MODULE 1

INTRODUCTION TO AGE-FRIENDLY AND INCLUSIVE ENVIRONMENTS

UNIT 3

BASIC PATHOPHYSIOLOGY OF AGEING

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DESIRE

DESIGN FOR ALL METHODS TO CREATE AGE-FRIENDLY HOUSING

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DESIRE will provide professionals in the building industry and home furnishings sector with the tools and skills to apply Design4All methods as an integral part of the design process, with the aim to create or adapt age friendly housing as a solution for the wellbeing, comfort and autonomy of the older adults or dependents at home.

The DESIRE training platform consists of six modules and 21 units.

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UNIT 3 – BASIC PATHOPHYSIOLOGY OF AGEING

This unit begins with an introduction to ageing as a process we all encounter. It goes on to cover demography and epidemiology of ageing and introduces the major determinants of ageing. In the final part of the unit focuses on explaining the basic pathophysiological mechanisms that describe the ageing process.

3.1 INTRODUCTION TO AGEING

IN A NUTSHELL

Ageing can be succinctly described as a multifactorial process in which an individual is influenced by various triggers throughout life. Therefore, both genetics and environmental factors play an important role in the biology of ageing. Internal and external factors, such as hormones, nervous system signals, or immune responses that help maintain homeostatic conditions, can influence the ageing process. Overall, genes and environmental factors enable growth, development and ageing.

3.1.1 Biology and theories of ageing

Chronological age is often used as a criterion for classification as an older adult. While this may seem straightforward, it is more complex in application. There are at least two reasons why age has often been set at about 65: retirement age and illness. In developed countries, the retirement age is about 65. However, there is no uniform retirement age across countries, and the usual retirement age varies by occupation (Holliday, 2006). It is undeniable that as we age, we become more prone to develop one of developing one or more chronic diseases (comorbidity). In older age, this is due to the breakdown of the maintenance function of the body, which is manifested in a gradual decline in biological and psychological functions that vary greatly from person to person (Bulterijs et al., 2015).

It is now a widely accepted notion that ageing is a multifactorial process, and several theories of ageing have attempted to explain it coherently (Vijg & Wei, 1995; Kirkwood & Austad, 2000). Biological theories of ageing are based on the belief that ageing or lifespan is part of the design of the organism and is distinct from disease because it occurs in any multicellular animal that reaches a certain size at reproductive maturity, occurs in all species after reproductive maturity, and has the same universal molecular aetiology, namely thermodynamic instability. Although the ageing process is clear and relatively well understood, false myths and stereotypes still circulate about it and misjudge the capabilities of older adults. Some of these myths and stereotypes are presented along with the true claims in Figure 1.3.1 to give readers a more vivid picture of how ageing actually affects people (Timiras, 2007).

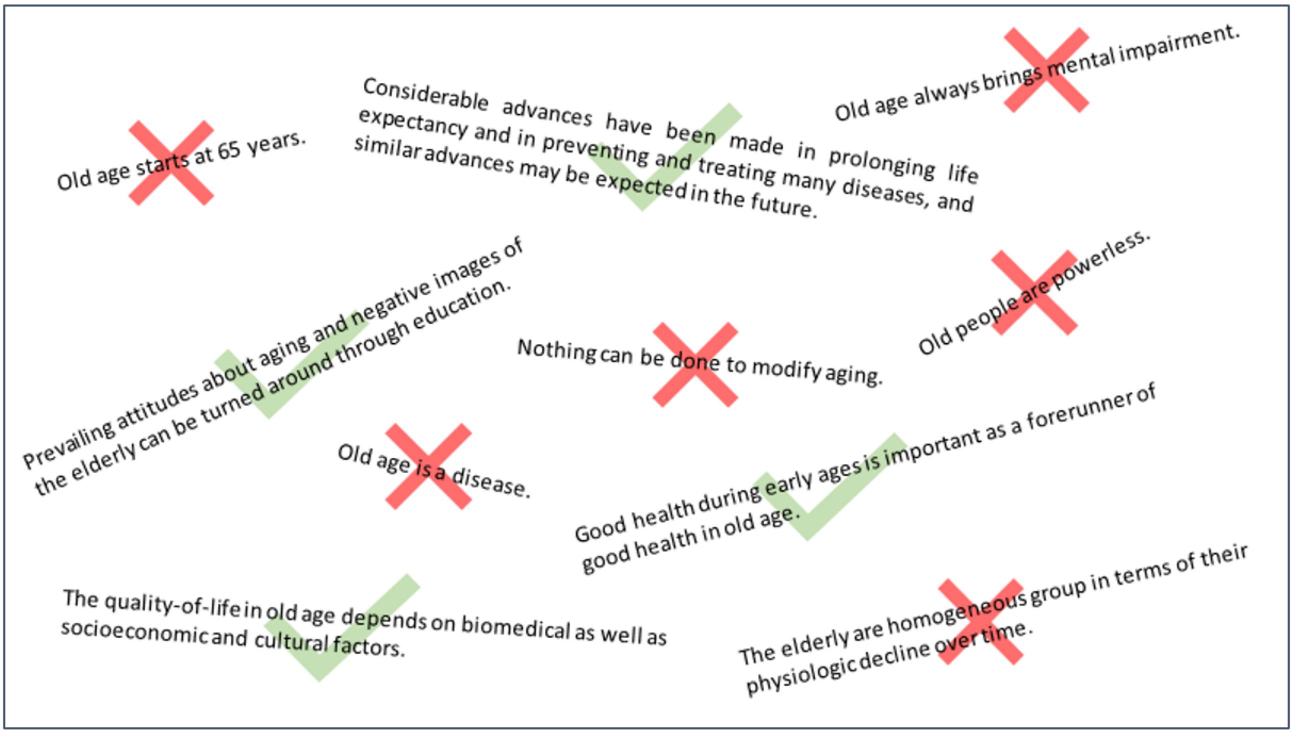

Figure 1.3.1 Myths and stereotypes about aging and older adults

One of the theories described by Darwin is the traditional theory of evolution, which holds that the design of today's organisms is the result of a gradually accumulative evolutionary process. This is essentially the premise of “survival of the fittest” which somehow did not fit with a concept of ageing. Subsequently, many theories were developed to correct Darwinian evolution, such as the theory of group selection, the theory of selfish genes, and the theory of evolvability. For example, the theory of evolvability states that organisms in general can develop characteristics that enhance their ability to evolve and adapt to external circumstances by altering the genetic design of subsequent generations. If ageing is a design trait, it could be advantageous if a species can regulate lifespan. For example, the lifespan of individual animals with the same genetic design could be adjusted to compensate for external conditions. Damage theories are another group of theories about ageing that have been propagated. These theories state that ageing is a consequence of wear and tear caused by damage to basic life processes that occur in accumulative microscopic steps, such as damage to chromosomes, accumulation of toxic byproducts, nuclear radiation, or the forces of entropy (Viña et al., 2007)

3.1.2 Epidemiology and demography of ageing

IN A NUTSHELL

In the 21st century, the European population is growing larger and older along with the rest of the world. In particular, the size and proportion of older adults is increasing significantly. As a result, the ratio of older to younger people is expected to change dramatically in the future. This brings with it the need to adapt lifestyles, including housing and living environments. Therefore, in order to achieve a good quality of life, it will be necessary to adapt buildings so that they are accessible to all people, especially the most vulnerable. To adapt it as effectively and efficiently as possible, it is required to higher awareness to the epidemiological and demographic characteristics of the elderly population.

The number of elderly people in the world has increased both in absolute and relative terms. The growth in numbers may be due to advances in medical science, which have improved survival rates for certain diseases, and due an increased birth rates. The ratio of the number of people born today to the number of people born before age 65 is critical to estimating the size of the workforce available to care for an elderly population (Marois et al., 2020). This ratio is declining, and the impact of this trend can be better represented in Figure 1.3.2, which shows the growth of the elderly population as a percentage of the total population in the United States (US).

THE ELDERLY POPULATION OF THE US: 1900–2050								
PERCENTAGE OF THE TOTAL POPULATION								
AGE (YEARS)	1900	1940	1960	1990	2010	2030	2050	CHANGE FROM 1900 TO 2050
65–74	2.9	4.8	6.1	7.3	4.3	12.0	10.5	+ 7.6
75–84	1.0	1.7	2.6	4.0	4.3	7.1	7.2	+ 6.2
85+	0.2	0.3	0.5	2.2	2.2	2.7	5.1	+ 4.9
65+	4.0	6.8	9.2	9.2	13.9	21.8	22.9	+ 18.9

Figure 1.3.2 Projection of population structure in the USA from 1900 to 2050

A similar phenomenon is observed in the European Union (EU), where the average age of the population is estimated to increase dramatically (see Figure 1.3.3). If we define older adults as those over the age of 65, they are estimated to make up 20.8 % of the estimated total population of 447.2 million in the 27 countries of the EU in 2021. However, by 2050, older adults are projected to represent 29.4 % of the total population in the EU. According to the World Health Organization (2015), the proportion of older adults living in good health has remained constant despite increases in average life expectancy, which may indicate that while people are living longer, a greater proportion of older adults are less healthy and consequently have a lower quality of life.

The gain in survival rates includes both active and dependent years. One of the major controversies in modern gerontological epidemiology is whether the gain in life expectancy is accompanied by a corresponding gain in dependency-free years. Although increased life expectancy may be associated with more disability, the overall effect is a pattern of decreasing disability. Moreover, not all disability is permanent. Some older people experience temporary episodes. Therefore, disability was used as the basis for defining quality of life. To this end, the concept of active life expectancy was transformed into a concept of quality-adjusted life years. According to this formulation, the goal of health care is to maximize the period of "healthy" years for the individual.

		AGE (YEARS)		
		> 65	≤ 75	≤ 80
EASTERN EUROPE	**2008**	14.3	6.0	3.0
	2020	17.3	6.9	4.3
	2040	24.4	12.6	7.8
	CHANGE	**+ 9.9**	**+ 6.6**	**+ 4.8**
WESTERN EUROPE	**2008**	17.8	8.5	4.9
	2020	20.9	10.1	6.2
	2040	28.1	15.0	9.3
	CHANGE	**+ 10.3**	**+ 7.5**	**+ 4.4**

Figure 1.3.3 Projection of the population structure in the EU from 2008 to 2040 in percentages

Although forecasts can vary with the future birth and death rates, they are likely to be reasonably accurate. By the year 2030, older population will have almost doubled and there will be as many people older than 75 years as there are today the ones who are older than 65 years. This demographic observation is calling for several urgent measures such as the redefinition of retirement age; encouragement of younger persons to invest in their health in order to avoid excessive dependency on public funds when they grow older; encourage volunteerism among older adults; provide professional services and change public programs to address the needs of an ageing society with emphasis on the living environment. As such "healthy" years could be increased using tools that successfully promotes active and healthy ageing and provides stimulating environment via the concepts of Universal Design (UD) and Design for All (D4All) based on which living environments are adapted and redesigned to meet the needs of older adults.

3.2 CHANGES IN BODY FUNCTION

IN A NUTSHELL

Since the body system structure is changing due to a natural process of ageing, everyday function of older adults becomes limited. This results in the fact that older adults have different needs in comparison to youth and adults. In order to preserve the satisfactory level of the lifestyle, living environment should be designed in a way to allow for living healthy and independent. Therefore, the professionals responsible for planning and building should be aware of older adult needs in living environments.

Ageing is a complex multifactorial process in which physiological changes usually underlie functional decline in later years. The body structure together with the body system function is changing due to a natural process. The most significant changes occur in body composition, musculoskeletal system, cardiovascular system, endocrine system and cognition that, all together can result in functional (dis)ability.

3.2.1 Changes in body composition

IN A NUTSHELL

As we age, body composition changes naturally meaning that there are significant alteartions in fat, muscle and bone mass. It is important to understand that these changes can affect health, physical function, and well-being. Although the general pattern of change is clear, a high degree of heterogeneity in body composition changes with age is observed (He et al., 2018).

Free fat mass is composed of muscle, organs, water, bone, and connective tissue. Muscle mass peaks in early adulthood, and a nonlinear decline in muscle in the upper and lower body is observed from about 45 years old. For bone mass, the peak is reached in men in their early 20s and in women in their mid-30s (Jackson et al., 2012; Nassis & Geladas, 2003). After that, the loss of bone mass is most noticeable in certain parts of the body, such as the hip, forearm, or spine. Unlike muscle and bone mass, fat mass increases in a curvilinear fashion with ageing (Baumgartner, 2000). These changes have significant implications for health and physical function. Therefore, interventions that prevent, attenuate, or even eliminate muscle and bone mass loss should be promoted (see Figure 1.3.8). As healthy lifestyle affects these changes in positive way, an environment that encourages physical activity may be a key strategy for maintaining healthy ageing.

3.2.2 Changes in musculoskeletal system

IN A NUTSHELL

Along with mass, the composition of muscles and bones changes as we age. Overall, the biological process of ageing systematically alters both the quantity and quality of skeletal muscle, resulting in a reduction in muscle strength and power capacity that, without preserving musculoskeletal function, could negatively affect the overall health of older adults. One of the effective means to help older adults maintain normal muscle function is physical activity, which is briefly introduced in this subsection.

At the end of puberty, skeletal muscle fibres develop and reach a normal size. At this time, an average person has about 12 % more type II fibres compared to type I fibres. With age, the size and number of muscle fibres decrease, which is most evident in type II fibres. Thus, the ratio between type II and type I fibres is altered in favour of type I fibres. Since these are slow-twitch fibres that are active during slow, prolonged movements and consist mainly of so-called antigravity muscles, the ability to generate power and immediate force is severely impaired in older adults. With ageing muscle mass is also severely reduced due to muscle fibre atrophy and muscle fibre loss (Wilkinson et al., 2018). In addition, higher amounts of intramuscular fat observed in older adults (see Figure 1.3.4) are associated with impaired mechanical properties of muscles (Pinel et al., 2021).

Two systems, namely the nervous system and the skeletal muscle system, are responsible for most age-related changes in muscle strength as the force in the muscle is generated by muscle contraction, initiated by the neuromuscular activation process. It can be described as a process by which the nervous system recruits and encodes the rate of muscle contraction (Frontera & Ochala, 2015). It has been shown that also the nervous activation capacity decreases during the ageing process. Furthermore, a decrease in motor control is observed with age due to qualitative and quantitative changes in the brain motor cortex and spinal cord (Delbono, 2003). In addition to changes in the nervous system and muscle typology, the architecture of skeletal muscle is also affected by the ageing process. In addition to the size and anatomical structure of skeletal muscle, a number of changes in skeletal muscle morphology affect its ability to contract and generate force. Presumably, older adults have shorter muscle fascicles, smaller pennation angles, and lower muscle density. Together with that a reduction in tendon stiffness is observed in older adults, which further affects the ability to produce force (Scanlon et al., 2014). Along with these anatomical and morphological characteristics of muscle, the mechanics of muscle contraction changes resulting in decreased strength and power.

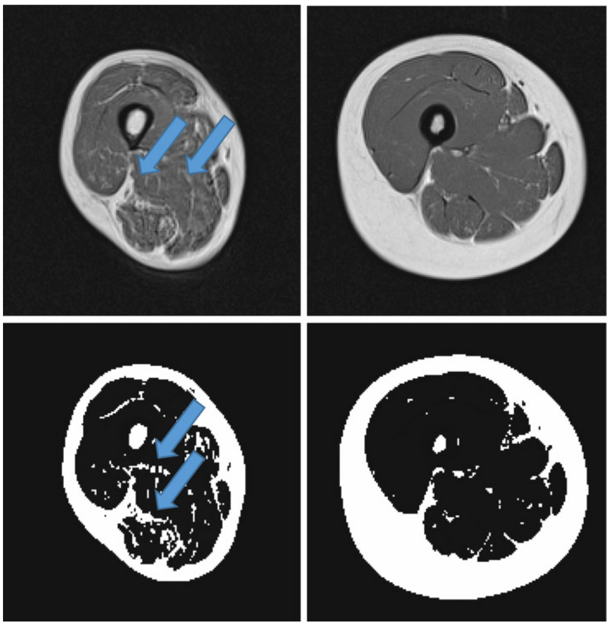

Figure 1.3.4 Magnetic resonance images showing the thigh muscles, from women aged 71 years (left upper and lower subfigures) and 21 years (right upper and lower subfigures) (Yoshiko et al., 2017). Increased amount of intramuscular fat is observed on two right figures.

Due to the many changes in the muscle and nervous system that accompany ageing, a decrease in muscle strength can have a significant impact on mobility in the elderly. The living environment of the elderly should therefore be designed to reduce the decline in function of muscles and nerves. Among the most effective means to counteract this decline are strength and power exercises, which should be integrated into the daily lives of older adults. This could preferably be accomplished by providing a environment that allows for the safe performance of resistance exercises (see Figure 1.3.5) for the upper and lower extremities.

SQUATS	RAISING FROM THE CHAIR	
BICEPS CURLS	LIFTING OBJECTS	
LUNGES	PICKING UP AN OBJECT FROM THE GROUND	
CHEST PRESSES	PUSHING LARGE OBJECTS SUCH AS DOORS	
FARMERS WALK EXERCISE	CARRYING SHOPPING BAGS	
FINE MOTOR SKILLS EXERCISES	UNLOCKING DOORS, HOLDING CUTLERY	

Figure 1.3.5 Association between strength exercises and daily functions

3.2.3 Changes in cardiovascular system

IN A NUTSHELL

The cardiovascular system changes with age and, as a result, changes in cardiovascular physiology occur. At some point these changes affect everyone, but the extent of the changes is very individual. Cardiac structure changes in such a way that the heart becomes larger but responds less and with a delay to various stimuli, resulting in less functional capacity. In addition, there are changes in the blood vessels and reflex control of the cardiovascular system that further impair cardiovascular function.

Cardiac hypertrophy is normally observed with healthy ageing. Most often left ventricle wall and to lesser extent left atrium are thickening. On the molecular level, myocytes (i.e., the muscle cell) number may decline due to increased cell death and reduced regenerative ability of the stem cells. Additionally, the vessels of older adults are less elastic resulting in the increase of peripheral resistance. This cause that the existing myocytes must grow in order to be capable of providing sufficient cardiac mechanical work (Pugh & Wei, 2001). As also number of cells in the sinus node pacemaker decreases ageing heart is also characterized by changes which affecting rhythm-generating system, making a heart more susceptible to both rhythm and conduction disorders (Pugh & Wei, 2001). Among structural changes in the heart and vessels, blood volume is also reduced in older adults and anemia can occur (Stauder et al., 2018). Suma sumarum cardiovascular response tolerance to physical stress is altered whit age which significantly effects the life of older adults.

Most age-related changes in cardiovascular function do not alter the way the heart works at rest, with the exception of increased blood pressure. These changes become more apparent when older adults exercise or play sports, which represents a kind of physical stress. The most notable are changes in heart rate, namely maximum heart rate appears to be reduced in both men and women. Meanwhile resting heart rate is not affected by age (Lakatta, 2015). When workload (or physical stress) increases, the heart of older adults is unable to increase its stroke volume to a sufficient level. Therefore, under overload conditions, heart failure may manifest. The structural changes mentioned earlier, along with changes in vascular tone, result in increased blood pressure (Pugh & Wei, 2001). Although most of these changes in the heart typically accompany the normal ageing process and cannot be avoided, some or most of them can be significantly reduced and delayed by a healthy lifestyle. Among other things, the cardiovascular system of older people benefits most from endurance exercise such as walking.

3.2.4 Endocrine system changes

The endocrine system is affected by age in various ways. In the course of normal ageing, a progressive loss of secondary cell mass of the endocrine glands, a decrease in the rate of hormone degradation, changes in the sensitivity of end organs and target tissues to hormones together with changes in the modulation of the feedback mechanism of the endocrine glands (Hackney & Lane, 2015).

As these structural changes affect the organs that are supported by the endocrine system it is only natural that the levels of sex steroid hormones decrease, adrenal gland function changes, and the growth hormone system changes. The body system of older adults is therefore changed, leading to menopause, andropause, adrenopause and somatopause, in both men and women (see Figure 1.3.6).

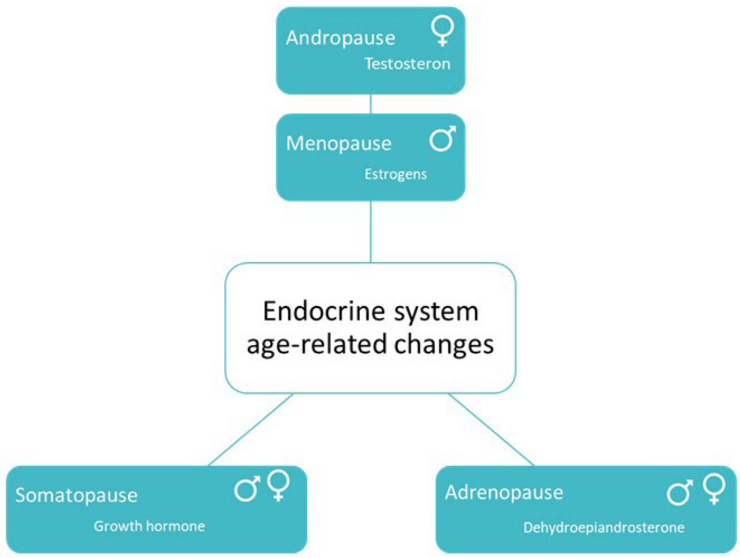

Figure 1.3.6 Interchange between menopause, andropause, adrenopause and somatopause in older adults

The decrease in estrogen levels, one of the major sex hormones in women, is due to the progressive loss of ovarian follicles during ageing. This can also be referred to menopause (Broekmans et al, 2009). A similar process is observed in men, the gradual decline of testosterone with ageing and is described under the term andropause. As a result of the deficiency of these two hormones, their role as physiological anabolic-androgenic mediators is diminished, leading to sarcopenia and osteoporosis in older adults. The term adrenopause refers specifically to adrenal androgenic hormones such as dehydroepiandrosterone and its sulfate conjugate form, whereas somatopause refers to a significant decline in growth hormone with age in both sexes (Toogood et al., 1996). In addition to these important changes in the endocrine system, thyroid hormone clearance also decreases with age and thyroid hormone secretion is reduced (Gauthier et al., 2020). Overall, these reductions and changes in selected hormones and endocrine glands function have far-reaching and varied consequences, which are reflected primarily in decreased health and quality of life.

3.2.5 Functional (dis)ability due to ageing

IN A NUTSHELL

Because age negatively affects some body systems that are critical to maintaining normal daily living functions, some older adults tend to have problems with vital needs, such as problems with locomotion (i.e., walking) and performing daily tasks. To counteract these changes, exercise and physical activity have been identified as effective ways to maintain functional capacity and health in older adults.

Maintaining balance while walking, standing, and moving depends on three primary systems that contribute to good posture, namely the sensory system, the motor system, and the cognitive system (see Figure 1.3.7 for details) (Shumway-Cook & Woollacott, 2012). As we age, it is commonly observed that structural changes in the eye itself lead to impaired vision (Owsley, 2016), such as visual acuity, contrast sensitivity, and altered depth perception (Bell et al., 1972). In addition to theses, sensory function changes, older adults have fewer proprioceptors in their muscles (Henry & Baudry, 2019), and this resulting in slower reflexes. As early as age 30, the function of the vestibular system begins to decline, leading to decreased sensitivity to head movements (Anson & Jeka, 2016). The ability to maintain the balance is therefore impaired.

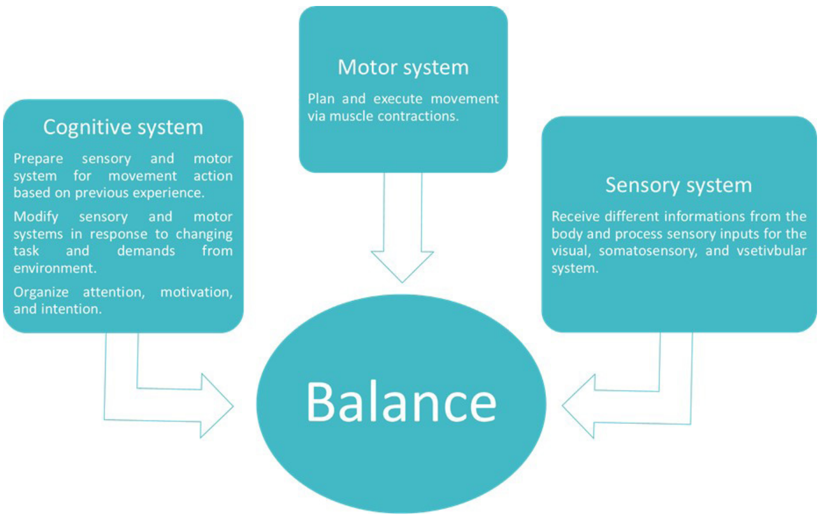

Figure 1.3.7 Three body systems that significantly affect balance and postural stability (Shumway-Cook & Woollacott, 2012)

With increasing age, not only changes in voluntary motor control, but also in automatic motor control of movements are observed. Loss of large motor neurons in the motor cortex and other areas of the motor system (Oliviero et al., 2006), along with a decrease in neurotransmitters such as dopamine, leads to impaired movement patterns in otherwise healthy older adults (Morgan, 1987). In addition, decreased lower limb mobility is observed in older adults, which significantly affects their posture and the ability to exert the movement with whole range of motion.

The changes in walking are most notable, as it is most common mode of locomotion. Older adults are walking slowly due to decrease in stride length and walking cadence, and also due to increased foot contact time with the ground (Shumway-Cook & Woollacott, 2012). Other age-related changes that affect gait speed and quality, are linked to some other characteristics of gait. The decrease in the ability to maintain balance during walking leads to an increased rate of falls in older adults (Kannus et al., 1999).

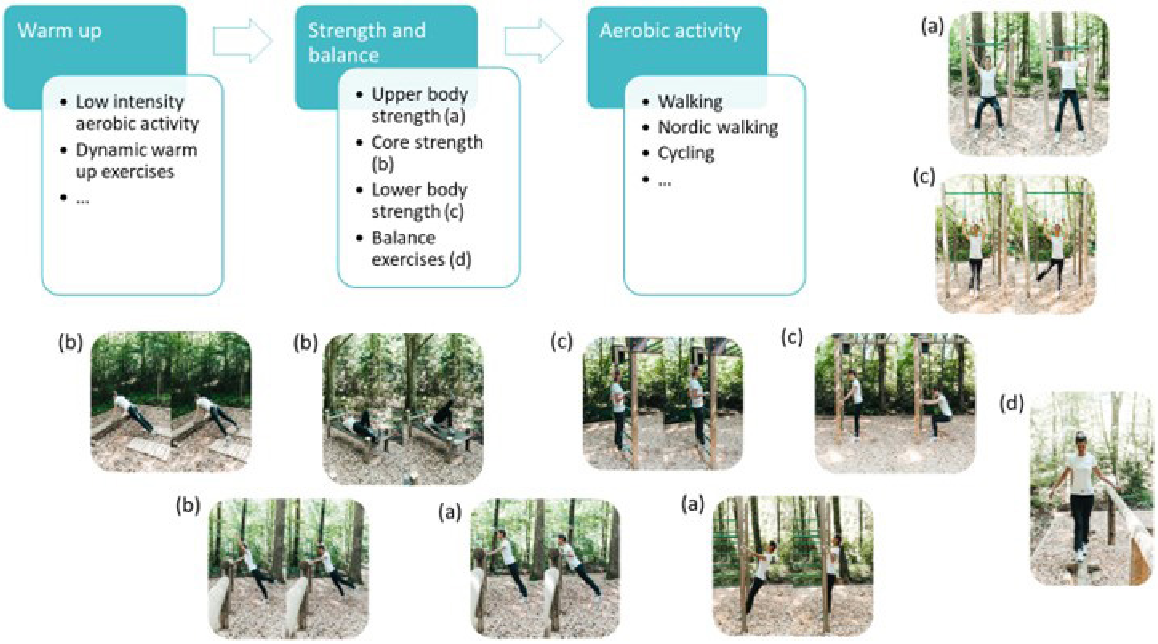

Figure 1.3.8 An example of exercises suitable to improve strength, endurance and balance of older adults

With the purpose to counteract against these alterations in movement ability physical activity programs have been shown to be effective in helping older adults to maintain walking function, balance and mobility and also reduce their overall risk of falls. Therefore, older adults should be encouraged and provided with the opportunity to exercise. A stimulating living environment could increase physical activity adherence of older adults. One of such examples could be outdoor environments designed purposely for exercise and physical activity (e.g., outdoor fitness). Ideally, the design of such places should not fit only to well-trained users but should be designed "for all". To demonstrate such good example in Figure 1.3.8 the exercises plan suitable for older adults from one of many local trail-run tracks in Slovenia is presented. Using the nature and simplistic training tools made of natural materials to perform specifical physical exercises that improve strength, power, balance, and general function is effective strategy to preserve health and mobility of older adults.

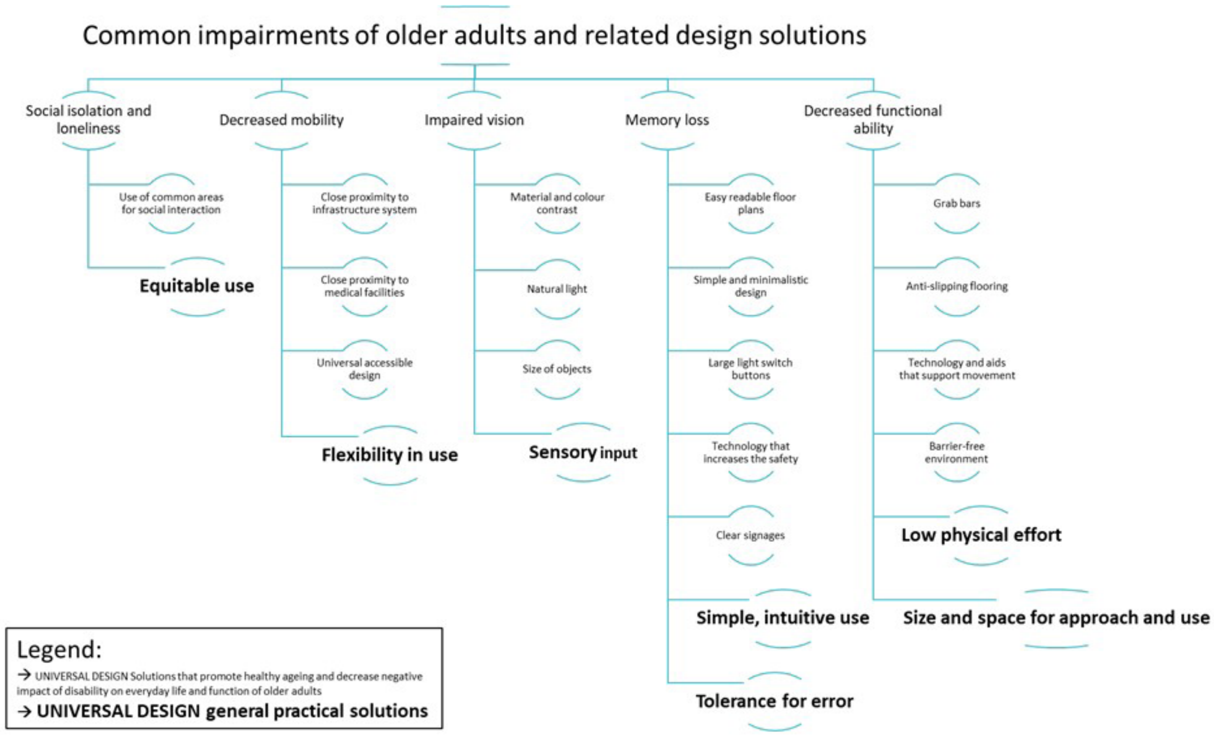

Figure 1.3.9 Practical guidelines on how to cope with important age-related changes when designing the living environment of older adults based on the Universal Design

By being aware of the social, cognitive and potential functional limitations of older adults, the living environment can be modified to meet their needs. As represented in Figure 1.3.9, safe and healthy ageing can be ensured through UD and planning of the environment. The knowledge of the physiology of ageing could contribute significantly to understanding the topic, interested readers are therefore invited to read Module 2 Ageing process and design on the interaction between the physiology of ageing, the living environment, and health.

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