the Energy Expenditure Subdomain.

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VARIABLE NAME	NORMALITY RANGES AND TRENDS	OUT OF RANGES
ACTIVITY ENERGY EXPENDITURE	Normality: from 45% to 120% of BMR	WHO recommends increasing physical activity energy to, at least, 75% of BMR Sedentary: <60% of BMR; Active: 60-90% of BMR; vigorous: >90% of BMR
BASAL METABOLIC RATE	Normality: Males: 1600 to 2000 Kcal/day Females: 1200 to 1600 Kcal/day It is estimated that the BMR decrease by 1-2% per decade.	No thresholds have been defined. Limits of the parameter to be considered valid could be considered as: Males: 1200-2500 - Females: 1000-2000 Obesity alters calculated BMR (4). In case of obesity (BMI>30), auxiliary equation should be used to calculate a surrogate body weight to be used in the Harris-Benedict equation proposed herein by using Wilkens equation and Lorenz equation. All equations need weight, height and age as inputs. This point will be further developed if TEE cannot be eventually monitored.
ENERGY INTAKE	Normality: Males: 2006 to 2891 Kcal/day Women: 1625 to 2318 Kcal/day	This is defined by the balance between TEE and energy intake. This balance should be zero or close to it in healthy normal weight subjects. Overfeeding: Energy Intake-TEE > 0; Underfeeding: Energy Intake-TEE<0
TOTAL ENERGY EXPENDITURE	Normality: For subjects between 60 and 69 years old Males: 2006 to 2891 Kcal/day Women: 1625 to 2318 Kcal/day	This is defined by the balance between TEE and total energy intake. This balance should be zero or close to it in healthy normal weight subjects. Overfeeding: EI-TEE > 0; Underfeeding: EI-TEE<0

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2.4 Nutrition Habits

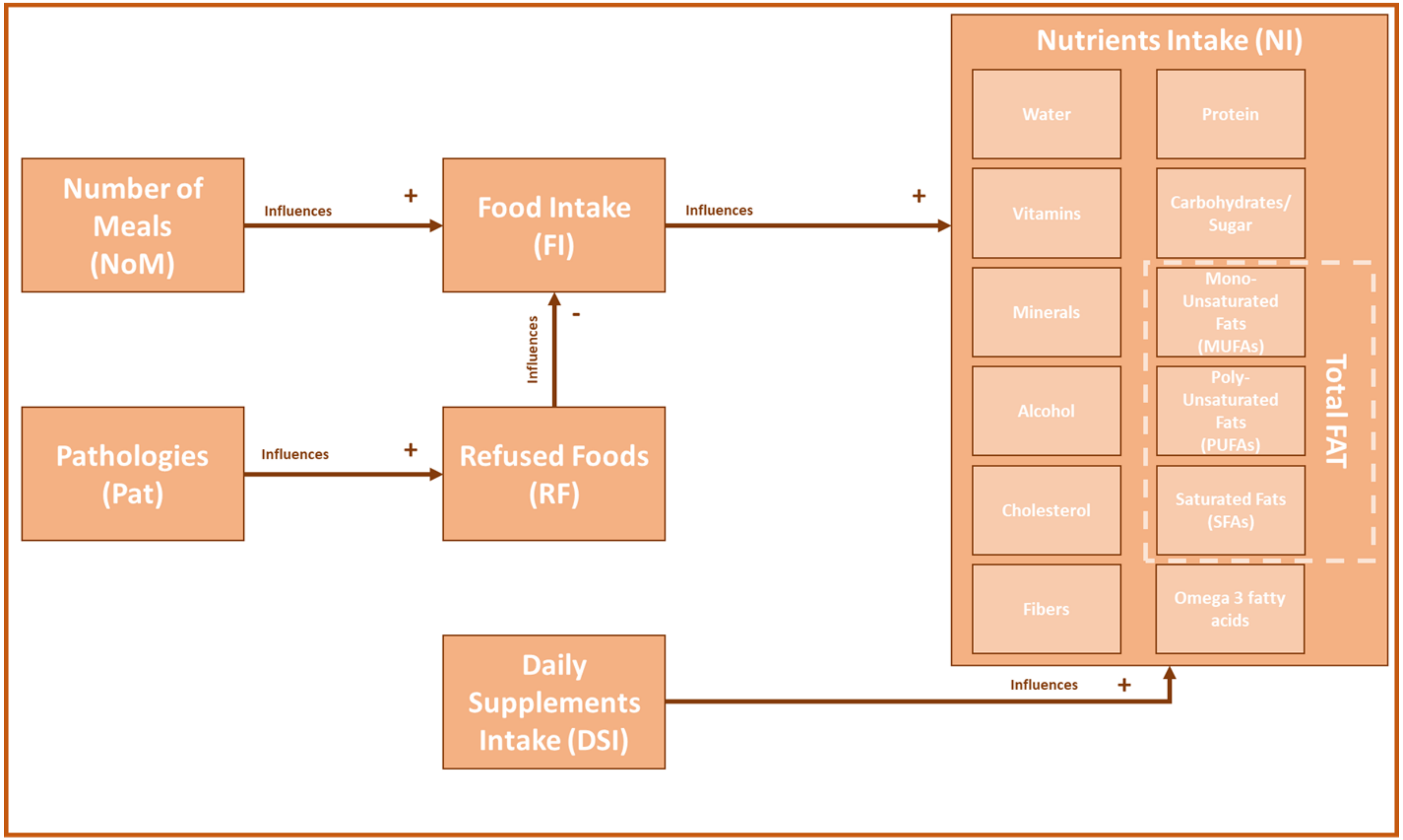

Figure 4 Relationships among variables in the Nutrition Habits Subdomain.

VARIABLE NAME	NORMALITY RANGES AND TRENDS	OUT OF RANGES
DAILY SUPPLEMENTS INTAKE	Values of this variable (daily total intake) are: -Protein (g/day) -Omega-3 fatty acids: EPA+DHA (mg/day) -Fiber (g/day) -Vitamin D (µg/day) -Vitamin B12 (µg/day) -Vitamin B6 (mg/day) -Folic acid (µg/day) -Vitamin E (mg/day) -Vitamin C (mg/day) -Vitamin A (µg/day) -Iron (mg/day) -Calcium (mg/day) -Zinc (mg/day) -Selenium (µg/day) -Magnesium (mg/day)	-Protein > 1.8 g/day -Omega-3 fatty acids (EPA+DHA) > 5000 mg/day -Fiber > 50 g/day -Vitamin D > 100 µg/day -Vitamin B12: an upper limit has not been established -Vitamin B6 > 25 mg/day -Folic acid > 1000 µg/day -Vitamin E > 300 mg/day -Vitamin C > 2000 mg/day -Vitamin A > 3000 µg/day -Iron > 45 mg/day -Calcium > 2500 mg/day -Zinc >25 mg/day -Selenium > 300 µg/day -Magnesium > 250 mg/day The indicated values correspond to the Tolerable Upper Intake Level for each nutrient.
FOOD INTAKE	See the uploaded Food Frequency Questionnaire for the complete set of variables Values of this variable are for example: - Whole milk - Skim milk - Low-fat yogurt - Regular yogurt - Low-fat cheese Etc.	n.a.
NUMBER OF MEALS	**Normality:** **from 4 to 7 meals per day.**	
NUTRIENT INTAKE	-Water (mL): 1500 ml/day -Total energy (Kcal): • 2006-2891 Kcal/day (males); • 1625-2318 Kcal/day (women)	n.a.

	-Protein (g and Kcal): 1,0 - 1,2 g/kg/day -Carbohydrates (g and Kcal): 50-60% of total energy -Simple sugars (g and Kcal): < 10% of total energy -Fat (g and Kcal): 25-30% of total energy -MUFAs (g and Kcal): 15-20% of total energy -PUFAs (g and Kcal): < 12% of total energy -SFAs (g and Kcal): < 10% of total energy -Omega-3 fatty acids: EPA+DHA (mg i Kcal): 250-500 mg/day -Cholesterol (mg): < 200 mg/day -Fiber (g): 30-40 g/day -Vitamin D (µg): 15 µg/day -Vitamin B12 (µg): 5 µg/day -Vitamin B6 (mg): 1.6 mg/day -Folic acid (µg): 400 µg/day -Vitamin E (mg): 12 mg/day -Vitamin C (mg): 110 mg/day -Vitamin A (µg): 700 µg/day -Sodium (mg): 1200-1500 mg/day -Iron (mg): 10 mg/day -Calcium (mg): 1200 mg/day -Zinc (mg): 9 mg/day -Selenium (µg): 60 µg/day -Magnesium (mg): 300 mg/day -Alcohol (g): <10-20g/day	
PATHOLOGIES	Values of this variable are presence (Yes/Not) of: -Hypertension -Osteoporosis -Type 2 diabetes -Atrophic gastritis -Constipation -Diarrhea	n.a.

2.5 Relationships among subdomains

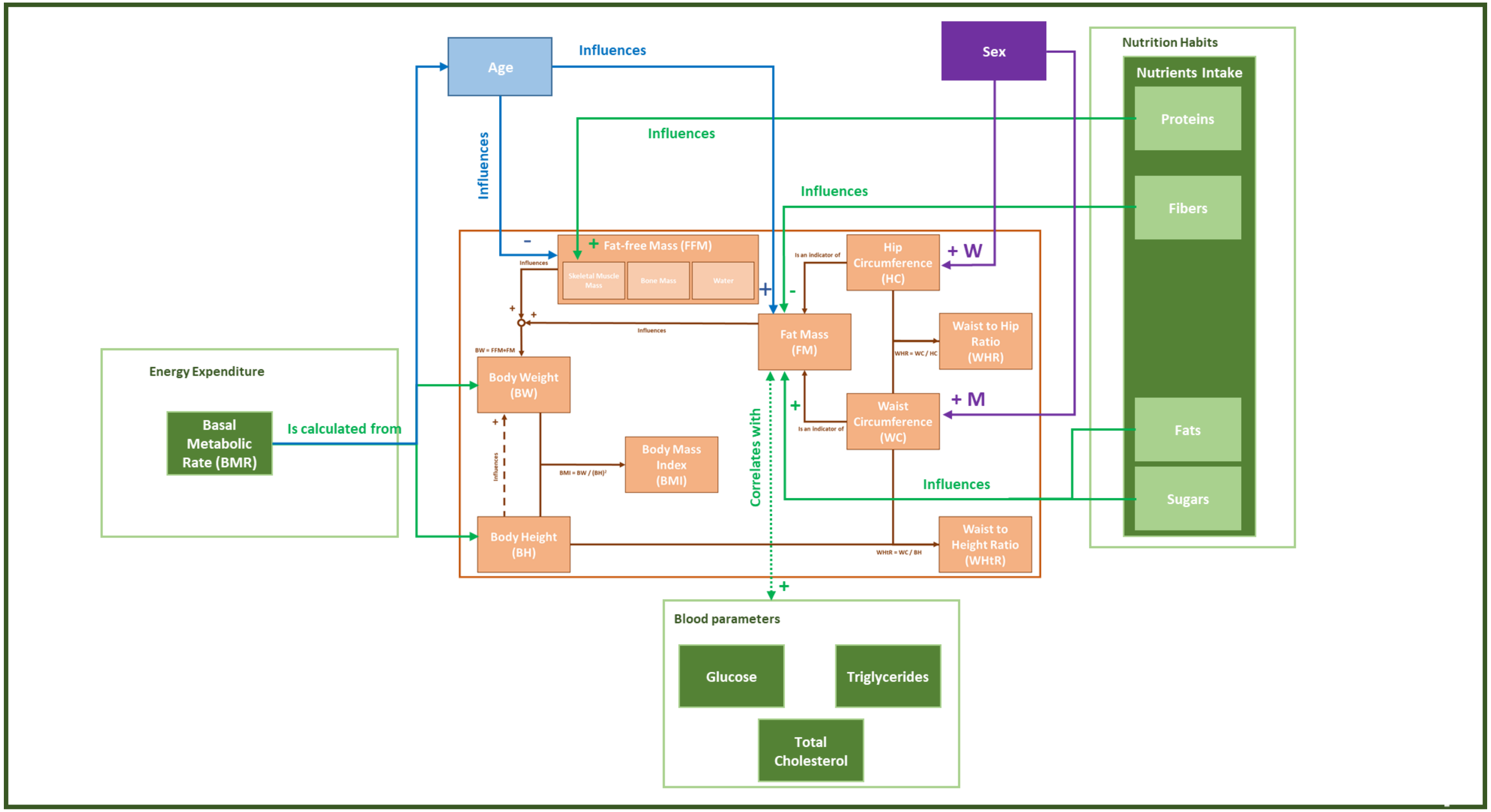

Figure 5 Relationships among the Anthropometric Characteristics subdomain and all the other nutritional subdomains

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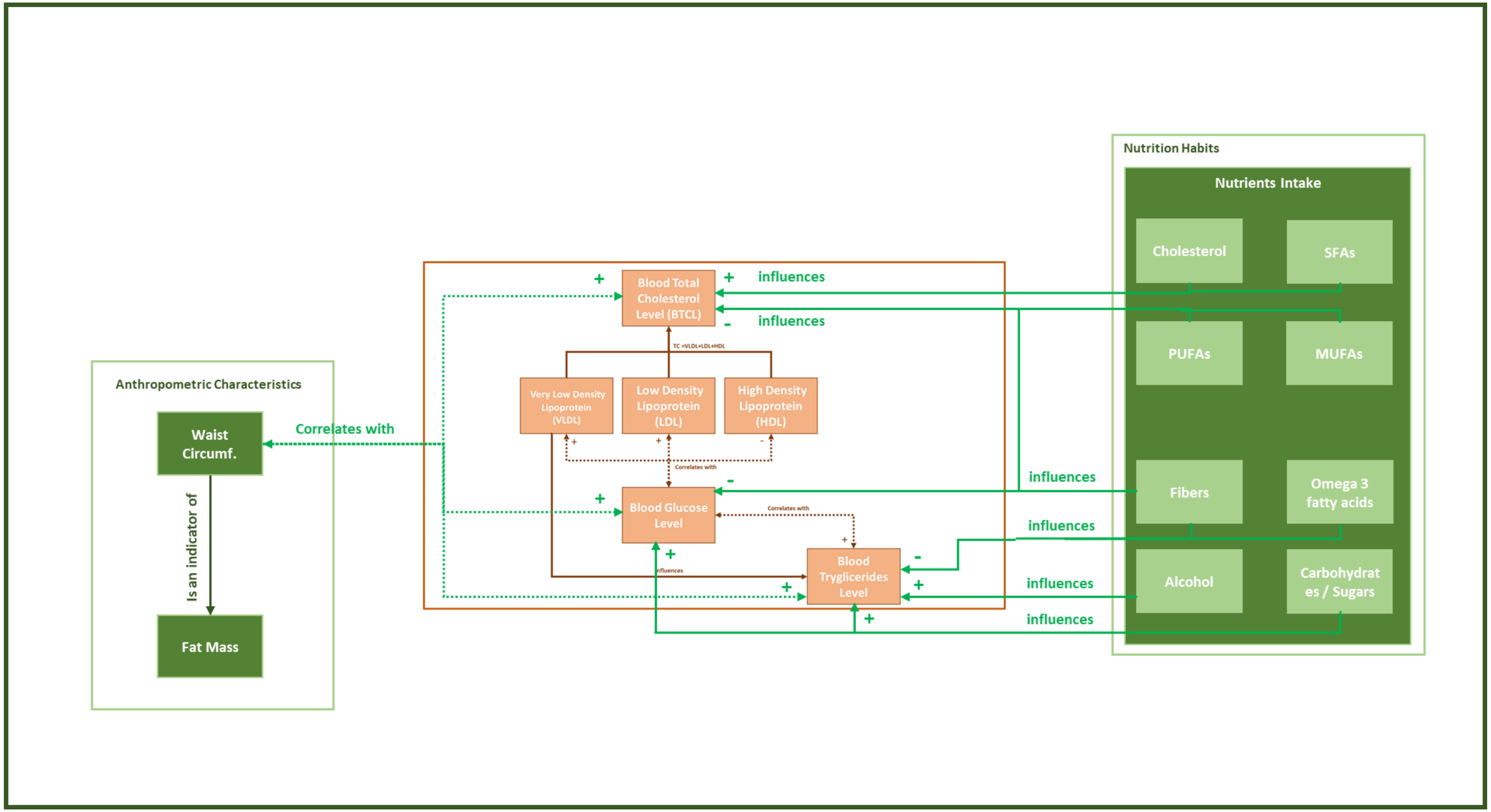

Figure 6 Relationships among the Blood Parameters subdomain and all the other nutritional subdomains.

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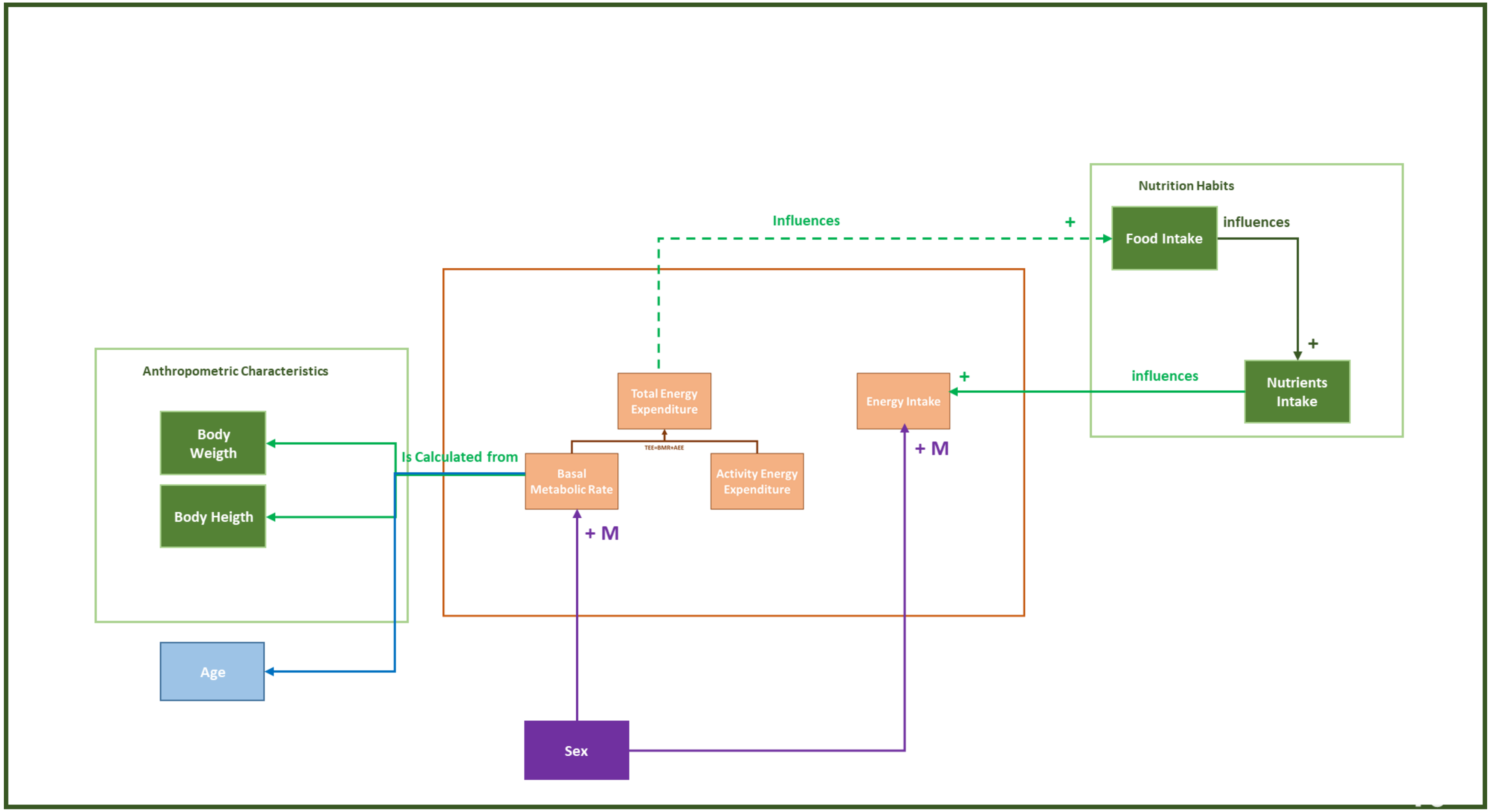

Figure 7 Relationships among the Energy Expenditure subdomain and all the other Nutritional subdomains.

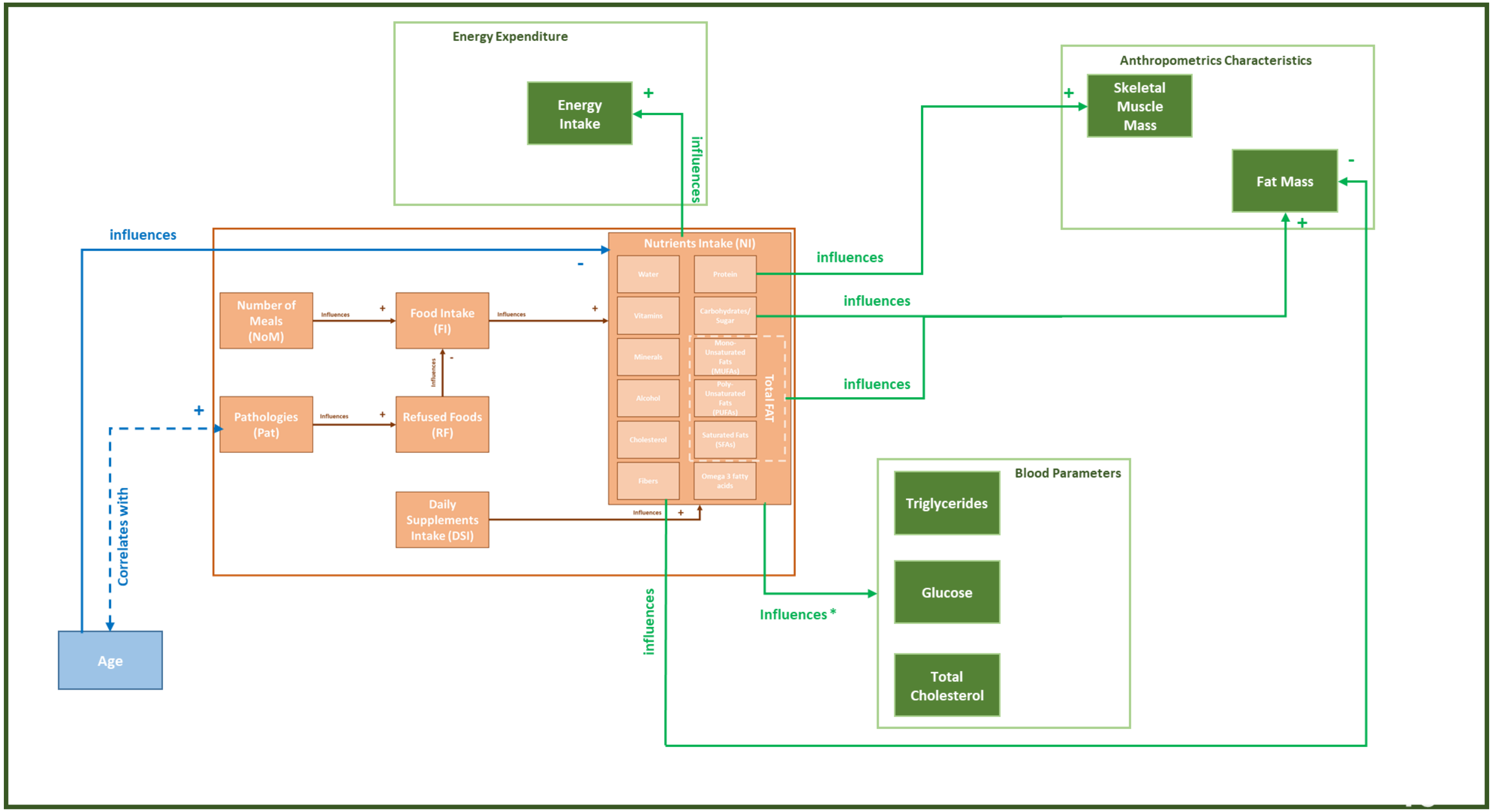

Figure 8 Relationships among the Nutrition Habits subdomain and all the other Nutritional subdomains.

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3. Measurement scenarios of the system variables

3.1 Anthropometric characteristics

VARIABLE	MEASUREMENT SCENARIO	UNITS	FORMULA	MEASUREMENT DEVICE	GOLD STANDARD MEASUREMENT
BODY WEIGHT	**Where**: at home (or health professional's office) **When**: morning after waking up (in fasting conditions) **Frequency**: at the initial point and every 15/30 days **Measurement precision**: ±0.5 Kg **Specific requirements (for the user)**: undressed and standing; empty bladder	kg	n.a.	Weighing scale Sensitized carpet Direct inquiry to the user	Weighing scale
BODY HEIGHT	**Where**: at home (or pharmacy, GP…) **Frequency**: at the initial point and at least once every four weeks **Duration of measurement**: seconds **Sampling frequency**: once **Measurement precision**: ±0.5 cm **Specific requirements (for the user)**: standing straight up, without shoes and with the back of the head, scapula, buttocks and heels resting against a wall and the heels touching each other. The measurement should be taken after a deep breath.	m or cm	n.a.	Measuring tape or height rod (by direct inquiry to the user) Sensitized wall or mirror Questionnaire	Stadiometer
BODY MASS INDEX	**Frequency:** at the initial point and every 15/30 days	kg/m^2	$BMI=BW/BH^2$	Derived Measure	Derived Measure
FAT MASS	**Where**: at home (or doctor's office, pharmacy, nutritionist's office, fitness centres…) **When**: in the morning after waking up (in fasting conditions) **Body Position:** In the case of skinfold thickness measurement, four districts (triceps, subscapular, suprailiac, thigh) could be taken by means of a calibrated caliper and averaged. **Frequency**: at the initial point and every 15/30 days Duration of measurement: seconds	kg or %	FM (kg) = – 11.938 + 1.606 *BMI – 8.511*Gender	Bio-impedance analysis (BIA) Skinfolds thickness Sensors for Skinfolds	Dual energy X-ray absorptiometry (DEXA)

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	Measurement precision: ±0.5 kg or ±1% (BIA) – 0.2 mm (Skinfold Thickness) **Specific requirements (for the user)**: Not to drink alcoholic beverages during the 24 hours prior to the measurement				
FAT-FREE MASS	**Where**: at home (or doctor's office, pharmacy, nutritionist's office, fitness centres…) **When**: in the morning after waking up (in fasting conditions) **Frequency**: at the initial point and every 15/30 days **Duration of measurement**: seconds **Measurement precision**: 0.5 kg or ±1% **Specific requirements (for the user)**: Not to drink alcoholic beverages during the 24 hours prior to the measurement.	kg or %	FFM (kg) = +14.966 + 0.588 *BMI + 18.694*Gender + 0.137*WC – 0.138*Age	Bio-impedance analysis (BIA) Derived by Equations	Dual energy X-ray absorptiometry (DEXA)
HIP CIRCUMFERENCE	**Where**: free living. **When**: early in the morning. **Body Position:** around the widest portion of the buttocks and the subject should stand with arms at the sides, feet positioned close together, and weight evenly distributed across the feet. **Frequency**: at the initial point and every 15/30 days. **Measurement precision**: ± 1 cm **Specific requirements (for the user)**: stay relax and take a few deep, natural breaths before the actual measurement.	cm		Stretch resistant tape (3D) body surface scanners	Measuring tape
WAIST CIRCUMFERENCE	**Where**: free living **When**: early in the morning **Frequency**: at the initial point and every 15/30 days **Measurement precision**: ± 1 cm	cm		Stretch resistant tape (3D) body surface scanners	Stretch resistant tape
WAIST-TO-HEIGHT RATIO	**Where**: free living **When**: early in the morning **Frequency**: at the initial point and every 15/30 days **Measurement precision**: ± 1 cm	unitless	WHtR=WC/BH	Derived measure	Derived measure

WAIST-TO-HIP RATIO	**Where**: free living **When**: early in the morning **Frequency**: at the initial point and every 15/30 days **Measurement precision**: ± 1 cm	unitless	WHR=WC/HP	Derived measure	Derived measure

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3.2 Blood Parameters

VARIABLE	MEASUREMENT SCENARIO	UNITS	FORMULA	MEASUREMENT DEVICE	GOLD STANDARD MEASUREMENT
BLOOD GLUCOSE LEVEL	**When:** This value should be manually entered, and will depend on the availability of this data by the user. **Frequency**: at the initial point and/or at any time that could be actualized. **Specific requirements (for the user**): measured in fasting condition	mg/dL or mmol/L	-	Questionnaire	Laboratory measurement
BLOOD TOTAL CHOLESTEROL LEVEL	**When:** This value should be manually entered, and will depend on the availability of this data by the user. **Frequency**: at the initial point and/or at any time that could be actualized. **Specific requirements (for the user)**: measured in fasting condition	mg/dL or mmol/L	-	Questionnaire	Laboratory measurement
BLOOD TRIGLYCERIDES LEVEL	**When:** This value should be manually entered, and will depend on the availability of this data by the user. **Frequency**: at the initial point and/or at any time that could be actualized. **Specific requirements (for the user)**: measured in fasting condition	mg/dL or mmol/L	-	Questionnaire	Laboratory measurement

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3.3 Energy Expenditure

VARIABLE	MEASUREMENT SCENARIO	UNITS	FORMULA	MEASUREMENT DEVICE	GOLD STANDARD MEASUREMENT
ACTIVITY ENERGY EXPENDITURE	**Where:** free living **When:** continuous monitoring during 24 hours **Frequency:** at the initial point and every month, during 5-7 days (at least one weekend day). (6) **Sampling frequency**: sample rate of accelerometers ranges between 0.01 seconds to 1 minute (optimal sampling rates for accelerometer-based human activity recognition are discussed by Khan et al) (7). Measurement precision: ±200Kcal/day	Kcal (total in 24 hours)	AEE=TEE-BMR	i)Accelerometers: preferably triaxial accelerometers or multisensor devices (i.e. Sensewear ArmBand). ii)Heart rate monitoring allows total energy expenditure (TEE) acquisition (not recommended due to imprecision). iii) Physical activity questionnaires: these questionnaires estimate physical AEE, usually using metabolic equivalents of tasks (METs). They are less accurate than direct methods.	-
BASAL METABOLIC RATE	**Where:** at home **Body position:** resting (for at least 30 minutes) **When:** early in the morning, after an overnight fasting (at least 12 hours) **Frequency:** once (at the initial point) **Duration of measurement**: 1 hour **Measurement precision**: ±200Kcal/day	Kcal	Harris-Benedict assisted by Wilkens and Lorenz equations for obese subjects.	i) Can be measured by heart rate monitoring (not recommended) or by accelerometers / multisensor devices (i.e. Sensewear). ii) BMR can be estimated by means of the Harris-Benedict equation (using body weight, height and age as inputs) assisted by Wilkens and Lorenz equations for obese subjects.	Indirect calorimetry
ENERGY INTAKE	**Where:** free living **When:** every dish of every meal and every intake of food. During the sampling period (3 days). **Frequency:** during 3 days every week. **Measurement precision**: ±200Kcal/day	Kcal	-	- Image recognition software from UB - Questionnaire	Questionnaire
TOTAL ENERGY EXPENDITURE	**Where:** free living **When:** continuous monitoring during 24 hours	Kcal	TEE=BMR+AEE	i) Heart rate monitoring (not recommended due to imprecision).	Indirect calorimetry for non-continuous measurements.

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	Frequency: at the initial point and every month, during 5-7 days (at least one weekend day). **Sampling frequency**: sample rate of accelerometers ranges between 0.01 seconds to 1 minute (optimal sampling rates for accelerometer-based human activity recognition are discussed by Khan et al) (6). **Measurement precision**: ±200Kcal/day		ii) Accelerometers: preferably triaxial accelerometers or multisensor devices (i.e. Sensewear ArmBand).	Doubly labelled water technique for free living individuals (specialized analytical facilities are required).

3.4 Nutrition Habits

VARIABLE	MEASUREMENT SCENARIO	UNITS	FORMULA	MEASUREMENT DEVICE	GOLD STANDARD MEASUREMENT
DAILY SUPPLEMENTS INTAKE	**Where:** free living **When:** User profiling. **Frequency:** At the initial time point. After that, up to user decision.	See list in the Ranges Section	-	- Text recognition from labels of supplements (indicating nutrient/s amount per serving). The user should manually introduce the daily amount (i.e. 2 capsules, 1 tablet....). Questionnaire: the user should indicate the nutrients/s amount per serving and the daily amount (i.e. 2 capsules, 1 tablet....).	Dietary History
FOOD INTAKE	**Where:** free living **When:** At the initial time point	# per day/week	-	Food frequency questionnaire	Food frequency questionnaire
NUMBER OF MEALS	**Where:** free living **When:** User profiling. **Frequency:** every 15-30 days (for monitoring).	Integer	-	- Questionnaire - App from UB can be used to monitor this variable.	Dietary History
NUTRIENT INTAKE	**Where:** free living **When:** every dish of every meal and every intake of food. During the sampling period (3 days). **Frequency:** during 3 days every week. **Measurement precision:** ±15% of the value (see list in the Ranges Section)	See list in the Ranges Section	-	-Image recognition software from UB - Dietary record	Duplicate diet approach
PATHOLOGIES	**Where:** free living **When:** User profiling. **Frequency:** At the initial point. After that, up to user decision.	-	-	Questionnaire	Medical history

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REFUSED FOODS	**Where:** free living **When:** User profiling. **Frequency:** At the initial point. After that, up to user decision.	-	-	Questionnaire	Dietary History

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4. Measurement scenarios for variables related to validation

4.1 Anthropometric characteristics

BODY WEIGHT

MEASUREMENT SCENARIO (PILOTS)

Subjects should remove outerwear, shoes and socks. Measurements should be performed in the morning at the same day time every 15 days. Subjects should be fasted overnight and should empty their bladder before taking the measurement.

The measurements should be done at least once every two weeks. Each measurement should be repeated twice.

BODY HEIGHT

MEASUREMENT SCENARIO (PILOTS)

Height should be taken at head level to the nearest centimetre with the subject standing barefoot, with feet together. The measurements should be done at least once every four weeks. Each measurement should be repeated twice

BODY MASS INDEX

MEASUREMENT SCENARIO (PILOTS)

The value should be calculated every time there is a change in body weight or body height.

FAT MASS

MEASUREMENT SCENARIO (PILOTS)

The deuterium oxide dilution technique is a reference technique for the evaluation of body composition. It is innocuous, non-invasive, simple, reproducible, and can be used directly in fieldwork but it is also expensive and impractical for use in the clinic. Therefore, the results obtained by deuterium oxide dilution are considered to be the “gold standard” for the study of the validity of other less expensive methods like Bioelectrical Impedance Analysis (BIA). BIA is based on the fact that lean tissue contains a high level of water and electrolytes so it acts as an electrical conductor, and fat acts as an insulator. Subjects should lie supine with their hands at their sides and with their legs abducted to 45°. The skin surfaces on the dorsum of the right foot and hand should be cleaned with ethanol before the procedure. Electrodes should be attached to the dorsal surfaces of the foot over the distal portion of the second metatarsal, and on the hand over the distal portion of the second metacarpal. Sensing electrodes will be attached to the anterior ankle between the tibial and fibular malleoli and to the posterior wrist between the styloid processes of the radius and ulna. All BIA measurements should be taken during temperatures ranging from 24°C to 34°C. The measurements should be done at least once every four weeks. Each measurement should be repeated twice.

FAT-FREE MASS

MEASUREMENT SCENARIO (PILOTS)

See Fat Mass.

HIP CIRCUMFERENCE

MEASUREMENT SCENARIO (PILOTS)

The measurement should be taken around the widest portion of the buttocks. The tape should be snug around the body, but not pulled so tight that it is constricting. The protocol also recommends the use of a stretch-resistant tape that provides a constant 100 g of tension through the use of a special indicator buckle; use of this type of tape reduces differences in tightness. The measurements should be made with the tape held snugly, but not constricting, and at a level parallel to the floor. The protocol recommends that the subject stands with arms at the sides, feet positioned close together, and weight evenly distributed across the feet. Moreover, it is recommended the subject stay relax and take a few deep, natural breaths before the actual measurement is made, to minimize the inward pull of the abdominal contents during the hip measurement.

The measurements should be done at least once every four weeks. Each measurement should be repeated twice.

WAIST CIRCUMFERENCE

MEASUREMENT SCENARIO (PILOTS)

The Subject should first locate the upper hip bone by placing his/her hands around the waist, squeezing slightly, and then moving the fingers downward until you feel the top curve of your hips. Afterwards, the subjects should lace a tape measure around his/her bare stomach just above the upper hip bone. Make sure the measuring tape is parallel to the floor (slanting can falsely increase your measurement). Also ensure that the tape measure is snug to the body, but not so tight that it compresses the skin. Exhale while measuring and relax your abdomen — sucking in is not allowed!

WAIST TO HEIGHT RATIO

MEASUREMENT SCENARIO (PILOTS)

The measurements should be done at least once every four weeks. Each measurement should be repeated twice.

WAIST TO HIP RATIO

MEASUREMENT SCENARIO (PILOTS)

The measurements should be done at least once every four weeks. Each measurement should be repeated twice.

4.2 Blood Parameters

BLOOD GLUCOSE LEVEL

MEASUREMENT SCENARIO (PILOTS)

Biochemical analyses could be performed depending on the duration of the pilot studies: minimum 1 month to be able to evaluate the impact of Nestore on biochemical parameters (cholesterol, glucose and triglycerides).

BLOOD TOTAL CHOLESTEROL LEVEL

MEASUREMENT SCENARIO (PILOTS)

Biochemical analyses could be performed depending on the duration of the pilot studies: minimum 1 month to be able to evaluate the impact of Nestore on biochemical parameters (cholesterol, glucose and triglycerides).

BLOOD TRIGLYCERIDES LEVEL

MEASUREMENT SCENARIO (PILOTS)

Biochemical analyses could be performed depending on the duration of the pilot studies: minimum 1 month to be able to evaluate the impact of Nestore on biochemical parameters (cholesterol, glucose and triglycerides).

4.3 Energy Expenditure

ACTIVITY ENERGY EXPENDITURE

MEASUREMENT SCENARIO (PILOTS)

Preferable measuring instrument: accelerometers
Where: free living
When: continuous monitoring during 24 hours
Frequency: continuously (during all the pilot)
Sampling frequency: sample rate of accelerometers ranges between 0.01 seconds to 1 minute (optimal sampling rates for accelerometer-based human activity recognition are discussed by Khan et al) (7).
Measurement precision: ±200 Kcal/day

BASAL METABOLIC RATE

MEASUREMENT SCENARIO (PILOTS)

Preferable measuring instrument: (1) Indirect calorimetry by using Fitmate PRO; (2) Multi-sensor Armband; (3) Equations. (In order of preference)
Where: in a quiet room with an ambient temperature of between 20–25°C (pilot study's office)
Body position: resting (for at least 30 minutes)
When: early in the morning, after an overnight fasting (at least 12 hours)
Frequency: once (at the initial point)
Duration of measurement: 1 hour
Sampling frequency: NA
Measurement precision: ±200 Kcal/day

ENERGY INTAKE

MEASUREMENT SCENARIO (PILOTS)

Preferable measuring instrument: 3-day dietary record supervised by a nutritionist
Where: pilot study's office
Frequency: at the initial and final point, during a 3-day period (and an intermediate point depending on the duration of the pilot study)

TOTAL ENERGY EXPENDITURE

MEASUREMENT SCENARIO (PILOTS)

Indirect calorimetry for non-continuous measurements. Doubly labeled water technique for free living individuals (specialized analytical facilities are required).

4.4 Nutrition Habits

DAILY SUPPLEMENTS INTAKE

MEASUREMENT SCENARIO (PILOTS)

Preferable measurement instrument: dietary history implemented by a nutritionist
Where: pilot study's office
When: at the initial point

FOOD INTAKE

MEASUREMENT SCENARIO (PILOTS)

Preferable measuring instrument: complete Food Frequency Questionnaire implemented by a nutritionist
Where: pilot study's office

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When: at the initial and final point

NUMBER OF MEALS

MEASUREMENT SCENARIO (PILOTS)

Preferable measurement instrument: dietary history implemented by a nutritionist
Where: pilot study's office
When: at the initial point

NUTRIENT INTAKE

MEASUREMENT SCENARIO (PILOTS)

Preferable measuring instrument: 3-day dietary record supervised by a nutritionist
Where: pilot study's office
Frequency: at the initial and final point, during a 3-day period (and an intermediate point depending on the duration of the pilot study)

PATHOLOGIES

MEASUREMENT SCENARIO (PILOTS)

Preferable measuring instrument: medical history
Where: pilot study's office
When: at the initial point

REFUSED FOODS

MEASUREMENT SCENARIO (PILOTS)

Preferable measurement instrument: dietary history implemented by a nutritionist
Where: pilot study's office
When: at the initial point

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Food Frequency Questionnaire

ON AVERAGE, HOW OFTEN HAVE YOU EATEN EACH OF THE FOLLOWING FOODS OVER THE PREVIOUS YEAR?

FOODS	Never <1 per month	1-3 per month	Once a week	2-4 per week	5-6 per week	Once a day	2-3 per day	4-5 per day	6+ per day
WHOLE MILK									
SKIM MILK									
LOW-FAT YOGURT									
REGULAR YOGURT									
LOW-FAT CHEESE									
REGULAR CHEESE									
FRUIT IN SYRUP									
CITRIC FRUITS (ORANGE, GRAPEFRUIT…)									
OTHER FRUITS (APPLE, BANANA…)									
FRESH FRUIT JUICES									
COMMERCIAL FRUIT JUICES									
SALAD									
VEGETABLES									
LEGUMES									
WHITE FISH (HAKE, COD…)									
BLUE FISH (SALMON, TUNA…)									
SEAFOOD									
CHICKEN, TURKEY OR RABBIT									
BEEF, VEAL, PORK OR LAMB									
COLD CUTS AND PATES									
EGGS									
POTATOES									
RICE, PASTA AND OTHER GRAINS									

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BROWN RICE AND WHOLEMEAL PASTA	
WHITE BREAD	
BROWN BREAD	
BREAKFAST CEREALS	
WHOLEGRAIN BREAKFAST CEREALS	
NUTS	
SWEETS, PASTRIES AND COOKIES	
DAIRY DESSERTS (PUDDINGS…) AND ICE CREAMS	
CHOCOLATE	
SALTY SNACKS (CHIPS, CRACKERS…)	
OLIVE OIL	
OTHER VEGETABLE OILS	
BUTTER, MARGARINE OR CREAM	
MAYONNAISE AND CREAMY SALAD DRESSINGS	
ALCOHOLIC BEVERAGES	
SWEETENED OR CARBONATED BEVERAGES	
READY-TO-EAT FOODS AND PRECOOKED DISHES (CROQUETTES, PIZZA, SOUPS…)	
SALT	
SUGAR	

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NESTORE

6 APRILE 2018

ANNEX 3
Cognitive and Mental Status and Social Behaviour

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AUTHOR (S):	Giovanna Rizzo, Alfonso Mastropietro, Christina Roecke (UZH)
CONTRIBUTORS:	Antonella Belfatto, Michele Girolami, Martin Sykora (LU-CIM)
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Short Abstract

This annex describes in detail the model of the Cognitive and Mental Status and Social Behaviour.
Among the health and well-being domains, this one refers to the psychological traits and states related to cognitive, mental, personality-related and social functioning in healthy older adults.
Specifically, it is composed by four subdomains: 1) **Cognitive Status** which describes a range of intelligence domains that describe biologically- and experience-/knowledge-driven facets of cognition and intelligence, 2) **Mental Status**, including traits in the area of subjective well-being, self and personality and social integration / feelings of loneliness. The two domains of status or trait variables will allow to describe a dispositional profile of a person's general resources in the cognitive and mental domain. These will be complemented by 3) **Mental Behaviour and States,** which capture the within-person processes mainly in emotional functioning that are observable in daily life on the basis of self-reported experiences and as information extracted from text bodies and speech, and 4) **Social Behaviour** which analyses the social context of the users involved in the studies and in using the NESTORE system. The social behaviour analysis aims at measuring both qualitatively and quantitatively some core variables describing the social behaviour of users in terms of (a) existence of social interactions through self-reported diaries and with sensing devices, (b) the number and duration of such interactions, and (c) possibly, the location of the interactions.
The combination of such variables will be used in order to define a social profile of the users and, in turn, to stimulate the users to keep interacting with others.

The document is composed of four subsections, describing:

- **Variables useful for the characterization and monitoring of the physiological status of the person along with his/her physical activity behaviour**: for each subdomain a table containing the related variables is provided, followed by a short description of the variable meaning. Each variable is classified with respect to its foreseen use in NESTORE (System=variable to be used in the system, Pilot=variable to be used during the system validation in Pilots), its importance (necessary, important), the factors negatively affecting the variable itself.

This part is specifically thought to support the development of ontology in Task 2.5 and also for profiling activities and, consequently, for personalization purposes (WP4 and WP5).

- **Relationships among the domain variables and variable ranges and/or trends corresponding to normal aging status and behaviour**: for each subdomain a scheme describing the relationships among the variable domains is provided (solid arrows = direct causal relationship, dashed arrows = indirect causal relationship, dotted arrows = correlation between); if a variable can be directly calculated from others, the formula is provided; variables foreseen as system variables are in orange, variables foreseen only in Pilots are in yellow. Moreover, for each domain a table containing the normality range and/or the normal trend physiologically occurred during aging, is provided for each system variable, if known. The consequences of out of range values (or trends) are also reported.

This part is specifically thought for the ontology and to support WP4 in the development of the Decision Support System.

- **Measurement scenarios of the system variables**: for each subdomain, the principal information describing how the variables should be measured by the system are reported in a dedicated table. Specifically, the table includes: measurement conditions (frequency, location, duration, etc.), measurements units, formulas to derive the variable value from other variables, measurement devices, gold standard measurements.

This part provides the functional system requirements from the point of view of the domain experts, in support to WP3 and WP5, for the development of the monitoring system.

- **Measurement scenarios for variables related to validation:** for each subdomain, some suggestions on how to measure the variables during pilots are provided.

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This part is thought to support the definition of Virtual Coach Validation Plan to be used in the pilots to assess the impact and the functional effectiveness of the Virtual Coach on the elderly subjects' status and behaviour (Task 2.6)

Key Words

Cognitive Status, Mental Status, Mental Behaviour and States, Social Behaviour

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1. Description of the subdomains and related variables

1.1 Cognitive Status

Table 1. List of variables of the Cognitive Status subdomain.

VARIABLE NAME	ACRONYM	TO BE USED IN SYSTEM/PILOT	PRIORITY	AFFECTED BY
ATTENTION SWITCHING	AS	System + Pilot	Necessary	Low education, low sensory functioning, depression
EVERYDAY PERFORMANCE	EP	System + Pilot	Necessary	Low education, low cognitive functioning
PROCESSING SPEED	PS	System + Pilot	Necessary	Low education, low sensory functioning, depression
VERBAL FLUENCY	VF	System + Pilot	Necessary	Low education, low sensory functioning, depression
VERBAL MEMORY	VM	System + Pilot	Necessary	Low education, low sensory functioning, depression
WORKING MEMORY	WM	System + Pilot	Necessary	Low education, low sensory functioning, depression

Attention Switching (AS): AS, the ability to switch attention, is a component of fluid intelligence. It assesses the visual-conceptual as well as visual-motor tracking ability to both hold attention on a simple task and to rapidly shift attention between different mental sets. Ref: Battery 1944; Giovagnoli et al. 1996; Reitan et al. 1992; Roy et al. 2013; Tombaugh 2004. Ref.: Army Individual Test Battery., 1944; Giovagnoli et al., 1996; Reitan, 1992; Roy, 2013; Tombaugh, 2004.

Everyday Performance (EP): The EP is the cognitive performance in daily life. Many psychometric tests have been proposed to assess it, nevertheless some were criticized for their low ecological validity. In response, the so-called everyday cognition tests have been developed to assess EP and the so-called far transfer, i.e., transfer to un-trained abilities that go beyond the immediate training domain. There are not many tests measuring everyday cognition available. The Everyday Performance Test (EPT) has been used in one of the largest cognitive training studies that also included a 10-year follow-up and is one of the only tests with well-understood psychometric properties and correlates. Ref.: Borella et al., 2017; Diehl et al., 1995; Guye et al. (in press); Schaie et al. 2005; Stine-Morrow et al., 2008; Tennstedt et al., 2013; Willis et al., 1992; Willis et al., 1993; Wolinsky et al., 2010.

Processing Speed (PS): PS describes the time needed to process information, i.e., to perform a mental task. Processing speed (or just “speed”) is considered one of the more basic cognitive functioning domains underlying performance in other cognitive abilities. It is highly correlated with performance in many other cognitive tasks and thus an efficient and representative candidate to represent the more biologically driven overall cognitive ability (i.e., fluid intelligence) of a person. Ref.: Aster et al., 2009; French et al., 1963; Gerstorf et al., 2006; Lachman et al., 2014; Sturm et al., 1993; Verhaeghen et al., 1997; Zimprich et al., 2002.

Verbal Fluency (VF): VF is the ability to produce as many words as possible from a given semantic category (e.g., animals) or according to a phonemic category (e.g., words with S). It is a speeded task but also reflects vocabulary, and is thus a measure of both fluid and cristallized intelligence. Ref.: Aschenbrenner et al., 2000; Gerstorf et al.,2006; Sturm et al., 1993; Thurstone et al., 1962; Tombaugh et al., 1999.

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Verbal Memory (VM): VM describes memory for verbal content that is recalled immediately after learning as well as after some longer-term retention interval. It is one of many components of episodic retrospective memory, one of the key subdomains of memory functioning. Ref.: Aschwanden et al., 2017; Gerstorf et al., 2006; Helmstaedter et al., 2001; Lezak, 1983; Rey, 1964; Schmidt, 1996.

Working Memory (WM): WM is a component of short-term memory that encompasses the short-term storage of information in order to process and hold information to make them available for later recall. Working memory is considered to be one of the very basic cognitive components that underlies many other cognitive abilities, similar to processing speed. Ref.: Gerstorf et al., 2006; Guye et al., 2017; Riediger et al., 2014; Welchester et al., 1997; Aster et al., 2009.

1.2 Mental Status

Table 2 List of variables of the Mental Status subdomain.

VARIABLE NAME	ACRONYM	TO BE USED IN SYSTEM/PILOT	PRIORITY	AFFECTED BY
PERSONALITY	Per	System + Pilot	Necessary	Transitions from youth, adulthood and late adulthood; life challenges
SOCIAL NETWORK / SOCIAL INTEGRATION	SNI	System + Pilot	Necessary	No family relations, lack of social support (loneliness)
SUBJECTIVE WELL BEING	SWB	System + Pilot	Necessary	Impaired physical and cognitive health, feelings of loneliness, high levels of neuroticism and low levels of self-efficacy

Personality (Per): Personality is a key dimension to describe the stable characteristics of a person along 5 dimensions, the so-called **Big Five**. These dimensions are associated with the social dimension (i.e., **extraversion**, **agreeableness**), the emotional dimension (i.e., **neuroticism**), the cognitive dimension (i.e., **conscientiousness**) and in general the attitude of a person to experiences in life (i.e., **openness to experiences**). Other sub facets of personality are **control beliefs** and **self-efficacy**. Control beliefs capture the degree and locus of control a person perceives to have over the positive and negative things occurring in his/her life. It involves both the perception of being able to master life in general and (on the negative side) the degree of perceived external constraints from the environment. Self-efficacy is personal judgement of one’s capacity to carry out certain actions in the future / when facing future situations. All these personality components represent a meaningful variable to describe and understand differences between individuals in how they function in daily life and how good or limited they profit from interventions regarding their health behaviors. Ref.: Aschwanden et al., 2017; Costa et al., 1989; Danner et al., 2016; Guye et al., 2017; Jerusalem et al., 1999; Lachman et al., 1998; Löckenhoff et al., 2011; Rammstedt et al 2007; Sander et al., 2017.

Social Network / Social Integration (SNI): Social relations are a key ingredient to well-being and health at all ages. They undergo characteristic changes across the adult lifespan, with the number of emotionally very close social network members remaining rather stable over the years, and the number of less close network members decreasing over the adult lifespan. Social relations can be assessed in terms of **quantity** (network size, frequency of contact), and **quality** (satisfaction with social relations in general and with individual relationship types in particular, e.g., with spouse, children, friends; social support). In a related vein, **loneliness** is an evaluative aspect to social relations that is often also used as a social well-being indicator. In addition, **social support** (received and provided) is an important quality characteristic of social relations, and in the NESTORE context, companionship/social distress as well as health-related social control could be important social network markers to be assessed at least at baseline/posttest and at intermediate time-points. Ref.: Butterfield et al., 2002; Carstensen et al., 1999; Cyranowski et al., 2013; De Jong Gierveld et al.,

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2010; Fiori et al., 2008; Lang et al., 2001; Lindenberger et al., 2010; Lövdén et al., 2005; Lubben et al., 1988; Lubben et al., 2006; Sander et al., 2017; Scholz et al 2003.

Subjective Well-Being (SWB): Subjective Well-Being is a multidimensional construct. In a common theoretical model, SWB consists of a cognitive component, the evaluation of how satisfied individuals are with their lives in general (**Life Satisfaction**) and with particular aspects of it (health, social relations, finances, etc.). The **emotional component** of SWB is conceptualized in two parts, capturing the **positive and negative affective** (PA and NA) states a person typically experiences. SWB is a key indicator of successful aging, and as such a typical outcome measure to assess how well individuals are doing in their lives in general. In aging studies it is further typical to screen individuals for depressive symptoms (depressive symptoms can be related to cognitive impairments). Ref.: Brink et al., 1982; Diener et al., 1985; Gerstorf et al., 2007; Krohne et al., 1996; Radloff et al., 1977; Riediger et al., 1998; Sheikh et al., 1986; Watson et al., 1988; Wilhelm et al., 2007; Yesavage et al., 1983.

1.3 Mental Behaviour and States

Table 3 List of variables of the Energy Expenditure subdomain.

VARIABLE NAME	ACRONYM	TO BE USED IN SYSTEM/PILOT	PRIORITY	AFFECTED BY
ACUTE STRESS	AS	System + Pilot	Necessary	mental disorders, low cognition level, traumatic events
DIMENSIONAL EMOTIONS		System + Pilot	Necessary	mental disorders, low cognition level, traumatic events
DISCRETE EMOTIONS		System + Pilot	Necessary	mental disorders, low cognition level, traumatic events
SENTIMENT VALENCE DETECTION	SVD	System + Pilot	Necessary	mental disorders, low cognition level, traumatic events

Acute Stress Detection (AS): AS indicates the presence of stress. High levels of stress are a significant determinant of well-being and it would be meaningful and well suited to capture prevalence of acute stress from any suitable deliberate or incidental textual data generated by users during interactions with the NESTORE coach and the social platform of the NESTORE system. In NESTORE the level of stress will be measured by Acute Stress Detection (ASD) which is the ability to measure whether a piece of textual / free-form (written) content contains words and expressions that are indicative of acute stress being experienced by the creator of the content. Ref.: Sykora et al., 2015; Thelwall et al., 2017; Zwahlen et al., 2008; Shankardass 2012; Lazarus et al., 1993.

Dimensional Emotions: Dimensional models of emotion attempt to conceptualize human emotions by defining where they lie in two or three dimensions. Most dimensional models incorporate valence and arousal or intensity dimensions. Dimensional models of emotion suggest that a common and interconnected neurophysiological system is responsible for all affective states. Dimensional emotions in NESTORE will be assessed using both a self-report tool (DimER) and sensing devices (DimED). **Dimensional Emotions Detection (DimED)** measures the valence and arousal / intensity of an emotion or rather a variety of affective states on a circumplex model (Russel 1980), expressed in a piece of textual / free-form (written) content. This would be meaningful and well suited to capture affective state variables from any suitable deliberate or

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incidental textual data generated by users during interactions with the NESTORE coach and the social platform of the NESTORE system. Ref.: Bradley et al., 1999; Nielsen, 2011; De Choudhury et al., 2012; Warriner et al. 2013. **Dimensional Emotions self-Report (DimER)** is a self-report aimed at assessing the Subjective Well-Being (SWB) status of a patient. SWB is a multidimensional construct, in a common theoretical model, it consists of a cognitive component, the evaluation of how satisfied individuals are with their lives in general (satisfaction with life) and with particular aspects of it (health, social relations, finances, etc.). The emotional component of SWB is conceptualized in two parts, capturing the positive and negative affective (PA and NA) states a person typically experiences. ASR is a key indicator of successful aging, and as such a typical outcome measure to assess how well individuals are doing in their lives in general. Ref.: Kunzmann et al., 2017; Riediger et al., 2011; Röcke et al., 2009; Watson et al., 1988; Wilhelm et al., 2007.

Discrete Emotions: This variable is related to the intensity (or arousal) of an emotion, from a range of discrete 'basic emotions' (Ekman 1992). Discrete emotions in NESTORE will be assessed using both a self-report tool (DER) and sensing devices (DED). **Discrete Emotions Detection (DED)** represents the ability of discerning and measuring the intensity (or arousal) of an emotion expressed in a piece of textual / free-form (written) content. This would be meaningful and well suited to capture emotion variables from any suitable deliberate or incidental textual data generated by users during interactions with the NESTORE coach and the social platform of the NESTORE system. . Ref.: Sykora et al., 2013; Sykora et al., 2013-August; Sykora et al., 2014; Gruebner et al., 2016; Gruebner et al., 2017; Ekman et al., 2016; Baglioni et al., 2016; Beattle et al., 2015; Harmann et al., 2001; kunzmann et al., 2014. **Discrete Emotions self-Report (DER** DER represents the ability to detect and measure the intensity (or arousal) of an emotion, from a range of discrete 'basic emotions' referring to the subject directly by means of a self-report. Ref.: Harmon-Jones et al., 2016; Watson et al., 1999; Levine et al., 2004; Kunzmann et al., 2017.

Sentiment Valence Detection (SD): SD is the ability to measure whether a piece of textual / free-form (written) content contains words and expressions that are 'broadly' (depending on the measurement tool) perceived as positive or negative. This is distinct to the previous variable, where instead of two (or more dimensions) on a circumplex model of affect, only one valence dimension is considered – i.e. positive / negative. Ref.: Baccianella et al., 2010; Goncalves et al., 2013; Hutto et al., 2014; Liu et al., 2016; Mohammad et al., 2013; Ravi et al., 2015; Tausczik et al., 2010; Thelwall et all., 2012; Wiebe et al. 2015; Ribeiro et al., 2016.

1.4 Social Behaviour

Table 4 List of variables of the Social Behaviour subdomain.

VARIABLE NAME	ACRONYM	USED IN SYSTEM/PILOT	PRIORITY	AFFECTED BY
INTERACTION DURATION	ID	System + Pilot	Necessary	No family relations, lack of social support (loneliness)
INTERACTION FUNCTION	IF	System + Pilot	Necessary	No family relations, lack of social support (loneliness)
INTERACTION LOCATIONS	IL	System + Pilot	Important	No family relations, lack of social support (loneliness)
SOCIAL INTERACTION SELF-REPORT	SIR	System + Pilot	Necessary	No family relations, lack of social support (loneliness)

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SOCIAL INTERACTION DETECTION	SID	System + Pilot	Necessary	No family relations, lack of social support (loneliness)
TOTAL NUMBER OF INTERACTIONS	TNI	System + Pilot	Necessary	No family relations, lack of social support (loneliness)

Interaction Duration (ID): The IDD is the sum of the durations of all the interactions for a user. IDD can be measured by considering the duration of the interactions detected with sensing devices (SID) and interactions detected with self-report tools (SIR). Similarly, to the TNI variable, also IDD can be computed with different time-scales, e.g. by considering short-term interactions (e.g. 24 hours) or long-term interactions (e.g. weeks or months). As a result, it will be possible to measure the IDD variable for every user hourly, daily, weekly or with other temporal scales. The duration of the social interactions allows revealing two interesting behaviours of the users:

1. A quantitative assessment of the total time a user spends interacting with other users
2. The temporal features of the user's interactions. More specifically, the IDD variable of user X reveals that he/she typically, has long-lasting interactions (e.g. hours) during the week-end while he/she is engaged in short interactions (e.g. minutes) during the working days.

[https://www.innovativeotsolutions.com/tools/esi] Ref.: Simmons et al. 2010; Fournet et al., 2014.

Interaction Function (IF): This variable describes the function related to the social interaction (e.g. practical help and support, keeping company, consolation / emotional support, etc)

Interaction Locations (IL): Being able to assign a location to the interactions happening indoor. According to the nature of the pilot site (co-housing, private homes etc.), it could be possible to detect the location of the interactions so that to reveal where interactions are more frequent and/or longer lasting and when such locations become active. Detecting the location of the interactions is another useful variable to assign the notion of context to the interactions and tailor coaching input. Ref.: Fournet et al., 2014.2.

Social Interaction Detection (SID): SID is a variable assessing the existence of social interactions of a subject with other subjects that join the experimentations. The SID variable detects *if* and *when* a user had an interaction with another user, such variable is measured by using sensing devices. According to the kind of "sensing" technology used in the NESTORE project, it will be possible to recognize when two users are in proximity, namely when two subjects lay within a distant range. The proximity (proxemics) among users is a good marker for recognizing the interactions (Hall et al., 1996). In an intuitive way, the more two users stay in contact along the time, the more they express the explicit intent of interacting (Pentland et al. 2010; Pentland 2010). The sensing technology used will influence the accuracy of the SID variable. Ref.: Granovetter et al., 1983; Montanari et al., 2017; Onnela et al., 2014; Stehlé et al., 2011; Sapiezynski et al., 2016; Hall et al., 1966; Harari et al., 2016.

Social Interaction self-Report (SIR): The SIR variable is a subjective report aimed at assessing the quantity and quality of social interactions of the subject in any given moment of being prompted. Social relations are a key ingredient to well-being and health at all ages. They undergo characteristic changes across the adult lifespan, with the number of emotionally very close social network members remaining rather stable over the years, and the number of less close network members decreasing over the adult lifespan. Social relations can be assessed in terms of quantity (network size, frequency of contact) and quality (satisfaction with social relations in general and with individual relationship types in particular, e.g., with spouse, children, friends; social support). In the social behavior domain, self-reported interactions can refer to the number and type of social interaction a person has in a particular situation. Ref.: Riediger et al., 2011; Levasseur et al., 2010; Mastrandrea et al., 2015; Hyett 1979; Collopy 1996; Smieszek et al., 2014.

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Total Number of Interactions (TNI): This variable counts the total number of interactions of a subject with other individuals in its social network. It can be measured by considering the interactions detected with sensing devices (SID) and interactions detected with self-report tools (SIR). The TNI can be computed with different time-scales, e.g. by considering short-term interactions (e.g. 24 hours) or long-term interactions (e.g. weeks or months). As a result, it will be possible to measure the TNI for every user hourly, daily, weekly or with other temporal scales. The amount of the interactions is a valuable indicator of the social activity of a user. Ref.: Fournet et al., 2014.

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2. Variables Relationships and ranges

2.1 Cognitive Status

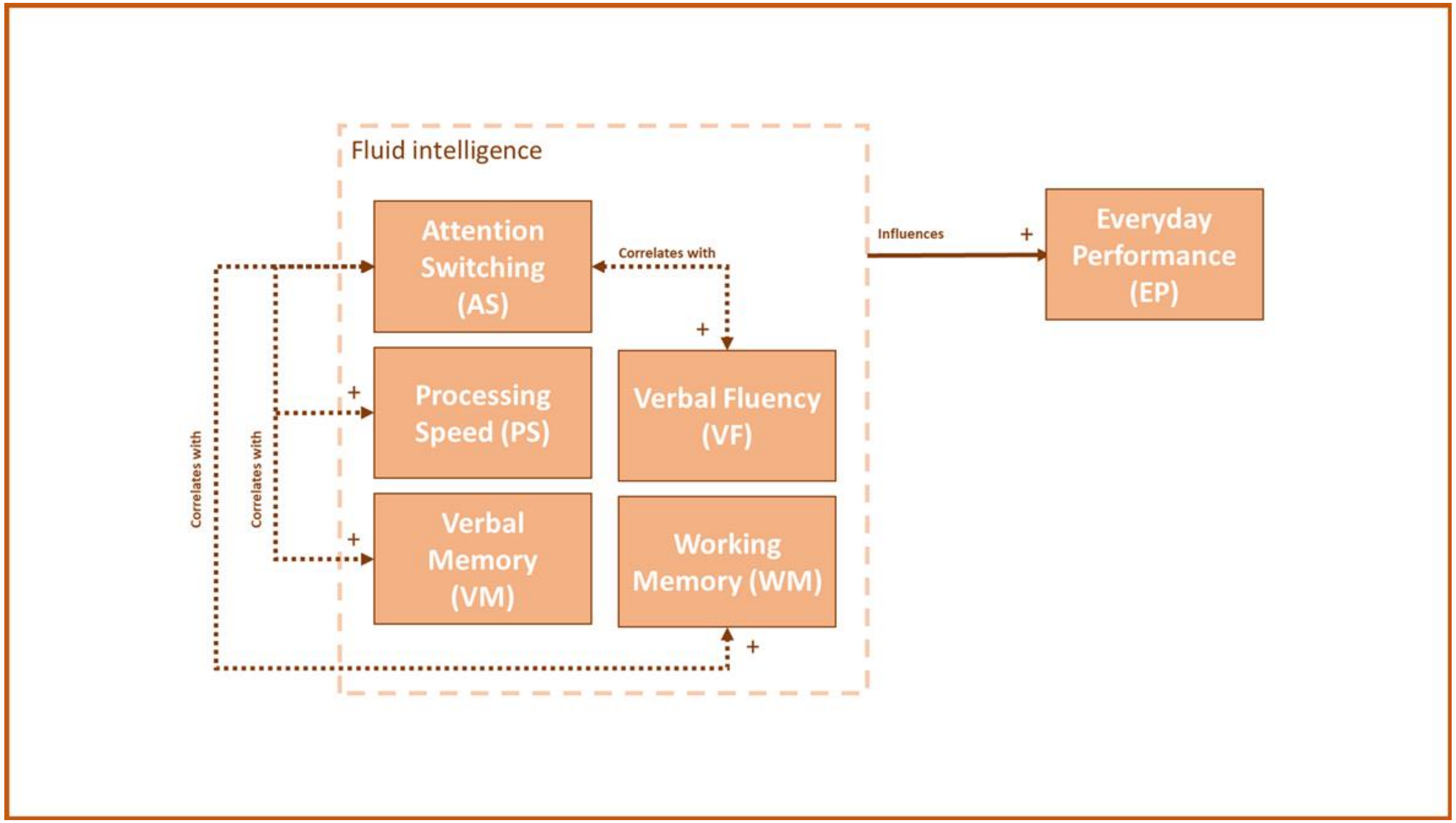

Figure 1 Relationships among variables in the Cognitive Status Subdomain

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VARIABLE NAME	NORMALITY RANGES AND TRENDS	OUT OF RANGES
ATTENTION SWITCHING	Norms are available for different age groups and according to education level. Outcome parameters for Trail-Making-Test (TMT): Score Trail A, Score Trail B, Trail B-A (Giovagnoli et al. 1996) Norms for Trail A: Total score: 25-53 s (age 65-69), 26-61 s(age 70-74) Norms for Trail B: Total score: 56-121 s (age 65-69), 64-159 s (age 70-74) (Tombaugh et al., 2004) Older adults perform slower than younger adults.	Total Score Trail B cut-offs: 3 minutes or 3 errors (the ‘3 or 3 rule’).
EVERYDAY PERFORMANCE	Not known, higher scores represent better functioning. There is a large lifespan sample (the ACTIVE trial: Tennstedt & Unverzagt, 2013; N = 2’800 aged 65+, Mean age: 73.6 years) which could be used to compare NESTORE scores to.	
PROCESSING SPEED	There are various cognitive speed tasks that are used in the literature. One famous test is the Digit Symbol Substitution Test, another the Identical Pictures Test. Digit Symbol Substitution Test: PR (percentile rank): 84 – 23 (age 65-69) 82 – 18 (age 70-74) No known norms for Identical Pictures Test Older adults show much slower performance than young and middle-aged adults. Processing speed is negatively correlated with chronological age. There are only small gender differences in older adults, indicating no gender or women outperforming men in processing speed tasks.	Reduced cognitive performance overall can be indicative of both normal aging but also of pathological processes such as dementia and mild cognitive impairment. Sensory functioning is highly related with cognitive functioning, so older adults who are hearing and vision impaired without correction are at risk for lower cognitive performance.

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VERBAL FLUENCY	There are so many different tests that are psychometric tests and not diagnostic tests. Many of these do not have norms. The typical unit of measure is the number of produced unique words within a predefined time period (usually 1 minute). Norms available for semantic category version (Animal naming) for different age groups, education level, gender (Aschenbrenner et. al. 2000; Tombaugh et. al 1999): >65years/women: 9-24 (1 minute); 14-36 (2 minutes) >65years/men: 7-24 (1 minute); 12-41 (2 minutes) Norms are also available for the phonemic category version (words with L, P, R) for different age groups (Sturm et. al. 1993). Older adults perform less well compared to young adults, but the age differences are smaller than for other fluid intelligence markers. There is some evidence for women outperforming men.	
VERBAL MEMORY	Norms for different parameters and age groups are available but need to be checked with regard to the different language versions (e.g., Schmidt, 1996) Older adults perform less accurate than younger adults. There is some evidence for women outperforming men in test of verbal memory.	Cut-offs are also available but also need to be considered for the different language versions.
WORKING MEMORY	There are so many different tests that are psychometric tests and not diagnostic tests. Many of these do not have norms. The typical unit of measure is reaction time and one would expect healthy older adults to perform slower and with lower accuracy than younger adults. The to be expected mean RT for a healthy older adult sample depends on the exact task demands and difficulty level and the exact age range. Depending on the test finally used, one can check norms for the NESTORE age group for a given test (e.g., digit span forward and backward).	

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2.2 Mental Status

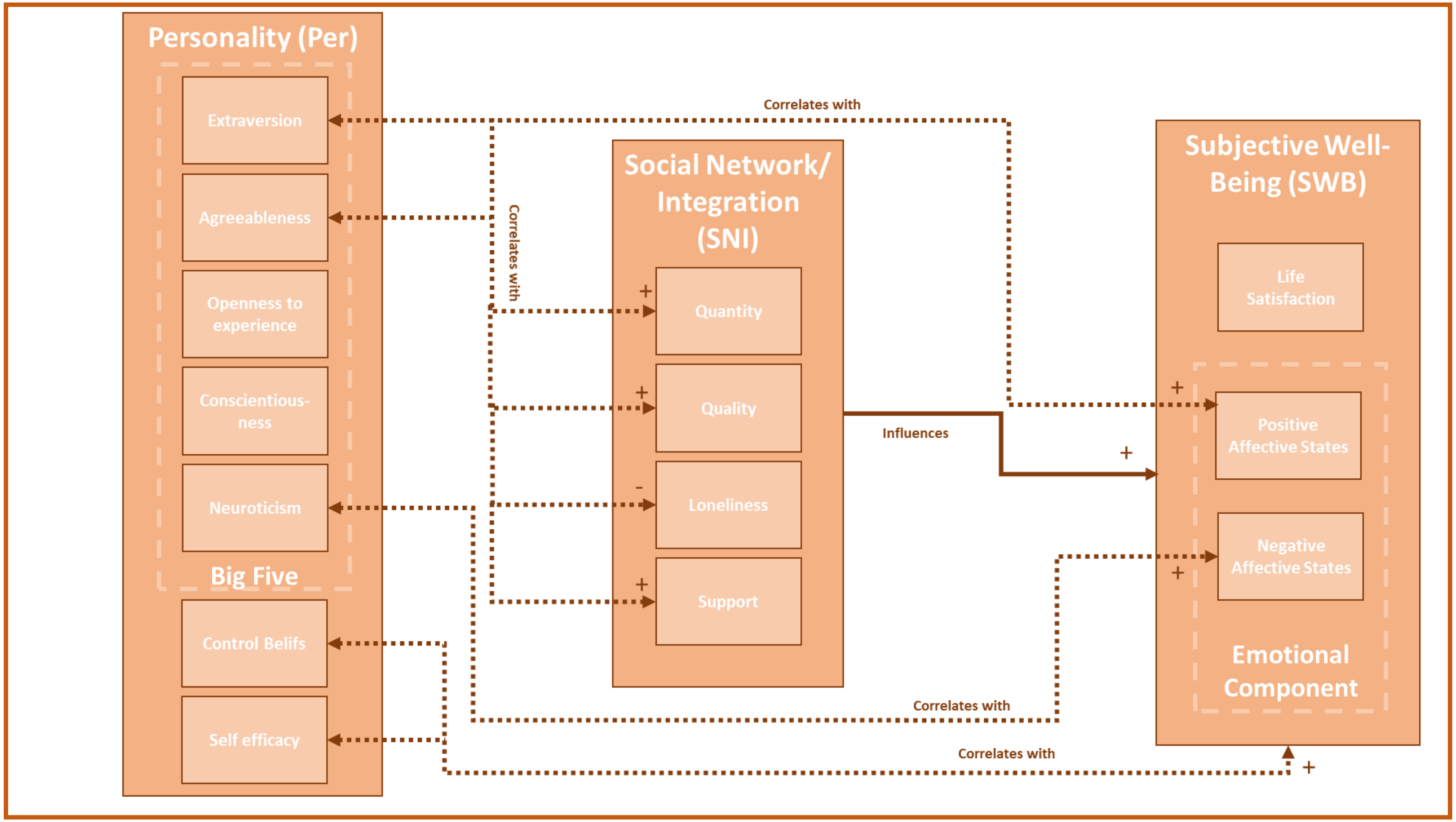

Figure 2 Relationships among variables in the Mental Status Subdomain.

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VARIABLE NAME	NORMALITY RANGES AND TRENDS	OUT OF RANGES
PERSONALITY	Personality: For all personality traits with the exception of Neuroticism (i.e., extraversion, openness, conscientiousness, agreeableness), higher scores reflect adaptive functioning and lower levels reflect maladaptive functioning. The opposite is true for Neuroticism. Control beliefs: High levels reflect positive functioning for mastery, and low scores reflect positive functioning for the perceived constraints facet. Self-Efficacy: High levels reflect adaptive functioning. In a healthy sample, one would expect the sample average for the adaptive personality traits (all but neuroticism/perceived constraints) to be above the response scale middle value, and for the maladaptive traits (neuroticism/perceived constraints) to be below the response scale mean value. Older adults typically report slightly lower levels of openness and extraversion than young and middle-aged adults, but higher agreeableness. For neuroticism, findings are inconsistent. Older adults typically report slightly higher levels of perceived external constraints, but no age differences in the sense of mastery have been found.	Personality (Big Five): range can be from 0 to 6. 0 would represent the lowest possible score, indicating a lack of positive personality characteristics in the personality traits extraversion, openness to experience, conscientiousness, and agreeableness. A score of 6, in contrast, would indicate very high levels and thus a highly positive personality profile in these traits. For neuroticism, the meaning of scores is the opposite: A score of 0 would indicate a rather positive personality profile, because neuroticism is a rather maladaptive personality trait. A score of 6 would indicate malfunctioning. Personal control: Score range from 0 to 6 0 in mastery = maladaptive 6 in mastery = highly adaptive 0 in perceived constraints = highly adaptive 6 in perceived constraints = maladaptive If scores for perceived constraints are recoded and one computes the average between master and constraints, 0 would be indicative of low levels of personal control (i.e., maladaptive) and 6 would indicate high levels of personal control (i.e., adaptive). Self-efficacy: 0 to 6, 6 indicates the most adaptive profile of self-efficacy, 0 the worst / most maladaptive.
SOCIAL NETWORK / SOCIAL INTEGRATION	Social network size/social interaction: Numbers are not possible for all of the measures, this can vary widely between individuals. In a healthy older adult sample, one would expect individuals to have 1-2 close confidants available and a few friends/acquaintances they regularly interact with. Social support and perceived satisfaction with social network: In a healthy older adult sample, one would expect people to receive and perceive moderate to high levels of emotional and practical support	• General: Reporting no support exchanges and very low levels of satisfaction (i.e., score of 0-2 would indicate very low levels of social integration at risk for pathological loneliness and depression and associated with this also physical health

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	(i.e., scores slightly above the response scale mean; such as around 4-5 on a scale from 0 = low support/low satisfaction to 6 = high support/satisfaction). Loneliness: In a sample of healthy older adults one would expect low levels of social and emotional loneliness (i.e., scores in the lower range of the response scale, i.e., around 0-2 on the exemplary scale from 0 = do not feel lonely to 6 = feel very lonely).	problems. No published cut-off scores for Berlin Social Support Scales or number of network members from Circle Diagram • Lubben Social Network Scale: <12 as a clinical cut-off point for social isolation (> 6 for each of the two subscales, Family vs. Friends) • De Jong Gierveld Loneliness Scale: Higher score (range: 0-3) indicates greater loneliness
SUBJECTIVE WELL BEING	In a healthy population: • positive affect is higher than negative affect levels on average (PA > NA). • Average positive affect levels should be above the scale middle of the response scale and negative affect levels should be close to the lower end of the response scale range and definitely way below the scale middle (i.e., if response scale is from 0 = typically not or never experienced at all to 6 = experienced very much / very often, the mean PA would be expected to be around 5 and the mean NA would be expected to be around 1) Cut-offs for the GDS scale: Original 30-item Version: • Original Version with 30-Items: normal 0-9 Typically, older adults (e.g., 65-75) report similar or higher overall levels of SWB (higher PA, lower NA) compared to younger adults (e.g., 20-30).	Having a pattern deviating from the normality ranges, such as below scale mean PA and above scale middle NA would indicate risk for depression and that overall things are not going well in life for this person. Cut-offs for the GDS scale: Original 30-item Version: • Original Version with 30-Items: normal 0-9, mild depressives: 10-19, severe depressives: 20-30 • Short 15-Item version: >5 indication of risk for depression, need to follow-up; >10 almost always indicative of depression For individuals with impaired health status and social integration (and in part cognition), PA would be lower and NA higher than for the healthy comparison group.

2.3 Mental Behaviour and States

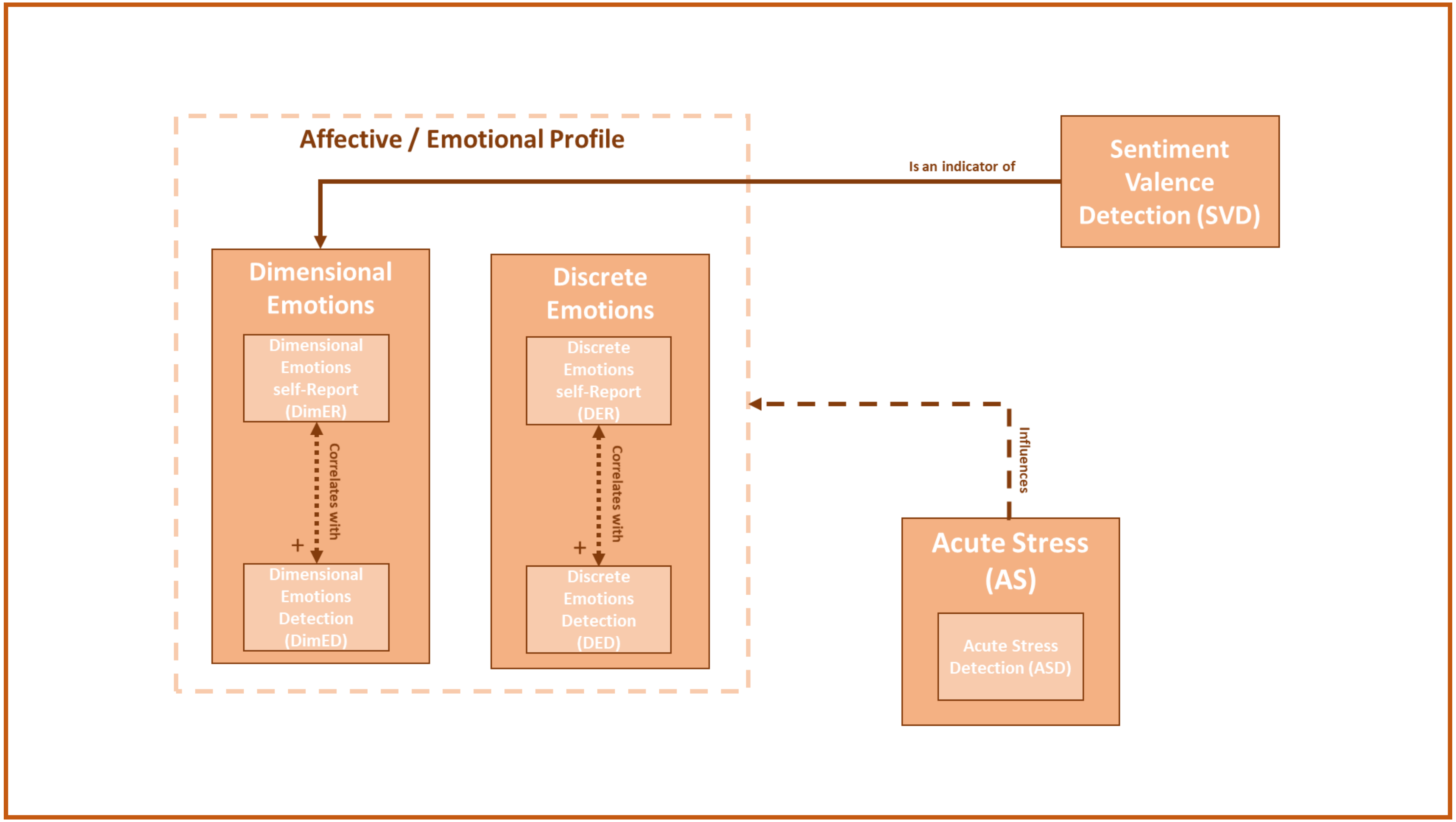

Figure 3 Relationships among variables in the Mental Behaviour and States Subdomain.

VARIABLE NAME	NORMALITY RANGES AND TRENDS	OUT OF RANGES
ACUTE STRESS	There are no universal “normal” ranges for intensity scores of stress expression measures. These types of (text analysis) detection tools, tend to output scores for each relevant dimension on a scale that can be subsequently post-processed and normalized in a number of meaningful ways deemed relevant to the application case and domain. TensiStrength tool outputs two scores, one for stress and one for relaxation, while STRESSCAPES produces a score indicating the intensity of the communicated stress experience, where the scores range from 0 (meaning there is no stress or relaxation detected) up to 100 (indicating the highest possible level of stress or relaxation that can be detected from the text material). The proportion of stress scores sensed is also highly dependent on the types of interactions (and personality) – i.e. who is communicating with whom, etc. Hence calibrating / establishing user specific baseline measurements over time might inform the specific use-cases. Given the positive affect bias (i.e. higher mean levels of positive emotions) in older adults (e.g. 65-75), it is expected that stress levels should be slightly lower for older than younger adults. Gender seems to play a confounding factor in stress as well. Although quite complex, there is some evidence that there are gender differences in terms of perceived stress in various situations as well as responses to perceived stress, including stress related to perceived gender roles.	Prolonged episodes of high levels of acute stress (as measured by the stress detection sensing tools, is a risk factor to chronic psychological stress, which in turn is linked to the onset of a number of chronic disease outcomes (e.g. asthma, obesity). However, there are no known / reported thresholds, as there are a variety of factors and case-specific considerations, including such ranges of scores used with available sensing tools. Also, frequent and very intense high scores of stress would generally not be desired in a healthy individual. Expressed levels of stress will differ for individuals scoring low on arousal within dimensional emotion models, such as long term low mood and depressed states. Mental health conditions in general, as well as physical health impairments, including factors such as chronic pain where individuals tend to show greater negative affect fluctuations than pain-free individuals, are also significant in stress response.
DIMENSIONAL EMOTIONS	**Dimensional Emotions Detection:** There are no universal “normal” ranges for scores of individual emotional dimensions, such as for valence or arousal. As with discrete emotional sensing, specific context / use-cases matter most. Effectively most scores within available ranges (for instance Choudhary et al. 2012 uses valence and arousal ranges on a 0-10 scale) are possible, as the combined dimensions would map onto specific mood / emotional states. Nevertheless, normally one would not expect extreme (very high / low) arousal and/or valence scores	**Dimensional Emotions Detection:** Extreme relative scores on emotional dimensions (i.e., valence and arousal) over prolonged time-periods can be indicative of emotional issues. For instance, very low levels of arousal as well as low valence scores might indicate depression / low mood conditions. Also, extreme variability along the measured emotional dimensions would also generally not be desired in an emotionally stable / healthy

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over prolonged time periods. Available detection tools, tend to output scores for each dimension on a scale that can be subsequently post-processed and normalized in a number of meaningful ways deemed relevant to the application domain. Hence calibrating / establishing user specific baseline measurements over time might be needed. Also, there are some seasonal and other events (e.g. holidays) that would cause basic variation in emotional dimensions.

Typically, older adults (e.g., 65-75) report similar or even higher mean levels of positive emotions compared to younger adults (e.g., 20-30). There is beginning evidence that discrete positive and negative emotions may show multidirectional age-related trajectories across the lifespan and into old age rather than uniform patterns of stability or change (Kunzmann et al., 2014). In daily life, older adults fluctuate overall less in their day-to-day emotional states than younger adults. Emotion sensing studies involving older demographics are generally lacking, hence there is limited evidence on normal value ranges using the here presented tools.

Dimensional Emotions Self-Report:
In a healthy sample

- Positive affect is higher than negative affect levels on average (PA > NA).
- Average positive affect levels should be above the scale middle of the response scale and negative affect levels should be close to the lower end of the response scale range and definitely way below the scale middle (i.e., if response scale is from 0 = currently not experienced at all to 6 = currently experienced very much, the mean daily PA would be expected to be around 5 and the mean daily NA would be expected to be around 1)
- Positive affect fluctuates more from day-to-day/moment-to-moment than negative affect. (There are several statistical indicators of affect fluctuations so no numeric information can be given here. Relatively the pattern would be expected to be like this: Fluctuation in PA > Fluctuation in NA)

individual (there is no set upper limit, but we could normalise the data 0 – 100).

Dimensional Emotions Self-Report:
The range of emotions depends on the overall status of the user, their mental health conditions (anxiety, depression, etc.), as well as physical health impairments, including factors such as chronic pain where individuals tend to show greater negative emotion fluctuations than pain-free individuals.
Having negative affect levels, on average, that are above the scale middle would be affiliated with the risk for depressive symptoms and high levels of neuroticism (i.e., lower levels of psychological health)

Having relatively flat affect trajectories from day-to-day and extreme swings in negative affect would also be indicative of an increased risk for mental pathology (i.e., depressivity/depression)

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	Typically, older adults (e.g., 65-75) report similar or even higher mean levels of daily positive affect compared to younger adults (e.g., 20-30). Typically, older adults fluctuate overall less in their day-to-day affective states than younger adults. Individuals in chronic pain tend to show greater negative affect fluctuations than pain-free individuals, so physical health impairments can be related to relatively greater so-called intraindividual variability in affective well-being.	
DISCRETE EMOTIONS	**Discrete Emotion Detection:** Please refer to Dimensional Emotions Detection **Discrete Emotion Self-Report:** Depending on the particular tool and set-up, there will be an expected range associated with each tool scale, with the scores for individual emotions usually ranging from 0 (no explicit emotion detected) upwards (the higher, the more intensely those emotions were experienced / recalled). However, for instance with the DEQ tool the range is between 4-28 for the total 8 emotions, although this can be customised (i.e. where only some DEQ Likert questions are employed). There are no universal "normal" ranges for scores of individual self-reported emotions, as a wide-range of emotions can be experienced. Nevertheless, in a healthy sample one would on average expect positive emotions to be higher than negative emotion levels. Average positive emotion levels should be above the scale middle of the response scale and negative emotion levels should be close to the lower end of the response scale range and definitely below the scale middle. Also, positive emotion levels fluctuate more from day-to-day / moment-to-moment than negative emotion levels. Typically, older adults (e.g., 65-75) report similar or even higher mean levels of positive emotions compared to younger adults (e.g., 20-30). Typically, older adults fluctuate overall less in their day-to-day emotional states than younger adults.	**Discrete Emotion Detection:** High relative scores of negative emotions over prolonged time-periods can be indicative of low mood, high levels of neuroticism (i.e., lower levels of psychological health) and other significant issues (e.g. frequent and high levels of fear -> anxiety, etc.). Some emotions have been shown (in statistical learning models) to be strongly linked to certain mental health issues, such as depression or bipolar disorders, however, these relationships are complex involving features such as higher use of first-person pronouns, lower use of third-person pronouns, smaller frequency of social interactions, etc. hence such links are non-trivial, yet they do exist and have been modelled in prior research. **Discrete Emotion Self-Report:** Having high negative emotion levels, on average, that are above the scale middle would be affiliated with the risk for depressive symptoms and high levels of neuroticism (i.e., lower levels of psychological / emotional health). Having relatively flat emotion trajectories from day-to-day and extreme swings in negative emotions would also be indicative of an increased risk for mental pathology (i.e., depressivity / depression). Degree of abnormality (weak, moderate, severe) The range of emotions depends on the overall status of the user, their mental health conditions (anxiety, depression, etc.), as well as physical health impairments, including

		factors such as chronic pain where individuals tend to show greater negative emotion fluctuations than pain-free individuals.
SENTIMENT VALENCE DETECTION	Please refer to Dimensional Emotions self-Report	Please refer to Dimensional Emotions self-Report

2.4 Social Behaviour

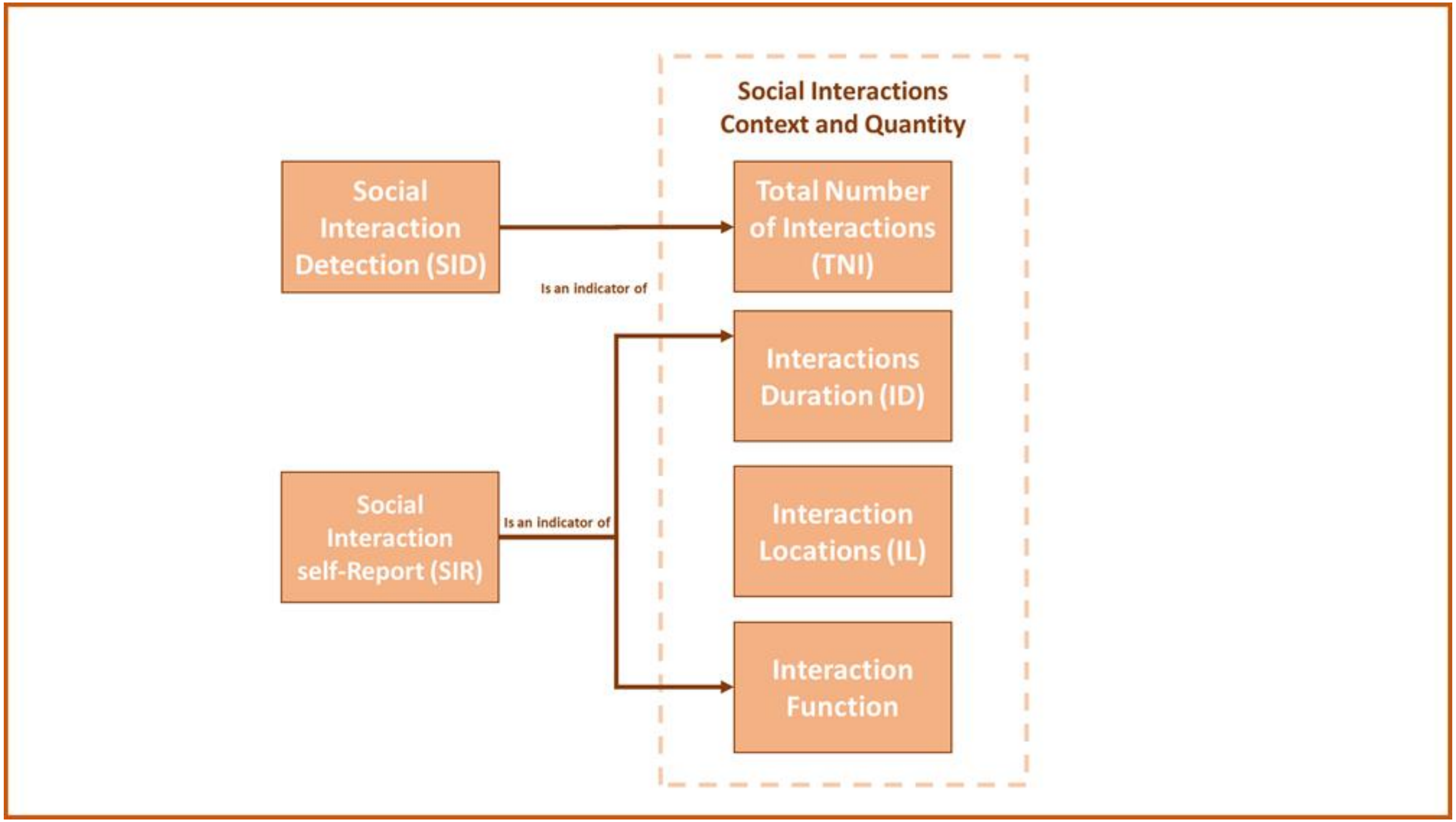

Figure 4 Relationships among variables in the Social Behaviour Subdomain.

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VARIABLE NAME	NORMALITY RANGES AND TRENDS	OUT OF RANGES
SOCIAL INTERACTION DETECTION	There is no known “normal” range of the number of social interactions that would be expected. This is highly person-specific and can for a given day range between zero (particularly if a person is not married or co-habiting with anyone) to multiple interactions on a given day. For example, for a married person who has the adult children living nearby, one might expect several interactions with the spouse each day and depending on the quality of the relationship with the adult children and their own daily routines, in-person interactions with each child once per week or less. Typically, older adults (e.g., 65-75) report similar numbers of emotionally very close others compared to younger adults (e.g., 20-30), but smaller overall network size. They tend to be as satisfied with their social network quality as young, particularly during the so-called Third Age. Individuals with health-related impairments that decrease their out-of-the-home mobility would be expected to have a smaller social network and less frequent (in person) interactions other than with their potentially available spouse. Moreover, the automatic detection of the social interactions is affected by the following considerations: • Existence of false-positive interactions, e.g. interactions too short or not significant • Interactions are detected only among users’ part of the same experiment	The increase/decrease of the social engagement of a user will be achieved by comparing the SID variable with respect to a base-line specific for the user so that to detect remarkable changes for him/her: • The total absence of interactions on the short and long term could indicate that a person might be at risk to feeling lonely and isolated. • Short and medium periods of low/absence of interactions might be caused by contingent situations such as: holidays or health conditions • Increase/decrease of interactions with respect to the base-line can be considered has a significant change of its social behaviour.
SOCIAL INTERACTION SELF-REPORT	Similarly, to the Social Interaction Detection, also the self-reported interactions do not follow a general scale, rather they are subjective to each user. It is worth to notice that the self-	Similarly, to the SID variable, also in this case the increase/decrease of the social engagement of a user will be achieved by comparing the SID variable with respect to a base-line specific for the user so that to detect remarkable changes: • The total absence of interactions on the short and long term could indicate that a person might be at risk to feeling lonely and isolated. • Short and medium time period of low/absence of interaction might be caused

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	reported interactions might differ from results obtained from the SID variables (sensing-based): • Absence of false-positive: if a user reported an interaction with another user, it happened in the realty. • The reports might be not symmetric among users: e.g. user A reports at time *t* an interaction with user B, while B does not report any interaction • Users tend to forget short interactions, while they remember more easily long-lasting ones, even though if reported for the given moment, such memory failures and retrospective biases should be minimized or even absent. • Users tend to overestimate the duration of the interactions when self-reported.	by contingent situations such as: holidays or health conditions
TOTAL NUMBER OF INTERACTIONS	Please refer to Social Networking.	The increase/decrease of the social engagement of a user will be achieved by comparing the TNI variable with respect to a base-line specific for the user so that to detect remarkable changes on the total number of interactions. The range of the TNI variable will be given as an integer value representing the total number of the interactions in a given a time-scale (hourly, daily, weekly etc.). Increase/decrease of interactions with respect to the base-line can be considered has a significant change of its social behaviour.
INTERACTIONS DURATION	Please refer to Social Network/ Social Integration.	The increase/decrease of the social engagement of a user will be achieved by comparing the IDD variable with respect to a base-line specific for the user so that to detect remarkable changes on the total duration of interactions. The range of the IDD variable will be given as a double value representing the cumulative time of the interactions in a given a time-scale (hourly, daily, weekly etc.) • Increase/decrease of the duration of the interactions with respect to the base-line can

		be considered as a significant change of its social behaviour.
INTERACTION LOCATIONS	The location of the social interactions also depends on the mobility of the user. Users with high mobility might interact with other people outdoor, people with reduced mobility will spend more time indoor (e.g. at home). In general, the range for this variable has to identify the locations (indoor or outdoor) where interactions take place. Locations of the interactions will be detected only indoor.	The range of the ILD variable will be given as a bivariate value $(x,y)_j$, where: • j is the location • x represents the number of interactions happening in j y is the cumulative duration of the interactions in j.

2.5 Relationships among subdomains

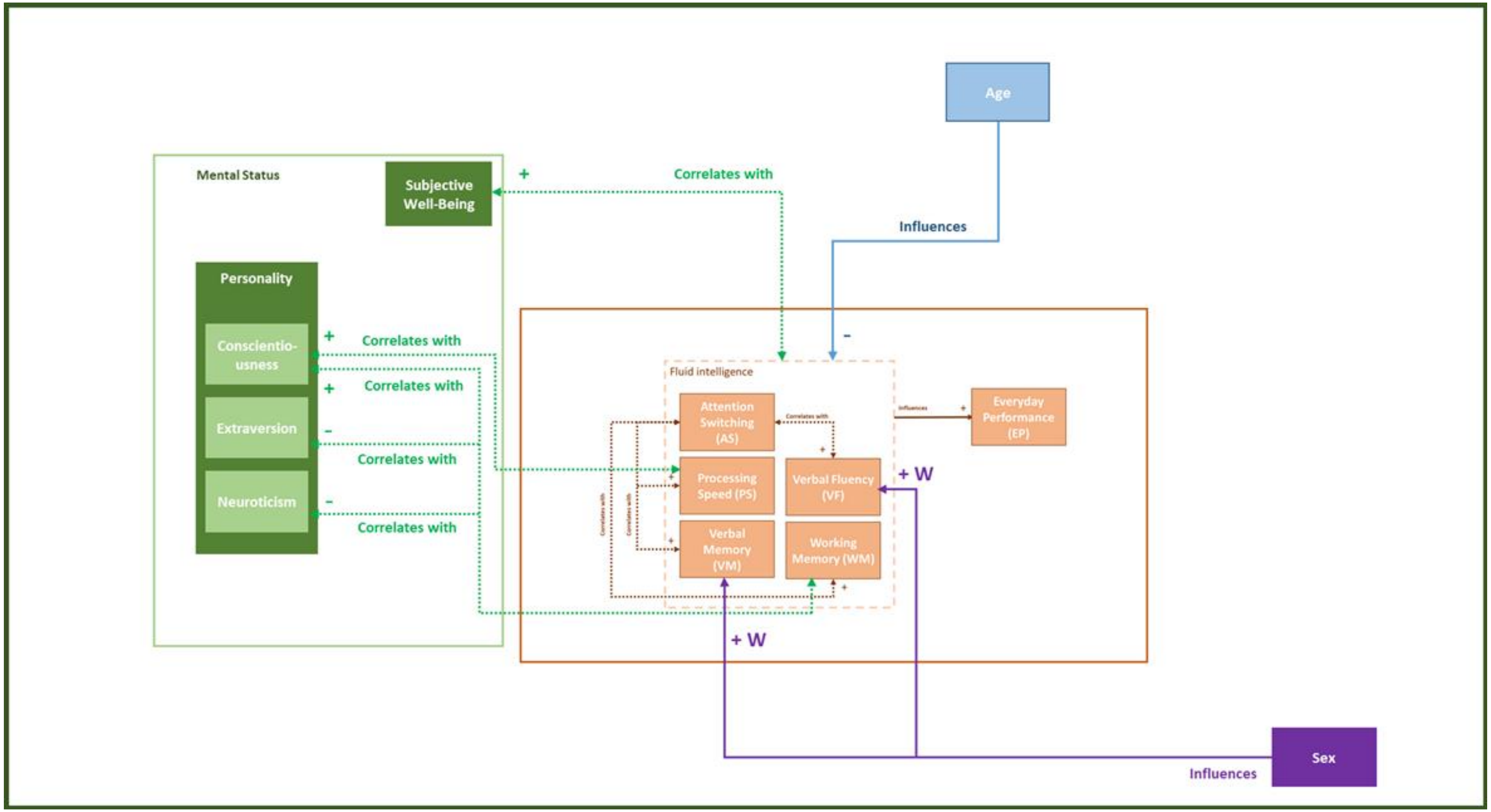

Figure 5 Relationships among the Cognitive Status subdomain and all the other Cognitive-Mental-Social subdomains.

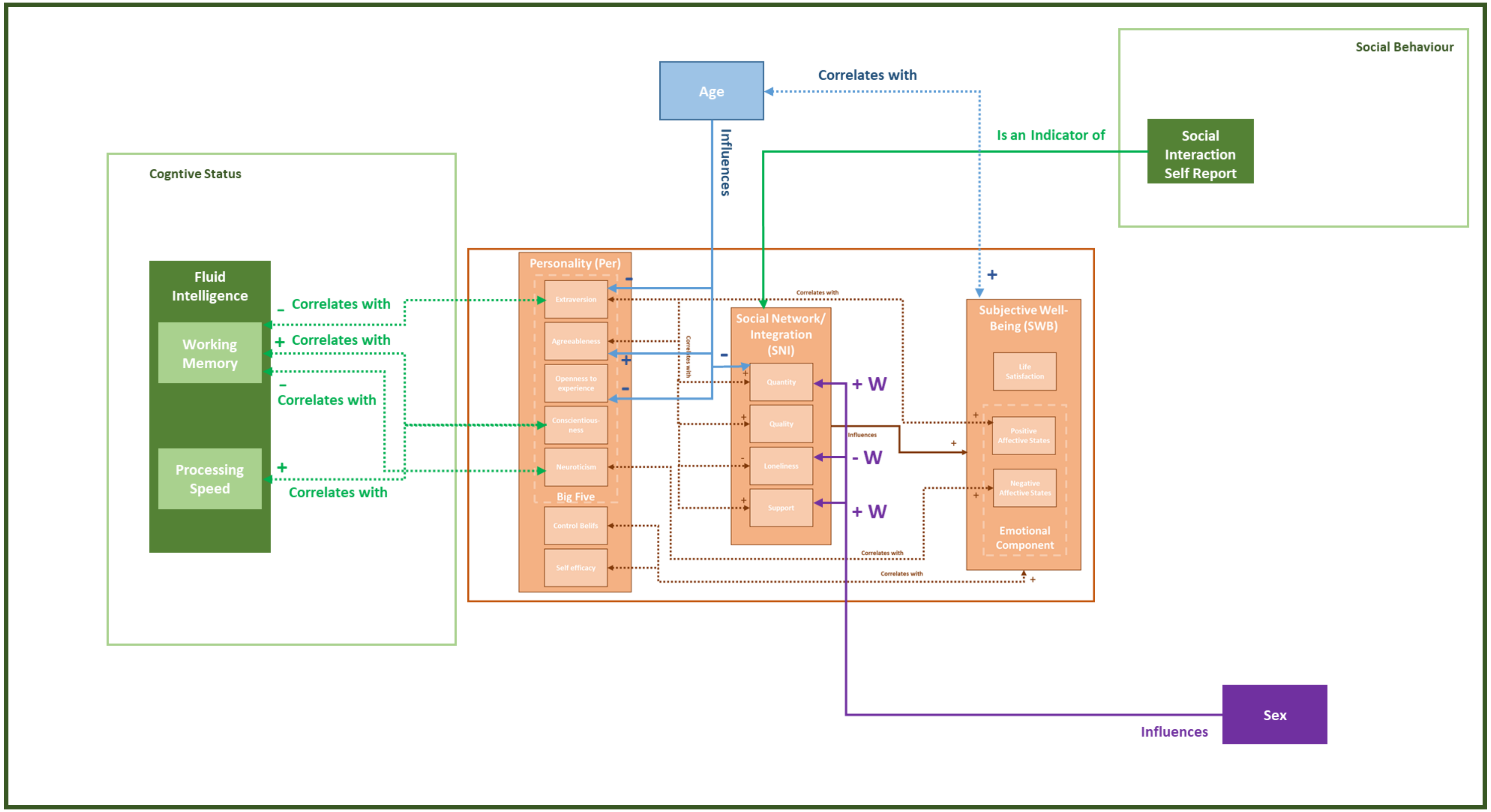

Figure 6 Relationships among the Mental Status subdomain and all the other Cognitive-Mental-Social subdomains.

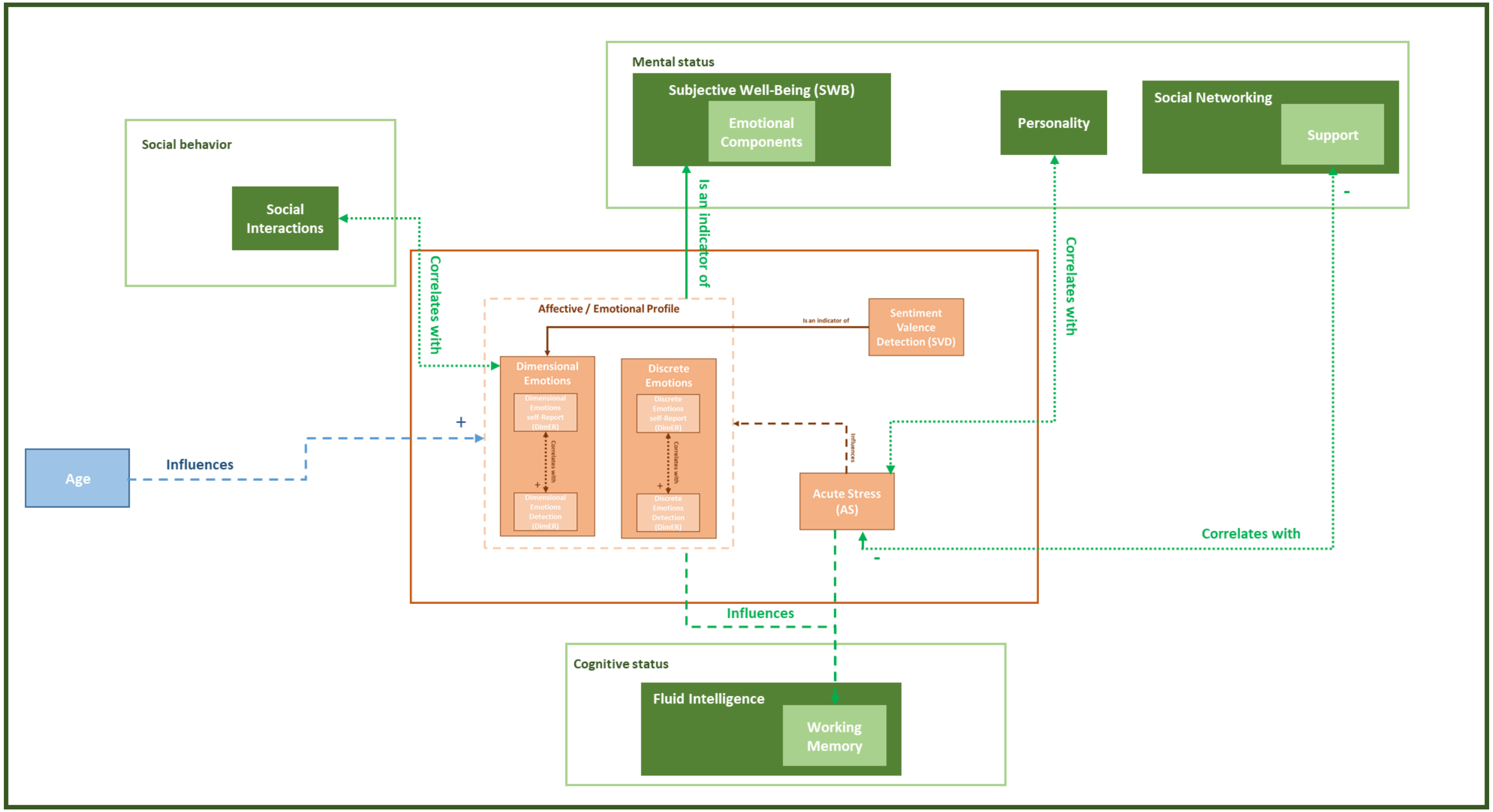

Figure 7 Relationships among the Mental Behaviour and States subdomain and all the other Cognitive-Mental-Social subdomains.

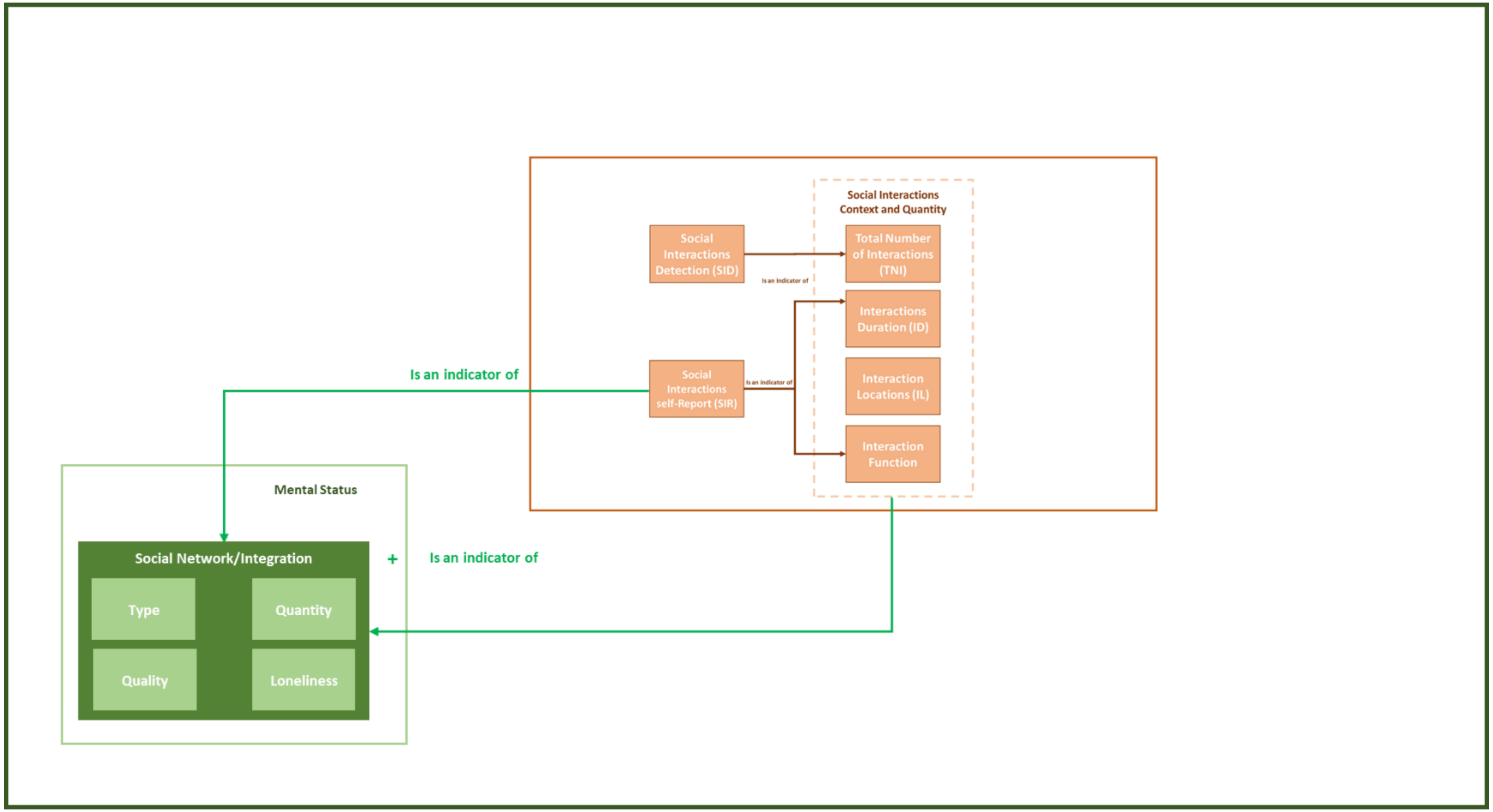

Figure 8 Relationships among the Social Behaviour subdomain and all the other Cognitive-Mental-Social subdomains.

3. Measurement scenarios of the system variables

3.1 Cognitive Status

VARIABLE	MEASUREMENT SCENARIO	UNITS	FORMULA	MEASUREMENT DEVICE	GOLD STANDARD MEASUREMENT
ATTENTION SWITCHING	**Frequency:** Twice, at baseline and at post-test	s	n.a.	Paper-pencil tasks, e.g., Trail-Making-Test A and B (TMT-AB)	Trail Making Test A & B.
EVERYDAY PERFORMANCE	**Frequency:** Twice, at baseline and at post-test	Number of correctly solved problems within pre-defined time period.	n.a.	Mainly paper and pencil based tests used in previous large aging studies.	Everyday Performance Test
PROCESSING SPEED	**Frequency:** Twice, at baseline and at post-test	Number of items solved in allocated time	n.a.	Paper and pencil based tests.	Digit Symbol Substitution Test Identical Pictures Test
VERBAL FLUENCY	**Frequency:** Twice, at baseline and at post-test	Number of unique words produced within a given time frame.	n.a.	Paper and pencil based tests.	Verbal Fluency Test
VERBAL MEMORY	**Frequency:** Twice, at baseline and at post-test	Number of words recalled in the given time/number of words correctly identified	n.a.	Paper and pencil based tests.	Rey Auditory Verbal Learning Test
WORKING MEMORY	**Frequency:** Twice, at baseline and at post-test	Reaction time usually in ms, sometimes accuracy scores also used.	n.a.	Paper-pencil and computerized psychometric tasks	N-Back task, Numerical updating task, Digit Span task

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3.2 Mental Status

VARIABLE	MEASUREMENT SCENARIO	UNITS	FORMULA	MEASUREMENT DEVICE	GOLD STANDARD MEASUREMENT
PERSONALITY	**Frequency:** Twice, at baseline and at post-intervention	Likert-type rating scales (typically between 0-6 or 1-7)	n.a.	Standardized questionnaire (pencil and paper test)	Personality traits/Big Five: **Big Five Inventory** (BFI-II) Control Beliefs: **Locus of control scale from Midlife in the United States Survey** (MIDUS) Self-Efficacy: **General Self-Efficacy Scale** (GSE)
SOCIAL NETWORK / SOCIAL INTEGRATION	**Frequency:** At baseline and post intervention	-Positive integer (network size) -Likert-type rating scales	n.a.	Standardized questionnaire (pencil and paper test)	Circle Diagram based on Antonucci model Lubben Social Network Scale 6 (LSNS-6) Berlin Social Support Scales De Jong Gierveld Loneliness scale
SUBJECTIVE WELL BEING	**Frequency:** Twice, at baseline and at post-intervention	Likert-type rating scales	n.a.	Standardized questionnaire (pencil and paper test)	Affect: Positive and Negative Affect Schedule (PANAS) Multidimensional Affect Questionnaire (MDBF) Life Satisfaction: Satisfaction with Life Scale (SWLS) Depressive Symptoms (as screening instrument): Geriatric Depression Scale (GDS)

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3.3 Mental Behaviour and States

VARIABLE	MEASUREMENT SCENARIO	UNITS	FORMULA	MEASUREMENT DEVICE	GOLD STANDARD MEASUREMENT
ACUTE STRESS	Achieved by running EMOTIVE+ on the available datasets.	Number of times stress-associated words are detected	n.a.	STRESSCAPES, TensiStrength (Sykora et al., 2015; Thelwall et al., 2017)	Stress Thermometer, Negative Affect Schedule (PANAS-X)
DIMENSIONAL EMOTIONS	**DimED**: Achieved by running EMOTIVE+ on the available datasets.	**DimED:** Number of times that an affect is expressed and the associated intensity	n.a.	**DimED:** ANEW – Affective Norms for English Words (Bradley and Lang, 1999) AFINN – is updated ANEW for informal text by Finn Å.N. (2011)	n.a.
	DimER: Frequency: 6 times daily between wake up and going to bed)	**DimER:** Likert-type rating scale (typically between 0 = not experienced at all to 6 = extremely or 1-7)	n.a.	**DimER:** standardized questionnaires	**DimER:** Positive and Negative Affect Schedule (PANAS; Watson et al., 1988) Multidimensional Affect Balance Scale (Wilhelm & Schoebi, 2007)
DISCRETE EMOTIONS	**DED:** Frequency: 6 times daily between wake up and going to bed).	**DED:** Number of emotions/number of times an emotion is expressed in a time period/intensity score of the emotion	n.a.	EMOTIVE (ref Sikora)	
	DER: Frequency: 6 times daily between wake up and going to bed).	**DER:** Number of emotions/number of times an emotion is expressed in a time period/intensity score of the emotion	n.a.	Self-Report	**DER:** Discrete Emotions Questionnaire (DEQ) (Harmon-Jones et al. 2016)
SENTIMENT VALENCE DETECTION	Frequency: Achieved by periodically running the tool(s)	Number of times that words / expressions that are highly correlated with positive and negative valence are detecting in the text	n.a.	SentiStrength-2 Vader – Valence Aware Dictionary and sEntiment Reasoner	

EmoLex

MPQA – Multi-Perspective Question Answering Subjectivity Lexicon

SentiWordNet

Bing Liu’s Opinion Lexicon

PANAS-t

LIWC – Linguistic Inquiry and Word Counts

3.4 Social Behaviour

VARIABLE	MEASUREMENT SCENARIO	UNITS	FORMULA	MEASUREMENT DEVICE	GOLD STANDARD MEASUREMENT
SOCIAL INTERACTIONS DETECTION	**Frequency**: continuous monitoring during specific time windows. E.g. 8AM to 8PM	For every user it will be defined the vector U_i, the list of interactions with other users with a timestamp. $U_i = [(U_1,[t_{start}, t_{end}]), (U_2, [t_{start}, t_{end}]), \dots , (U_m, [t_{start}, t_{end}])]$	Algorithm for detecting the interactions based on the analysis of signals from the sensing devices (Received Signal Strength).	Wearable device needed for recognizing interactions (e.g. proximity sensor)	1.Observers: annotating when users interact 2.Self-reported diaries or questionnaires: asking for qualitative/quantitative metrics of the interactions of every user once or several times per day. 3.More recently in psychology, sensing approaches have been used that are based on SMS, call-logs from smartphones. Furthermore, the analysis of the social network (Facebook and twitter contacts) can be used also as gold standards
SOCIAL INTERACTIONS SELF-REPORT	**When**: There could be both time-contingent assessments (i.e., randomly in pre-defined time-windows between wake up and going to bed) to cover everyday life as a whole There could also be event-contingent sampling, i.e.,	Likert-type rating scales (typically between 0-6 or 1-7)	n.a.	Paper and pencil questionnaires	Single items used in the literature, e.g., Riediger et al., 2014, including self-developed measures following De Jong Gierveld loneliness scale and social interactions

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	assessments of relationship/interaction quality each time an interaction occurs **Frequency**: Measured daily, possibly several times/day				taxonomy (see text of WP 2 D2.1)
TOTAL NUMBER OF INTERACTIONS	**Frequency**: short term analysis (e.g. hourly, daily). The frequency of the analysis can be configured	Positive integer	Given the interactions detected with the SID variable (the list Ui), $TNI_i = \sum_{d=i}^{k} size(U_i)$, where d is the time scale (e.g hours, days)	wearable device needed for recognizing interactions (e.g. proximity sensor)	1.Observers: annotating when users interact 2.Self-reported diaries or questionnaires: asking for qualitative/quantitative metrics of the interactions of every user once or several times per day.
INTERACTIONS DURATION	**Frequency**: short term analysis (e.g hourly, daily). The frequency of the analysis can be configured	Double value representing a duration (seconds)	Given the interactions detected with the SID variable (the list Ui), $IDD_i = \sum_{d=i}^{k} duration\ of\ interactions(U_i)$, where d is the time scale (e.g. hours, days)	wearable device (e.g. wristband)	1.Observers: annotating the duration of the interactions 2.Self-reported diaries or questionnaires: asking for qualitative/quantitative metrics of the interactions of every user once or several times per day.
INTERACTION LOCATIONS	**Frequency**: short term analysis (e.g. hourly, daily). The frequency of the analysis can be configured	Positive integer representing the interactions happening	Algorithm correlating the interactions among users with signals received from specific locations	wearable device and tag BLE deployed on specific locations	1.Observers: annotating the locations of the interactions 2.Self-reported diaries or questionnaires:

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	in a specific location. Lj = k		asking where the interactions happen

4. Measurement scenarios for variables related to validation

4.1 Cognitive Status

ATTENTION SWITCHING

MEASUREMENT SCENARIO (PILOTS)

Assessment by means of **Trail Making Test A & B**. (Tombaugh T.N. 2004) performed twice: at baseline to assess the pre-intervention status and at post-test to see whether cognitive training (i.e., serious games) have had an effect.

EVERYDAY PERFORMANCE

MEASUREMENT SCENARIO (PILOTS)

Paper and pencil test: Everyday Performance Test (Tennstedt & Unverzagt, 2013).
The test should be performed twice: at baseline to assess the pre-intervention status and at post-test to see whether cognitive training (i.e., serious games) have had an effect
Possibility to extract parameters from verbal or activity information that reflects cognitive activities.

PROCESSING SPEED

MEASUREMENT SCENARIO (PILOTS)

Assessed by means of paper and pencil tests as Digit Symbol Substitution Test (Wechsler Adult Intelligence Test Battery; Aster et al., 2009, Neubauer, & Horn, R., 2009).
, Identical Pictures Test (French, Ekstrom, & Price, 1963). Performed twice: at baseline to assess the pre-intervention status and at post-test to see whether cognitive training (i.e., serious games) have had an effect.

VERBAL FLUENCY

MEASUREMENT SCENARIO (PILOTS)

Assessed by means of the Verbal Fluency Tests. (“Words with F” / Animals) performed twice: at baseline to assess the pre-intevention status and at post-test to see whether cognitive training (i.e., serious games) have had an effect.

VERBAL MEMORY

MEASUREMENT SCENARIO (PILOTS)

Assessed by means of paper and pencil tests as Rey Auditory Verbal Learning Test (Schmidt, M., 1996). performed twice: at baseline to assess the pre-intervention status and at post-test to see whether cognitive training (i.e., serious games) have had an effect.

WORKING MEMORY

MEASUREMENT SCENARIO (PILOTS)

Paper-pencil and computerized psychometric tasks as N-Back task (e.g., Li et al., 2008), Numerical updating task (e.g., Riediger et al., 2014), Digit Span task (Wechsler, 1997; Klingberg, 2010) performed twice: at baseline to assess the pre-intervention status and at post-test to see whether cognitive training (i.e., serious games) have had an effect.
Note: There are also computerized versions of working memory tasks available for smartphones to assess cognitive performance repeatedly in daily life.

4.2 Mental Status

PERSONALITY

MEASUREMENT SCENARIO (PILOTS)

Assessment by means of questionnaires assessed twice, once a t baseline and once post intervention even if changes are unlikely to occur.

Questionnaires to be used are:

- Personality traits/Big Five:

Big Five Inventory (BFI-II)

- Control Beliefs:

Locus of control scale from Midlife in the United States Survey (MIDUS)

- Self-Efficacy:

General Self-Efficacy Scale (GSE)

SOCIAL NETWORKING

MEASUREMENT SCENARIO (PILOTS)

Assessment by means of questionnaires performed twice, once a t baseli9ne and once post intervention.

There are numerous scales assessing status information on relationship /network quantity and quality including support and loneliness, depending on whether one is interested in the overall network or romantic relations etc. Some scales that have been used in prominent aging studies are listed below:

Social Network size:

a) Circle Diagram based on Antonucci model (e.g., as used in Berlin Aging Study)

Possibly more economic in terms of time for NESTORE:

b) Lubben Social Network Scale 6 (LSNS-6)

(Separate 3-item scales for family and friends)

- How many relatives/friends do you see or hear from at least once a month?
- How many relatives/friends do you feel at ease with that you can talk about private matters?
- How many relatives/friends do you feel close to such that you could call on them for help?

(0 – 5 or more)

Satisfaction with Social Network and particular relationships:

Satisfaction with social relations items (single items, e.g., as used in Berlin Aging Studies)

- How satisfied are you with your friendships, the things you do together with your friends, and how you get along with your friends?
- How satisfied are you with your family life – with the time you spend with your family and with the things you do with your family?

⍰ 1 (not at all) – 5 (very much)

Social Support (received and provided):

Berlin Social Support Scales (received and provided social support)

- Received Social Support (10 items): e.g., A person close to me has shown me that she likes and accepts me; a person close to me was there for me
- Provided social support (10 items): e.g., I have shown a person close me that I like and accept him/her; I have expressed concern about the well-being of a person close to me.

⍰ Response scale regarding the previous month: 0 (does not apply at all) – 6 (applies very well)

Loneliness (social loneliness [SL] and emotional loneliness [EL]):

Short form of De Jong Gierveld Loneliness scale

- I experience a general sense of emptiness [EL]
- I miss having people around me [EL]
- I often feel rejected [EL]
- There are plenty of people I can relate on when I have problems [SL]

- There are many people I can trust completely [SL]
- There are enough people I feel close to[SL]

 Response scale (yes-(2)/more or less-(1)/no-(0)):

Emotional loneliness score range: 0 (not emotionally lonely) to 3 (intensely emotionally lonely); negatively phrased items: count neutral and positive responses (more or less and yes)
Social loneliness score range: 0 (not socially lonely) to 3 (intensely socially lonely); positively phrased items: count neutral and negative responses (“more or less” and “no”)

Other NESTORE-relevant variables in this area could be:
Companionship / Health-related social control

SUBJECTIVE WELL-BEING

MEASUREMENT SCENARIO (PILOTS)
Assessment by means of questionnaires performed twice, once a t baseli9ne and once post intervention.
Questionnaires to be used are:
- Affect:
Positive and Negative Affect Schedule (PANAS)
Multidimensional Affect Questionnaire (MDBF)
- Life Satisfaction:
Satisfaction with Life Scale (SWLS)
- Depressive Symptoms (as screening instrument):
Geriatric Depression Scale (GDS)

4.3 Mental Behavior and States

ACUTE STRESS DETECTION

MEASUREMENT SCENARIO (PILOTS)
Using EMOTIVE on a (i) daily / weekly / monthly basis, per (ii) user or (iii) immediate social network. This may help provide a basis for not only an approximate representation of a particular user’s tendency to experience and communicate messages indicative of acute stress, but any trends or patterns in this over time, as well as the aggregate stress profiles of the user’s immediate social network.

DIMENSIONAL EMOTIONS

MEASUREMENT SCENARIO (PILOTS)

DIMENSIONAL EMOTIONS DETECTION:
On a daily / weekly / monthly basis, per user or immediate social network. This may help provide a basis for not only an approximate representation of a particular user’s emotional profile, but their feelings and variability in emotional and affective experiences over different granularities of time, as well as the aggregate emotional / affective profile of the user’s immediate social network.
Another use-case could involve the analysis of all emotions / affect over certain types of (coach encouraged) activities, and how these differ between various other types of activities. Finally, it would also be sensible to compare emotions measured using the tool(s) with respect to all the users, or a matched group of users.

DIMENSIONAL EMOTIONS SELF-REPORT:
Throughout intervention in daily life:
Measured daily, possibly several times / day

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- Time-contingent (at pre-defined time points or randomly during pre-defined time windows between wake up and going to bed)
- Event-contingent based on intervention-related events, perceived successes or obstacles related to health-behaviour changes in other domains (cognition, social interactions, etc.)

DISCRETE EMOTIONS

MEASUREMENT SCENARIO (PILOTS)

DISCRETE EMOTIONS DETECTION:

Using EMOTIVE on a daily / weekly / monthly basis, per user or immediate social network. This may help provide a basis for not only an approximate representation of a particular user's emotional profile, but their feelings and variability in emotional and affective experiences over different granularities of time, as well as the aggregate emotional / affective profile of the user's immediate social network.

Another use-case could involve the analysis of all emotions / affect over certain types of (coach encouraged) activities, and how these differ between various other types of activities. Finally, it would also be sensible to compare emotions measured using the tool(s) with respect to all the users, or a matched group of users.

DISCRETE EMOTIONS SELF-REPORT:

The use of discrete emotion survey-tools can be administered 6 times per day, at various frequencies, although keeping in mind subject fatigue, due to the length of particular survey-tools and direct nature of interaction required.

SENTIMENT VALENCE DETECTION

MEASUREMENT SCENARIO (PILOTS)

On a daily / weekly / monthly basis, per user or immediate social network. This may help provide a basis for not only an approximate representation of a particular user's emotional profile, but their feelings and variability in emotional and affective experiences over different granularities of time, as well as the aggregate emotional / affective profile of the user's immediate social network.

Another use-case could involve the analysis of all emotions / affect over certain types of (coach encouraged) activities, and how these differ between various other types of activities. Finally, it would also be sensible to compare emotions measured using the tool(s) with respect to all the users, or a matched group of users.

4.4 Social Behaviour

SOCIAL INTERACTION DETECTION

MEASUREMENT SCENARIO (PILOTS)

SCENARIO 1 (HIGHLY RECOMMENDED)

Requirements: a smart wristband to be worn and some BLE (Bluetooth Low Energy) tags to be deployed on the environment.

Users wake up and wear the wristband all the day long. The wristband emits and records signals (e.g., Bluetooth BLE messages) in order to detect proximity with other users wearing the wristband. The wristband uploads data collected periodically on the cloud.

If the wristband needs to be recharged, users recharge it every day (at night, before going to bed).

Primary users will receive The full wristband with all the sensors

Secondary users (e.g. relatives or friends or caregivers) will receive a reduced wristband for detecting the interactions with the primary users. The reduced wristband does not provide any sensing capability.

SCENARIO 2

Requirements: a wristband to be worn, a mobile application as a recording unit and some BLE tag (tiny sensors) to be deployed on the environment.

Users wear the wristband; they have to also carry the smartphone all day long. The wristband only emits signals, but it cannot record any data. The mobile application records the signals emitted by other wristband. The app also uploads periodically the data collected to the cloud.
If the wristband needs to be recharged, users have to recharge it daily together with the smartphone.
Primary users will receive the full wristband with all the sensors
Secondary users (e.g. relatives or friends or caregivers) will receive a reduced wristband for detecting the interactions with the primary users. The reduced wristband does not provide any sensing capability.

SCENARIO 2 IS PRONE TO ERRORS AND INACCURACIES:

Technical constraints related to the use of personal and heterogeneous smartphones
2 devices to be always worn (the wristband and the smartphone)
Perception of control from the users.

SOCIAL INTERACTION SELF-REPORT

MEASUREMENT SCENARIO (PILOTS)

Assessment performed by means of paper and pencil tests. Measured 6 times daily. Time-contingent (i.e., at pre-specified or random time points) or event-contingent (participants are asked to respond to these questions each time they are in an interaction) or combination of both

TOTAL NUMBER OF INTERACTIONS

MEASUREMENT SCENARIO (PILOTS)

Please refer to Social Interactions Detection and Social Interactions self-Report

INTERACTIONS DURATION DETECTION

MEASUREMENT SCENARIO (PILOTS)

Please refer to Social Interactions Detection

INTERACTION LOCATIONS DETECTION

MEASUREMENT SCENARIO (PILOTS)

The pilot site can be equipped with tag deployed in a number of point of interests. Point of interests are public and shared locations where users are free to interact. Examples are: living room, kitchen, gym etc. Tag deployed in such locations emit a signal so that user devices can record them. The number of the point of interests will depend on the pilot site and the available sensors.

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