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PhD Thesis

Psycho-physiological parameters influencing healthy aging in elderly women

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To my family

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List of Abbreviations

ACC	**A**ccelerometry
AH	**A**ctiheart
BM	**B**ody **M**ass
BMI	**B**ody **M**ass **I**ndex
BP	**B**odily **P**ain
CoM	**C**entre of **M**ass
CRF	**C**ardiorespiratory **F**itness
CV	**C**oefficient of **V**ariation
CVI	**C**oefficient of **V**ariation **I**ndex
CVD	**C**ardiovascular **D**isease Risk Factors
CW	**C**ost of **W**alking
EC	**E**nergy **C**ost
FeO_2	**F**raction of **O**xygen in Expired Air
$FeCO_2$	**F**raction of **C**arbon **D**ioxine in **E**xpired **A**ir
GC	**G**ait **C**ycle
GH	**G**eneral **H**ealth
GV	**G**ait **V**ariability
HC	**H**ip **C**ircumference
HR	**H**eart **R**ate
HR_{max}	**M**aximal **H**eart **R**ate
HRPF	**H**ealth-**R**elated **P**hysical **F**itness
HRPFI	**H**ealth-**R**elated **P**hysical **F**itness **I**ndex
HRQoL	**H**ealth-**R**elated **Q**uality of **L**ife
iMVC	**I**sometric **M**aximal **V**oluntary **C**ontraction
$iMVC_{BW}$	**I**sometric **M**aximal **V**oluntary **C**ontraction correct for total body weight
IPAQ	**I**nternational **P**hysical **A**ctivity **Q**uestionnaire
LPA	**L**ight **P**hysical **A**ctivity
MCS	**M**ental **C**omponent **S**ummary
MH	**M**ental **H**ealth
MPA	**M**oderate **P**hysical **A**ctivity
MVPA	**M**oderate and **V**igorous **P**hysical **A**ctivity

$MVPA_{10}$	**M**oderate and **V**igorous **P**hysical **A**ctivity in 10-min bouts
$MVPA_{all}$	Overall **M**oderate and **V**igorous **P**hysical **A**ctivity Total
Net_{CW}	**E**nergy **C**ost of **W**alking
OA	**O**lder **A**dults
PA	**P**hysical **A**ctivity
PAL	**P**hysical **A**ctivity **L**evel
PC	**P**rincipal **C**omponent
PCS	**P**hysical **C**omponent **S**ummary
PF	**P**hysical **F**unctioning
PWS	**P**referred **W**alking **S**peed
RE	**R**ole-**E**motional
RER	**R**espiratory **E**xchange **R**atio
RMR	**R**esting **M**etabolic **R**ate
RoM	**R**ange of **M**otion
RP	**R**ole-**P**hysical
SED	**S**edentary
SF	**S**ocial **F**unctioning
SHR	**S**leeping **H**eart **R**ate
SMR	**S**tanding **M**etabolic **R**ate
VE	**V**entilation
$\dot{V}O2$	**O**xygen **C**onsumption
$\dot{V}CO_2$	**C**arbon **P**roduction
$\dot{V}O_{2max}$	**M**aximal **O**xygen **C**onsumption
$\dot{V}O_{2abs}$	**M**aximal **O**xygen **C**onsumption Relative to Body Mass
$\dot{V}O_{2peak}$	**P**eak **O**xygen **U**ptake
$\dot{V}O_{2rel}$	**M**aximal **O**xygen **C**onsumption **A**bsolute **V**alues
VPA	**V**igorous **P**hysical **A**ctivity
VT	**V**itality
WC	**W**aist **C**ircumference
WHR	**W**aist to **H**ip **R**atio
WHtR	**W**aist to **H**eight **R**atio
YA	**Y**oung **A**dults

CONTENTS

Abstract

This thesis describes the results obtained from different studies evaluating treadmill walking in younger and older women, in order to study the influence of gait stability, evaluated through gait variability, on physical activity level maintained in daily living and the influence of energy cost of walking and health-related physical fitness qualities on gait speed and gait variability. Moreover, the manuscript describes the different effects of physical activity levels calculated as overall physical activity or accumulated in bouts of at least 10 min and physical fitness on health related quality of life in the same population.

21 young adults (YA: age 22.6±2.9 yrs; BMI 22.5±2.6 kg·m^{-2}) and 21 older adults (OA: age 68.3±3.3 yrs; BMI 26.1±3 kg·m^{-2}) were recruited. A kinematic analysis was performed with an optoelectronic system to calculate gait variability during treadmill walking at different speeds. Simultaneously, the net cost of walking was analysed with indirect calorimetry and calculated subtracting resting metabolic rate measured during standing from gross metabolic rate. To provide an accurate estimation of physical activity level during free-living activities, the subjects worn an activity monitor for almost 7 complete and consecutive days, inferring time spent in sedentary, light, moderate or vigorous physical activity. Skinfold thickness was measured to obtain body fat. Cardiorespiratory fitness was determined by indirect calorimetry using a maximal treadmill test. Isometric maximal voluntary contraction was evaluated on a horizontal leg press, and by hand-grip strength. Flexibility was assessed by V Sit & Reach test. Gait speed, defined as the preferred walking speed of the subject, was measured as the time taken to walk the middle 10m of 14m. To assess maximal isometric strength, they performed a hand-grip strength test. Health-related quality of life was measured with the Short-Form 36 Health Status Survey (v2) that provided the physical and the mental component summary score.

The main findings of this study were that: (i) a good gait stability and a high preferred walking speed seem to be able to ensure elevated levels of physical activity in healthy older women; (ii) the energy cost of walking was influenced by the speed but did not influence gait speed at any of the analysed speeds; (iii) a significant association was found only between hand-grip strength and gait stability; (iv) there was a positive relationship between the level of cardiorespiratory fitness and the physical component summary of health-related quality of life; (v) there was a positive relationship between the level of physical activity (both overall physical activity and accumulated in bouts of at least 10

min) and physical functioning; (vi) there was a negative relationship between sedentary time and vitality and role-emotional; (vii) physical activity and physical fitness did not influence the mental component summary.

The present results showed that in healthy elderly women, a good gait stability and a high preferred walking speed seem to be able to ensure elevated level of PA.-Moreover, the net cost of walking is not affected by age allowing a high preferred walking speed and an elevated level of physical activity. Even if almost all the population met current physical activity recommendations, accumulating a minimum of 30 min of daily moderate physical activity in bouts of 10 min or more, the significant difference between $MVPA_{all}$ and $MVPA_{10}$ has to be taken into consideration when tailored intervention for the elderly population has to be provided.

Keywords: successful aging, gait stability, physical activity, physical fitness, quality of life.

1. AGING

According to World Health Organization (WHO, 2010), most of the developed world countries have accepted the chronological age of 65 years as an “arbitrary” definition of “elderly” or older person.

Aging, physiologically, is not the same for the entire population: often individuals with the same age can dramatically differ in their response to exercise (ACSM, 2014). Indeed, older age can be considered as a disorder of the self-regulation system in an organism and as a destructive/detrimental process, in which adaptive features are decreasing while the chance of death is increasing (Tosato et al., 2007).

Globally, the population is ageing rapidly. Between 2015 and 2050, the proportion of the world’s population over 60 years will nearly double, passing from 12% to 22%. Older adults make important contributions to society as family members, volunteers and as active participants in the workforce. While most have good mental health, many older adults are at risk of developing mental or neurological disorders, substance abuse, as well as other health conditions such as diabetes, hearing loss and osteoarthritis. Furthermore, as people age, they are more likely to experience several concurrent comorbidities (United Nations, 2015), with significant clinical conditions or physiological limits, affecting both their ability to move independently and their level of physical activity.

According to the 2011 Italian Census, the percentage of the population aged 65 and above increased from 18.7% (more than 10,645,000 people) in 2001 to 20.8% in 2011 (more than 12 million people). The increase was also noticeable for older age groups: the 75-year-old population has risen from 8.4% in 2001 (about 5 million people) to 10.4% in 2011 (6 million people). Even the "oldest old", or ultra-85-year-olds, have increased their share of the total resident population (from 2.2% in 2001 to 2.8% in 2011) (ISTAT, 2011).

Aging is physiological and inevitable, but since the mean age of the population tends to increase, it is crucial to tackle this process in the best possible way. That is, trying to maintain a good quality of life, and to ensure a high level of independence. For example, it is well known that intense aerobic exercise activity slows down aging, keeping the individual healthy. That's why it is important to promote and teach physical activity properly.

In 2065, the resident population in Italy will be 61.3 million. The population is aging gradually: the mean age is anticipated to increase from 43.5 years in 2011 to a maximum of 49.8 years in 2059. Following the year 2059, it is expected that that the average age will stabilize to 49.7 years. This is indicative of a supposed conclusion of the aging process. The increase in the number of elderly people is particularly accentuated: the ultra-65-year-old, now 20.3% of the total population, will increase until 2043, when they will exceed 32%. After that year, however, the amount will consolidate around 32/33%, with a maximum of 33.2% in 2056 (ISTAT, 2011).

Many scientists have tried to estimate the proportions of the sedentary life-style amongst the elderly: for example, the Italian cardiovascular epidemiological observatory conducted a survey between the years 2008 and 2012, and calculated that in the elderly population between 75 and 79 years the prevalence of physical inactivity over time is high in both genders, but especially in women: among them 53.3% follow a sedentary lifestyle compared to 28.7% in men (Progetto Cuore, 2008/2012). There are statistically significant differences in the interregional comparison, with lower physical activity levels among older people in the southern regions: the most active elderly are residents in Valle d'Aosta (average score of 129), Friuli Venezia Giulia (112), whereas the least active are residents in Campania (73), Sicily and Molise (76) (Passi d'Argento, 2012).

1.1 UNDERSTANDING HUMAN AGING

The physiological parameters and the performance of an individual tend to improve starting infancy, until reaching to an optimum state between adolescence and the age of 30. From then on, functional capabilities decrease, they undergo a deterioration that varies at all ages according to lifestyle and genetic characteristics (McArdle et al., 2015). It is also possible to state that the biological age does not necessarily correspond to the chronological age. It is also known that biological aging is caused by an accumulation of injuries in passing time in the tissues and cells of the body; more specifically, every human being needs to produce energy, especially through oxidative phosphorylation of metabolites from food. This causes the production of toxic radicals of oxygen or free radicals (ROS), which damage their membrane, proteins and DNA. This is why cells are exposed to oxidative stress and undergo a progressive destruction of DNA, leading to immune system senescence (Chodzko-Zajko, 2014). Aging involves many changes in the body and mind that are most visible in the elderly.

First, men and women reach the highest levels of strength between ages 20 and 40, when muscle cross-sectional area is largest. From then onwards, the concentric force of most muscle groups decreases, although in women the decrease begins later. Muscles of older adults act with less force, and show a downward shift in their force-velocity relationship. Numerous studies have shown a decrease in both the number and the size of muscle fibers in the elderly. The elderly person has less strength and suffers from the age-associated sarcopenia: it is amplified/enhanced by the reduction of physical activity, and histologically it is seen as a progressive reduction in the transverse muscle area. The first cause of muscle strength reduction between the ages of 25 and 80 years is the reduction of 40/50% of muscle mass, due to muscle fiber atrophy and loss of motor units. Additionally, the "muscle quality" is also negatively affected by the increase of intra muscular and sub cutaneous fat. This may be partially responsible for the drop in specific force and correlated with a higher risk of developing metabolic diseases.

Humans tend to gain fat with age and over the years body fat content increases, being redistributed from periphery to the body's center, while fat-free mass decreases (Chodzko-Zajko et al., 2009). This is largely attributed to three factors: diet, physical inactivity, and reduced physiological ability to mobilize fat stores.

Aging also affects the central nervous system: the effects of time are highlighted by a decrease in neuromuscular performance, due to a 40% reduction in spinal cord axons and a 10% decrease in nerve conduction velocity.

Even cardiovascular function and aerobic capacity change with age, in particular oxygen consumption ($\dot{V}O_{2max}$) decreases annually by 0.4/0.5 $mlO_2 \cdot kg^{-1} \cdot min^{1}$ in adult women and men. It also decreases twice as fast in sedentary subjects in respect to active individuals. There are other factors besides the level of physical activity that affect the decrease in $\dot{V}O_{2max}$, such as hereditariness which causes an increase in fat mass over muscle mass. The decrease in aerobic power, related to aging, is influenced by decreases in central and peripheral functions. The cardiovascular function declines, but regular aerobic exercise is associated to a decreased risk of cardiovascular disease in middle-aged and older adults (Kenney et al., 2012).

Aging is also accompanied by a reduction of peripheral blood flow to the muscles, due to the decrease in muscular capillaries. Moreover, advanced age also involves changes in the endocrine function. Approximately 40% of individuals between the ages of 65 and 75 years and 50% of the elderly with more than 80 years of age present a glucose intolerance, causing one of the most common diseases: type 2 diabetes.

There is also evidence that changes in muscle strength, body composition, and age-related bone mass are also related to hormonal changes. The last two changes concern body composition and bone mass. As for body composition, cross sectional studies show that after 18 years of age, both men and women progressively increase their body weight and fat mass, whereas from this moment onwards lean body mass decreases as fat increases. For the latter, it is crucial to talk about osteoporosis, a major problem for women in menopause. It is a disease that causes a loss of bone mass, as resorption prevails and the bone becomes porous, less compact and more susceptible to primary fractures. Bone mass may decrease by 30% to 50% in people aged 60 years (McArdle et al., 2015).

Aging is also associated with a progressive decline in perception, motor behavior, cognitive and mnemonic functions. Advanced age amplifies susceptibility to chronic conditions and disabilities, and this decreases the quality of life (Chodzko-Zajko, 2014).

Throughout the years there have been improvements that help people to live longer: in particular disease prevention, better sanitation, more effective treatment of age-related diseases, improved nutrition and health care (Lunenfeld and Stratton, 2013). Currently, the goal of research is to increase the quality of life in elderly people and not only to extend life but also to improve it. Thirty percent of all deaths from heart disease, cancer and diabetes are due to physical inactivity. Quality of life and independent living improve by changing the lifestyle and consequently cardiovascular and functional capacity improves and reduces mortality (Lunenfeld and Stratton, 2013; McArdle et al., 2015).

With advancing age, aerobic and resistance training are important to maintain cognitive and cerebral health: an effect produced, in part, by vascular-mediated mechanisms such as increases in brain perfusion, and the ability of cerebral blood vessels to respond to blood flow demands (Hayes et al., 2014).

The greatest health benefits derive from strategies that promote regular physical activity throughout one’s lifetimes, as a 30-minute daily walk reduces the risk of a cognitive decline. At any age, behavioral changes, becoming more physically active, quitting cigarette smoking, and controlling body weight and blood pressure act independently to delay all-cause mortality and aging effects, caused by diseases and environmental factors. (McArdle et al., 2015).

Older people face special physical and mental health challenges, which need to be recognized (United Nations, 2015). With advancing age, structural and functional deterioration occurs in most physiological systems, even in the absence of a discernible disease (Chodzko-Zajko et al., 2009). These age-related physiological changes can influence the activities of daily living and the preservation of physical independence in older adults; for example, maximal aerobic capacity and strength decline with aging ("Sarcopenia").

Many changes occur with aging, but despite this it is possible to counteract them practicing physical exercise in order to slow down aging: trying to maintain functional capabilities and a higher lifestyle, ensuring greater independence for which it is not simply "aging" but a "successful aging".

1.2 SUCCESSFUL AGING

Aging, as described above, is accompanied by an inevitable structural and functional decline, although the extent and rate may vary. Today, successful aging means diverting from the common aging process, in order to postpone or minimize the consequences that it implies. For example, practicing physical activity seems to be one of the few lifestyle modifications that can affect the physiological system and the risk factors for illnesses. It is associated with better mental health and better social integration (Chodzko-Zajko, 2014).

However, finding a universal definition of successful aging is not easy because of the complexity of the aging process and the social changes occurring in the context of different cultures and norms. The concept of successful aging is often associated with the concept of "wellness", that is "a state of physical, psychic, social welfare and not just absence of illness". In turn, it is simply associated with the term "health", or alternatively the concept of being in good physical health. Different interpretations have led to a conceptual and terminological change from "successful aging" to "healthy aging", "aging well", "harmonious aging", "robust aging", "optimum aging", "positive aging", "productive aging" and "active aging". Successful aging can be reflected by two perspectives: one examines the concept of successful aging as a state of being at a given moment. For example, Rowe and Khan (1997) argue that they have adopted a biomedical approach and objective measures, referring to successful aging as a positive end to normal aging. The other perspective looks at successful aging as a process, and how a subject adapts to the process of aging itself. Baltes and Baltes (1990) show it as a process that includes 3 components: selection, optimization, compensation. Ultimately, we can state that successful aging is a state of well-being at old age that comprises physical, mental and social features.

Interviews have been conducted to understand what elderly people perceive to be a good state at an old age. Results show that, often, the absence of dementia only is seen as an important component for successful aging. Respondents show little interest for total absence of disease, while focusing much more on overall health, functional abilities and cognitive abilities. For the older people, to live without pain, and to be able to perform the activities of daily living, is much more important than living in the absence of illness. This is because it implies maintaining a level of independence, such as living alone in their own home and not in an institution; having in their eyes an end to a "successful aging" corresponds to a sudden and painless death (Nosraty et al., 2015).

Another term is “health-span”, the total number of years a person remains in excellent health; this addresses areas beyond age-related diseases and prevention, referring to maintenance of improved physiologic function and physical fitness. For elderly people, the primary goal is vitality, on the contrary older adults fear to suffer from a decrease in muscular strength, cardiorespiratory function, poor joint range of motion, as well as sleep disturbances, relating directly to functional limitations regardless of disease status. Four components establish a successful aging: physical health, spirituality, emotional and educational health, and social satisfaction. To achieve this state of well-being, the physical, cognitive, and interpersonal relationships must be valued.

1.3 PHYSICAL ACTIVITY OPTIONS FOR HEALTHY OLDER ADULTS

Increasing age is associated with an augmented risk of chronic disease, such as cardiovascular diseases or atherosclerosis. Physical activity (PA) significantly reduces this risk, mitigating the age-related biological changes and their associated effect on health and well-being, preserving functional capacity and improving life expectancy (Chodzko-Zajko, 2014). Atherosclerosis is a multifactorial degenerative disease affecting large- and medium-sized caliber arteries. The more a subject is sedentary and inactive, the greater is the risk of atherosclerosis. Morris et al. (1953) experiment demonstrated an impressive link between the level of physical activity in certain works and the risk reduction of coronary heart disease (McArdle et al., 2015).

Therefore, it can be stated that physical activity can reduce and delay the effects of aging. The benefit derived from it is not only the increase in life expectancy, but also the prevention of premature mortality by improving the quality of life and maintaining a high threshold of independence.

Physical activity refers to body movement that is produced by the contraction of skeletal muscles, that increases energy expenditure (ACSM, 2014). Individuals age differently and adapt variously to the same exercise program: this wide diversity depends on the combination of the genetics and the lifestyle of the individual. Three features are important for longevity: practicing regular physical activity, maintaining a good social network and maintaining a positive mentality. It can be stated that regular physical exercise increases the average life expectancy, through the influence it has on the development of chronic illnesses, by mitigating the changes associated with aging and ultimately by maintaining functional capacities (Chodzko-Zajko, 2014). First of all, physical activity can slow down the biological degeneration of neuromuscular functions. In fact, it was demonstrated that older people who remain active for 20 years or more show a reaction rate equal to or greater than that of inactive young adults (Bherer et al., 2013). Another ability that can be maintained is the aerobic capacity, or how much a person can carry and consume oxygen. Practicing aerobic exercise means increasing $\dot{V}O_{2max}$ and aerobic power, and results in a decrease in oxidative stress.

The substantial evidence that physical activity reduces the risk of falls and injuries from falls is particularly important to older adults, preventing or mitigating functional limitations. It is an effective therapy for many chronic diseases (Nelson et al., 2007). Health promotion associations include exercise in their general recommendations (Haskell et al., 2007), as a fundamental lifestyle component.

Older adults that practice regular physical activity have benefits that continue to occur throughout life. Therefore, promoting exercise is even more important because elderly are the least physically active people. Furthermore, physical activity is associated with a decrease of depression and anxiety.

There are many techniques for the assessment of physical activity, ranging from behavioral observation and self-report to motion sensors. Elderly are generally less physically active than younger population (Chodzko-Zajko, 2014). Indeed, young adults spend on average 9% of their active time on high intensity activities, while the corresponding percentage among the elderly was found to be 4% (Westerterp, 2013). A decrease of physical activity with increasing age and an increase of physical activity with exercise training affect body composition, and to a lesser extent, body weight (Westerterp, 2013).

The most popular types of physical activities among older people are always of low intensity (walking, gardening, golf, low impact aerobic activities, dancing, Tai-chi). Advancing age is associated with a decline in physical activity volume and intensity, and for healthy aging it is essential to include aerobic activity and muscle-strengthening activity.

Physical activity intervention, where walking is the primary mode of exercise, have shown a benefit for treating gross functional deficits in the aged. However, the role of a reduced or an increased habitual walking activity in attenuating the changes in ambulatory mechanics associated with aging, is unclear. Physical activity is a modifiable risk factor for the decline in musculoskeletal and cardiovascular fitness, and thus it may be paramount to reduce the risk of gait deficits in the aging population. Many studies have shown that physical activity interventions may result in modest improvements in strength, balance, and gait performance. The reported changes in gait and physical function might be attributable, at least in part, to this decline in physical activity with age (Boyer et al., 2012).

Although physical activity cannot fully counteract the age-related gain in fat mass, in active men and women the shift towards fat stores lessens with aging, which is more advantageous for reducing the risk of cardiovascular and metabolic diseases (Kenney et al., 2012).

WHO (2010) has defined guidelines for the elderly population, in order to improve cardio-respiratory and muscular fitness, bone and functional health, reduce the risk factors, depression and cognitive decline.

1. Older adults should practice at least 150 minutes of moderate-intensity aerobic physical activity throughout the week, or perform 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, older adults 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. Older adults, with poor mobility, should perform physical activity to enhance balance and prevent falls, for 3 or more days per week.
5. Muscle-strengthening activities, involving major muscle groups, should be done for 2 or more days a week.

When older adults cannot do the recommended amounts of physical activity due to health conditions, they should be as physically active as their abilities and conditions allow them.

1.4 PHYSICAL FITNESS FOR HEALTHY OLDER ADULTS

The physical fitness is defined as a state of well-being with at low risk of health problems, according to the following parameters: body composition, cardio-respiratory fitness, muscular strength and flexibility (ACSM, 2014). With aging, body composition changes, in particular fat mass increases and fat-free mass decreases (St-Onge and Gallagher, 2010). Although physical activity can not fully counteract age-related fat-accumulation, more active men and women have lower fat deposits, which is more beneficial in reducing the risk of cardiovascular diseases and improving metabolic profile (Kenney et al., 2012).

Cardio-respiratory fitness, in particular $\dot{V}O_{2max}$, is a fundamental parameter for healthy or unhealthy people. Lower $\dot{V}O_{2max}$ values are associated with cardiovascular diseases; on the contrary, high levels of $\dot{V}O_{2max}$ produces numerous health benefits (Kalyani et al., 2014). Cardiorespiratory fitness is considered a health-related component, as low cardio-respiratory levels have been associated with a marked increase in the risk of premature death for many pathologies, specifically for cardiovascular diseases. The increase in cardiorespiratory levels has been associated with a reduction in the risk of death for all causes (Warburton et al., 2006). High cardiopulmonary levels are associated with high levels of physical activity, which in turn are associated with many health benefits.

Muscular strength is reduced with aging and this is the result of decreases in both physical activity and muscle mass. An endurance training could prevent the losses in muscle mass associated to age in older men and women (Kalyani et al., 2014). Aging is accompanied by significant changes in body composition that can adversely affect functional status, such as decreased muscle mass and strength. Changes of skeletal muscle are essential for locomotion (Hayes et al., 2014). Elderly subjects are most affected by muscle mass loss. Practicing muscle strength training could beneficially stimulate protein synthesis and conservation, slowing down the normal and unavoidable loss of muscle mass and strength (ACSM, 2009). In addition, muscle strength is a component that can indirectly improve or maintain:

- the bone mineral density, which is related to osteoporosis;
- glucose tolerance;
- the tendon muscle integrity, which is associated with a lower risk of injury;
- the ability to carry out activities of daily living, which is related to perceiving quality of life and self-efficacy, along with other mental health indicators;
- lean body mass and basal metabolism, which are linked to weight control (Chodzko-Zajko, 2014).

The articular range of motion (RoM) decreases with age, and consequently there is a decline in flexibility. Yet, there is some evidence that flexibility can be increased in the major joints by ROM exercises (Stathokostas et al., 2012). Flexibility is very important in carrying out various movements and thus in carrying out the activities of daily living.

It has been observed that:

- moderate and vigorous activity is associated with elevated cardiovascular reserve and skeletal muscles adaptations that allow the elderly to support the load of exercise, with less cardiovascular stress and muscular fatigue (Chodzko-Zajko et al., 2009);
- cardiovascular activities and higher levels of physical activity reduce the risk of cognitive decline and dementia (Bherer et al., 2013);
- prolonged aerobic exercise appears to slow the age-related accumulation of central body fat, and it confers a cardio-protective function (Chodzko-Zajko et al., 2009);
- flexibility can be improved in the major joints range of motions (Chodzko-Zajko et al., 2009);
- the strength in the elderly may increase more with dynamic strength exercises than with isokinetic or isometric measures (Granacher et al., 2012);

- various exercises, including aerobic, strength and balance activities, reduce the risk of falling (Gregg et al., 2000).

Practicing regular physical activity means maintaining a good level of fitness, which means having all the skills to maintain a good level of independence. The increase of physical fitness reduces the risk of premature death, while conversely a decrease in physical fitness increases the risk. The small fitness improvements are associated with a significant reduction in risk of premature death. For this reason, sedentary people experiencing a modest improvement in physical fitness have by association great improvements in the state of well-being (Warburton et al., 2006).

1.5 PSYCHOLOGICAL AND COGNITIVE BENEFITS

In addition to all the benefits that physical activity involves at the physiological level, there is clear evidence that physical activity involves psychological and cognitive benefits. The psychological aspects that have been studied include psychological well-being, quality of life, depression, mood and cognitive performance (Steptoe et al., 2015).

Psychological mechanisms include self-efficacy, which is the confidence a person has in completing a task successfully. Psychological well-being is a multifaceted construct that includes 4 components: emotional well-being, self-perception, physical well-being and global perception. The effects of physical activity on health-related quality of life are generally positive, more in aerobic training and in flexibility training. Physical activity also protects from depression, playing an antidepressant role. People who are physically less active have a greater risk of depression, and people who are more depressed tend to become less physically active (Chodzko-Zajko, 2014).

Arent et al. (2000) showed that seniors participating in physical activity experience mood improvement, meaning having a positive mood increase and a decrease in negative mood.

Physical activity favors cognitive performance: a person's ability to perform mentally challenging tasks, which tends to diminish with advancing age.

The basic cognitive functions mostly affected by age are attention and memory. Perception shows significant age-related declines mainly attributable to declining sensory capacities. Fratiglioni et al. (2004) reported that three lifestyle factors can play a significant role in slowing the rate of cognitive decline and preventing dementia: a socially integrated network, cognitive leisure activity, and regular physical activity. Recent studies suggest that physical exercise also protects against dementia (Larson et al., 2006).

1.6 WALKING

Mechanical work during walking is a complex biomechanical variable: total mechanical work is the sum of external work, about 60% of total work, and internal work. The first represent "*the work done to raise and accelerate the body CoM within the environment*", while the second is "*the work associated with the acceleration of body segments, mainly limbs, with respect to the CoM*" (Saibene and Minetti, 2003). CoM is an imaginary point where all the mass is concentrated (Winter, 1979), so it reflects movements of all the body or the segments at which it refers to. Walking has been classically described by an inverted pendulum paradigm (Margaria, 1976): continuous accelerations and decelerations occur and velocity falls to zero at each step because of the heel impact to the ground. This is the reason why locomotion is not particularly efficient compared with other gait patterns (Saibene and Minetti, 2003). According to the inverted pendulum model, the CoM position is adjusted from the ankle plantarflexor moment. This model is used to appropriately define the human body segment system during orthostatic posture.

Many papers have studied the metabolic cost of locomotion (Margaria, 1976). Gross energy cost reflects the energy consumed per unit of covered distance ($J \cdot kg^{-1} \cdot m^{-1}$), and shows a U-shaped relationship when plotted versus walking speed (di Prampero, 1986). Instead, the net energy cost of walking, calculated as gross steady-state $\dot{V}O_2$-standing $\dot{V}O_2$, reflects gait economy. Pintar and colleagues (2006) demonstrated that different levels of cardiorespiratory fitness can influence the relative intensity of PWS: it means that at same workload, represented by speed of walking, people with lower maximal oxygen uptake exhibited higher relative intensities (worked at a higher percentage of $\dot{V}O_{2max}$) with respect to fitter counterparts.

PA effects on walking economy are less studied. Only Martin et al. (1992) investigated the impact of PA, subjectively assessed, on aerobic demand in young and older adults at 7 speeds, but the results showed no effects of PA.

Walking is simple and a widespread physical activity that has substantial benefits for health. Walking can be performed at light intensity, moderate intensity or at vigorous intensity. Walking is a convenient mode of exercise because is very easy to apply in everyday activities and it requires a significant amount of metabolic energy (Lee and Buchner, 2008). Walking is the most commonly reported activity in adults who meet the physical recommendations. The importance of walking derives from its accessibility. Walking is a universal form of physical activity, that is appropriate to promote regardless of sex, ethnic group, age, education, or income level. Walking does not require expensive equipment, nor special skills or facilities. It can be done indoors or outdoors. In this regard, walking is particularly important for its potential to reduce disparities in health, related to lack of physical activity. The public health benefits of promoting walking extend beyond its direct benefits, deriving from physiologic effects in individuals who are more physically active. Walking outdoor increases the contact with natural environments. There is increasing evidence that exposure to natural environments improves mental health. Walking is often a group activity that results in social interaction, which also has an independent effect on health, as indicated by evidence that low social interaction is associated with increased mortality (Lee and Buchner, 2008).

Many studies have shown the importance of walking as a physical activity to improve health, to reduce physical inactivity and to increase the physical activity level (Warburton et al., 2006). Indeed, it was shown that walking reduces the cardiovascular risk, diabetes type 2, osteoarthritis and osteoporosis (Thompson et al., 2003).

Walking is a motor movement performed automatically, but at the same time it is very complex; unfortunately, in the elderly it could be no longer executed independently. This motion changes throughout life, especially after 70 years of age. Elderly persons require attention for motor control while walking, because the risk of falling is greater than in younger adults (Bridenbaugh and Kressig, 2011). Moreover, gait variability has been correlated with the risk of falling in the elderly, due to a loss of strength and flexibility (Kang and Dingwell, 2007), and it may influence the economy of walking (Malatesta et al., 2003), necessitating greater effort and leading to a reduction in walking level during the day.

The underlying factors contributing to changes in walking performance in the aging population are unclear. They may include changes in muscle strength, balance, joint mobility and cardiovascular fitness. Many studies have demonstrated that in the elderly people, there are several factors underlying these gross changes in walking performance, including decreasing joint ranges of motion, an increased reliance on hip musculature for power generation, and a reduction in the ankle joint movement and power, compared to healthy young control subjects (Boyer et al., 2012).

Reports have shown that the number of walking step per day and the walking speed decrease with advancing age. In the advanced age, gait changes and in particular, reduced self-selected walking speed, are important determinants of relative functional independence for the aged, and of the degree of mobility that is maintained through the aging process (Boyer et al., 2012).

Human locomotion is represented by complex movements and the musculoskeletal system that allows to maintain stability and balance, while the body is continually moving (Ting, 2007). Each sequence is characterized by a series of interactions between the two multi-segmented lower limbs and the total body mass. The two successive contacts of the same foot on the ground describes the gait cycle (Perry and Burnfield, 2010).

1.7 GAIT STABILITY AND GAIT VARIABILITY

As walking is the most frequent activity of daily living, gait stability is an important parameter for well-being in the elderly. During walking, stability comprises direct and indirect biomechanical aspects (Hamacher et al., 2011). Gait stability is an important and necessary factor for walking without falling, and the evaluation of foot trajectories provides the key to understand this parameter. Gait stability is analyzed with stability measurements (direct assessment), and measures of kinematic variability (indirect assessment). The indirect assessment is associated to fall risk, that is evaluated by the spatial-temporal time series of the foot.

Gait stability is one contribute for quantifying the dynamic stability of elderly individuals. The term "stability" refers to the correct behavior of a system affected by small perturbations. On the contrary, the incorrect behavior is the gait instability. The gait instability in older population is a major fall risk factor. In the literature, gait variability is used to study the stability and instability of walking. In fact, assessment of gait variability via biomechanical measurements of foot kinematics provides a viable option for the quantitative evaluation of gait stability (Hamacher et al., 2011).

Gait variability was originally considered to represent noise of instrumentation or physiological noise (Hausdorff, 2005) and different parameters were used to describe gait variability, for example spatial-temporal parameters such as step width, stride time and step length. Temporal measurements of variability were capable of distinguishing between “fallers” and “non-fallers”, whereas spatial variability were compatible with the age groups. Indeed, step width and stride velocity proved to be more capable of discriminating between old versus young adults. Calculation of gait variability with coefficient of variation (standard deviation/mean·100%) and its statistical measurement of the dispersion of group data points in a data series relative to the mean, is often used to evaluate reliability (stability) of measurements, including gait outcomes and gait variability itself (Hamacher et al., 2011).

Gait variability has been selected as a primary outcome for a randomized controlled trial for falls, because these often occur during walking, among elderly, and are driven by gait dysfunction.

This dissertation aims to find the aspects influencing physical activity, gait speed, gait stability, and finally health-related quality of life in elderly women.

2. OVERALL STUDY DESIGN AND CHARACTERISTICS

An observational study was conducted (Fig. 2.1). The first day (i) medical screening, (ii) maximal cardiorespiratory test and (iii) preferred walking speed were performed. After one week, (iv) anthropometric measurements, (v) body composition, (vi) additional physical fitness tests (maximal strength and flexibility) were performed, with participants wearing an (vii) activity monitor for one week. After 7 days (viii) gait parameters and (ix) energy cost were collected during treadmill walking.

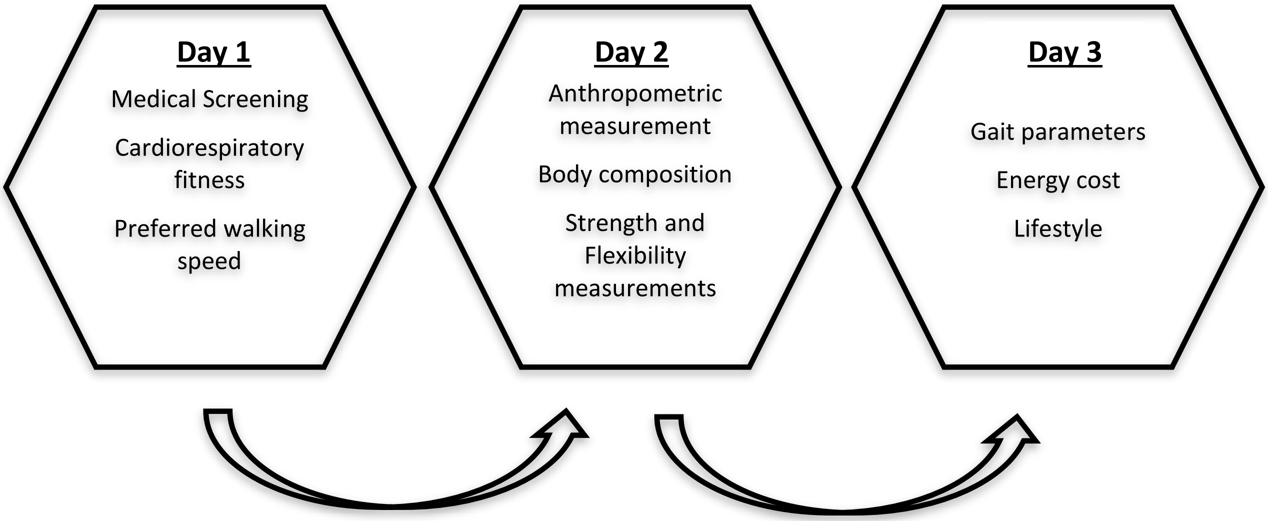


Figure 2.1 Study design

2.1 SUBJECTS

Young women were recruited among University students; while elderly women were recruited from the Community by word of mouth through research personnel.

Inclusion criteria:

- Study population: 20 young women and 20 older women.
- Ages eligible for the study: females of 18 years and older (young adults: 18-40 years; older adults: 65-75 years).
- Normal weight or overweight: 18.5-24.9 kg·m^{-2} and 25-29.9 kg·m^{-2} Body Mass Index (BMI) (WHO, 2004)
- Active and inactive people according to International Physical Activity Questionnaire (IPAQ) classification (Craig et al., 2003): 600-1500 METs·min·wk^{-1} and < 600 METs·min·wk^{-1}, respectively.

- Without medical conditions that preclude the possibility to carry out functional assessments or activities of daily living.
- Signed, written informed consent obtained for the study.

Exclusion criteria:

- Current history of an acute or chronic disease or illness that would confound the normative outcome of the study;
- Current use of systemic medications that may confound the outcome of the study.

The number of subjects analysed in the three Chapters of the current thesis was variable for technical reasons; in Chapter 3, 15 older adults and 15 young adults were considered; in Chapter 4 and in Chapter 5, 21 older adults and 21 young adults were analysed.

All procedures were in agreement with the Declaration of Helsinki for the study on human subjects and the local ethical committee approved the experimental protocol.

International Physical Activity Questionnaire

The short self-administered format of the International Physical Activity Questionnaire was used to obtain an estimate of subject's physical activity over 7 days. The IPAQ measures the various levels of PA, from sedentary to very active conditions. It is composed of 7 questions and evaluates the frequency and the duration of the participation in vigorous, moderate, walking and sedentary activities of the past 7 days. IPAQ is considered to have reasonable measurement properties for monitoring population PA levels in diverse settings in both adult and older adult populations (Tomioka et al., 2011). A sample of questionnaire is available in Appendix 1.

Quality of life

Health related quality of life (HRQoL) was measured with the 2nd version of the Italian Short-Form 36 Health Status Survey (SF-36v2) that provides scores of eight health domains: physical function (PF), role-physical (RP), bodily pain (BP), general health (GH), mental health (MH), role emotional (RE), social function (SF), vitality (VT). All these domains were summarized in the psychometrically-based physical component summary (PCS) and mental component summary (MCS). The SF-36v2 uses norm-based scoring: it means that each scale was normalized on reference data so as to have the same mean (50 points) and the same standard deviation (10 points) in the general 1998 U.S. population. A sample of questionnaire is Appendix 2.

2.2 PROCEDURES

2.2.1 ANTHROPOMETRY

Age, Height and Weight

The age classification was 18-40 years for young adults and 65-75 years for older adults (ACSM, 2014). For the American College of Sports Medicine (ACSM) the “adult age” guidelines apply to individuals aged between 18 to 64 years, while the “old age” has been defined from age 65 years or older. Kulminski et al. (2008) divided the “old age” in: younger old ages 65-74 years, old ages 75-84 years and the older ≥ 85 years.

The height and weight were measured in light clothing with a mechanical column scale (Seca 201, Deutschland). In the first half of adulthood mean body weight increases by approximately 3 kg in men and 4 kg in women. After the age of 60, these differences are in the order of approximately 1 kg for men, and among women mean weight exceeds by approximately 2 to 3 kg (Kuczmarski et al., 2000).

Body Mass Index

The Body Mass Index was used to assess weight relative to height and was calculated by dividing body weight in kilograms by height in squared meters ($kg \cdot m^{-2}$) (ACSM, 2014).

The normative values of BMI, in young and older adults, are: 18.5-24.9 $kg \cdot m^{-2}$ for normal weight, while 24.9-29.9 $kg \cdot m^{-2}$ for overweight (Kuczmarski et al., 2000; WHO, 2004). Body weight and BMI tend to decrease after 60 years of age (Villareal et al., 2005). In the elderly, the relationship between BMI and mortality is not the same (Babiarczyk and Turbiarz, 2012) because a BMI of 25–27 $kg \cdot m^{-2}$ may not to be a risk factor for all-cause and cardiovascular mortality in people aged ≥ 65 years (Price et al., 2006).

Waist circumference

The waist circumference (WC) was taken at the midpoint between the lower margin of the tenth rib and the iliac crest. This point is defined as a “natural waist” (WHO, 2008). The simple measurement of the waist circumference was suggested to be a good index for body fat distribution and for subsequent health risks.

The WC is often associated with the risk of cardiometabolic diseases because it is correlated with the abdominal fat mass; in particular, that of subcutaneous and intra-abdominal depots (Lean et al., 1995; Klein et al., 2007). The National Cholesterol Education Program (NCPE, 2001) recommends using waist circumference cut-offs of >88cm for women (Heyward, 2010). Women who have waist circumferences greater than value are considered to be at an increased risk for cardiometabolic disease. These cut-offs are derived from a regression curve that identified the WC values associated with a BMI ≥30 kg·m^{-2} (Lean et al., 1995; Klein et al., 2007).

The protocol suggested by the American College of Sports Medicine (ACSM) (2014) was followed:

- All measurements were made with a flexible yet inelastic tape measure.
- The tape was placed on the skin surface without compressing the subcutaneous adipose tissue.
- Duplicate measures at each site were taken and retested if duplicate measurements were not within 5 mm.
- Measurement sites were rotated through to allow time for the skin to regain normal texture.
- The measure was taken two times and the value was the average of two measures.

The more recent cut-off points for females are: very low (<70cm); low (70-89cm); high (90-109cm) and very high (>109cm) (Bray, 2004).

Hip circumference

The Hip circumference (HC) was taken around the widest portion of the buttocks, with the tape parallel to the floor (WHO, 2008).

We followed the protocol suggested by the ACSM (2014).

Waist to hip ratio

The waist to hip ratio (WHR) is an indirect measure of lower and upper body fat distribution and it has been used as an anthropometric measure of central adiposity and visceral fat (Heyward and Gibson, 2014).

To calculate the WHR, the waist circumference (in centimetres) is divided by the hip circumference (in centimetres). The measurement site for waist circumference, however, has not been universally standardized (Heyward, 2010).

Young adult women with WHR value in excess of 0.82 is at high risk for adverse health consequences (Heyward, 2010); while for elderly women, the WHR cut-off value is 0.90 (ACSM, 2014). Health risks increase with WHR but the risks vary with age and sex (ACSM, 2014).

Waist to height ratio

Waist to height ratio (WHtR) is the ratio between waist circumference in cm and height in cm. The WHtR has been suggested as a better indicator of adiposity and health risks than waist circumference alone (Heyward, 2010).

The risk increases with the values of WHtR above 0.5, while it is also suggested that values above 0.6 indicate substantially increase risk (Ashwell, 2009).

2.2.2 PHYSICAL FITNESS

Fat mass

The thickness of subcutaneous adipose tissue was measured with skinfolds at specific body sites (Heyward and Gibson, 2014), that represent one of the most indirect, feasible, reliable, valid, and popular methods of field estimation of body composition (Morrow et al., 2011).

The most widely applied field technique involves measuring the skinfold fat thickness at one or more sites and using the values obtained to estimate body composition. The principle behind skinfold measurements is that the amount of subcutaneous fat is proportional to the total amount of body fat. It is assumed that close to one-third of the total fat is located subcutaneously (ACSM, 2014).

Skinfold thickness was measured to the nearest mm. These readings were made at four sites on all subjects, at the biceps, triceps, subscapular and suprailiac areas (Heyward, 2010):

- Biceps: fold was lifted over the belly of the biceps brachii at the level marked for the triceps and on line with the anterior border of the acromial process and the antecubital fossa. Caliper was applied 1 cm below the finger.
- Triceps: Using a tape measure, the distance between the lateral projection of the acromial process and inferior margin of the olecranon process was measured on the lateral aspect of the arm with elbow flexed at 90°. Midpoint was marked on lateral side of the arm. Fold was lifted 1 cm above marked line on the posterior aspect of the arm. Caliper was applied at marked level.
- Subscapular: Fold was along natural cleavage line of skin just inferior to the inferior angle of the scapula, with caliper applied 1 cm below fingers.

- Suprailiac: Fold was grasped posteriorly to the midaxillary line and superiorly to the iliac crest along natural cleavage of skin with the caliper applied 1cm below fingers.

A Harpenden skinfold caliper (Baty, UK) was used with the following characteristics: dial graduation of 0.20 mm; measuring range from 0 mm to 80 mm; measuring pressure of 10 $gr \cdot mm^{-2}$ (constant over range); accuracy of 99.00% and repeatability of 0.20 mm.

The protocol suggested by ACSM (2014) was followed:

- All measurements were made on the right side of the body with the subject standing upright.
- The caliper was placed directly on the skin surface, 1 cm away from the thumb and finger, perpendicular to the skinfold, and halfway between the crest and the base of the fold.
- The pinch was maintained while reading the caliper.
- The caliper was read 1-2 s (not longer) after fold grasping.
- Duplicate measures at each site were taken and retested if duplicate measurements were not within 1-2 mm.
- Measurement sites were rotated through allow time for the skin to regain its normal texture and thickness.

Body density was estimated using Durnin and Womersley's formulas (1914) (Table 2.2.2.1)

Table 2.2.2.1 Durnin and Womersley formulas

Age (y)	**Women**
17-19	d=1.1549-0.0678*log(bic+tric+sub+sup)
20-29	d=1.1599-0.0717*log(bic+tric+sub+sup)
30-39	d=1.1423-0.0632*log(bic+tric+sub+sup)
50+	d=1.1339-0.0645*log(bic+tric+sub+sup)

Body fat was calculated from density using Siri's (1956) equation:

% fat= (4.95/density-4.50)·100

The normative values are shown in Table 2.2.2.2.

Table 2.2.2.2 Fitness categories for body composition (% Body Fat) of women by Age

%		Women			
		20-29 y	**30-39 y**	**60-69 y**	**70-79 y**
99	Very lean	11.4	11.2	13.9	11.7
95		14.0	13.9	17.7	16.4
90	Excellent	15.1	15.5	20.2	18.3
85		16.1	16.5	22.0	21.2
80		16.8	17.5	23.3	22.5
75	Good	17.6	18.3	24.6	23.7
70		18.4	19.2	25.7	24.8
65		19.0	20.1	26.7	25.7
60		19.8	21.0	27.5	26.6
55	Fair	20.6	22.0	28.3	27.6
50		21.5	22.8	29.2	28.2
45		22.2	23.7	30.1	28.9
40		23.4	24.8	30.8	30.5
35	Poor	24.2	25.8	31.5	31.0
30		25.5	26.9	32.6	31.9
25		26.9	28.1	33.3	32.9
20		28.2	29.6	34.4	34.0
15	Very poor	30.5	31.5	35.6	35.3
10		33.5	33.6	36.6	36.4
5		36.6	36.2	38.2	38.1
1		38.6	39.0	40.3	40.2

ACSM, 2014

Maximal oxygen uptake

The maximal test to measure the maximal oxygen uptake ($\dot{V}O_{2max}$) was performed on the treadmill with breath-by-breath indirect calorimetry: Quark CPET (Cosmed, Italy). This system measurement is made up of: ventilation (VE), oxygen consumption ($\dot{V}O_2$), carbon dioxide production ($\dot{V}CO_2$), averaged expiratory concentration of O_2 (FeO_2) and CO_2 ($FeCo_2$).

The calibrations suggested by the manufacturers were performed prior to each test:

- the turbine, set with a 3-litre syringe to ensure accurate volume measurements;
- the O_2 and CO_2 analysers, with a reference gas of known composition (16% O_2 and 5% CO_2);
- the room air calibration, performed automatically before each test, to ensure that the CO_2 and O_2 registered coincided with theoretical atmospheric values;
- and the delay calibration.

Before the test, the subject performed a warm up of 12 minutes: 2 min for each speed of 3 $km \cdot h^{-1}$ to 5.5 $km \cdot h^{-1}$ with an increase of 0.5 $km \cdot h^{-1}$.

Cardiorespiratory fitness was measured by a modified Balke treadmill test. The protocol maintained a fixed speed (4 $km \cdot h^{-1}$ for older adults and 5.5 $km \cdot h^{-1}$ for adults) and the test started by setting the incline at 0 per cent and then increasing the incline at 2 per cent after 1 minute and 1 per cent thereafter every minute. The test finished when subjects reached the maximal exhaustion. This protocol was suited for the subject, because it offers an adequate stimulus to reach the volitional fatigue in 10-12 min (Figure 2.2.2.1).

Figure 2.2.2.1 An older adult during $\dot{V}O_{2max}$ test

$\dot{V}O_{2max}$ test was stopped when at least two of the three following criteria were fulfilled. For adults (Midgley et al., 2007):

- a plateau in oxygen uptake, or failure to increase oxygen uptake by 150 $ml \cdot min^{-1}$ between the final two workloads;
- achievement of ± 5 bpm of age predicted maximal Heart Rate (HR_{max});
- a respiratory exchange ratio > 1.1 for the last minute.

For the older adults the criteria were (Hugget et al., 2005):

- a plateau in oxygen uptake or failure to increase oxygen uptake by 1.5-2 $mlO_2 \cdot kg^{-1} \cdot min^{1}$;
- achievement of ± 10 bpm of age predicted HR_{max};
- a respiratory exchange ratio between 1.0 and 1.15.

In young and older women the HR_{max} was calculated with Tanaka's formula= 208-(0.7·age) (Tanaka et al., 2001) and at the end of the test the value for the Borg's scale was asked. All data was averaged every 30 seconds, and the $\dot{V}O_{2max}$ was calculated by taking the average value of the last minute of the test. The normative values are presented in Table 2.2.2.3.

Table 2.2.2.3 Percentile values for maximal aerobic power in women ($ml \cdot kg^{-1} \cdot min^{-1}$)

Percentile	**20-29 (y)**	**30-39(y)**	**>60(y)**
90	44.2	41.0	35.2
80	41.0	38.6	31.2
70	38.1	36.7	29.4
60	36.7	34.6	27.2
50	35.2	33.8	25.8
40	33.8	32.3	24.5
30	32.3	30.5	23.8
20	30.6	28.7	22.8
10	28.4	26.5	20.8

Ratames, 2012

Before the test, the following precautionary measures were taken by each participant:

- food, drink, medications and smoke restriction for at least 3 hours before the test;
- avoid any kind of vigorous activity for at least 48 hours before the test;
- if possible, a minimum of 8 hours sleep;
- before the test, every participant had to pass a medical examination where the medical history, an ECG and a blood pressure measurement were assessed;
- to allow a safe and effective test execution, older adults subject were ECG-monitored also during the $\dot{V}O_{2max}$ test.

Maximum aerobic capacity usually declines with age; for this reason, when older and younger individuals work at the same absolute MET level, the relative exercise intensity will usually be different. In other words, the older individual will be working at a greater $\%\dot{V}O_{2max}$ than their younger counterpart. Nonetheless, physically active older adults may have aerobic capacities comparable to or greater than those of sedentary younger adults (ACSM, 2014).

Maximal isometric strength test

Isometric maximal voluntary contraction (iMVC) was assessed with the maximal isometric strength test. Two force plates measured the iMVC (Twin Plates, Globus, Italy) and they were fixed onto the foot platform of a horizontal leg press.

The protocol began after the warm-up; subjects sat on a chained horizontal leg press (Tecnogym, Italy) with a knee angle of 90° and a hip angle of 45°.

The subject placed their feet on two force plates of 240 by 400 mm (Twin plates, Globus, Italy) with a sampling frequency of 1000 Hz fixed on the foot platform, and were asked to exert maximal force as fast and as hard as possible after a verbal cue. iMVC was measured three times and the best value was taken. Each trial lasted a maximum of 5 seconds with a 3 minute rest between trials (Figure 2.2.2.2).

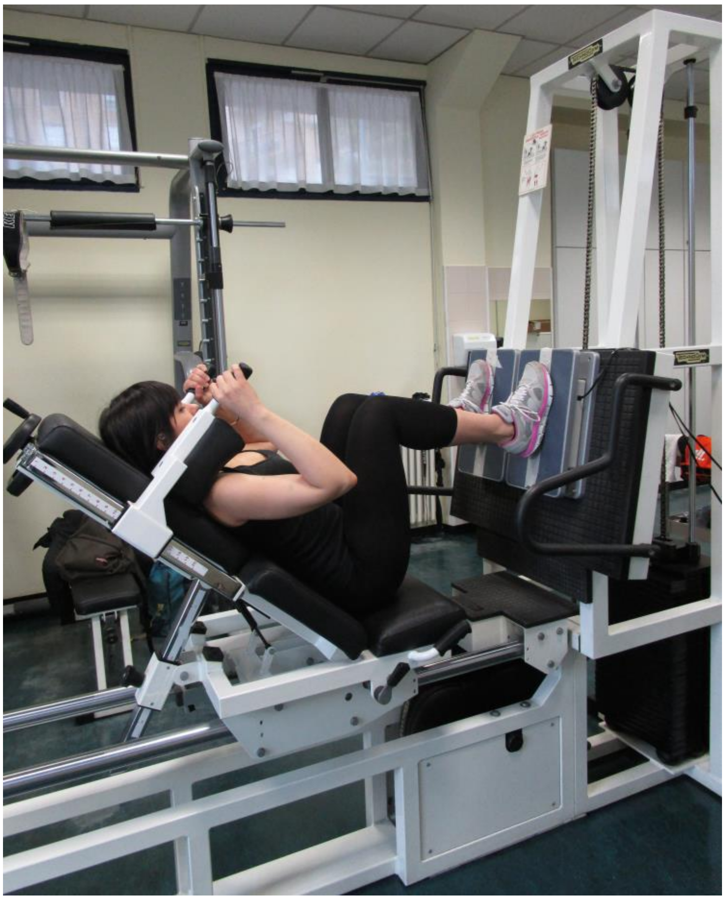


Figure 2.2.2.2 A young adult during the iMVC test

A specific software (Tesys I-metrics, Globus, Italy) automatically draws the force/time curve for both lower limbs.

The best score was used to evaluate performance, summing the strength of both limbs. Maximal strength was defined as the greatest force (in Newton) but the results were normalized for kg of body mass ($N \cdot kg^{-1}$).

Hand-grip strength test

Grip strength is an index of the power the hand can exert and the maximum grip strength is an important predictor for hand function (Hanten et al., 1999). Hand-grip strength is registered as maximum kilograms of force during a trial (Ribom et al., 2011).

The subject sat in a straight-backed chair with the feet flat on the floor, the shoulder was adducted and neutrally rotated with the elbow flexed at 90° with the forearm in a natural position, and the wrist was extended between 0-30 degrees and between 0-15 degrees of ulnar deviation. The dynamometer was oriented vertically and in line with the forearm (Innes, 1999).

IMVC was measured three times and the maximal isometric strength for left and right hand was expressed in kg and the maximal strength was defined as the greatest force. The results were normalized for newton of body mass ($N \cdot kg^{-1}$).

The normative values are presented in Table 2.2.2.4.

Table 2.2.2.4 Normative values of Hand-grip (in kg)

	20-29(y)	**30-39(y)**	**>60(y)**
Excellent	>36	>36	>33
Good	33-36	34-36	31-33
Average	26-32	28-33	25-30
Fair	22-25	25-27	22-24
Poor	<22	<25	<22

Ratames, 2013

Grip strength is lower in women than in men. In women, it is observable an increase of grip strength until a maximum about the age of 35 years. Further on, increasing age was inversely related with grip strength (Günther et al., 2008). The grip strength increases in early adult life and declines progressively after the second or third decade of life (Hanten et al., 1999).

V Sit and Reach

The V Sit and Reach test is the most widely used test for flexibility assessment and is a reflection of hamstring, hip and lower back flexibility. It is important for the prevention of chronic lower back pain and the promotion of a healthy lifestyle (ACSM, 2014). This test is used in young and older adults (Marrow, 2005).

The protocol consisted of: the subject sat on a mat with a tape placed between the legs; the heels were 30.5 cm apart and were touching a taped line positioned at 38.1 cm; subject bended slightly forward with both hands stretched out whilst exhaling. This position was held for 2 seconds. The legs remained straight, the angle at an ankle was 90 degrees. The fingertips were also overlapped and in contact with the measuring tape. Three trials were measured and the best value was taken (Marrow, 2005).

The normative values are presented in Table 2.2.2.5.

Table 2.2.2.5 Normative values of the V Sit & Reach test (in cm)

Percentile	18-25(y)	26-35(y)	36-45(y)	>65(y)
90	60.96	58.42	55.88	50.80
80	55.88	53.34	53.34	45.72
70	53.34	50.80	48.26	43.18
60	50.80	50.80	45.72	43.18
50	48.26	48.26	43.18	38.10
40	45.72	43.18	40.64	35.56
30	43.18	40.64	38.10	33.02
20	40.64	38.10	35.56	27.94
10	35.56	33.02	30.48	22.86

Heyward, 2010

Preferred walking speed

The preferred walking speed (PWS) was assessed with the Racetime 2 Light Radio kit (Microgate, Italy) equipped by two photocells (Polifemo Radio Light, Microgate, Italy) and a chronometer (Racetime 2, Microgate, Italy) that measured the time required to cover 10 m in a corridor.

The protocol is as follows:

- Subjects were instructed to walk along a line 10-m section at a comfortable walking pace (Dal et al., 2010; Beauchet et al., 2012; Panizzolo et al., 2013).
- A minimum of three trials were used to assess the mean preferred speed (Dal et al., 2010).
- The PWS was measured as the time taken to walk 10 meters out of the total of 14 meters; with 2 meters omitted from both the starting and finish point of the overall distance (Dal et al., 2010; Beauchet et al., 2012).

Many studies have shown that the elderly have a slower walking speed (approximately 20%) relative to younger adults. This factor is a strategy to preserve the mechanical function of the leg muscles (Panizzolo et al., 2013). This age related reduction in walking speed reflects a reduced motor capacity that may be linked to a greater incidence of falls and a comparatively high metabolic rate in older adults for a given speed. Examining the muscular mechanisms linked with a reduced walking speed in older adults may be important for understanding and treating gait deficits associated with aging (Panizzolo et al., 2013).

2.2.3 PHYSICAL ACTIVITY

Actiheart

The physical activity (PA) level during free-living activities was assessed for one week with an activity monitor (CamNtech, UK), the Actiheart (AH) that combined heart rate (HR) and movement signals (ACC). The AH is minimally invasive, small, light and simply claps with two ECG electrodes.

After positioning the electrodes and testing the integrity of the heart rate signal, the AH was set to a long-term recording with an epoch length of 1-min. At the end of the week, data were downloaded. The "typical week" included at least three weekdays and one weekend day covering at least 10 consecutive hours (Ekelund et al., 2004). PA was assessed using the branched model equation, studied by Brage et al. (2005), that improved measurement precision of PA estimation, weighting the relative contribution of activity and HR according to different counts and HR thresholds.

To assess the physical activity level, the time spent in sedentary (SED, <1.5 METs) or moderate (MPA, > 3 METs) to vigorous (VPA, > 6 METs) physical activity was calculated (Pate et al., 1995). MPA and VPA were summed to obtain the total amount of time participants spent in moderate and vigorous physical activity (MVPA, > 3 METs). To define minutes passed in sedentary intensities, the minutes of sleeping were subtracted from the numerical value <1.5 METs given by the software for every selected day.

The subsequent values were entered in the software as individual calibration:

- Sleeping heart rate (SHR), which was set as the highest value of the 30 lowest minute-by-minute heart rate readings during the 24-hr period. The software determined the average sleeping heart rate for all nights of the analysis and then provided an overall average for all the acceptable days.
- The measured $\dot{V}O_{2max}$ value, expressed in $ml \cdot kg^{-1} \cdot min^{-1}$.
- The highest value of the HR_{max} reached during the maximal test.
- The individual HR/$\dot{V}O_2$ relationship: the equation of the line generated from the plotted point represented the individual HR/$\dot{V}O_2$ relationship, and allows to extrapolate $\dot{V}O_2$ values from a known HR to put in to the AH software.

- The measured resting metabolic rate (RMR) was measured with indirect calorimetry (Fitmate, Cosmed, Italy). The Fitmate is validated with the Douglas bag method and the RMR is calculated with a fixed respiratory exchange ratio (RER) of 0.85 (Nieman et al., 2006). This instrument is used on both adults and the elderly between 18 to 83 years of age (Nieman et al., 2006; Amirkalali et al., 2008).

A 15-minute test duration is used with the first 5 minutes discarded (Compher et al., 2006) and the average value of the last 10 minutes is considered for further analysis.

The RMR was calculated on the basis of a Weir (1949) simplified equation:

RMR ($kcal \cdot day^{-1}$)= $3.9 \cdot \dot{V}O_2 + 1.1 \cdot (\dot{V}O_2 \cdot 0.85) \cdot 1.44$

Abbreviated Weir Equation:

RMR ($kcal \cdot day^{-1}$)= $6.9624 \cdot \dot{V}O_2$

The RMR value was converted from $kcal \cdot day^{-1}$ to $MJ \cdot day^{-1}$=(RMR·4.186)/1000 (Brockway, 1987).

As indicated by Rennie et al. (2000), the individual calibration is the more accurate procedure.

2.2.4 GAIT AND METABOLIC PARAMETERS DURING TREADMILL WALKING

Gait instability is a major fall risk factor and walking is one of the most frequent dynamic activities of daily living, so that it is necessary to identify individuals with an unstable gait (Hamacher et al., 2011).

For the biomechanical assessment, every subject had to wear close-fitting clothes (or a swimsuit) and habitual sports shoes for the correct markers placement.

The gait was evaluated simultaneously both biomechanical and metabolic data at six different speeds (3.0 - 3.5 - 4.0 - 4.5 - 5.0 - 5.5 $km \cdot h^{-1}$) on a motor driven treadmill (TMX425C, Trackmaster, Cosmed, Italy).

The protocol comprised:

- 10 minutes standing on the treadmill: in this phase the subject was captured in a standing position for 5 sec to provide the reference for Centre of Mass (CoM) evaluation and to assess standing metabolic rate, useful for the calculation of net energy cost.
- 6 minutes walking at 3.0 $km \cdot h^{-1}$: the subject has to walk continuously without any support.

- 5 min of sitting: this rest period is added to allow metabolic values to return to basal conditions;
- 6 minutes walking at 3.5 $km \cdot h^{-1}$.
- 5 min of sitting.
- 6 minutes walking at 4.0 $km \cdot h^{-1}$.
- 30 min of sitting.
- 6 minutes walking at 4.5 $km \cdot h^{-1}$.
- 5 min of sitting.
- 6 minutes walking at 5.0 $km \cdot h^{-1}$.
- 5 min of sitting.
- 6 minutes walking at 5.5 $km \cdot h^{-1}$.

For biomechanical analysis the main spatial-temporal gait parameters (stride length; step length; step width; stance phase; swing phase; double support time; step frequency; stride time) and the gait variability were calculated. For the metabolic analysis gross and net energy cost of walking were calculated.

Gait parameters

An optoelectronic system (Smart-E, BTS, Italy) allowed the collection of biomechanical data; this system is composed by nine infrared TV cameras positioned around a working volume and it provides the reconstruction of the position of body landmarks during a sequence. Every camera is surrounded by an array of LED (Light-Emitted Diodes) mounted around the lens, emitting a stroboscopic light with a wavelength of 880 nm (Zago et al., 2015).

Before each acquisition, the system was calibrated with a static phase called the "axes sequence" which provides for the static position and the reference orientation of the three axes (x, y, z); while the second calibration was the dynamic phase, otherwise called the “wand sequence” to mathematically reconstruct the working volume within which the acquisition must be made.

The markers were attached always by the same operator to reduce variability; furthermore, these markers were positioned onto the near bone prominences of the major joints. On each subject 23 markers were placed on the body, while 3 other markers were positioned at the treadmill base. In particular, the anatomical landmarks were: left and right tragus, glabella, 7th cervical vertebra spinous process, left and right acromia, lateral epicondyles of the left and right humerus, left and right radius styloid process, sacrum, left and right anterosuperior iliac spines, left and right greater trochanters, left and right femoral lateral epicondyles, left and right lateral malleoli, left and right heels and toe and finally left and right midpoint of the shoes (Figure 2.2.4.1). An additional marker was positioned on the treadmill to check its speed.

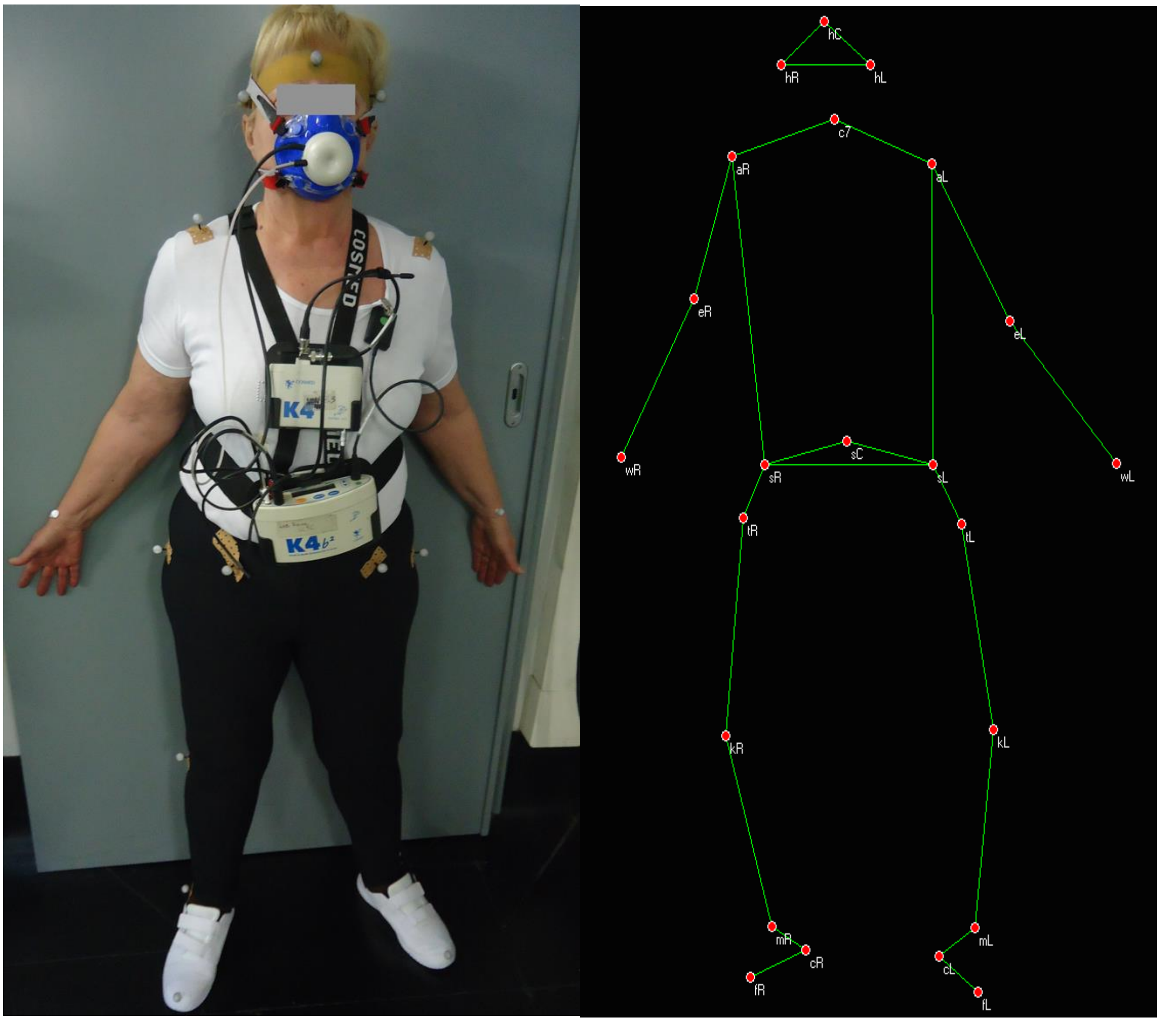


Figure 2.2.4.1 An older adult ready for the acquisition of data during treadmill walking and the relevant biomechanical model

The biomechanical acquisitions were captured for 30 seconds of the gait cycles from the 3rd to the 4th minute of each speed test.

After the acquisition, the movement was reconstructed in 3D using a biomechanical model that allowed us to recognize every single marker. Marker coordinates were tracked following a previously created biomechanical model. Customized software within Matlab (The MathWorks Inc., Natick, MA, USA) was developed for data processing. Each gait cycle was time-normalized to a standard 100 values sequence and standard spatiotemporal gait parameters were computed from all of the steps (Zago et al., 2017).

Metabolic Parameters

The energy cost of walking (EC) was assessed with $K4b^2$ (Cosmed, Italy), a portable, light (<1 kg) breath-by-breath gas analysis system (McLaughlin et al., 2001; Duffield et al, 2004). Before every measurement, $K4b^2$ was warmed-up for at least 45 minutes. After the calibration process and before test commencement, the ambient humidity and physical characteristics of the participant were entered into the $K4b^2$. The acquisition was conducted in telemetry mode and lasted about 100 min, including the time for the subject's preparation. During the acquisition, the $K4b^2$ device was fixed on its harness, and a silicon mask (Hans Rudolph, Inc., USA) was mounted on the subject's face.

Metabolic data were collected continuously. Data stored on $K4b^2$ were downloaded and later analyzed with the dedicated software. After filtering data (6 point smoothing), we calculated the standing metabolic rate (SMR) by generally analyzing from 4th to 9th minute of the first 10 minutes of the acquisition. The energy cost was calculated for every speed by considering the averaged 3 minutes of $\dot{V}O_2$ steady state ($ml \cdot min^{-1}$) from the 3rd to the 6th minute.

We obtained the value of $\dot{V}O_2$ from $ml \cdot min^{-1}$ and we divided it by body mass (kg). To obtain the gross energy cost (EC) we divided $\dot{V}O_2$ by the speed expressed in m/min and finally to obtain the net EC, we subtracted the SMR from the Gross EC.

In particular:

- we converted $\dot{V}O_2$ from $ml \cdot min^{-1}$ to $J \cdot min^{-1}$ with the following equation (Garby and Astrup, 1987):

  $\dot{V}O_2\ (J \cdot min^{-1}) = \dot{V}O_2\ (ml \cdot min^{-1}) \cdot (4.94 \cdot RER + 16.04)$

- Subsequently, to obtain the relative values we divided by body mass (BM):

  $\dot{V}O_2\ (J \cdot kg^{-1} \cdot min^{-1}) = \dot{V}O_2\ (J \cdot min^{-1})\ /\ BM\ (kg)$

- To obtain gross EC we divided $\dot{V}O_2$ by speed, expressed in m/min:

  $\text{Gross EC}\ (J \cdot kg^{-1} \cdot m^{-1}) = (J \cdot kg^{-1} \cdot min^{-1})/\text{speed}\ (m \cdot min^{-1})$

  $\text{Net EC}\ (J \cdot kg^{-1} \cdot m^{-1}) = [(J \cdot kg^{-1} \cdot min^{-1}) - \text{SMR}\ (J \cdot kg^{-1} \cdot min^{-1})]/\ \text{speed}\ (m \cdot min^{-1})$.

3. INFLUENCE OF ENERGY COST OF WALKING AND HEALTH RELATED PHYSICAL FITNESS ON GAIT SPEED AND GAIT VARIABILITY IN ELDERLY WOMEN

Abstract

Gait speed typically decreases and gait variability typically increases in elderly. The aim of this study was to define the influence of energy cost of walking on gait speed and of health-related physical fitness on gait variability in elderly women. 30 healthy young and older women were recruited in the study. Energy cost of walking (Net_{CW}) was analysed with indirect calorimetry while a kinematic analysis was performed with an optoelectronic system to calculate gait variability (GV) during treadmill walking at different speeds. Gait speed was defined as the preferred walking speed of the subject. To assess health related physical fitness (HRPF), subjects underwent skinfold thickness measurement for body fat; lower limbs and hand-grip strength tests for isometric maximal voluntary contraction; a V Sit & Reach test for flexibility; and a maximal treadmill test for cardiorespiratory fitness. Significant associations, adjusted for age, body mass index and number of falls, were identified neither between Net_{CW} and the PWS, nor between HRPF and GV. However, results showed that Net_{CW} was influenced by the speed and a significant association was found between hand-grip strength and gait stability. Furthermore, results indicated that in healthy elderly women GV is not affected by age allowing a high PWS; step width coefficient of variation was found to be a better indicator of gait variability than stride time and length and double support coefficients of variation.

Keywords: gait stability; gait speed; energy cost; physical fitness; older adults.

3.1 INTRODUCTION

Aging is accompanied by detriments in physical function which are predictive of falls, fractures, psychological impairments, loss of independence and mortality. Thus, remaining functionally independent and maintaining a high quality of life are two common goals among older adults. Exercise is a key intervention for improving physical function in this population, and albeit walking is the most common physical activity in older adults, a large proportion of falls occurs during locomotion. These falls are often attributed to a decreased quality of gait, due to age-related, peripheral and central impairments (Bridenbaugh and Kressig, 2011).

Gait variability can be considered an indirect assessment of gait stability, in particular using variability of temporal or spatial measures (Hamacher et al., 2011). GV tended to increase with age and it has been related to future mobility disability with self-reported and performance-based measures of functional status (Hausdorff et al., 2001). Besides, Toebes et al. (2015) established that decreased stability of gait was more strongly associated with fear of falling than muscle strength.

Energy cost of walking (C_W) is emerging as another significant factor related to functional performance among older adult (Wert et al., 2013). Increased C_W has the potential to yield adverse functional consequences for older adults, as the amount of energy used during walking comprises a greater portion of the total energy available (Schrack et al., 2013). In fact, it has been demonstrated that the age-associated increase in C_W may result in a slowing of gait speed (Schrack et al., 2013), while an elevated gait speed may be a simple and accessible indicator of the health of the older person (Studenski et al., 2011), also preventing the risk of falls (Almeida et al., 2011).

To permit preventive strategies to become effective, it is therefore imperative to identify individuals with an unstable gait, verifying factors related to a slow gait speed and a high GV. According to the literature, it's plausible to hypothesize that a high gait speed and a low GV can allow a good gait quality, consequently preventing falls risk. No previous studies of walking in elderly adults have focused on factors that influence GV, taking into account all health-related physical fitness (HRPF) parameters. Furthermore, no previous studies have considered the influence of C_W at different speeds on gait speed. The aim of this study was to define the influence of C_W and health-related physical fitness on gait speed and GV in elderly women.

3.2 METHODS

3.2.1 SUBJECTS

15 young women (mean±SD, median: age 22.8±3.3, 22.0 years; height 1.63±0.07, 1.65 m; mass 58.7±4.4, 59.0 kg; BMI 22.1±2.0, 22.1 kg·m^{-2}) and 15 older women (age 68.2±2.9, 68.0 years; height 1.58±0.07, 1.58 m; weight 64.8±9.5, 64.0 kg; BMI 26.0±2.7, 26.2 kg·m^{-2}) were recruited. Informed consent was obtained from all participants included in the study. All participants were physically healthy, without any medical conditions that preclude the possibility to carry out functional assessments or activities of daily living.

3.2.2 STUDY DESIGN

An observational study was conducted. An ethical approval has been obtained from the institutional review board. The study was developed in three days. The first day medical screening, a physical activity questionnaire, anthropometric measurements, maximal cardiorespiratory test and the evaluation of the preferred walking speed were performed. The number of falls in the previous year was also collected. After one week, fat mass, strength and flexibility were measured. After 7 days C_W and gait parameters were collected.

3.2.3 EXPERIMENTAL PROCEDURES

The waist circumference and hip circumference were taken: the first at the "natural waist" and the second around the widest portion of the buttocks (ACSM, 2014). Later, it was calculated the waist to hip ratio and the waist to height ratio (see paragraph 2.2.1). During the medical screening, the number of cardiovascular disease risk factors (CVD) were evaluated according to the ACSM classification (ACSM, 2014). The number of falls was used to classify the subjects in fallers and non-fallers. The self-administered short format of the International Physical Activity Questionnaire was used to obtain an estimate of subject's physical activity (see paragraph 2.1).

The preferred walking speed was measured with photocells and the subjects were instructed to walk at their comfortable walking pace. Skinfold thickness was measured to the nearest mm at four sites on the right side of the body, at the biceps, triceps, subscapular and suprailiac areas. Body density was calculated using Durnin and Wormesley formula (1974). Body fat was calculated from density using Siri's equation (1956). Isometric maximal voluntary contraction was measured by two force plates. Flexibility was measured by V Sit & Reach test. After a warm up of 12 minutes, maximal oxygen consumption ($\dot{V}O_{2peak}$) was evaluated during a modified Balke treadmill test (Balke and Ware, 1959) with breath-by-breath indirect calorimetry. The test finished when subjects reached the maximal exhaustion, which was controlled by the achievement of at least two of three conditions based on Midgley et al. (2007) and Hugget et al. (2005) criteria for adults and for older adults, respectively. To calculate $\dot{V}O_{2peak}$, data were averaged at 30-s intervals, and the mean value of the last minute of the test was taken into consideration (see paragraph 2.2.2).

Energy cost of walking (C_W) was assessed with indirect calorimetry and the protocol comprised 10-min standing on the treadmill in order to obtain standing metabolic rate (SMR). Each subject had to walk continuously for 6 minutes without any support on a motor driven treadmill at six different speeds (3.0 - 3.5 - 4.0 - 4.5 - 5.0 - 5.5 $km \cdot h^{-1}$) with 5 min of rest between speeds. C_W was calculated for every speed considering the averaged oxygen consumption ($\dot{V}O_2$) from the 3rd to the 6th minute. $\dot{V}O_2$ was converted from $ml \cdot min^{-1}$ to $J \cdot min^{-1}$ with Garby's equation (1987). To obtain gross C_W, $\dot{V}O_2$ (adjusted for body weight) was divided by speed expressed in m/min and finally to obtain net C_W (Net_{CW}), SMR was subtracted from gross C_W. The participants were subjected to simultaneous capture of their motion data and they gait was recorded at 120 Hz with a 9-cameras three-dimensional optoelectronic motion capture system, calibrated under the manufacturer guidelines before trials. Twenty-three body landmarks were positioned on each participant, and three additional markers were positioned on the treadmill base. For biomechanical acquisitions subjects were captured in a standing position for 5 seconds to provide the reference for orthostatic position; the gait cycles were captured for 30 seconds from the 3rd to the 4th minute of each speed test (see paragraph 2.2.4). Marker coordinates were tracked following a previously created biomechanical model. Customized software within Matlab was developed for data processing. Each gait cycle was time-normalized to a standard 100 values sequence and standard spatiotemporal gait parameters were computed from all of the steps. Only right-side values were further used because they were not statistically different from the left-side ones (Mann-Whitney U Test). The magnitude of the variability was calculated using coefficient of variation (CV).

3.2.4 STATISTICAL ANALYSIS

Statistical analysis was carried out with a commercial software package (STATVIEW 5.0). Nonparametric tests were used because data were not likely to be normally distributed.

All data are presented as the means ± standard deviation, median. Statistical significance was set at $p<0.05$. Differences between young adults and older adults were evaluated using Mann-Whitney U Test, with height as a covariate in stride length analysis. Friedman Test was utilized to analyze the differences between speeds.

A health-related physical fitness index (HRPFI) was calculated using Z-scores (Knaeps et al., 2016) of all five fitness parameters. The Z-score for percentage fat mass was inversed to account for the fact that a lower fat percentage is better than a higher one. The mean of both Z-scores of hand-grip and iMVC was computed to attain an average Z-score for strength fitness. An average composite Z-score was created for fat mass, cardiorespiratory fitness, muscular fitness and flexibility where all four parameters were equally weighed. The coefficient of variation index (CVI) was calculated using four gait parameters (step width, stride length, stride time and double support). The fitness and gait parameters used for HRPFI and CVI computation is based on the weighting identified using a principal component (PC) analysis that determines the main correlation pattern among multiple measures; only the first PC was retained (1PC). Backward stepwise regression analysis, adjusted for age, BMI and number of falls, was performed to evaluate the significance of associations between Net_{CW} and PWS or between HRPFI and CVI.

3.3 RESULTS

3.3.1 DIFFERENCES BETWEEN OLDER ADULTS AND YOUNG ADULTS

All anthropometric values (BMI, WC, HC, WHR and WHtR) of OA were significantly ($p<0.05$) greater when compared with YA. According to health conditions analysis, only the number of risk factors resulted significantly ($p<0.001$) higher in OA than in YA. Fat mass was significantly ($p<0.0001$) greater in OA than in YA, while strength (hand-grip, iMVC), flexibility (V Sit & Reach) and cardiorespiratory fitness ($\dot{V}O_{2peak}$) were significantly ($p<0.05$) lower in OA than in YA (see Table 3.3.1.1).

Table 3.3.1.1 Anthropometric parameters, Health conditions and Health-Related Physical Fitness

	Older Adults		**Young Adults**		p-value
	mean±SD	Median	mean±SD	Median	
Anthropometric parameters					
WC (cm)	87.2±9.6	89.5	72.1±4.8	73.2	0.0001
HC (cm)	98.7±9.8	100.0	92.4±4.1	92.9	0.0443
WHR	0.9±0.1	0.9	0.8±0.1	0.8	<0.0001
WHtR	0.6±0.1	0.6	0.5±0.0	0.4	<0.0001
Health conditions					
CVD (n)	2.9±1.1	3.0	1.1±0.9	1.0	0.0002
Falls (n)	0.3±0.6	0.0	0.0±0.0	0.0	0.3507
IPAQ (METs·min·wk^{-1})	3642±2276	3546	2559±2256	1866	0.1524
PWS (km·h^{-1})	4.9±0.5	4.8	5.2±0.7	5.1	0.0930
Health-Related Physical Fitness					
Fat Mass (%)	35.4±2.2	35.4	25.5±1.8	25.4	<0.0001
Hand-grip (N·kg^{-1})	2.3±0.8	2.2	3.5±1.0	3.7	0.0026
iMVC (N·kg^{-1})	12.7±2.8	12.8	17.1±3.1	17.8	0.0007
V Sit & Reach (cm)	28.1±9.4	26.0	36.6±10.0	39.0	0.0202
$\dot{V}O_{2peak}$ ($mlO_2 \cdot kg^{-1} \cdot min^{-1}$)	27.1±3.9	25.8	38.9±4.4	39.3	<0.0001

Data are presented as mean±standard deviation and median. WC: waist circumference; HC: hip circumference; WHR: waist to hip ratio; WHtR: waist to height ratio; CVD: cardiovascular disease risk factors; IPAQ: international physical activity questionnaire; PWS: preferred walking speed; iMVC: isometric maximal voluntary contraction; $\dot{V}O_{2peak}$*: maximal oxygen consumption. P-values were obtained by Mann-Whitney U Test.*

Taking spatial gait parameters into consideration, step width did not differ between the age groups; only stride length was found significantly (*p*<0.05) higher in YA than in OA, except for 4.0 km·h^{-1} (see Figure 3.3.2.1 A and B). Considering temporal gait parameters stance/swing percent (except for stance at 5 km·h^{-1}) were significantly (*p*<0.05) higher in OA than in YA and in YA than in OA, respectively (see Figure 3.3.2.1 C and D); likewise stride time resulted significantly (*p*<0.01) longer in YA than in OA (see Figure 3.3.2.1 F).

Net_{CW} of walking was at any speed greater in OA than in YA, but significantly (p<0.05) different only at the slower speeds (3.0-3.5-4.0 km·h^{-1}) (see Figure 3.3.2.1 G). No statistical differences in terms of CV were found between groups except for stride time (OA: 2.1±0.5, 2.2; YA: 1.7±0.4, 1.7 s; p<0.05), stride length (OA: 3.0±1.0, 2.7; YA: 2.4±1.1, 2.2 m; p<0.05) and double support (OA: 9.8±5.2, 10.1; YA: 5.6±3.4, 4.1%; p<0.05) at 3 km·h^{-1} and for stride length (OA: 1.9±0.3, 1.9; YA: 1.6±0.4, 1.6 m; p<0.05) at 5.5 km·h^{-1}. Across all subjects, the step width variability was larger than stride length and time and double support variability (see Figure 3.3.2.1 H). Across all subjects, step width variability exceeded stride length variability by 86.4%, stride time variability by 89.6% and double support variability by 5.04%.

3.3.2 SPEED DIFFERENCES

Step width significantly (p<0.0001) differed between speeds and stride length significantly (p<0.0001) increased with speed (see Figure 3.3.2.1 A and B). Stance, expressed in percentage, significantly (p<0.001) decreased with increasing speeds, while swing, expressed in percentage, significantly (p<0.0001) rose with increasing speeds (see Figure 3.3.2.1 C and D). Double support and stride time significantly (p<0.0001) decreased with increasing speeds (see Figure 3.3.2.1 E and F).

Net_{WC} was significantly (p<0.0001) influenced by walking speed. Both groups exhibited a similar U-shaped relationship between Net_{WC} and walking speed. The speed that corresponded to the lowest Net_{WC} was slightly slower for the YA (4 km·h^{-1}) compared with the OA (4.5 km·h^{-1}) (see Figure 3.3.2.1 G). When expressed as a percentage of preferred walking speed, for the older adults only the lowest point of the Net_{WC} was approaching to the preferred walking speed (see Figure 3.3.2.2).

Step width (p<0.01) and double support (p<0.05) CVs significantly increased with speed. Stride time and length CVs significantly decreased with speed (p<0.0001) (see Figure 3.3.2.1 H).

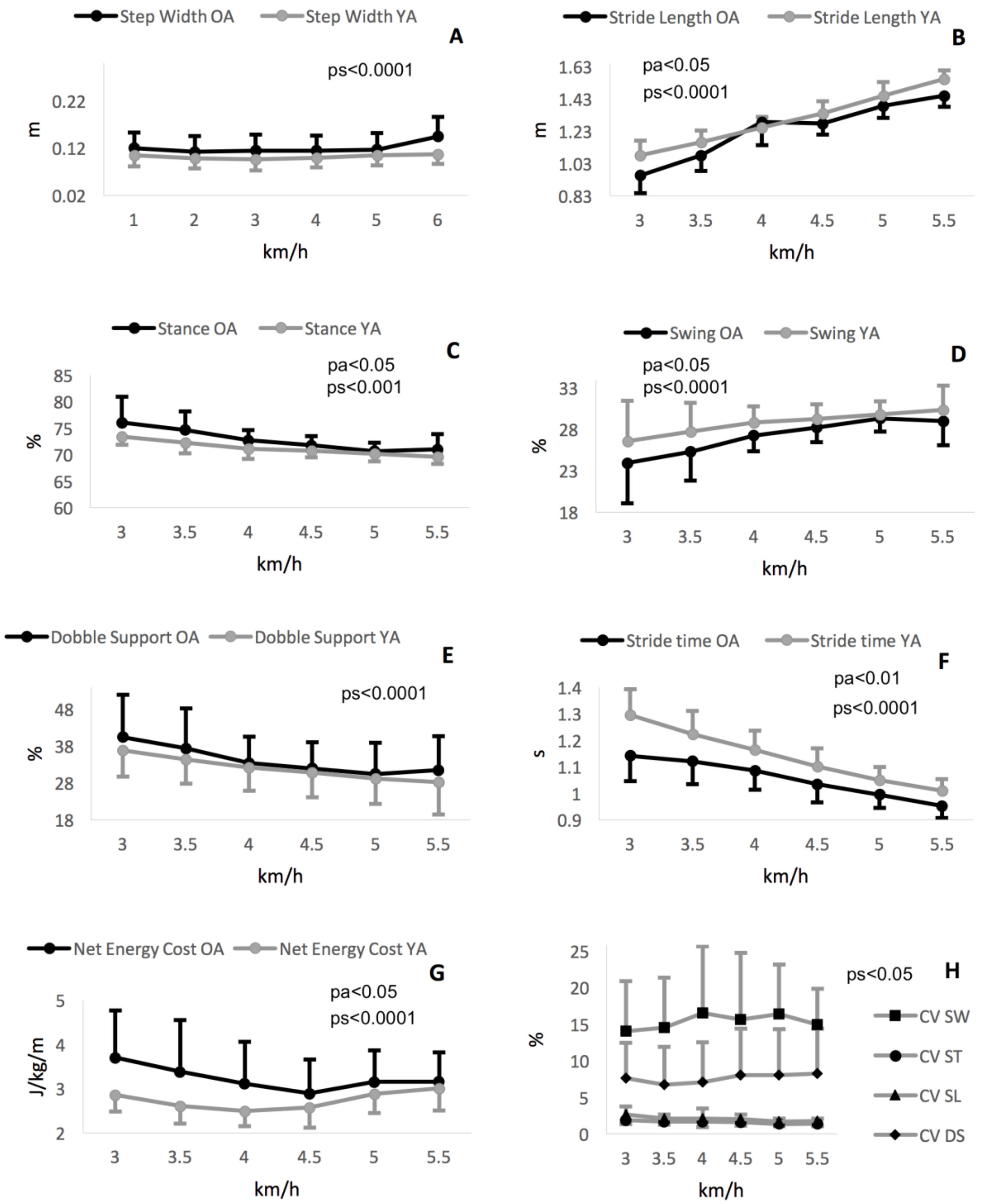


Figure 3.3.2.1 Mean ± standard deviations (Mean±SD) of spatial and temporal gait parameters, and Net Energy Cost of walking vs. walking speed for young (YA) and older adult (OA) women. The mean values (YA and OA) of coefficient of variation (CV) of step width (SW), stride time (ST), stride length (SL), and double support (DS) are presented in Figure 3.3.2.1 H. P-values for age group (pa) and speed (ps) comparisons are shown. Differences between age-groups and speeds were obtained by Mann-Whitney U Test and Friedman Test, respectively.

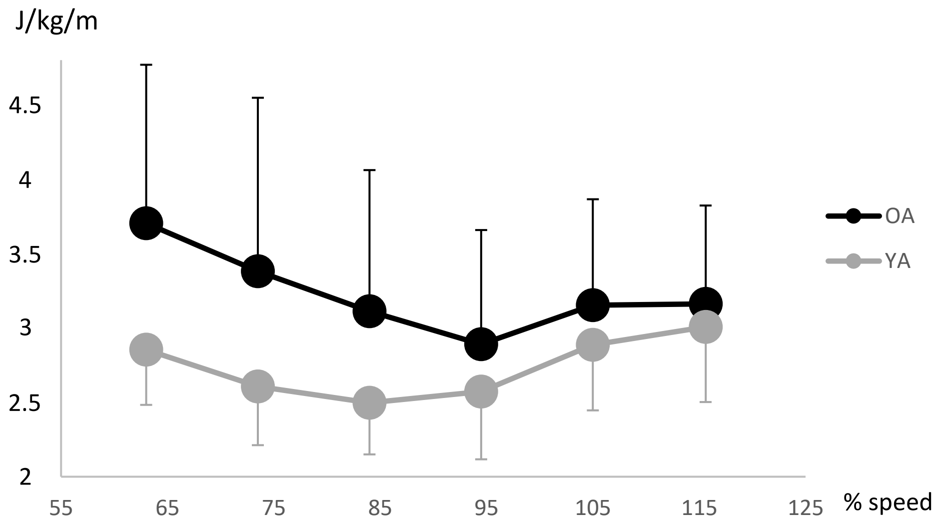


Figure 3.3.2.2 Mean ± standard deviation (Mean±SD) of Net Energy Cost of walking vs. % walking speed for young (YA) and older adult (OA) women.

3.3.3 REGRESSION SUMMARY

Significant associations, adjusted for age, BMI and number of falls, were identified neither between Net_{WC} and the PWS, nor between HRPI and CVI.

In OA a significant (p<0.01), strong (according to Dancey & Reidy's classification, 2004), and negative (r=-0.67) correlation was found between HG and CVI, meaning that stronger older women had lower CVI. Accordingly, a significant association of HG with CVI could be demonstrated (R^2=0.41; β=-0.037; p<0.01): each 1 N·kg^{-1} less of HG was associated with an increase of 3.6% in CVI.

3.4 DISCUSSION

In this research, treadmill walking at different speeds in two groups of young and older adults was assessed in terms of gait stability and C_{W}. The aim was to study the influence of C_W of different speeds on gait speed, and of the health-related physical fitness parameters on gait stability. The main findings were that: (1) Net_{CW} was influenced by the speed but did not influence the PWS; (2) a significant association was found only between hand-grip strength and CVI.

The study populations were composed of healthy young and older adults, according to medical screening and the number of CVD (ACSM, 2014). Older women resulted on average overweight, according to all anthropometric parameters (ACSM, 2014), but they had elevated levels of physical activity, in particular of moderate and vigorous intensity

(Hurtig-Wennlöf et al., 2010), and a high PWS (Malatesta et al., 2010). Only one older woman was classified as "faller", according to Almeida et al. classification (Almeida et al., 2011). On average, our subjects had grip strength, and flexibility values below the average (Ratames, 2012; Heyward and Gibson, 2014).

The Net_{CW} and speed relationship is U-shaped, with an individual's walking speed selected to coincide with the lowest metabolic cost (Bastien et al., 2005). The Net_{CW} increases with age, resulting in an upward shift in the Net_{CW}–speed relationship during aging. In our study both groups exhibited a similar U-shaped relationship between Net_{CW} and walking speed, but only in OA the speed with to the lowest Net_{CW} corresponded to their PWS, OA maintaining a Net_{CW} greater than in YA at any speed. No previous studies have considered the influence of Net_{CW} of different speeds on the PWS. In our study no significant associations, adjusted for age, BMI and number of falls, were identified between Net_{CW} and the PWS, demonstrating that a more efficient gait do not influence gait speed.

Assessment of GV via biomechanical measures of foot kinematics provides a viable option for the quantitative evaluation of gait stability. The variabilities of spatial and temporal step kinematics are independent descriptors of locomotion control in healthy young and older adults. The effect of aging on GV has earlier been investigated in several studies but conflicting results have been reported. Our results are in accordance with Kang & Dingwell (2008) who reported no difference in GV between young and older adults. Our data are, on the contrary, inconsistent with those reported by Grabiner et al. (2001), demonstrating that the walking velocity conditions do not influence the variability of the gait variables. These differences can be due to the health condition of the older adults involved in the present study. Owings & Grabiner (2004) suggest that for healthy young and older adults step width variability is a more meaningful descriptor of locomotion control. Our results seem to support these findings, demonstrating that step width CV was a better indicator of GV than stride time and length CV and double support CV. Previous studies demonstrated that stride time variability and stride length variability could be improved by increasing muscle strength (Wang et al., 2015); moreover, stride time variability correlated significantly with strength (grip and knee extension strength), balance and health and mental status (Hausdorff et al., 2001). In the present study, CVI was used as an indicator of age-related deficits in mobility function and was significantly associated only with strength, and in particular only with grip strength.

The limitations of the study included: 1) the small sample size; 2) a poor population heterogeneity, in terms of health conditions and health-related physical fitness and gait parametres; 3) the absence of men in the population.

3.5 CONCLUSION

Hand-grip strength is a quick and simple evaluation of muscular function that can be measured feasibly in clinical and field settings. However, until now, it was unknown how hand-grip strength performance related to other common measures of physical health and function in healthy older adults. Our study underlined that a higher muscle strength (hand-grip) is related to a reduced gait variability. These results need to be taken into consideration when recommending health-related physical fitness tests protocols to older adults during lifespan.

More research on the influence of C_W on gait speed and of health-related physical fitness on GV is needed in the older age groups including men, for understanding which are the parameters important to maintain or enhance with age in order to maintain independence, providing them the opportunity to sustain a better quality of life.

4. STUDY OF THE ASSOCIATION OF GAIT VARIABILITY AND PHYSICAL ACTIVITY

Abstract

Gait variability can be considered an indirect assessment of gait stability, in particular regarding temporal or spatial variability measures. Physical activity, such as walking, is advised to the elderly and can be improved by gait stability. The aim of this study was to investigate the associations between gait stability and physical activity in younger and older women.

Forty-two healthy younger and older women were recruited in the study. To assess physical activity, the subjects wore a multi-sensor activity monitor for a whole week, inferring the time spent in moderate to vigorous physical activity (MVPA). MVPA were analysed in bouts of at least 10 subsequent minutes, $MVPA_{10}$ and in overall minutes $MVPA_{all}$. A kinematic analysis was performed with an optoelectronic system to calculate gait variability - expressed as standard deviation (SD) and coefficient of variability (CV) of step width, stride length, stance and swing time - during treadmill walking at different speeds.

Elderly women, with a high preferred walking speed (5 $km \cdot h^{-1}$), and with moderate step width variability (CV = 8–27%), met the recommended levels of physical activity ($MVPA_{all}$ and $MVPA_{10}$). Furthermore, gait variability (CV), adjusted for age, and number of falls, was significantly and negatively associated with $MVPA_{all}$ at 3.5 $km \cdot h^{-1}$, and with $MVPA_{10}$ at 4 $km \cdot h^{-1}$.

In a population of healthy elderly women (65-75yr), gait variability was significantly and negatively associated with the level of physical activity. Healthy elderly women, with moderate gait variability (step width variability), and a high preferred walking speed, seem to be able to meet the recommended levels of physical activity.

Keywords: gait stability, treadmill walking, daily activity, older adults

4.1 INTRODUCTION

With age, structural and functional deterioration occurs in most physiological systems, despite the absence of evident diseases. The term "Elderly" applies to individuals aged 65 yrs. or older (ACSM, 2009).

Regular physical activity, including aerobic exercise and muscle-strengthening activity, is essential for healthy aging. Regular physical activity increases average life expectancy, because of its positive influence on chronic disease development, as it reduces age-related biological changes and their associated effects on health and well-being, and it maintains functional capacity (Chodzko-Zajko et al., 2009). Remarkable evidence shows how physical activity reduces the risk of falls and injuries from falls, prevents or mitigates functional limitations and is an effective therapy for many chronic diseases (Nelson et al., 2007). Older populations are generally less physically active than younger adults (Chodzko-Zajko et al., 2009). Although older/elder adults may spend the same amount per day in exercise and lifestyle physical activities as younger normally active adults, the most popular/common types of physical activities among older adults are significantly less demanding (walking, gardening, golf, low impact aerobic activities) than the ones performed by adults (Chodzko-Zajko et al., 2009).

Walking is an easily attainable and a healthy form of physical activity which can be carried out at light, moderate or vigorous intensity. It is a convenient and daily type of exercise, requiring a significant amount of metabolic energy. Furthermore, it is the most commonly reported activity in adults who meet physical recommendations (Besser and Dannenberg, 2005). The public health benefits of walking go beyond its direct benefits on physiological qualities. Walking is often a group activity that results in social interaction, which also has effects on health as indicated by evidence revealing that low social interaction is associated with increased mortality (Besser and Dannenberg, 2005). Walking is a complex motor task generally performed automatically by healthy adults; however, walking is often no longer performed automatically by the elderly. Actually, significant changes occur in gait across the life span, particularly after the age of 70. When walking, older adults require more attention concerning motor control than younger adults. Falls, often with serious consequences, can be the result. Gait impairments are one of the greatest risk factors for falls (Maki, 1997; Bridenbaugh and Kressig, 2011). Therefore, it is essential to identify individuals with an unstable gait in order to provide preventive and effective strategies.

Variability can be considered an indirect assessment of gait stability, in particular using variability of temporal or spatial measures (Hamacher et al., 2011). Variability tends to increase with age (Hausdorff et al., 2001; Gouelle et al., 2016) and has been related to future impaired mobility (Brach et al., 2007). Increased gait variability was further associated with many factors that are related to fall risks, such as strength, balance, and gait, but also with vitality, mental status, and quality of life. Variability was also strongly associated with self-reported and performance-based measures of functional status (Hausdorff et al., 2001).

Previous studies on walking in elderly adults have largely focused on factors that influence variability. Egerton et al. (2017) have recently tried to determine if temporal-spatial gait characteristics are associated with free-living ambulatory physical activity in relatively-healthy older people. Elhadi et al. (2016) hypothesised that some biomechanical factors might contribute to the lack of walking of older adults. However, only a small number of studies have examined the influence of gait stability on the level of physical activity maintained by the general older population.

The aim of this study was to compare treadmill walking at different speeds in younger and older women, in order to understand if there is an association among gait parameters, and particularly, of gait stability, on physical activity level (PAL).

4.2 METHODS

4.2.1 SUBJECTS

Twenty-one young women and twenty-one young older women (22.6±2.9yr; 68.3±3.3yr, respectively) were recruited in the study. Informed consent was obtained from all participants involved in the study. The inclusion criteria were: young women aged between 18 to 40 years and older women aged between 65 to 75 years, physically healthy and presenting no medical conditions that could prevent carrying out functional assessments or activities of daily living. Exclusion criteria included any current history of acute or chronic diseases or illnesses that would influence the regular outcome of the study. Anthropometric measurements are reported in Table 4.2.1.1.

Table 4.2.1.1 Anthropometric measurements in Older Adults and Young Adults

	Older Adults		**Young Adults**				
Measurements	M	SD	M	SD	p-value	power	ES
Height (m)	1.57	0.07	1.62	0.07	0.0139	0.713	-0.7
Weight (kg)	64.5	9.1	59.1	5.9	0.0287	0.595	0.7
BMI ($kg \cdot m^{-2}$)	26.1	3.0	22.5	2.6	0.0001	0.992	1.3
WC (cm)	87.2	9.4	72.0	6.1	<0.0001	1.000	2.0
HC (cm)	98.7	9.4	93.0	5.5	0.0213	0.646	0.8
WHR (cm/cm)	0.88	0.05	0.77	0.05	<0.0001	1.000	1.2
WHtR (cm/cm)	0.56	0.06	0.44	0.04	<0.0001	1.000	2.4

Data are presented as mean (M), standard deviation (SD).

BMI: body mass index, WC: waist circumference, HC: hip circumference, WHR: waist to hip ratio, WHtR: waist to height ratio.

4.2.2 STUDY DESIGN

An observational study was conducted for three days to ensure a sufficient rest between trials. The research included a medical screening on the first day, a quality of life questionnaire, in addition to anthropometric measurements, a maximal cardiorespiratory test and the evaluation of the preferred walking speed. After one week, the resting metabolic rate was evaluated and participants wore an activity monitor for one week. After seven days, gait parameters and energy cost of walking were collected.

4.2.3 EXPERIMENTAL PROCEDURES

Before starting the project, each subject had a complete medical examination; anthropometric measurements and the number of falls in the previous year were collected (see paragraph 2.2.1). Each subject completed a 36-item generic quality of life questionnaire, the Short Form 36v2 (see paragraph2.1). Resting metabolic rate was measured with indirect calorimetry.

The sleeping heart rate was evaluated with the activity monitor used to measure physical activity during the free-living observation period and was computed as the highest value of the 30 lowest minute-by-minute heart rate readings during the 24-hr period.

The preferred walking speed was assessed with the Polifemo Radio Light and Racetime 2 (Microgate, Italy) equipped by two photocells and a chronometer. Maximal oxygen consumption ($\dot{V}O_{2max}$) was evaluated during a modified Balke treadmill test (1959) to exhaustion with breath-by-breath indirect calorimetry. To calculate $\dot{V}O_{2max}$, all data were averaged on 30 seconds, and the mean value of the last minute of the test was taken into consideration. Maximal heart rate was considered as the highest value at the end of the test (see paragraph 2.2.2).

Gait parameters and energetic measurements were collected simultaneously. A portable breath-by-breath gas analysis system was used to store data, later downloaded and analysed with the dedicated software. Assessment of gait variability via biomechanical measures of foot kinematics provides a viable option for quantitative evaluation of gait stability. Participants gait was recorded at 120 Hz with a 9-cameras three-dimensional optoelectronic motion capture system (BTS Spa, Milano, Italy), calibrated under the manufacturers guidelines before trials. On each participant, 23 body landmarks were positioned by the same expert operator to reduce variability. The protocol comprised 1-minute standing on the treadmill and later, each subject had to walk continuously for 6 minutes without any support on a motor driven treadmill at six different speeds (3.0 - 3.5 - 4.0 - 4.5 - 5.0 - 5.5 $km \cdot h^{-1}$) with 5 minutes of rest between speeds. Customised software within Matlab (The MathWorks Inc., Natick, MA, USA) was developed for data processing. Marker coordinates were filtered with a 15 Hz, low-pass 2nd order Butterworth filter. Each gait cycle (GC) was time-normalised to a standard 100 values sequence. Standard gait parameters (e.g. stride length, step width and stance/swing phase duration) were computed. Only the right values were considered because they did not statistically differ from the left ones (Student's t-test). The magnitude of the variability was calculated using both standard deviation (SD) and coefficient of variation (CV) (see paragraph 2.2.4).

To provide an accurate estimation of PAL during free-living activities, the Actiheart was worn for almost 7 complete and consecutive days. The participants were requested to carry on with their habitual lifestyle while wearing the activity monitor (see paragraph 2.2.3).

4.2.4 STATISTICAL ANALYSIS

Statistical analysis was carried out with the commercial software package STATVIEW 5.0. Normal distribution was verified and data were presented as the mean ± standard deviation. Statistical significance was set at $p<0.05$.

Differences between young adults (YA) and older adults (OA) were evaluated using a one-way ANOVA, with height as a covariate in stride length analysis. Two-way ANOVA was used to assess any significant differences in measured parameters 1) between groups (OA vs YA), 2) among speeds, and 3) interaction between the two subject groups and the different speeds. If the ANOVA indicated significant differences, post-hoc Bonferroni method was used to perform multiple pair-wise comparisons among the subject groups and test speeds. A one-way ANOVA was applied to analyse differences between $MVPA_{all}$ and $MVPA_{10}$. Agreement between MVPA (all or 10) and ACSM guidelines (an average of 30 minutes per day) was computed using One-Sample Sign Test. Cohen's d effect size (ES) was also determined.

The Pearson correlation test was used to study the correlation between the gait variables and the physical activity outcome measures. The first Principal component (1PC) was used to summarise data of gait SD and CV of stride length, step width, stance and swing time, given that gait variability data (SD or CV) are linked to a unique latent variable. Two backward stepwise regression analysis models were performed to examine the associations between 1PC (CV) and $MVPA_{all}$ or $MVPA_{10}$. The first model studied the bivariate association between CV and $MVPA_{all}$ and CV and $MVPA_{10}$ (Unadjusted model). The second model controlled for age and number of falls (Adjusted model).

4.3 RESULTS

4.3.1 DIFFERENCES BETWEEN OLDER ADULTS AND YOUNG ADULTS

As expected, statistically significant ($p<0.05$) differences, with a medium, large and huge effect size, were detected between the two groups regarding mean age, height, weight, body mass index (BMI), waist circumference (WC), hip circumference (HC), waist to hip ratio (WHR) and waist to height ratio (WHtR) (see Table 4.2.1.1). All subjects were classified as having a healthy weight (Queensland Government, 2013).

No significant differences in MCS and PCS scores were found between groups; nevertheless, YA obtained a significantly higher ($p<0.001$) PF score, a subscale of PCS, than OA. Both , $\dot{V}O_{2max}$ and HR_{max} were significantly higher ($p<0.0001$), with a huge effect size, in YA compared to OA. The number of falls was significantly different ($p<0.05$) between the two groups, with a medium effect size. No statistical differences were found between groups in terms of preferred walking speed, sleeping heart rate and resting metabolic rate (Table 4.3.1.1). Older women, with a high preferred walking speed (5 km·h^{-1}), met the recommended levels of physical activity ($MVPA_{all}$ and $MVPA_{10}$).

Table 4.3.1.1 Preferred walking speed, quality of life and physiological measurements in older adults and young adults

	Older Adults		**Young Adults**				
Measurements	M	SD	M	SD	p-value	power	ES
MCS	48.4	9.7	47.1	7.2	0.6232	0.076	0.2
PCS	53.3	6.8	56.9	5.4	0.0664	0.438	-0.6
PCS (PF)	52.9	4.9	56.8	1.1	0.0009	0.956	-1.1
PWS (km·h^{-1})	4.8	0.5	5.0	0.7	0.2461	0.198	-0.4
Falls (n)	0.5	1.0	0.0	0.0	0.0250	0.619	0.7
$\dot{V}O_{2max}$ (ml·kg^{-1}·min^{-1})	26.9	5.1	39.3	4.7	<0.0001	1.000	-2.6
HR_{max} (bpm)	162.3	6.4	194.7	8.1	<0.0001	1.000	-4.6
RMR (MJ/die)	5.5	0.9	5.9	1.2	0.2046	0.229	-0.4
SHR (bpm)	59.4	4.8	58.1	8.3	0.5294	0.093	0.2

Data are presented as mean (M), standard deviation (SD).

MCS: mental component summary, PCS: physical component summary, PF: physical function, PWS: preferred walking speed, $\dot{V}O_{2max}$: maximal oxygen uptake, HR_{max}: maximal heart rate, RMR: resting metabolic rate, SHR: sleeping heart rate.

Table 4.3.1.2 lists the minutes of physical activity, in particular time spent in SED, LPA, MPA, VPA, $MVPA_{all}$ and $MVPA_{10}$, for OA and YA. $MVPA_{all}$ was significantly (p=0.0026) higher than $MVPA_{10}$. Only the time spent in VPA was significantly higher (p<0.05), with a large effect size, for YA when compared with OA.

Table 4.3.1.2 Sedentary and physical activity behavior

	Older Adults		Young Adults				
Measurements	M	SD	M	SD	p-value	power	ES
SED (min)	685.9	116.8	730.3	111.7	0.2150	0.221	-0.4
LPA (min)	223.5	104.0	201.2	67.1	0.4143	0.122	0.3
MPA (min)	61.2	63.4	55.0	46.4	0.7179	0.064	0.1
VPA(min)	0.2	0.7	5.8	10.3	0.0166	0.686	-0.8
$MVPA_{all}$ (min)	61.4	63.7	60.8	52.2	0.9727	0.050	0.01
$MVPA_{10}$ (min)	29.4	41.7	28.0	29.3	0.8950	0.052	0.04

Data are presented as mean (M), standard deviation (SD).

SED: sedentary time; LPA: light physical activity; MPA: moderate physical activity; VPA: vigorous physical activity; $MVPA_{all}$: moderate and vigorous physical activity total; $MVPA_{10}$: moderate and vigorous physical activity in 10-min bouts.

A statistical difference was found in step width (p<0.05), with small and medium effect size, between the age groups. Stride length was significantly higher (p<0.05), with medium, large and huge effect size, in YA than in OA (Figure 4.3.1.1).

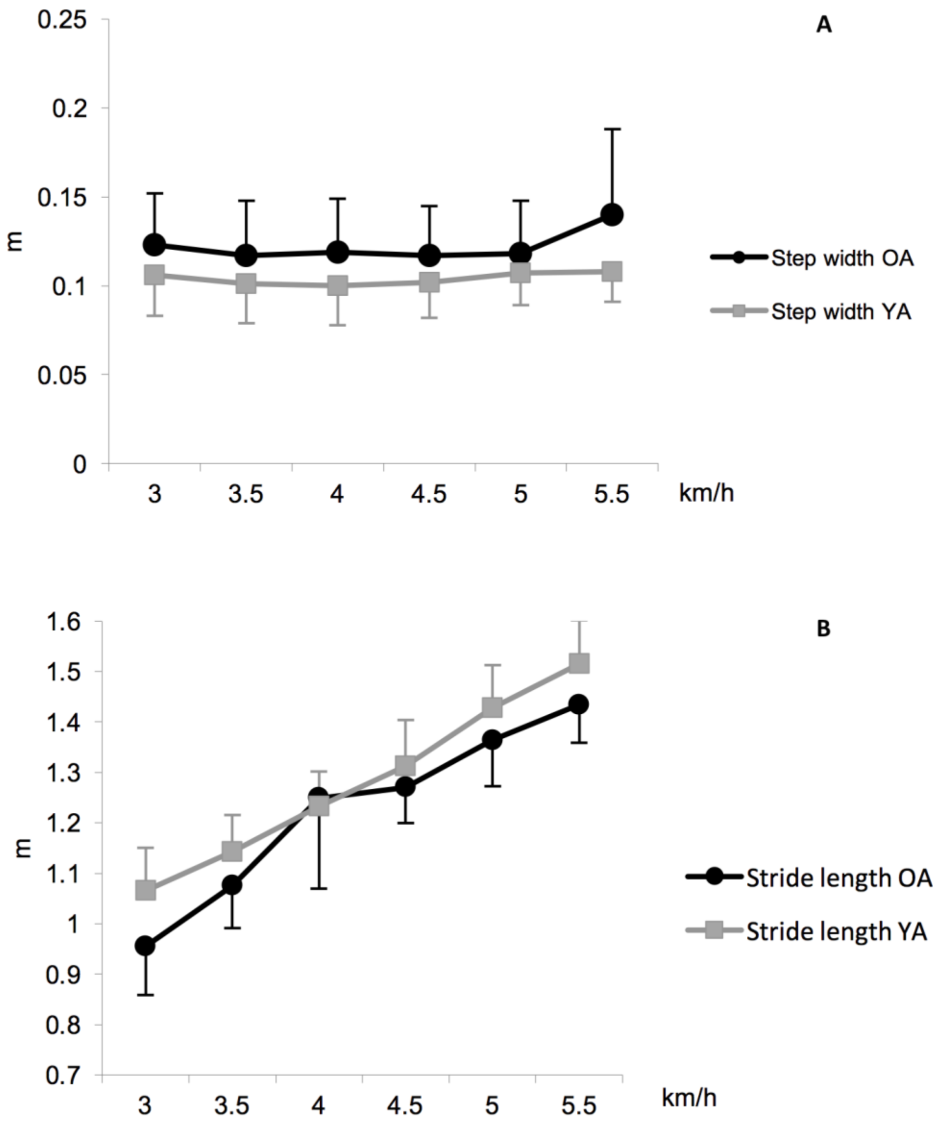
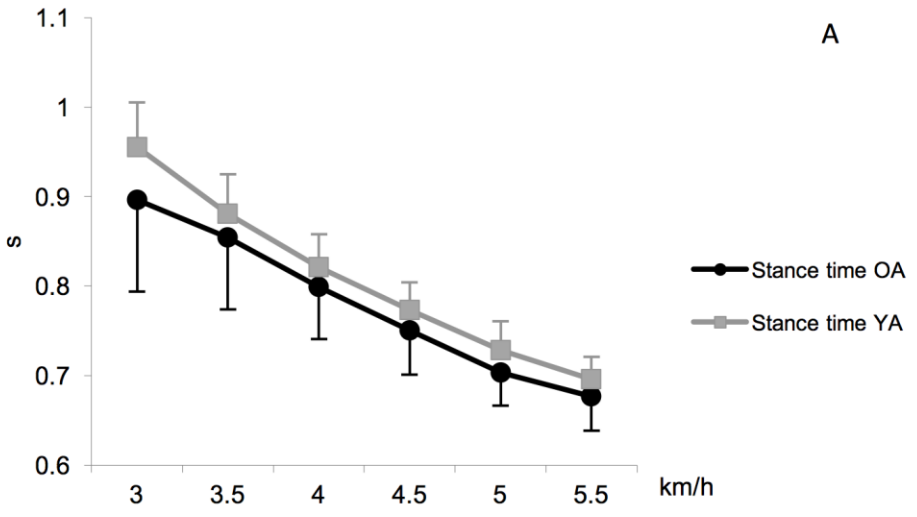


Figure 4.3.1.1 Step width (A) and stride length (B) at different walking speeds (mean+SD)

Swing and stance time measured related to the six speeds are shown in Figure 4.3.1.2. Swing and stance time were significantly higher (p<0.05), with small, medium, large and huge effect size, in YA than in OA. The walking velocity variability, expressed in terms of SD and CV, of the OA was not significantly different with respect to the YA.



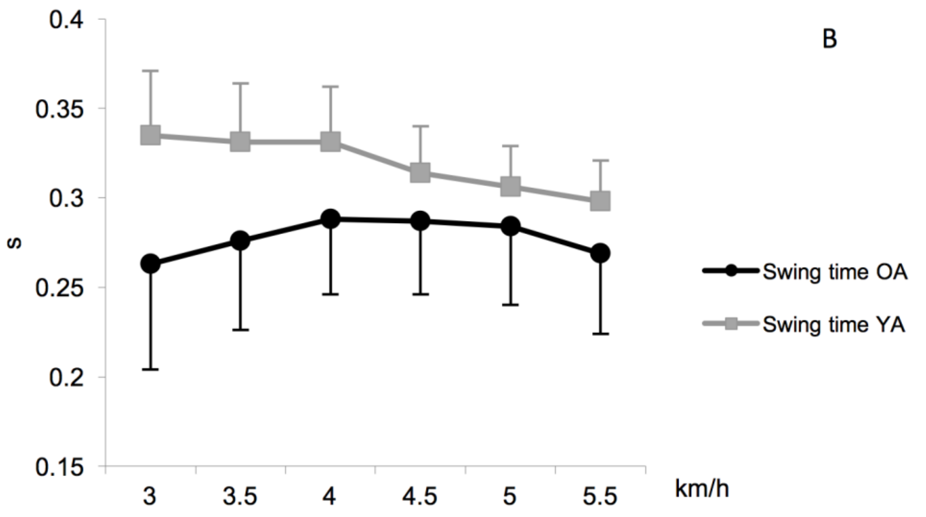


Figure 4.3.1.2 Stance (A) and swing (B) time at different walking speeds (mean+SD)

4.3.2 SPEED DIFFERENCES

The step width did not significantly differ between speeds, while stride length significantly increased with speeds (p<0.05) (Figure 4.3.1.1). Stance time significantly decreased with the increasing of the speed (p<0.0001), while swing time did not significantly increase for each speed (Figure 4.3.1.2).

Significant differences in stance and swing time standard deviations were found between speeds (p<0.05). The stride length variability, step width variability, stance variability and swing variability, identified as (SD)±standard deviation, for 3, 3.5, 4, 4.5, 5 and 5.5 km·h^{-1} are represented in Figure 4.3.2.1.

The stride length, stance and swing time coefficients of variation were significantly (p<0.001) influenced by speeds. The stride length variability, step width variability, stance variability and swing variability, expressed as (CV)±standard deviation, for 3, 3.5, 4, 4.5, 5 and 5.5 km·h^{-1} are presented in Figure 4.3.2.1.

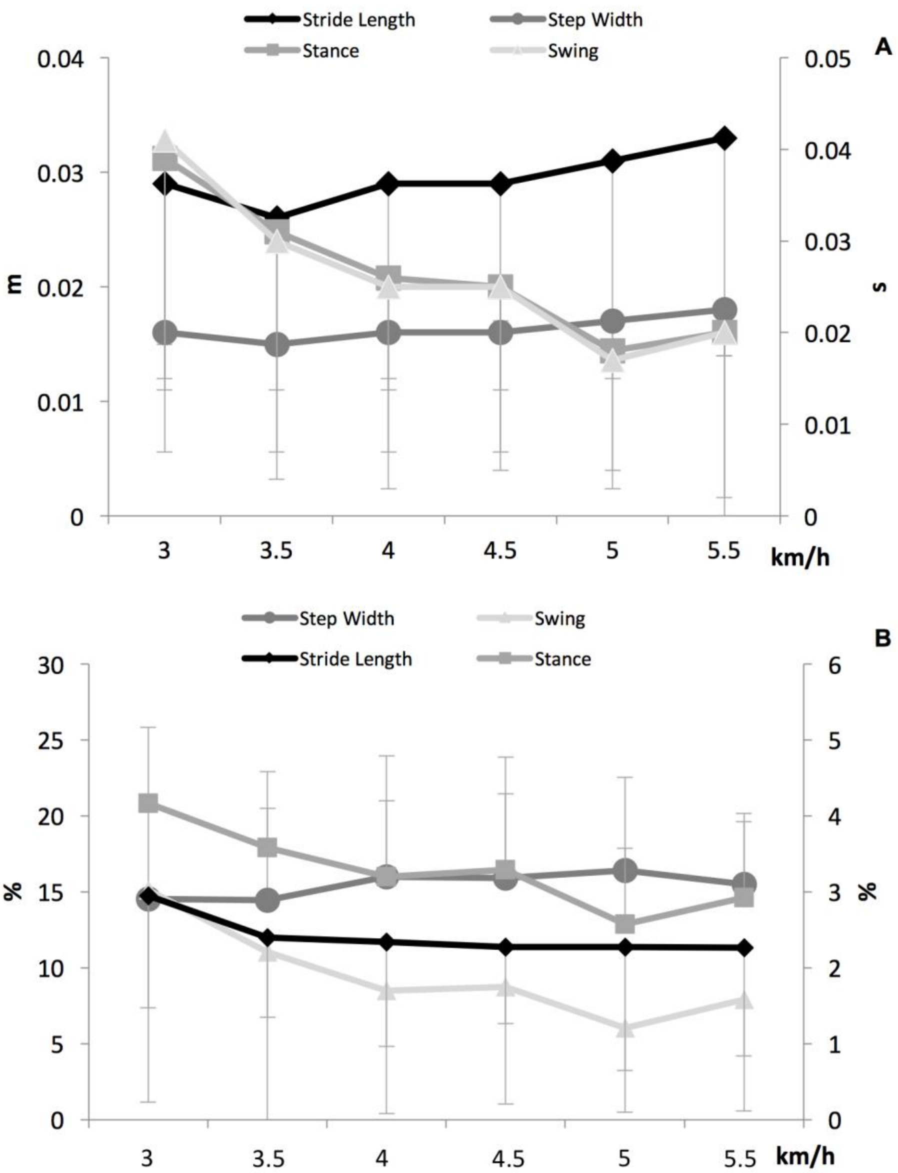


Figure 4.3.2.1 The mean values (YA and OA pooled) of gait variability expressed as SD (A) and CV (B) (mean+SD)

When CV was taken into account, step width variability appeared to be larger than all the other gait parameters. A low step width variability can be considered by CV < 8% (lowest 5% of data), a moderate step width variability can be considered by CV = 8–27% (middle 90% of data), and a high step width variability can be considered by CV > 27% (highest 5% of the data). Older women, with moderate step width variability, met the recommended levels of physical activity ($MVPA_{all}$ and $MVPA_{10}$).

4.3.3 REGRESSION SUMMARY

A significant, moderate and positive correlation was found between preferred walking speed and both $MVPA_{all}$ (r = 0.324, p = 0.0360) and $MVPA_{10}$ (r = 0.376, p = 0.0135), while no significant correlations were found between any gait parameters (stride length, step width, stance and swing time) and physical activity level. Significant, moderate and negative correlations were found between 1PC (CV) and both $MVPA_{all}$ (p<0.05) and $MVPA_{10}$ (p<0.05) for each speed, while no significant correlations were found either between 1PC (SD) and $MVPA_{all}$ or between 1PC (SD) and $MVPA_{10}$. For this reason, only 1PC (CV) was considered among the measures of gait variability. 1PC (CV) was significantly (p<0.05) and negatively associated with $MVPA_{all}$ at 3, 3.5, 4, 4.5, 5, 5.5 $km \cdot h^{-1}$, while 1PC (CV) was significantly (p<0.05) and negatively associated with $MVPA_{10}$ only at 3.5, 4, 4.5, 5 $km \cdot h^{-1}$ (Unadjusted Model). 1PC (CV) remained a significant (p<0.05) indicator of $MVPA_{all}$ also after adjusting for age, and number of falls, only at 3.5 $km \cdot h^{-1}$ and of $MVPA_{10}$ only at 4 $km \cdot h^{-1}$ (Adjusted Model). In all models, 1PC (CV) explains less than 20% of the variance (Table 4.3.3.1).

Table 4.3.3.1 Backward stepwise regression analysis between 1PC (CV) and $MVPA_{all}$ and $MVPA_{10}$

	Model 1 Unadjusted						Model 2 Adjusted					
	$MVPA_{all}$			**$MVPA_{10}$**			**$MVPA_{all}$**			**$MVPA_{10}$**		
Speed	β	R^2	*p*	β	R^2	*p*	β	R^2	*p*	β	R^2	*p*
3	-3.289	0.106	0.0356*	-1.789	0.082	0.0664	-3.355	0.142	.1158	-1.839	0.127	.1560
3.5	-4.345	0.154	0.0102*	-2.333	0.116	0.0274*	-4.325	0.187	0.0470*	-2.322	0.157	0.0871
4	-3.758	0.120	0.0246*	-2.730	0.166	0.0075*	-3.547	0.139	0.1233	-2.594	0.189	.0452*
4.5	-3.793	0.116	0.0272*	-2.184	0.101	0.0406*	-3.523	0.131	0.1458	-1.979	0.121	0.1732
5	-5.269	0.152	0.0108*	-2.648	0.100	0.0411*	-4.965	0.159	0.0830	-2.374	0.117	0.1888
5.5	-4.162	0.110	0.0319*	-2.176	0.079*	0.0722	-3.892	0.119	0.1808	-1.921	0.096	0.2740

**Statistically significant*

In the two models all subjects were analysed together (YA and OA)

4.4 DISCUSSION

In this research, treadmill walking at different speeds in two groups of younger and older adults was assessed in terms of gait parameters and, particularly, of gait stability in order to study its association with physical activity level.

The main findings of this study were that, (1) OA were as active as YA, despite being less fit for cardiorespiratory fitness; (2) VPA resulted significantly higher in YA than in OA; (3) $MVPA_{all}$ resulted significantly higher than $MVPA_{10}$; (4) OA presented a different walking pattern than YA, although the age related differences in walking variability were not significant; (5) gait variability, expressed as CV, influenced the level of physical activity maintained, when expressed as $MVPA_{all}$ and $MVPA_{10}$, for both OA and YA.

Physical activity in older adults is crucial for the prevention of diseases, preserving independence and improved quality of life. Maintaining sufficient physical activity levels in older people is an important goal. Therefore, it is essential to identify gait characteristics of people at risks of future decline of PAL, or to identify possible interventions in order to help older people remain sufficiently physically active (Ergeton et al., 2017).

Direct measures of physical activity are generally considered more accurate, are not prone to response and recall biases and are often used to validate indirect measures of physical activity (Kolwaski et al., 2012). Accelerometry yields an objective measurement of physical activity and has been applied in large population-based studies of adults and older people monitoring overall physical activity, intensity-specific physical activity and time spent being sedentary (Hansen et al., 2013). The Actiheart was developed to overcome the limitations of using solely HR or ACC data to predict physical activity. The addition of a physiological variable (HR) should provide an improved evaluation of physical activity than exclusively accelerometry data, over a wide range of activities (Crouter et al., 2008). Variability of conventional spatio-temporal parameters, such as the standard deviation and the coefficient of variation, offers a viable method for quantitative evaluation of gait stability. The kinematic analysis system is one of the most specific and accurate methods to study the gait variability (Hamacher et al., 2011; Gouelle et al., 2016).

The study populations were composed of healthy and physically-active younger and older adults, with an elevated preferred walking speed and a good quality of life. The majority of individuals (52% of the elderly and 62% of the adults) reached recommended levels of physical activity if $MVPA_{all}$ are considered. Moreover, only 24% of the elderly achieved recommended levels of physical activity, compared to 43% of the adults, if $MVPA_{10}$ are taken into account. In this case, most of the subjects failed to accumulate the health recommendations of 30 minutes of MVPA on 5 or more days per week. A closer focus on the range of moderate intensity activity achieved by older versus younger adults may be useful, particularly in the light of the debate about the extent of intensive activity for the benefit of older adults (Davis and Fox, 2007). There were no significant differences between groups regarding the minutes spent in sedentary activity, light activity, and moderate activity. Older adults performed significantly less vigorous activities than the younger counterparts. In particular, no significant differences were detected between the time spent in MVPA when accumulated in bouts of at least 10 consecutive minutes or when overall minutes of MVPA were considered. The absence of difference between age groups in overall activity is consistent with the finding of another study (Laudani et al., 2013). Furthermore, young and older adults showed similar preferred walking speeds, in accordance with Kang & Dingwell (2008). Indeed, the average PWS of the elderly in this study is high when compared with literature data collected in women aged 65-75 years (Studenski et al., 2011). In addition, according to Almeida et al classification (2011) (‘‘fallers’’ having suffered two or more falls in the previous year; ‘‘nonfallers’’ having suffered either no falls or only one fall in the previous year) all younger adults and 18 older adults can be classified as ‘‘nonfallers’’, while only 3 older adults were classified as a ‘‘faller’’.

The present results support the previous outcomes of a stride length impairment in elderly people (Daley and Spinks, 2000), showing a decrease in stride length in older populations at almost all speeds. Indeed, in the present study, stride length ranges from 1.07 to 1.52 m in younger populations and from 0.96 to 1.43 m in older populations, respectively. A slowing of gait is also commonly reported in elderly individuals. According to Daley & Spinks (2000), older adults over 67 years of age spend a significantly longer time in the stance phase and a significantly shorter time in the swing phase than younger adults. The present results do not confirm these data, demonstrating that young adults spend more time in both stance and swing phases compared to elderly people. Probably, our subjects did not need to modify their stance phase in order to obtain an increased postural stability; as a matter of fact, they are still able to avoid a decline in speed of walking, typical of elderly.

Gait variability has become an important indicator in assessing human motor performance. According to the literature, the treadmill was used to collect a high number of consecutive gait cycles to investigate gait variability (König et al., 2014). Furthermore, Owings and Grabiner (2004) suggested that, compared to the variability of spatial and temporal step kinematics, treadmill walking may be an acceptable representation of overground walking (Owings and Grabiner, 2004). Increased gait variability is a risk factor for falls in older adults. A greater variability has been demonstrated in older adults for stride length (Kang and Dingwell, 2008) or step width (Grabiner et al., 2001; Owings and Grabiner, 2004), regardless of differences in speed. Our results do not support these findings, because walking velocity variability of older adults did not significantly differ from that of younger adults. Our data are consistent with those reported by Grabiner et al. (2001) demonstrating that the walking velocity conditions influenced the variability of the gait variables. Step width variability was larger than stride length variability when considering CV. In agreement with the literature, the results suggest that, for healthy younger and older adults, gait variability of spatial parameters is a more important descriptor of locomotion control than gait variability of temporal parameters, and step width variability represents the more sensitive descriptor of locomotion control (Owings and Grabiner, 2004). Our cut-off values are very close to the classification of Brach et al. (2005): low step width variability (step width variability CV < 7%; lowest 5% of sample), moderate step width variability (step width variability CV = 7–30%; middle 90% of sample), and high step width variability (step width variability CV > 30%; highest 5% of the sample). However, Brach et al. (2005) found that extreme step width variability (i.e. either too much or too little) was associated with a history of falls in older adults, walking at or close to normal walking speed.

Hence, it would be interesting to study the impact of gait stability on physical activity participation. Egerton et al. (2017) found that shorter step length, shorter step time, shorter swing time and higher cadence were associated with less activity. Therefore, their results did not support the view that a worsening gait, analysing gait asymmetry, caused a decline in the level of physical activity maintained by rather healthy older people. They could not evaluate gait variability, recommending examining the relationship between gait variability and physical activity in future research. Our study showed that gait variability (CV), at different speeds (3.5 or 4 $km \cdot h^{-1}$), was significantly and negatively associated with the level of physical activity ($MVPA_{all}$ or $MVPA_{10}$). Our models explained only 20% of the variance, meaning that other variables influencing physical activity have not been taken into consideration.

The limitations of the study include: 1) the small sample size; 2) a poor population heterogeneity; 3) the absence of men in the population; 4) self-selection women (selection bias); 5) only one age group (65-75yr). Indeed, our findings cannot be generalised across the general older adult population, but our findings may be useful for healthy women aged between 65 and 75. Gait performance varies from 75 years and, in particular, after 80 years (Agner et al., 2015) and it differs between men and women at the highest speeds (Barrett et al., 2008). Future research is needed for a better understanding of the association of gait stability on the level of physical activity in a wide range of population, including men and less healthy and older women.

4.5 CONCLUSION

In a population of healthy elderly women (65-75yr), gait variability was significantly and negatively associated with level of physical activity. Healthy older women, with moderate gait variability (step width variability), and a high preferred walking speed, seem to be able to meet the recommended levels of physical activity. As a practical application, these findings should be taken into account in the design of interventions aimed to improve overall activity.

5. ASSOCIATIONS BETWEEN OBJECTIVELY MEASURED PHYSICAL ACTIVITY LEVELS AND PHYSICAL FITNESS AND HEALTH-RELATED QUALITY OF LIFE IN ELDERLY WOMEN

Abstract

In previous studies, aimed to analyze the associations between physical activity (PA) levels and physical fitness and health-related quality of life (HRQoL), the differences between PA levels calculated as overall PA ($MVPA_{all}$) or accumulated in bouts of at least 10 min ($MVPA_{10}$) were not taken into account. Therefore, the aim of this study was to compare the different effects of $MVPA_{all}$ or $MVPA_{10}$ and physical fitness on HRQoL in a population of young and older women.

PA levels were objectively evaluated for 7 consecutive days. Physical fitness was determined with a hand-grip strength test and a maximal treadmill test. HRQoL was measured with the Short Form 36 Health Status Survey (SF-36v2).

Although young women resulted more fit than older women, no differences were detected for MVPA (nor $MVPA_{all}$ neither $MVPA_{10}$) or HRQoL between groups. $MVPA_{all}$ was significantly higher than $MVPA_{10}$. Regression analysis revealed that there was a positive relationship between the level of cardiorespiratory fitness (CRF) and the Physical Component Summary of HRQoL, and between the level of PA (both $MVPA_{all}$ and $MVPA_{10}$) and Physical Functioning.

These results will be useful for designing PA programs, aiming to improve CRF and that could also positively affect HRQoL.

Keywords: older adults, physical activity assessment, physical fitness, sedentary behavior

5.1 INTRODUCTION

The substantial increases in life expectancy at birth achieved over the previous century, combined with medical advances, escalating health and social care costs, and higher expectations for older age, have led to international interest in how to promote a healthier old age and how to age “successfully” (Bowling and Dieppe, 2005). Maintenance of independence in elderly individuals has been linked to the concept of “successful aging”, describing an avoidance of disease and disability, a maintenance of high physical and cognitive function, and a sustained engagement in social and productive activities (ACSM, 2014). Health-Related Quality of Life (HRQoL) is part of a multidimensional approach that considers physical, mental, and social aspects. In the elderly, the quality of life is affected by factors such as aging, health status, physical activity (PA) and disability (McPhee et al., 2016). Many diseases can significantly impair the HRQoL, in particular in frail population and older adults, and PA plays an important role in improving HRQoL. PA has also a crucial role in primary and secondary prevention of several chronic diseases and premature death; notably, older adults that practice regular moderate PA, as walking or cycling, attain many health benefits. Some studies have showed that there is also a positive relationship between physical fitness and HRQoL. Specifically, in elderly population, higher level of cardiorespiratory fitness (CRF) have been associated with higher levels of HRQoL (Warburton et al., 2006). Physical fitness may be an important factor that explains why regular PA improves HRQoL (Gusi et al., 2015). There is a wide range of questionnaire-based tools designed to ascertain HRQoL and the Short Form 36 Health Status Survey (SF-36v2) has been accepted as HRQoL measure and it has been recommended as good outcome measure across a range of ages, participant characteristics and illness conditions (Sayer et al., 2006).

The association between PA and HRQoL has been studied in an adult (Anokye et al., 2012) or an older adult population (Halaweh et al., 2015) or considering both groups (Bertheussen et al., 2011). In general, higher levels of PA appear to be associated with HRQoL, and PA can help older adults reclaim or maintain a healthy aging process: a physically active lifestyle, including increasing leisure time PA, may result in a better long term HRQoL among elderly persons. Relatively regular moderate PA can help elderly prevent a decline in HRQoL and even improve their enjoyment of life. Only few studies have used objective measures of PA, for instance using the accelerometers that should be a favorite method of objective measurement of PA, given that they have an increased capacity to capture different movements (Pruitt et al., 2008).

If there are many studies analyzing the associations between PA and HRQoL, the associations between physical fitness and HRQoL have not been sufficiently examined. The scarce literature that is available shows that people with better physical fitness scores usually report higher percentile scores for different HRQoL domains. Many studies have evaluated physical fitness using aerobic or strength measures; positive correlations have been observed between physical fitness and both physical and mental health-related factors in the general population and in the elderly. Principally, Sörensen et al. (2007) and Sloan et al. (2009) showed a positive relationship between the level of CRF and Physical Component Summary and the mental and physical health components of HRQoL in an adult population, respectively. Garber et al. (2010) showed a positive association between CRF and Physical Function in an elderly population. Moreover, Olivares et al. (2011) and Sayer et al. (2006) showed a positive association between physical fitness and Physical Component Summary and between General Health and HRQoL, respectively, in a sample including both adults and older adults. Physical fitness may be an important factor that explains why regular PA improves HRQoL, especially the HRQoL dimensions that relate closely to physical function. In fact, PA and physical fitness are closely related because physical fitness is mainly determined by PA patterns (Olivares et al., 2011).

Only a few studies have investigated the associations between HRQoL and PA and physical fitness. Hörder et al. (2013) pointed out that older persons with a high fitness and also those who attained recommended levels of walking had better results in most aspects of HRQoL. Wanderley et al. (2011) demonstrated through objective measurements of PA and fitness that among relatively healthy older individuals, higher PA levels and better physical fitness were associated with higher HRQoL. However, Wanderley et al. (2011) did not take the differences between PA levels calculated as overall PA ($MVPA_{all}$) or accumulated in bouts of at least 10 min ($MVPA_{10}$) into account, though only this last seems to be potentially more helpful for increasing average life expectancy (ACSM, 2009) and nearly half of older adults did not perform any sustained 10-min moderate-to-vigorous physical activity bouts (Davis and Fox, 2007). Therefore, the aim of this study was to compare the different effects of $MVPA_{10}$ and $MVPA_{alll}$ and physical fitness on HRQoL in a population of young and older adults.

5.2 METHODS

An observational study was conducted and an ethical approval has been obtained from the local review board before beginning the study. Twenty-one young women and 21 older women were recruited in this study. Written informed consent was obtained from all subjects after detailed explanation of aims, benefits, and risks involved with this investigation. Anthropometrics parameters are reported in Table 5.2.1.

Table 5.2.1 Anthropometric measurements in older adults and young adults

	Older adults	**Young adults**	**Total**	**ES**
	mean±SD	mean±SD	mean±SD	d
Age (y)	68.3±3.3	22.6±2.9*	45.4±23.3	-15.1
Weight (kg)	64.5±9.1	59.1±5.9*	61.8±8.0	-0.7
Height (m)	1.6±0.1	1.6±0.1*	1.6±0.1	0.7
BMI (kg·m^{-2})	26.1±3.0	22.5±2.6*	24.3±3.3	-1.3
n falls	0.5±1.0	0.0±0.0*	0.3±0.8	-0.7

**Statistically significant difference between Older Adults and Young Adults (t-test, p<0.05).*

BMI: body mass index

Two sessions on separate days were performed: (i) medical screening, anthropometric parameters (height, weight, and body mass index BMI) (see paragraph 2.2.1), number of falls, HRQoL and maximum oxygen consumption ($\dot{V}O_{2max}$) were determined on first day, and each subject worn an activity monitor; (ii) after one week, isometric maximal voluntary contraction (iMVC) was measured.

Health-Related Quality of Life

HRQoL was assessed using the Short Form 36v2 questionnaire, developed to measure functional health and well-being from the patient's point of view. Two composite scores are derived from these subscales: the Physical Component Summary (PCS: PF, RP, BP, GH) and the Mental Component Summary (MCS: VT, SF, RE, MH), cumulative scores obtained by using calculation algorithms provided by the authors (Ware and Sherbourne, 1992) (see paragraph 2.1).

Physical Activity

To provide an accurate estimation of PA, the Actiheart (AH, CamNtech, UK) was worn for almost 7 complete and consecutive days and the participants were requested to carry on with their habitual lifestyle while wearing the activity monitor. The Branched model was used to assess PA level, where HR and ACC data are weighted and combined (Brage et al., 2004), after entering individual calibrations (Brage et al., 2006). Time spent in SED, LPA or MPA to VPA were considered (Pate et al., 1995). MPA and VPA were summed to obtain the total amount of time participants spent in moderate and vigorous PA (MVPA ≥ 3 METs). Since PA guidelines (Nelson et al., 2007) recommend to accumulate MVPA in bouts of at least 10 minutes, MVPA was analyzed as overall PA ($MVPA_{all}$) or accumulated in bouts of at least 10 consecutive minutes ($MVPA_{10}$) (see paragraph 2.2.3).

Health-Related Physical Fitness

Maximal oxygen consumption ($\dot{V}O_{2peak}$) was evaluated during a modified Balke treadmill test to exhaustion (Balke and Ware, 1959) with breath-by-breath indirect calorimetry. The protocol maintained a fixed speed (4 km·h^{-1} for older adults and 5.5 km·h^{-1} for young adults) and the test was started by setting the incline at 0 per cent; the incline was increased by 2 per cent after 1 minute and by 1 per cent thereafter every minute. The test finished when subjects reached the maximal exhaustion. To calculate $\dot{V}O_{2peak}$, data were averaged at 30-s intervals, and the highest value of the last minute of the test was taken into consideration. $\dot{V}O_{2peak}$ was computed in absolute values ($\dot{V}O_{2abs}$) and relative to body mass ($\dot{V}O_{2rel}$). Hand-grip strength measurement (isometric maximal voluntary contraction, iMVC) was performed using a hydraulic hand dynamometer, recording the best score of three trials. iMVC was defined as the greatest force and was divided by the participants' weight to correct for total body weight ($iMVC_{BW}$) (see paragraph 2.2.2).

5.2.1 STATISTICAL ANALYSIS

Descriptive statistics were used to characterize the sample according to PA, physical fitness and HRQoL variables. Means and standard deviations (SD) were computed and normality of distribution was determined for all continuous variables.

The unpaired t-test was performed to determine differences between young adults (YA) and older adults (OA) and between $MVPA_{all}$ and $MVPA_{10}$. The one-sample t-test was performed to determine differences between $MVPA_{all}$ or $MVPA_{10}$ and PA guidelines. The effect size was assessed computing Cohen's d Effect Size (ES): effects sizes of 0.20, 0.50, 0.80 and >1 were considered small, medium, large, and huge (Cohen, 1992).

Pearson's correlation coefficient was used to examine the correlation between HRQoL, physical fitness and the level of PA. The data were further analyzed with backward stepwise regression analysis, adjusted for age, BMI and number of falls, with HRQoL as the dependent variable and PA or physical fitness as independent variables. Analyses of associations for any subscales and for PCS and MCS were carried out separately. PCS and MCS scores were presented as mean adjusted for mean age. Separate models were fitted for each indicator of physical fitness and PA to avoid unstable estimates resulting from the collinearity among those indicators. Hence different models were estimated: model 1 ($\dot{V}O_{2abs}$) and (iMVC); model 2 (SED); model 3 (LPA); model 4 (MPA); model 5 (VPA); model 6 ($MVPA_{10}$); model 7 ($MVPA_{all}$).

Threshold for statistical significance was set at $p<0.05$ and analysis was undertaken using StatView version 5.0.1.

5.3 RESULTS

Table 5.3.1 shows the main characteristics of the study population and the differences observed between YA and OA. Statistically significant ($p<0.05$) differences, with a large or medium ES, were detected between the two groups with regard to mean age and BMI and weight, height and number of falls, respectively.

The mean scores on PCS and MCS were higher (55.1±6.3) and lower (47.7±8.5) than the norm for the general population, respectively (Ware and Sherbourne, 1992). In general, YA reported better HRQoL than OA; nevertheless, the only statistically significant difference between young and older adults was the PF item ($p<0.001$), with a huge ES (Table 5.3.1).

Table 5.3.1 HRQoL, measures

	Older adults	Young adults	Total
HRQoL	mean±SD	mean±SD	mean±SD
PCS	53.3±6.8	56.9±5.4	55.1±6.3
MCS	48.4±9.7	47.1±7.2	47.7±8.5
PF	52.9±4.9	56.8±1.1*	54.9±4.0
RP	51.6±7.0	51.9±6.0	51.8±6.4
BP	52.8±9.8	55.3±7.3	54.1±8.6
GH	49.6±5.3	53.8±9.0	51.7±7.6
VT	55.1±7.8	53.7±4.7	54.4±6.4
SF	48.7±8.6	50.0±7.2	49.3±7.8
RE	47.7±9.8	47.0±7.0	47.4±8.4
MH	49.2±8.8	49.7±6.8	49.5±7.7

**Statistically significant difference between older adults and young adults (t-test, p<0.05; ES=1.1).*

PCS: Physical Component Summary; MCS: Mental Component Summary; PF: Physical Functioning; RP: Role-Physical; BP: Bodily Pain; GH: General Health; VT: Vitality; SF: Social Functioning; RE: Role-Emotional; MH: Mental Health.

PA represented the time spent in SED, LPA, MPA, VPA, $MVPA_{all}$ and $MVPA_{10}$, for YA and OA. The proportion of 'physically active' individuals, when overall PA is examined, ranged from 62% to 48% for YA and OA, respectively. On the contrary, if MVPA is measured considering time spent in bouts of at least 10 consecutive minutes, only 43% and 24% of the population met current PA recommendations (Nelson et al., 2007), for YA and OA, respectively. In fact, $MVPA_{all}$ was significantly (p<0.01) higher than $MVPA_{10}$. Time spent in VPA was significantly (p<0.05) lower for OA when compared with YA, with a medium ES (Table 5.3.2).

Table 5.3.2 Physical Activity measures

Physical Activity	Older adults mean±SD	Young adults mean±SD	Total mean±SD
SED (min·day^{-1})	685.9±116.8	730.3±111.7	708.1±115.1
LPA (min·day^{-1})	223.5±104.0	201.2±67.1	212.3±87.2
MPA (min·day^{-1})	61.2±63.4	55.0±46.4	58.1±55.0
VPA (min·day^{-1})	0.2±0.7	5.8±10.3*	3.0±7.7
$MVPA_{all}$ (min·day^{-1})	61.4±63.7	60.8±52.2	61.1±57.5
$MVPA_{10}$ (min·day^{-1})	29.4±41.7	28.0±29.3	28.7±35.6

**Statistically significant difference between older adults and young adults (t-test, p<0.05; ES=0.7).*

SED: sedentary; LPA: light physical activity; MPA: moderate physical activity; VPA: vigorous physical activity; $MVPA_{all}$: overall moderate and vigorous physical activity total; $MVPA_{10}$: moderate and vigorous physical activity in 10-min bouts.

According to the normative values for the hand-grip both YA and OA had poor strength. For $\dot{V}O_{2max}$ values YA were above the average, while OA were between the 50th and the 60th percentile (Ratames, 2012). YA were more fit than OA (Table 5.3.3); actually, both CRF ($\dot{V}O_{2abs}$ and $\dot{V}O_{2rel}$ with a huge ES) and maximal strength (iMVC with a medium ES and $iMVC_{BW}$ with a huge ES), expressed in relative or absolute values, resulted significantly higher in YA with respect to OA (p<0.05).

Table 5.3.3 Physical Fitness measures

Physical Fitness	Older adults mean±SD	Young adults mean±SD	Total mean±SD	ES d
$\dot{V}O_{2abs}$ (l/min)	1.7±0.3	2.3±0.3*	2.0±0.4	2.0
$\dot{V}O_{2rel}$ (ml·kg^{-1}·min^{-1})	26.9±5.1	39.3±4.7*	33.1±7.9	2.6
iMVC (N)	151.4±52.3	190.6±60.2*	171.0±59.1	0.7
$iMVC_{BW}$ (N·kg^{-1})	2.3±0.7	3.2±1.0*	2.7±1.0	1.1

**Statistically significant difference between older adults and young adults (t-test, p<0.05).*

$\dot{V}O_{2abs}$: maximal oxygen consumption in absolute values; $\dot{V}O_{2rel}$: maximal oxygen consumption relative to body mass; iMVC: isometric maximal voluntary contraction; $iMVC_{BW}$: isometric maximal voluntary contraction correct for total body weight.

With regard to correlations between the eight HRQoL dimensions, and the two summary scores, the dimensions that correlated best each other were PF, RP, BP, SF and RE. Correlation coefficients between the summary scores and each HRQoL domains and each of the physical fitness variables indicated that only CRF was significantly ($p<0.05$) and positively correlated with several domains of HRQoL. If PA variables are taken into account, a significant but negative correlation was demonstrated between SED and VT item and between VPA and SF item ($p<0.05$). The HRQoL dimensions that correlated least well with the PA or physical fitness data were RP, RE and MH (Table 5.3.4).

Table 5.3.4 Pearson's correlation between HRQoL and Physical Activity and Physical Fitness

	Health-Related Quality of Life dimensions (HRQoL)									
	PCS	MCS	PF	RP	BP	GH	VT	SF	RE	MH
HRQoL										
PCS	1.000									
MCS	-.150	1.000								
PF	.756***	.182	1.000							
RP	.651***	.455**	.614***	1.000						
BP	.813***	.184	.640***	.622***	1.000					
GH	.701***	.004	.477**	.396**	.403**	1.000				
VT	.101	.796***	.246	.457**	.354*	.172	1.000			
SF	.267	.724***	.461**	.626***	.465**	.115	.526***	1.000		
RE	.038	.862***	.337*	.598***	.321*	.005	.644***	.695***	1.000	
MH	-.038	.872***	.260	.424**	.225	.174	.715***	.538***	.604***	1.000
Physical Activity										
SED	.107	-.105	.013	.055	.035	.203	-.314*	-.040	-.046	-.015
LPA	.034	.159	.033	.022	.144	.008	.285	.150	.109	.099
MPA	-.076	-.004	-.009	-.055	-.061	-.209	.214	-.039	-.016	-.092
VPA	.114	-.142	.221	-.077	-.016	.154	.145	-.363*	-.160	.020
$MVPA_{all}$	-.057	-.023	.021	-.063	-.061	-.179	.224	-.086	-.037	-.085
$MVPA_{10}$	.023	-.024	.129	.064	-.052	-.074	.140	-.108	.011	-.029
Physical Fitness										
$\dot{V}O_{2abs}$	.309*	-.005	.419**	.015	.366*	.175	.120	.087	.015	.072
$\dot{V}O_{2rel}$	.392**	.015	.535***	.100	.360*	.307*	.076	.192	.084	.057
iMVC	.164	-.029	.155	.085	.101	.188	-.010	-.011	-.014	.043
$iMVC_{BW}$	.243	-.055	.257	.129	.100	.280	-.062	.058	-.010	.000

*In bold significant Pearson's correlation between Health-Related Quality of Life and Physical Fitness and Physical Activity. *p<0.05; **p<0.01; ***p<0.001*

PCS: Physical Component Summary; MCS: Mental Component Summary; PF: Physical Functioning; RP: Role-Physical; BP: Bodily Pain; GH: General Health; VT: Vitality; SF: Social Functioning; RE: Role-Emotional; MH: Mental Health; SED: sedentary; LPA: light physical activity; MPA: moderate physical activity; VPA: vigorous physical activity; $MVPA_{all}$: overall moderate and vigorous physical activity total; $MVPA_{10}$: moderate and vigorous physical activity in 10-min bouts; $\dot{V}O_{2abs}$: maximal oxygen consumption in absolute values; $\dot{V}O_{2rel}$: maximal oxygen consumption relative to body mass; iMVC: isometric maximal voluntary contraction; $iMVC_{BW}$: isometric maximal voluntary contraction correct for total body weight.

Adjusted regression analyses, for age, BMI, and number of falls, obtained for each HRQoL domain with respective R^2, β and p values, are shown in Table 5.3.5. Fitter individuals, subjects with a higher $\dot{V}O_{2abs}$, had a significantly (p<0.05) greater chance of scoring higher on PCS, PF and BP domains. YA and OA were more likely to score higher on PCS, PF and BP with each unit increase in $\dot{V}O_{2abs}$. For example, each 1 LO_2/min was associated with an increase of 4.5% in PCS. No associations were found between iMVC and any HRQoL domain. Subjects with higher levels of PA were significantly (p<0.05) more likely to score higher on PF and RE (when LPA is considered), PF (when MPA and VPA are taken into account), when compared with individuals with lower PA levels. VPA seems to negatively influence SF and RE domains. Higher sedentary time was significantly (p<0.05) associated with increased prevalence of having poor scores for VT and RE domains. YA and OA, who attained recommended levels of PA ($MVPA_{all}$), had significantly better results only in PF domain. The same associations were found when $MVPA_{10}$ was considered. However, none of the PA or physical fitness variables showed significant associations with MCS, RP, GH, and MH domains.

Table 5.3.5 Backward stepwise regression analysis, adjusted for age, BMI and number of falls between HRQoL and Physical Activity and Physical Fitness

	R2	β	p
Model 1			
PCS vs $\dot{V}O_{2abs}$	0.095	4.216	0.0466
PF vs $\dot{V}O_{2abs}$	0.327	9.494	0.0004
BP vs $\dot{V}O_{2abs}$	0.134	6.182	0.0172
Model 2			
VT vs SED	0.099	4.390	0.0425
RE vs SED	0.210	3.370	0.0283
Model 3			
RE vs LPA	0.190	2.971	0.438
PF vs LPA	0.356	5.113	0.0022
Model 4			
PF vs MPA	0.356	5.120	0.0022
Model 5			
PF vs VPA	0.343	4.825	0.0031
SF vs VPA	0.224	5.631	0.0071
RE vs VPA	0.183	2.842	0.0506
Model 6			
PF vs $MVPA_{10}$	0.349	6.781	0.0009
Model 7			
PF vs $MVPA_{all}$	0.357	5.137	0.0021

PCS: Physical Component Summary; PF: Physical Functioning; BP: Bodily Pain; VT: Vitality; SF: Social Functioning; RE: Role-Emotional; $\dot{V}O_{2abs}$: maximal oxygen consumption in absolute values; SED: sedentary; LPA: light physical activity; MPA: moderate physical activity; VPA: vigorous physical activity; $MVPA_{all}$: overall moderate and vigorous physical activity total; $MVPA_{10}$: moderate and vigorous physical activity in 10-min bouts.

5.4 DISCUSSION

This observational study investigated the associations between PA levels, calculated as overall PA or accumulated in bouts of at least 10 min and physical fitness and HRQoL in healthy young and older women. Our results suggested that (i) there is a positive relationship between the level of CRF and the Physical Component Summary of HRQoL; (ii) there is a positive relationship between the level of PA (both $MVPA_{all}$ and $MVPA_{10}$) and Physical Functioning; (iii) there is a negative relationship between sedentary time and Vitality and Role-Emotional; (iv) PA and physical fitness do not influence the Mental Component Summary. To the best of our knowledge, this is the first study to evaluate the associations between objectively measured PA levels, calculated as overall PA or accumulated in bouts of at least 10 min, sedentary time, physical fitness and HRQoL.

The study population was composed of healthy, physically-active women, with a good quality of life. Older women resulted on average overweight, according to BMI classification, while young women were normal weight. Many studies have demonstrated that a higher BMI was associated with poorer physical function (Garber et al., 2010). In this study, there were no significant differences between groups for time spent in SED, LPA and MPA, even if elderly performed less than half of the minutes of VPA of young women (Hurtig-Wennlöf et al., 2010). In older women, PA is important for the prevention of disease, maintenance of independence and improvement of quality of life (Halaweh et al., 2015). In this study, a significant difference was detected between the time spent in MVPA, when accumulated in bouts of at least 10 consecutive minutes or when overall minutes of MVPA are considered. This is in contrast with a previous study (Metzeger et al., 2008), which demonstrated that the results for bout minutes of MVPA were similar to the patterns produced for overall MVPA. Considering $MVPA_{all}$, both groups reached recommended levels of PA, while taking into account $MVPA_{10}$ both young and older women only approached the values dictated by the guidelines (WHO, 2010). The average HRQoL of the young and older women were medium score (Ware and Sherbourne, 1992), and for the physical fitness, our subjects were in general below the average, in particular for CRF (Martin et al., 1992; ACSM, 2014). The objective measures of physical activity are generally considered the most accurate (Kolwalski et al., 2012), and in particular accelerometry has been used both on young and older adults to evaluate the daily PA, intensity and time spent in sedentary activities (Hansen et al., 2013). The Actiheart is a device that could be even more accurate, taking both movement counts and HR into consideration. Tests of maximal aerobic capacity are indeed the gold standard for cardiorespiratory fitness assessments, and objective and accurate measurement of oxygen consumption is imperative to understand the best mechanisms for preventing disease and disability in the elderly population (Schrack et al., 2014). It was demonstrated that anthropometry, and the number of falls are important correlates of HRQoL (Gouveia et al., 2017). Thus, these covariates were inserted in the regression models to explore the associations of PA and physical fitness with each HRQoL summary components and domains.

Our findings suggest that there is a relationship between physical fitness and HRQoL, in particular between CRF and the physical components. Similar results have recently been found in adults (Sörensen et al., 2007; Sloan et al., 2009) and also in older persons (Olivares et al., 2011), using field tests or submaximal tests. A strong relation between grip strength and HRQoL, as demonstrated by Sayer et al. (2006), was not confirmed in our study. When objectively measured, CRF was the most important independent fitness indicator, explaining 30% of Physical Functioning. Low level of CRF has been identified as a predictor of adverse health outcomes (Lee et al., 2010) and the use of direct measurement of $\dot{V}O_{2\max}$ results the mandatory choice to detect elderly people that can live independently. The demonstrated relation between PA (both $MVPA_{all}$ and $MVPA_{10}$) and HRQoL is in line with previously reported dose–response relations between PA and HRQoL in adults (Anokye et al., 2012) and in elderly (Hörder et al., 2013; Halaweh et al., 2015). Wanderley et al. (2015) and Bertheussen et al. (2014) found that PA was consistently associated with better physical health or physical and mental health, respectively, in males and females and in young and old adults. On the contrary, our data demonstrated a relation only between PA and Physical Functioning. Bertheussen et al. (2011) analyzed all aspects of PA (frequency, duration, and intensity), finding that all of them were associated with HRQoL. In our study we have tried to discriminate the differences between the different intensities of PA: LPA was associated with Physical Functioning and Role-Emotional dimensions, underlying that LPA influences both physical and mental health; otherwise, MPA and VPA were associated only with Physical Functioning domain. Nevertheless, VPA can also have detrimental effects on HRQoL, in particular on Social Functioning and Role-Emotional domains, both corresponding to mental health. This may indicate that a high intensity of PA is not important for mental health in young and elderly women. Puetz (2006) demonstrated considerable evidence that the greatest risk for low vitality is associated with sedentary lifestyle; in agreement with this statement, our results showed a negative influence of SED on both Vitality and Role-Emotional, both representing mental health.

No significant associations were observed between Mental Component Summary, Role-Physical, General Health, and Mental Health domains and either PA or physical fitness. In fact, it was previously suggested (Rejeski and Mihalko, 2001) that the associations of PA on HRQoL are less important in areas where elderly people obtain values at or above the norm. In this sense, with the exception of MCS, the mean values of RP, GH, and MH domains obtained by the participants of this study were at or slightly above the norm.

The present study had several strengths: (i) PA and CRF were measured objectively; (ii) SF-36v2 is a valid, and reliable measure of HRQoL; (iii) LPA, MPA, and VPA were taken into consideration, and (iv) the different associations of both $MVPA_{all}$ and $MVPA_{10}$ and HRQoL were considered.

The limitations of the study included: (i) the cross-sectional design; (ii) the small sample size; (iii) a poor population heterogeneity, in terms of health conditions, physical activity and physical fitness; (iv) the absence of men in the population. This study was conducted only with healthy women, which means that results cannot be generalized to frail populations. Further researches are required taking into consideration men and unhealthy young and older people.

In conclusion, this research demonstrated, through objective measurements of PA and physical fitness, that among healthy young and older women a high level of PA and also a good CRF are related to HRQoL. If improved HRQoL is a goal when encouraging young and older women to be physically active, CRF seems to be the principle pathway. However, when implementing a new PA program, vigorous physical activities have to be implemented with caution if a positive effect on mental health is wanted. On the contrary, sedentary time is to be reduced because of its negative effect on vitality. Even if almost all the population met current PA recommendations, accumulating a minimum of 30 min of daily moderate PA in bouts of 10 minutes or more, and no differences between the associations with HRQoL were detected, the significant difference between $MVPA_{all}$ and $MVPA_{10}$ has also to be taken into consideration when tailored intervention for the elderly population has to be provided.

6. CONCLUSION

Aging is accompanied by an inevitable structural and functional decline and this process can be delayed by successfully aging, *in primis* practicing physical activity. Even if aging is an integral and natural part of life, successful aging involves subjective criteria that are difficult to assess with objective measurements. Assessments have included self-rated health, participation in activities of daily living, independence and overall life satisfaction.

With age, fat mass increases and fat free mass, muscle strength, balance and CRF decrease. Physical activity cannot contrast the accumulation of fat but exercise can reduce the risk of cardiovascular disease and improve the metabolic profile.

The fear of falling reduces the physical activity level and consequently the quality of life, and is associated with the risk of falls; the loss of balance in daily life can increase this risk. A potential cause could be the age-related deterioration of gait quality, such as variability and stability. In fact, the gait variability is associated with the risk of falling and it increases with age (Toebes et al., 2015).

Regular participation in moderate physical activity is integral to good health and maintaining independence, contributing to lowering risk of falls, fall-related injuries and increase the life expectancy. Practicing regular physical activity allows the elder to improve the patterns of movement and consequently to be self-confident about themselves (Carter et al., 2001).

With advancing age, the type of physical activity changes, especially walking. This exercise is a convenient mode of exercise because it is very easy to apply in everyday activities and it requires a significant amount of metabolic energy. It is very accessible, and a universal form of physical activity that is appropriate to promote regardless of sex, ethnic group, age, education, or income level. In addition, walking is often a group activity that results in social interaction, which also has an independent effect on health as indicated by evidence that low social interaction is associated with increased mortality (Lee and Buchner, 2008).

There is a growing interest to applying the PWS measurement to predict adverse outcomes in the elderly. The PWS is a measure of considerable importance, particularly for older adults, as it is predictive of outcomes such as functional dependence, disability, and survival (Montero-Odasso et al., 2005). The PWS is relevant to older adults wishing to remain safe and independent. Different studies have also identified other determinants

of PWS such as age, stature, and strength (Bohannon, 2008).
Practicing in regular physical activity means maintaining a good level of fitness, which means having all the skills to maintain physical independence.

The dissertation aimed to shed light on the perspectives related to the role of (i) gait stability in reaching the physical activity level suggested by international guidelines; (ii) energy cost of walking in maintaining a high gait speed; (iii) health-related physical fitness in preserving a good gait stability; (iv) physical fitness in keeping a high health-related quality of life; and (v) physical activity in sustaining a high health-related quality of life.

Can gait variability influence the level of physical activity maintained by elderly women?
The gait stability influences the level of physical activity maintained but only when expressed as $MVPA_{all}$. In fact, in older women, $MVPA_{all}$ were significantly higher than $MVPA_{10}$. Our results show that a gait stability with coefficient of variation values lower than 3% for stride length, stance and swing time and 15% for step width, and a high preferred walking speed (5 $km \cdot h^{-1}$), seem to be able to ensure elevated levels of physical activity in healthy older women.
The elderly persons seem to reach the level of physical activity suggested by the guidelines because they have a high PWS and maintain a good stability while walking. In particular, alongside with walking, there are several activities that can maintain high levels of physical activity such as Tai Chi, dance or various housekeeping. They maintain the subjects active, allow to improve the balance by increasing the gait stability and reducing the risk of falling.
Many activities in daily life can be turned into a balance enhancing movement or position with a little creativity, making balance training one of the easiest modalities of exercise to integrate. For example: while standing in line, cooking, combing your hair, or doing dishes, move your feet closer together or stand on one leg if possible during the task. Attempt to rise from the chair without using your arms, advance to rising using only one leg for support.

Can energy cost of walking influence gait speed in elderly women?

The relationship between net energy cost of walking and speed has a characteristic "U shaped" curve, with an individual walking speed selected to coincide with the lowest metabolic cost. The net cost of walking increases with age, resulting in an upward shift in the net cost of walking–speed relationship during aging. In our study both groups exhibited a similar U-shaped relationship between the net cost of walking and walking speed, but only in older adults the speed with the lowest energy cost of walking corresponded to their PWS, elderly women maintaining a net cost of walking greater than younger counterparts at any speed. No previous studies have considered the influence of net cost of walking of different speeds on the PWS.

The energy cost of walking is influenced by the speed but does not influence gait speed at any of the analyzed speeds. An age-related increase of the net cost of walking values was found for healthy older adults and needs to be taken into consideration when recommending walking as an exercise modality.

Can health-related physical fitness influence gait variability in elderly women?

Strength is important for stability and correct balance during the gait walking. In our study a significant association was found only between hand-grip strength and coefficient of variation index and underlined that a higher muscle strength (hand-grip) is somehow related to gait variability. These results need to be taken into consideration when recommending health-related physical fitness tests protocols for older adults during lifespan. In fact, hand-grip is a simple and non-invasive test. It is considered as one of the most reliable physical measurements of human strength and as the single element representing the total body force. It gives an important result of the general health and function in healthy people, and it seems to have implications for human walking.

Try to do strength exercises for all of your major muscle groups on 2 or more days per week for 30 minutes at a time. Don't exercise the same muscle group on 2 subsequent days. For example, the exercises are: sit-to-stand, mini-squats, calf raises, sideways leg lift, leg extension and wall press-up.

Can objectively measured physical fitness influence health-related quality of life in elderly women?

Our findings suggest that there is a relationship between physical fitness and HRQoL, in particular between CRF and the physical components. Similar results have recently been found using field test or submaximal tests. When objectively measured, with a maximal test, CRF is the most important independent fitness indicators, explaining 30% of Physical Functioning. Low level of CRF has been identified as a predictor of adverse health outcomes and the use of direct measurement of $\dot{V}O_{2max}$ results the mandatory choice to detect independent elderly women. If improved HRQoL is a goal when encouraging young and older women to be physically active, CRF seems to be the principle pathway.

Can objectively measured physical activity levels influence health-related quality of life in elderly women?

In our results there is a positive relationship between the level of PA with both $MVPA_{all}$ and $MVPA_{10}$ and Physical Functioning. Monitoring PA in the elderly is essential, because PA is important for the prevention of disease, maintenance of independence and improved quality of life. There are different methods for monitoring PA, such as questionnaires, but because of the particular limitations of self-reporting PA, objective techniques, as accelerometry, are necessary to obtain consistent results. Even if almost all the population met current PA recommendations, accumulating a minimum of 30 min of daily moderate PA in bouts of 10 minutes or more, and no differences between the associations with HRQoL were detected, the significant difference between $MVPA_{all}$ and $MVPA_{10}$ has also to be taken into consideration when tailored intervention for the elderly population has to be provided. Furthermore, because of the negative relationship between sedentary time and vitality and role-emotional, sedentary time is to be reduced.
For active females, if the goal is to reach a minimum of 30 min·day^{-1} of MVPA, it is sufficient that they walk at their PWS (5 km·h^{-1}) because the relative intensity of this activity falls in the moderate range. If the main objective is to sustain a prolonged activity, women might walk at a speed near the minimization point energy cost (from 4 to 4.5 km·h^{-1}).

The physical activity guidelines for older adults advise: at least moderate-intensity PA for >30 minutes (in >10 minute bouts) on at least 5 days weekly. However, only 14% of women aged 65–74 and 4% of women aged 75 or over achieve this amount of PA. For this reason, increasing physical activity is very important and the final messages are:

- the elderly seem to reach the level of physical activity suggested by the guidelines because they have a high PWS and maintain a good stability while walking;
- the energy cost of walking does not influence gait speed, otherwise hand-grip strength influences gait stability;
- successful aging is related to overall life satisfaction and vitality, and CRF seems to be the principal pathway for HRQoL improvement.

In order to understand possible determinants of successful aging, physical activity, gait speed, gait stability, and health-related quality of life were studied on a healthy cohort of young and older adults. Further investigations should be performed with a larger group of subjects, in particular with elderly >75 years, including men and frail population.

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Appendix 1: IPAQ questionnaire

QUESTIONARIO INTERNAZIONALE SULL'ATTIVITA' FISICA

Siamo interessati a conoscere i tipi di attività fisica che le persone fanno come parte della vita quotidiana. Le domande riguarderanno il tempo che lei ha trascorso in attività fisiche negli **ultimi sette giorni**. Cortesemente, risponda ad ogni domanda anche se non si considera essere una persona attiva. Pensi, per favore, alle attività svolte al lavoro, come parte del lavoro svolto in casa ed in giardino, per spostarsi da un luogo all'altro e nel suo tempo libero come divertimento, esercizio fisico o sport.

Pensi a tutte le attività **vigorose**, energiche che ha svolto negli **ultimi sette giorni.** Le attività fisiche **vigorose** sono quelle che richiedono uno sforzo fisico duro e che la fanno respirare con un ritmo molto più frequente rispetto al normale. Pensi *soltanto* a quelle attività fisiche che lei ha svolto per almeno 10 minuti consecutivamente.

1. Durante gli **ultimi sette giorni**, in quanti giorni lei ha svolto attività fisica vigorosa come sollevare oggetti pesanti, zappare, fare aerobica, o pedalare in bicicletta ad una certa velocità?

________ **giorni per settimana**

☐ Nessuna attività fisica vigorosa ---------------------→ **Vada alla domanda 3**

2. Quanto tempo in totale di solito trascorre in attività fisiche **vigorose** in uno di quei giorni?

________ **ore per giorno**

________ **minuti per giorno**

☐ Non sa / non è sicuro/a

Pensi a tutte quelle attività **moderate** che lei ha svolto negli **ultimi sette giorni**. Le attività moderate sono quelle che richiedono uno sforzo fisico moderato e che la fanno respirare con un ritmo un po' più frequente rispetto al normale. Pensi soltanto a quelle attività fisiche che lei ha svolto per almeno 10 minuti consecutivamente.

3. Durante gli **ultimi sette giorni,** quanti giorni lei ha svolto attività fisica **moderata** come portare pesi leggeri, andare in bicicletta ad un ritmo regolare oppure giocare il doppio a tennis? Non includa il camminare.

_____ **giorni per settimana**

☐ Nessuna attività fisica moderata --------------------→ **Vada alla domanda 5**

4. Quanto tempo lei di solito dedica alle attività fisiche moderate in uno di quei giorni?

_______ **ore per giorno**

_______ **minuti per giorno**

☐ Non sa / non è sicuro/a

Pensi al tempo da lei trascorso **camminando** negli **ultimi sette giorni**. Includa il tempo trascorso sia al lavoro sia a casa, nello spostarsi da un luogo ad un altro e qualsiasi altro cammino che lei ha fatto solo per divertimento, sport, esercizio fisico o per passatempo.

5. Durante gli **ultimi sette giorni,** in quanti giorni lei ha **camminato** per almeno 10 minuti di continuo?

_______ **giorni per settimana**

☐ Nessuno --------------------→ **Vada alla domanda 7**

6. Di solito quanto tempo ha trascorso, in uno di quei giorni, **camminando?**

_______ **ore per giorno**

_______ **minuti per giorno**

☐ Non sa / non è sicuro

L'ultima domanda riguarda il tempo trascorso stando **seduto** dal lunedì al venerdì negli **ultimi sette giorni**. Includa il tempo in cui rimane seduto al lavoro, in casa, nello svolgere un corso di formazione, durante il suo tempo libero. Questo può includere il tempo trascorso seduto alla scrivania, nel far visita ad amici, leggendo, o seduto/a o sdraiato/a per guardare la televisione.

7. Durante gli **ultimi sette giorni**, in un giorno della settimana, quanto tempo ha trascorso stando seduto?

_______ **ore per giorno**

_______ **minuti per giorno**

☐ **N**on sa / non è sicuro

Qui termina il questionario, grazie per la collaborazione.

La Sua Salute e il Suo Benessere

ISTRUZIONI: Questo questionario intende valutare cosa Lei pensa della Sua salute. Le informazioni raccolte permetteranno di essere sempre aggiornati su come si sente e su come riesce a svolgere le Sue attività consuete. Ringraziandola per la collaborazione, la preghiamo di rispondere alle seguenti domande.

Per cortesia faccia una crocetta ☒ sulla casella che meglio corrisponde alla Sua risposta.

1. **In generale, direbbe che la Sua salute è:**

Eccellente	Molto buona	Buona	Passabile	Scadente
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

2. **<u>Rispetto ad un anno fa</u>, come giudicherebbe, <u>ora</u>, la Sua salute in generale?**

Decisamente migliore adesso rispetto ad un anno fa	Un po' migliore adesso rispetto ad un anno fa	Più o meno uguale rispetto ad un anno fa	Un po' peggiore adesso rispetto ad un anno fa	Decisamente peggiore adesso rispetto ad un anno fa
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

3. Le seguenti domande riguardano alcune attività che potrebbe svolgere nel corso di una qualsiasi giornata. La <u>Sua salute</u> La limita <u>attualmente</u> nello svolgimento di queste attività?

Per cortesia faccia una crocetta ☒ per ogni domanda

	SI, mi limita parecchio	SI, mi limita parzialmente	NO, non mi limita per nulla
a <u>Attività fisicamente impegnative</u>, come correre, sollevare oggetti pesanti, praticare sport faticosi	☐ 1	☐ 2	☐ 3
b <u>Attività di moderato impegno fisico</u>, come spostare un tavolo, usare l'aspirapolvere, giocare a bocce o fare un giretto in bicicletta	☐ 1	☐ 2	☐ 3
c Sollevare o portare le borse della spesa	☐ 1	☐ 2	☐ 3
d Salire <u>qualche</u> piano di scale	☐ 1	☐ 2	☐ 3
e Salire <u>un</u> piano di scale	☐ 1	☐ 2	☐ 3
f Piegarsi, inginocchiarsi o chinarsi	☐ 1	☐ 2	☐ 3
g Camminare <u>per un chilometro</u>	☐ 1	☐ 2	☐ 3
h Camminare <u>per qualche centinaia di metri</u>	☐ 1	☐ 2	☐ 3
i Camminare <u>per circa cento metri</u>	☐ 1	☐ 2	☐ 3
j Fare il bagno o vestirsi da soli	☐ 1	☐ 2	☐ 3

4. **Nelle <u>ultime 4 settimane</u>, per quanto tempo ha riscontrato i seguenti problemi sul lavoro o nelle altre attività quotidiane, <u>a causa della Sua salute fisica</u>?**

	Sempre	Quasi sempre	Una parte del tempo	Quasi mai	Mai
a Ha ridotto il tempo dedicato al lavoro o ad altre attività	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
b Ha reso meno di quanto avrebbe voluto	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
c Ha dovuto limitare alcuni tipi di lavoro o di altre attività	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
d Ha avuto difficoltà nell' eseguire il lavoro o altre attività (ad esempio, ha fatto più fatica)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

5. **Nelle <u>ultime 4 settimane</u>, per quanto tempo ha riscontrato i seguenti problemi sul lavoro o nelle attività quotidiane, <u>a causa del Suo stato emotivo</u> (quale il sentirsi depresso o ansioso)?**

	Sempre	Quasi sempre	Una parte del tempo	Quasi mai	Mai
a Ha ridotto il tempo dedicato al lavoro o ad altre attività	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
b Ha reso meno di quanto avrebbe voluto	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
c Ha avuto un calo di concentrazione sul lavoro o in altre attività	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

6. Nelle <u>ultime 4 settimane</u>, in che misura la Sua salute fisica o il Suo stato emotivo hanno interferito con le normali attività sociali con la famiglia, gli amici, i vicini di casa, i gruppi di cui fa parte?

Per nulla	Leggermente	Un po'	Molto	Moltissimo
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

7. Quanto dolore <u>fisico</u> ha provato nelle <u>ultime 4 settimane</u>?

Nessuno	Molto lieve	Lieve	Moderato	Forte	Molto forte
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6

8. <u>Nelle ultime 4 settimane</u>, in che misura il <u>dolore</u> L'ha ostacolata nel lavoro che svolge abitualmente (sia in casa sia fuori casa)?

Per nulla	Molto poco	Un po'	Molto	Moltissimo
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

9. Le seguenti domande si riferiscono a come si è sentito <u>nelle ultime 4 settimane</u>. Risponda a ciascuna domanda scegliendo la risposta che più si avvicina al Suo caso. Per quanto tempo nelle <u>ultime 4 settimane</u> si è sentito...

	Sempre	Quasi sempre	Una parte del tempo	Quasi mai	Mai
a vivace e brillante?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
b molto agitato?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
c così giù di morale che niente avrebbe potuto tirarLa su?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
d calmo e sereno?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
e pieno di energia?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
f scoraggiato e triste?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
g sfinito?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
h felice?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
i stanco?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

10. Nelle <u>ultime 4 settimane</u>, per quanto tempo la <u>Sua salute fisica o il Suo stato emotivo</u> hanno interferito nelle Sue attività sociali, in famiglia, con gli amici?

Sempre	Quasi sempre	Una parte del tempo	Quasi mai	Mai
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

11. Scelga la risposta che meglio descrive quanto siano VERE o FALSE le seguenti affermazioni.

	Certamente vero	In gran parte vero	Non so	In gran parte falso	Certamente falso
a Mi pare di ammalarmi un po' più facilmente degli altri	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
b La mia salute è come quella degli altri	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
c Mi aspetto che la mia salute andrà peggiorando	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
d Godo di ottima salute	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

Grazie per la Sua gentile collaborazione!