UNIVERSIDADE da MADEIRA

CENTRO DE COMPETÊNCIA DE CIÊNCIAS SOCIAIS
DEPARTAMENTO DE EDUCAÇÃO FÍSICA E DESPORTO

HEALTH IN MADEIRA: A COMPREHENSIVE STUDY OF AGING, BODY COMPOSITION, PHYSICAL ACTIVITY AND FUNCTIONAL FITNESS

Élvio Rúbio Quintal Gouveia

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Élvio Rúbio

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List of abbreviations

ACSM	American College of Sports Medicine
AGS	American Geriatrics Society
ALST	Appendicular lean soft tissue
ALTM	Arm lean tissue mass
ANCOVA	Analysis of covariance
ANOVA	Analysis of variance
ARA	Autonomous Region of Azores
ARM	Autonomous Region of Madeira
BM	Body Mass
BMD	Bone Mineral Density
CDC	Centers for Disease Control and Prevention
CSMI	Cross-sectional moment of inertia
FAB	Fullerton Advance Balance Scale
FF	Functional Fitness
FM	Fat mass
FN	Femoral Neck
FSI	Femoral Strength Index
GSR	Gait Stability Ratio
GV	Gait velocity
HAS	Hip Strength Analysis program
INE	Statistics Portugal
IOF	International Osteoporosis Foundation
kcal/min	Kilocalories per minute
kJ/min	Kilojoules per minute
LLTM	Leg lean tissue mass

LS	Lumbar Spine (L2-L4)
MET	Metabolic Equivalent Task
MLRA	Multiple regression analysis
NPARD	Portuguese Programme Against Rheumatic Diseases
PA	Physical Activity
PF	Physical fitness
RALST	Relative appendicular lean tissue mass
RALTM	Relative arm lean tissue mass
RLLTM	Relative legs lean tissue mass
RLTM	Relative lean tissue mass
SFT	Senior Fitness Test
SL	Stride Length
SREC	Regional Secretary of Education and Culture
TFM	Total fat mass
TLTM	Total non-bone lean soft tissue mass
TM	Total mass
U.S.DHHS	U.S. Department of Health and Human Services
UMa	University of Madeira
USA	United States of American
WHO	World Health Organization

Abstract

Physical Activity (PA) and functional fitness (FF) are predictors of a healthy and independent lifestyle in older adults.

The purpose of this study was: (1) to construct reference values for FF; (2) to describe sex- and age-related changes in FF, balance, gait, PA, body composition, and bone health/strength; and (3) to determine their variation and co-variation with respect to PA.

This cross-sectional study included 401 males and 401 females aged 60-79 years old. FF was assessed using the Senior Fitness test and balance by the Fullerton Advance Balance scale (FAB). Gait parameters: gait velocity (GV), stride length (SL), cadence and gait stability ratio (GSR) were measured. Femoral strength index (FSI) and bone mineral density (BMD) of the total body, lumbar spine, hip region and total lean tissue mass (TLTM) and total fat mass (TFM) were determined by dual-energy x-ray absorptiometry-DXA. PA was assessed during face-to-face interviews using the Baecke questionnaire. Demographic and health history information were obtained by structured telephone interview.

In both sexes, a significant main effect for age-group was found for FF parameters, balance scores, gait performances, TLTM and hip, LS and total BMD and FSI. Likewise there were significant main effects for age-group for total PA in women and sports related PA in men. Men scored significantly better than women in FF (except in upper- and lower-body flexibility), balance, GV, SL, GSR and had higher BMD and TLTM compared with women. Active subjects scored better in FF, balance, and gait than their average and non-active peers. PA and FF exerted only a minor influence in the differentiation of BMD and FSI among the elderly while constitutive factors like age, height, body mass, TLTM and TFM entered as the most significant contributors.

This study gives scientific support to public policies at the community level, targeted to increase PA, FF and TLTM, thereby contributing to improved quality of life in older adults.

Key words: Aging, Physical Activity, Functional Fitness, Bone mineral density and Body composition

Resumo

A actividade física (AF) e a aptidão funcional (AptF) são predictores de um estilo de vida independente e saudável nos idosos.

Os objectivos deste estudo foram: (1) construir valores normativos para a AptF; (2) descrever as mudanças associadas à idade e sexo na AptF, equilíbrio, mobilidade, AF, composição corporal e saúde/força óssea; e (3) analisar a variação e co-variação das variáveis anteriores em relação à AF.

Este estudo transversal incluiu 401 homens e 401 mulheres (60-79 anos). A AptF foi avaliada a partir da *Senior Fitness test* e o equilíbrio através da *Fullerton Advance Balance scale* (FAB). Os parâmetros do passo: velocidade do passo (VP), amplitude do passo (AP), cadência, e ratio de estabilidade do passo (REP) foram determinados. O índice de força do fémur (IFF), a densidade mineral óssea (DMO) do corpo inteiro, coluna, região do fémur e tecido muscular total (TMT) e massa gorda total (MGT) foram determinados por absorciometria radiológica de dupla energia (DEXA). A AF e a informação de saúde foram avaliadas por entrevista.

Um efeito significativo da idade foi encontrado na AptF, FAB, mobilidade, TMT e DMO na região do fémur em ambos os sexos, na DMO da coluna, corpo inteiro, IFF, AF total nas mulheres e *score* desportivo nos homens. Os homens obtiveram valores significativamente mais elevados na AptF (excepto na flexibilidade), equilíbrio, VP, AP, REP, DMO e TMT comparativamente às mulheres. Indivíduos mais activos obtiveram *scores* mais elevados na AptF, FAB, e mobilidade do que os pares classificados como não activos ou de nível médio. A AF e a AptF exercem apenas um papel minor na diferenciação da DMO e IFF, enquanto que os factores constitutivos como a idade, altura, massa corporal, TMT e MGT apresentaram-se como os contribuidores mais significantes.

Este estudo suporta a importância da implementação de políticas públicas ao nível da comunidade, direccionadas para um aumento AF, AptF e TMT e consequentemente, da qualidade de vida nos adultos idosos.

Palavras-chave: Envelhecimento, Actividade Física, Aptidão Funcional, Densidade Mineral Óssea e Composição Corporal

Résumé

L’activité physique et l’aptitude fonctionnelle (AptF) sont les prédicteurs d’un salubre style de vie indépendant chez les plus âgées.

Le but de cette étude a été de: (1) construire des valeurs normatives pour l’AptF; (2) décrire les changements associés à l’âge et au sexe dans l’AptF, l’équilibre, la mobilité, l’AF, la composition corporelle et la santé/la force osseuse; et (3), finalement, analyser la variation et la co-variation des variables antérieures par rapport à l’AF.

Cette étude transversale d’observation a évalué les caractéristiques de 401 hommes et de 401 femmes (60-79 ans). L’AptF a été évaluée à partir du *Senior Fitness test* et celle de l´équilibre au moyen du test *Fullerton Advance Balance scale* (FAB). Les paramètres de la démarche: vitesse de la démarche (VP), l’amplitude de la démarche (AP), la cadence et le ratio de stabilité de la démarche (REP) ont été déterminés. L’index de force du fémur (IFF), la densité minérale osseuse (DMO) de tout le corps, de la colonne, de la région du fémur et du tissu musculaire total (TMT) et la masse grasse totale (MGT) ont été déterminés à travers l’absorptiométrie radiologique de double énergie (DEXA). L’AF et l’information de santé ont été évaluées par le biais d’entretiens.

Un effet significatif de l’âge a été trouvé chez l’AptF, FAB, mobilité, TMT et DMO dans la région du fémur chez les deux sexes, dans la DMO de la colonne, de tout le corps, l’IFF, l’AF totale chez les femmes et le *score* sportif chez les hommes. Ceux-ci ont obtenu des valeurs significativement plus élevées dans l’AptF (exception faite au niveau de la flexibilité) équilibre, VP, AP, REP, DMO et TMT par rapport aux femmes. Les individus plus actifs ont obtenu des *scores* plus élevés au niveau de l’AptF, FAB, et de la mobilité que ceux classés comme non-actifs ou de niveau moyen. L’AF et l’AptF n’exercent qu’un rôle mineur dans la différenciation de la DMO et de l’IFF, tandis que les facteurs constitutifs tels que l’âge, la hauteur, la masse corporelle, le TMT e la MGT se sont présentés comme les contributeurs les plus importants.

Cette étude souligne l’importance de la mise en place de politiques publiques au sein de la communauté, orienté vers une augmentation de l’AF, de l’AptF et du TMT et, par conséquent, de la qualité de vie chez les adultes âgés.

Mots-clés: Vieillissement, Activité Physique, Aptitude Fonctionnelle, Densité Minérale Osseuse, Composition Corporelle.

Resumen

La actividad física y la aptitud funcional en los mayores son indicadores de un estilo de vida saludable e independiente. Los objetivos de este estudio son (1) construir valores de referencia para la aptitud funcional; (2) describir los cambios en el equilibrio, la marcha, la composición corporal, la actividad física, la aptitud funcional, el estado y la fuerza ósea en función del sexo y la edad; (3) evaluar cómo varían de forma aislada y en conjunto todas las variables mencionadas anteriormente en relación a la actividad física.

En este trabajo han sido analizados una única vez los parámetros anteriores en el mismo número (401) de hombres y mujeres con edades comprendidas entre los 60 y los 79 años de edad. La aptitud funcional ha sido evaluada mediante el *Senior Fitness test* y el equilibrio a través de la escala de *Fullerton Advance Balance*. Igualmente se han medido otros parámetros como la velocidad de la marcha, la amplitud del paso, la cadencia y la estabilidad de la marcha. La prueba de absorciometría radiológica de energía doble (DXA) ha sido utilizada para medir el índice de resistencia femoral, la masa del tejido muscular total y la masa grasa total la densidad mineral ósea (DMO) medida esta última en el cuerpo entero, la columna vertebral y la región del fémur. La actividad física se evaluó por medio del cuestionario de Baecke a través de entrevistas personales directas. La información demográfica y el historial de salud se obtuvieron mediante entrevistas telefónicas estructuradas. Los resultados muestran que la edad tiene un efecto significativo en ambos sexos en los parámetros siguientes: la aptitud funcional, el equilibrio, la movilidad, la masa del tejido muscular y la DMO del fémur. Sin embargo en las mujeres la edad afecta también significativamente el índice de resistencia femoral y la DMO de la columna, y del cuerpo entero.

Los hombres superaron por mucho a las mujeres en todos los parámetros de la aptitud funcional a excepción de la flexibilidad. Resultados similares han sido obtenidos en lo que se refiere al equilibrio, la velocidad de la marcha, la masa del tejido muscular total y la amplitud y la estabilidad del paso. Los individuos más activos obtuvieron mejores resultados en la actividad física, el equilibrio y la movilidad que los clasificados como no activos. La actividad física y la aptitud funcional ejercen apenas un papel secundario en la DMO y en el índice de resistencia femoral, mientras que otros factores como la edad, la altura, la masa corporal, el tejido muscular y masa grasa son los factores de mayor peso.

Este estudio refuerza la necesidad de la implementación de políticas comunitarias con el objetivo de aumentar la actividad física, la aptitud funcional y la masa muscular a fin de mejorar la calidad de vida de los mayores.

Palabras clave: envejecimiento, actividad física, aptitud funcional, densidad mineral ósea, composición corporal

Chapter 1

Introduction and outline of the thesis

1.1 Introduction

Advancements in medical and pharmaceutical technology, health care, nutrition and sanitation have resulted in lower death rates throughout the world. People are living longer and the population worldwide is growing older. Between 2000-2030, the worldwide population aged $\geq$ 65 years is projected to increase from approximately 550 million to 973 million (U.S. Department of Health and Human Services [U.S.DHHS], 2001). International comparisons in the year 2000 showed that Italy, Greece and Sweden were the nations with the highest percentage of total population aged 65 and older (18.1% and 17.3, respectively). Portugal ranked 11th on this list, with 15.4% of its population older than 65 years (Kinsella & Velkoff, 2001). More recently, data confirmed that Portugal was one of the most aged countries of Europe with 17.1% of its total population older than 65 years of age in 2008 (Statistics Portugal [INE], 2009). Particularly, in the Portuguese Autonomous Region of Madeira, the elderly (> 65 years) are projected to comprise approximately 57.4% of the total population by 2050 (INE, 2002).

The increase in the number of older adults, combined with the age-associated increase in chronic diseases and disability (development of functional limitations), poses major health, economic and social challenges in developed and developing countries (American College of Sports Medicine [ACSM], 2006). In addition to the economics of chronic disease, there are individual issues related to physical inactivity such as lower quality of life, loss of functional independence, depression, social isolation, mood disorders, decreased longevity and impairments in the cognitive function (ACSM, 2009; Jones & Rose, 2005). Extending people’s active life expectancies and maintaining autonomy and independence for the older people are key goals in the policy framework for active aging (World Health Organization [WHO], 2002).

Numerous research studies have reported many health and performance related benefits of engaging in regular physical activity (PA). It has been shown that certain levels of fitness, not only protects the individual from a number of chronic diseases, but also promotes better performances in daily living activities, as well as enhances participation in a variety of sports and recreational activities (Jones & Rose, 2005). Promoting PA and physical fitness are major purposes of many organizations, namely, ACSM, WHO and Centers for Disease Control and Prevention (CDC). They have postulated that regular exercise and PA contribute to a healthier and independent lifestyle in older adults and greatly improve their functional capacity and quality of live.

The human degeneration is an inevitable process involved in biological aging. It takes part of natural human aging, referring to the way most people age and is characterized by a gradual decline in physical function and disease (Jones & Rose, 2005). The aging process leads to profound changes in the cardiopulmonary, musculoskeletal, nervous and, immune systems (Taylor & Johnson, 2008). Particularly, bone-forming cells decline in activity with advancing age (Brockstedt, Kassem, Eriksen, Mosekilde, & Melsen. 1993; Stenderup, Justesen, Clausen, & Kassem, 2003) as do the levels of total PA (Daly et al., 2008). In addition, the gradual loss of muscle mass (sarcopenia) is associated to impairments in physical function, dependence and reduced quality of life (Janssen, Heymsfield, & Ross, 2002).

A large body of evidence reinforces that PA and exercise may attenuate some of the observed changes in aging (ACSM, 2006). Particularly, the benefits of PA include increased muscle and bone mass, muscle strength, flexibility, aerobic endurance, dynamic balance, self-confidence and self-esteem. PA and exercise also helps to reduce the symptoms of various chronic diseases such as arthritis, depression, type 2 diabetes, osteoporosis, sleep disorders and heart disease (Nelson et al., 1994; ACSM, 2006).

Among older adults, functional fitness (FF) is defined as having the physical capacity to perform normal everyday activities, safely and independently, without undue fatigue (Rikli & Jones, 2001). Improving FF components (lower and upper muscular strength, aerobic endurance, lower and upper-flexibility and agility/dynamic balance) enables older adults to maintain independence in performing activities of daily living (Rikli & Jones, 2001; Brill, 2004). One of the most evident and clinically relevant age-related changes is the decline in muscular strength, at least in part, because of reduction of muscle mass (Roubenoff, 2000; Janssen, Heymsfield, Wang, & Ross, 2000; Bouchard, Blair, & Haskell, 2007). The reduction of FF levels can contribute to a decline in general functional capacity, specifically, in normal everyday activities like climbing stairs, walking distances, carrying groceries and many other common tasks (Rikli & Jones, 2001). Particularly, maintaining strength and muscle function is also an important factor against the risks for fall and fall-related injuries (American Geriatrics Society [AGS], 2001). Agility (involving speed and coordination) and dynamic balance (maintaining postural stability while moving) are important composite variables since both must work together for the successful performance of common mobility tasks (Rikli & Jones, 2001). This FF component is related to gait pattern and a number of investigations have revealed that certain changes in these variables may be predictive of falling in older people (Cromwell, & Newton, 2004; Lord, Sherrington, Menz, & Close, 2007). Large epidemiological studies have identified many risk factors for falling in older adults. Socio-demographic factors, medical condition, muscle weakness, deficits in balance, gait or vision, mobility limitation, cognitive impairment, impaired functional status and postural hypotension have been shown to be strongly associated to falls (Rubenstein, 2006; Lord et al., 2007; Tinetti & Kumar, 2010).

The musculoskeletal system, which is influenced by many factors, such as age, gender, race and environment (Ebersole, Hess, Touhy, & Jett, 2005) is the main factor responsible for loss of the ability to perform essential daily tasks, due to the decrease in muscular strength. In addition, the enhanced bone fragility, characterized by low bone mineral density (BMD) and changes in bone material properties and bone geometry, including microarchitectural deterioration of cancellous bone (Kanis et al., 2008) resulting in bone fractures, seem to be a major worldwide health concern. Data from the Surgeon General's Report on Bone Health and Osteoporosis (U.S.DHHS, 2004) suggest that, each year, an estimated 1.5 million individuals suffer an osteoporotic-related fracture in the United States of American (USA). These fractures result in more than half a million hospitalizations, over 800 000 emergency room encounters, more than 2 600 000 physician office visits and the placement of nearly

180 000 individuals into nursing homes. Hip fractures are by far the most devastating type of fracture, accounting for about 300 000 hospitalizations each year. Osteoporosis-related disability is considered to confine patients to more immobile days in bed than chronic obstructive pulmonary disease, stroke, myocardial infarction or breast cancer (International Osteoporosis Foundation [IOF], 2001) and has an enormous impact on society's healthcare costs. The annual direct care expenditures for osteoporotic fractures in the United States ranges from 12 to 18 billion dollars (U.S.DHHS, 2004). The personal disability and financial burden of osteoporosis will likely become even more substantial in future, with the number of hip fractures worldwide projected to increase from an estimated 1.7 million in 1990 to over 6.3 million by 2050 (Cooper, Campion, & Melton, 1992).

In Europe, the number of all osteoporotic fractures in 2000 was estimated at 3.79 million, of which 0.89 million were hip fractures (179 000 in men and 711 000 in women) (Kanis & Johnell, 2005). The incidence of hip fractures/year in women and men over 65 years was 67.9/10 000 and 26.1/10 000, respectively (IOF, 2001). The total direct cost of this disease was estimated at €31.7 billion, which is expected to increase to €76.7 billion in 2050 based on the expected demographic changes in Europe (Kanis & Johnell, 2005). Portugal has been recognized as a high risk country for the development of hip fracture (Kanis & Johnell, 2005). The Portuguese Programme Against Rheumatic Diseases (NPARD) identified osteoporosis as a national health priority. The number of hip fractures increased from 8500 in 2000 (rate: 8.24 per 10 000 population) to 9 821 in 2007 (rate: 9.26 per 10 000 population). The direct hospital costs were €51 321 300 and €53 433 131, in 2000 and 2007, respectively (IOF, 2008).

A growing body of evidence suggests benefits of PA and fitness in attenuating age-related functional decline and established chronic diseases and frailty (Bouchard et al., 2007). This research strengthens that older adults can increase their activity levels and their physical fitness by increasing the amount of PA in their daily routines and by participating in a structured exercise program. Although the increase of PA and PF have their advantages and should be encouraged, structured exercise protocols may be needed to address specific weaknesses identified in the FF performances. Though successful aging is a difficult concept to define, due to its multidimensionality, the key for successful aging comprises the task of creating a PA environment that promotes positive physical, social, mental, emotional and spiritual activities into daily living (Jones & Rose, 2005). In the presence of chronic health conditions, generally establish with aging, the focus tends to shift from disease prevention to functional mobility. Much of the usual age-related decline in physical capacity is postponable through proper attention to PF levels and PA. Especially important is the early detection of physical weaknesses and appropriate changes in PA habits.

1.2 Frame of reference

The WHO has adopted the term “active ageing” to “express the process of optimizing opportunities for health, participation and security in order to enhance quality of life as people age" (WHO, 2002: pp. 19-32). Active Ageing, a Policy Framework, was developed by WHO's Ageing and Life Course Programme as a contribution to the Second United Nations World Assembly on Ageing, held in April 2002, in Madrid, Spain. The WHO Policy Framework argues that strategies to promote active and successful aging must be integrated into a comprehensive and far-reaching public policy that embraces a multifactorial approach to successful aging (see Figure 1).

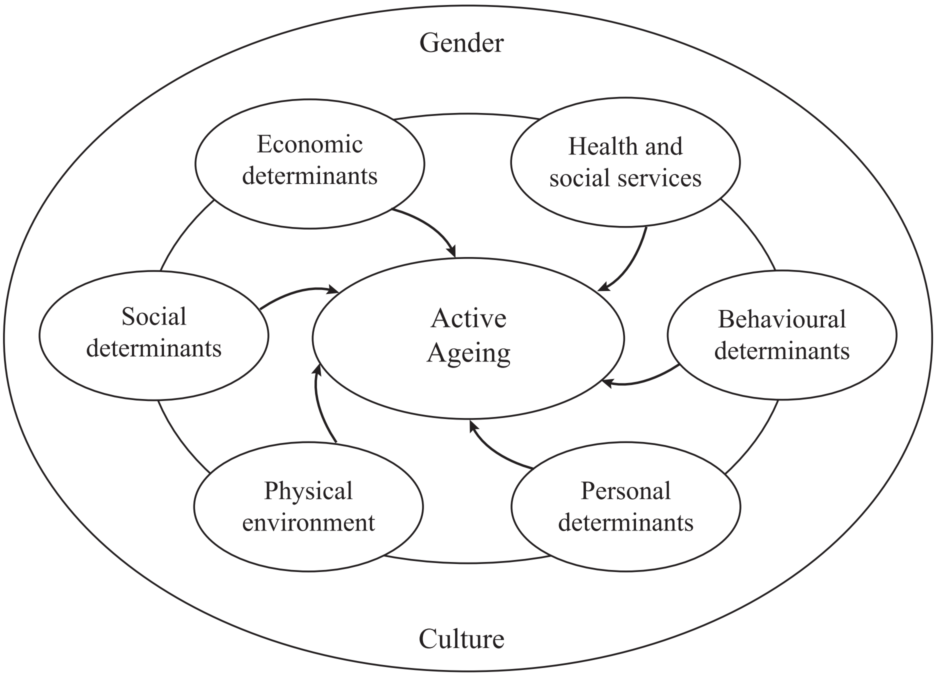

Figure 1.1 The determinants of active ageing (WHO, 2002).

The most significant message of the WHO Active Aging Policy Framework is the notion that there are numerous and diverse determinants associated with active and successful aging. Promotion strategies of successful and active aging, should consider a complex combination of economic, social, personal, environmental, and behavioral determinants. This means that, to age successfully, older persons will need to be not only physically active, but also socially, intellectually, culturally, and (for many seniors) spiritually active (Chodzko-Zajko & Schwingel, 2010). The WHO Active Aging Policy Framework targets the promotion of an active ageing process, the maintaining autonomy and independence among older people, and thereby to promote health and quality of life (WHO, 2002).

Culture and gender are considered by WHO Active Aging Policy Framework as cross-cutting determinants within the framework for understanding active ageing. Cultural heritage could be defined as lifestyle, activities, rituals, values, world view, language, material culture and other assets and habits shared by a group or population (Cohen & Cohen, 2006). The active aging is strongly determined by these cultural values and traditions which surrounds all individuals and shapes the way in which we age because it influences all of the other determinants. Cultural and gender determinants also influence health-seeking behaviors. In many societies of 21st Century, girls and women have lower social status and less access to nutritious foods, education, meaningful work and health services. Women's traditional role as family caregivers may also contribute to their increased poverty and disease in older age. On the other hand, boys and men are more likely to suffer debilitating injuries or death due to violence, occupational hazards, and suicide. They also engage in more risk taking behaviors such as smoking, alcohol and drug consumption and unnecessary exposure to the risk of injury (WHO, 2002).

Health and social services systems need to be integrated, coordinated and cost-effective. Health promotion, disease prevention and equitable access to quality primary care are pillars of active ageing. In addition, curative services (primary health care sector), long-term care (with focus on maintaining quality of life) and mental health services (especially depression) play a crucial role in active ageing (WHO, 2002).

The actively participation and the adoption of healthy lifestyles are important at all stages of the lifespan. One of the myths of ageing is that it is too late to adopt such lifestyles in the later years. On the contrary, engaging in appropriate PA, healthy eating, not smoking and using alcohol and medications wisely in older age can prevent disease and functional decline, extend longevity and enhance one's quality of life (WHO, 2002).

Biological and genetics factors are used to establish aging. Aging is a set of biological processes, including psychological changes that are genetically "determined". Epidemiological studies consistently show increasing age and a positive family history for dementia's disease to be the most important risk factors (Williams, 2003). However, lifestyle behaviours such as not smoking, personal coping skills and a network of close kin and friends can effectively modify the functional decline and the onset of disease (WHO, 2002).

Physical environment is a multidimensional concept and is a key component to achieving healthy PA behaviors in all people, but is of particular importance for elderly (Morrow & Mood, 2006). Older people who live in an unsafe environment or areas with multiple physical barriers are less likely to get out and therefore more prone to isolation, depression, reduced fitness and increased mobility problems (WHO, 2002). On the other hand, every year, thousands of older adults are injured (especially, in consequence of falls) in home accidents that could have been prevented (Rose, 2010; Tinetti, 2003).

Social network refers to the web of social relationship and contacts that an individual may have (Kane, 1995). Social support (assistance), opportunities for education and lifelong learning, protection from violence and abuse are key factors in the social environment that enhance health, participation and security as people age (WHO, 2002).

Economic factors, including income, work and social protection, have a particularly significant effect on active aging (WHO, 2002). A large percentage of older people do not have reliable or sufficient incomes. The access to health care, adequate and confortable houses and nutritious foods are affected. A large body of evidence indicates that socioeconomic status is a strong predictor of mental health (Back & Lee, 2010), bone health (Brennan et al., 2010) all-cause mortality and mortality due to specific causes, such as cardiovascular disease and cancer (Fried et al., 1998; Faggiano, Partanen, Kogevinas, & Boffetta, 1997).

1.3 Central topics

1.3.1 Physical activity

PA is a broad term that encompasses occupational activity (work), domestic chores, required programs of physical education and leisure activity (exercise, sport, training, dance and play) (Shepard, 1994). PA comprises any bodily movement produced by skeletal muscles that results in a substantial increase over resting energy expenditure (Casperson, Powell, & Christenson, 1985). PA is the most variable component of an individual's total daily energy expenditure, which consists of basal metabolic rate (i.e., the energy needed to maintain the body at rest) and the thermic effect of food (i.e., the energy required to digest food) in addition to PA. The high degree of both intra- and inter-individual variability in habitual PA patterns makes the assessment of this complex behavior in free-living population a very difficult task (Dishman, Washburn, & Heath, 2004). PA is commonly characterized by as having four dimensions: frequency, intensity, time and type.

PA has mechanical, physiological and behavioral components. From a biomechanical point of view, PA/energy expenditure may be obtained from information regarding force, velocity, acceleration, mechanical power, or mechanical work produced by the body. A physiologist describes PA in terms of energy expenditure, using measures as O_2 uptake, metabolic energy expenditure (e.g., in kilocalories or kilojoules), metabolic power (kcal/min or kJ/min) or multiples of resting energy expenditure (MET). A behaviorist approach addresses the type and context of the activity (Malina, Bouchard, & Bar-Or, 2004).

Laboratory and field methods are used to assess PA using information from diaries, questionnaires, direct observations, heart rate frequency, doubly labeled water, pedometers and accelerometers, oxygen uptake and calorimetry chamber as examples. The selection or choice of the best method/instrument should be based on sample size, the type of study and target population. The current trend suggests simultaneous use of methods, techniques or tools in a multimode approach (Malina et al., 2004).

1.3.2 Functional fitness

Several terms are used in the discussion of elderly function and sometimes they are incorrectly used interchangeably. PF is a state or a condition that permits the individual to carry out daily activities without undue fatigue and with sufficient reserve to enjoy active leisure (Pate, 1988). Casperson et al. (1985) defined PF as a multidimensional concept that has been defined as a set of attributes that people possess or achieve that relates to the ability to perform PA.

With the increment of the older adults' population, the ability to enjoy a mobile, active, and independent lifestyle into the later years will depend to a large degree on how well they maintain their personal PF level. Rikli & Jones (2001) state that, whereas health promotion and the avoidance of lifestyle diseases (heart disease, obesity, diabetes, etc.) are the major goals of most of the youth fitness tests, for older adults, whose chronic health status generally has already been established, the focus tends to shift from disease prevention to functional mobility.

Rikli & Jones (2001) defined FF as the physical capacity to perform normal everyday activities safely and independently without undue or fatigue. Functional performance tests measure the physical capacity of older adults to perform normal everyday activities (Moore, Mars, & Durstine, 2009). Spirduso, Francis, & MacRae (2005) define functional performance as the observable ability to perform tasks of daily living or field tests that simulate everyday tasks. Assessment of functional status, defined as the level at which the person is performing the tasks, and the roles of daily activity (Hedrick, 1995) is complex and require integrated function of many of the body systems and categories of exercise, namely, aerobic, anaerobic, endurance, strength, flexibility, neuromuscular and functional performances (Moore et al., 2009).

1.3.3 Aging

Aging refers to a process or group of processes occurring in living organisms that, with the passage of time, lead to a loss of adaptability, functional impairments and eventually death (Spirduso et al., 2005). Taylor & Johnson (2008) defined biological aging as a slow, progressive, structural and functional changes that take place at the cellular, tissue and organ levels, ultimately affecting the function of all body systems. Understanding the fundamental processes and causes of aging, with the aim to enhance and maximize the quantity and quality of life for humans, are the basis of gerontologic research (Spirduso et al., 2005).

Numerous theories have been proposed to explain the process of aging, but neither of them appear to be fully satisfactory (Davidovic et al., 2010). Taylor & Johnson (2008) proposed that these can be grouped into five broad categories of aging: wear and tear theories, genetics theories, general imbalance theories, accumulation theories, and the dysdifferentiative hypothesis of aging and cancer. Jones (2005) divided the theories of aging in three main categories: biological, psychological and sociological. Biological theories of aging – including genetic, damage and gradual imbalance theories – focus on the factors that cause senescence of the body and increase the risk of morbidity and mortality with age. Psychological theories focus on the influence of psychological processes and personality characteristics on the aging process. Sociological theories focus on the influence of the social and physical environments on aging.

The modern biological theories of aging in humans fall into two main categories: programmed and damage or error theories (Jin, 2010). The programmed theories imply that aging follows a biological timetable, perhaps a continuation of the one that regulates childhood growth and development. This regulation would depend on changes in gene expression that affect the systems responsible for maintenance, repair and defense responses. The programmed theory has three sub-categories: programmed longevity, endocrine theory and immunological theory. The damage or error theories emphasize environmental assaults to living organisms that induce cumulative damage at various levels as the cause of aging. The damage or error theory includes: wear and tear theory, rate of living theory, cross-linking free radical theory and somatic DNA damage theory.

The complexity of the aging derives from an aggregate of causes that led to development and polarization of the theories of aging. In this context, Jones (2005) and Jin (2010) believe that no single theory fully explains the phenomenon of aging process, but each offers some clues. Many of the proposed theories interact with each other in a complex way.

The most common indicator used to define old age is chronological age (passage of time from birth in years). Again, no consensus exists for the definition of old age. There is recognition that the term "elderly" is an inadequate generalization that obscures the variability of a broad age group. Physiologic aging does not occur uniformly across the population. Therefore, it is not satisfactory to define "elderly" by any specific chronologic age or set of ages. Individuals of the same chronologic age can differ intensely in their physiologic age and response to and exercise stimulus. In addition, it is difficult to distinguish the effects of aging per se on physiologic function from the results of deconditioning and/or disease (ACSM, 2006). Jones & Rose (2005), refer to old age as very complex phenomena integrating in this concept the three main

1.4 Physical geography of Madeira Island

Surrounded by the Atlantic Ocean, the archipelago of Madeira is located approximately for 600 km from the African coast (Marrocos) and 900 km from the Portuguese capital, Lisbon. The latitude is defined by the parallels 32° 38'N and 32° 38'N and the longitude changes between 16 39'W and 17º 16'W (Quintal, 2001). Madeira Island represents 93% of the archipelago's area, with 90% of the landmass above 500 m. The archipelago is formed by the island of Madeira (with an area of 741 km^2, a length of 57 km and 22 km wide), Porto Santo (with an area of 42.17 km^2, length of 12 km and 6 km wide), Desertas (14 km^2) and Selvagens (4 km^2). The last two of which are uninhabited.

The climatic conditions on Madeira coupled with the mountain relief, allow an enormous assortment of crops to be cultivated (Quintal, 1985). Temperatures do not show thermal variations throughout the year. The climate is mild with average temperatures of 23ºC in the summer and 17ºC in the winter. The primitive volcanic foci responsible for the central mountainous area, reach the highest peaks in Pico Ruivo (1862 m), Pico das Torres (1851 m) and Pico do Arieiro (1818 m).

According to Census 2001, the archipelago of Madeira registered a population of approximately 245 011 people, distributed by the island of Madeira (240 537) and Porto Santo (4 474). The Autonomous Region of Madeira (ARM) is organized into eleven disctricts. The Madeira Island, comprises the following disctricts and inhabitants: Calheta (11 946), Câmara de Lobos (34 614), Funchal (103 961), Machico (21 747), Ponta do Sol (8 125), Porto Moniz (2 927), Ribeira Brava (12 494), Santa Cruz (29 721), Santana (8 804) e São Vicente (6 198). The Island of Porto Santo has one municipality with which is shares its name (4 474) (INE, 2002).

Madeira's population is characterized by a low educational level. In 2002, about 31.5% of the resident population didn't have any academic qualification, 27.6% had only the primary school and 12.7% of the population were illiterate (INE, 2002). Industry is not very diversified and consists basically of artisanal activities (embroidery, tapestries and wickerwork) oriented to the external market. The largest industries are associated with the activities of food, beverages (and especially Madeira wine), tobacco and construction (Portuguese Eurostat, 2004). Fundamentally, agriculture in Madeira is based on three platforms. Cattle raising is one of them, which of course provides abundant fertilizer for the land. The second area is planting and lastly, the excellent irrigation systems provided by the extensive Levadas systems allow for more productive crops. Even the driest areas of the island are provided with adequate water through theses 'channels' to ensure abundant crops (Portuguese Eurostat, 2004). Tourism is an important sector in the region's economy since it contributes to 20% of the region's gross domestic product, providing support throughout the year for commercial, transport and other activities and constituting a significant market for local products.

1.5 Aims and hypothesis of the thesis

To our knowledge no attempt has been made in order to characterize the aging process of Madeira older adults and the factors that can influence health, PA participation and quality of life during aging. This major clinic and epidemiologic concern justifies the need for research in this domain. The present study emerged from the need to implement strategies that promote active and successful aging, integrated into a comprehensive and far-reaching public policy, based in a multifactorial approach to enhance of PA environmental and increase the levels of FF. The central purposes of this study are threefold:

1. To construct reference and criterion-reference standards for FF parameters for older adults;
2. To study the associations between levels of PA, FF, other lifestyle and constitutive factors and bone health/strength;
3. To identify the sex- and age-related changes in FF parameters, whole body non-bone lean tissue

mass, non-bone appendicular lean tissue mass and their association with PA levels.

Consequently, we hypothesized that:

1. Older men have better performances in FF and are more active than older women;
2. Better performances in FF are associated to higher bone strength of the LS, total body, femur (FN, trochanter, Ward's triangle and total hip) and an increased FSI, after controlling for biological and environmental variables;
3. High levels of total PA are associated with better performances in FAB scores and all gait parameters (GV, SL, GSR and cadence) in older adults;
4. Daily PA is positively associated to total lean mass, arm lean mass and leg lean mass in older adults.

1.6 Outline of the thesis

This thesis is structured according to the so-called "Scandinavian model", and comprises 5 manuscripts submitted for publication in health and social sciences journals. This thesis has 10 chapters.

The first Chapter covers the introduction. Besides focusing in the research hypotheses that drove us to this study, throughout this introduction we present the most relevant aspects of current knowledge about determinants of aging, for a better understanding of this process. The World Health Organization policy framework, that embraces a multifactorial approach to successful aging, is also described. This theoretical model considers that there are numerous and diverse determinants associated with active and successful aging, in which our aim of study is included. The central topics, namely, PA, FF and aging are briefly described. Physical geography of ARM is also presented in this chapter. We conclude the introduction section with the purposes and hypothesis of the study.

In Chapter 2, the general methodology is described. Study design and sampling process are presented, as well as the measurement's protocols. The state of the art relating the associations between PA, fitness and bone health/strength is presented in Chapter 3. This section reinforces the reciprocal relationship between PA and PF and their beneficial effects on bone health/strength.

The two major issues discussed in Chapter 3 will be considered as focusing in the studies included in this thesis (Chapters 4, 5, 6, 7 and 8). All the manuscripts followed a similar structure: title, abstract, key words, introduction, methods, results, discussion, acknowledgments, references and appendices. Chapter 4, 'Functional Fitness and Physical Activity of Portuguese Community-residing Older Adults', provides cross-sectional information about the variation in FF according to age, sex, and level of PA.

Bone quality has been associated with genetic factors and several environmental influences. PA, one of the key putative environmental determinants of bone health, has been associated with increases in bone mass. Chapter 5, ‘Physical Activity and Bone Mineral Density in Elderly Men and Women’ describes the association between PA, other lifestyle and constitutive factors and bone health/strength.

Chapter 6, ‘Functional Fitness and Bone Mineral Density in Elderly’, studies the association between FF tests and BMD at multiple body sites and with FSI, after controlling for constitutive factors (age, sex, height, body mass and body composition). Age-related declines in balance are well documented and have been associated to impairments in physical function and dependence, which are important contributors to falls. Chapter 7, ‘Balance, Mobility and Physical Activity in a Community-dwelling Elderly Men and Women’, provides cross-sectional information about sex- and age-related differences in balance and gait in relation to total PA levels in community-dwelling older adults aged 60-79 years.

The association between PA and lean tissue mass is complex, and gender-, age- and body segment-dependent. Chapter 8, ‘Non-bone Lean Tissue Mass and Physical Activity in Elderly Portuguese Men and Women’, discusses the association between daily PA and non-bone lean soft tissue mass among the elderly and documents sex- and age-related changes.

The chapter 9 comprises a summary of the major findings, the implications and the contribute to the current knowledge in the health and social sciences domains.

Finally, chapter 10 presents the descriptive statistics (mean, standard deviation and percentiles) for somatic dimensions, body composition and bone (appendix J), functional fitness balance and gait parameters (appendix K), and PA at work, sports and leisure time (appendix L) for men and women who participated in this present research.

1.7 References

American College of Sports Medicine. (2006). *ACSM's guidelines for exercise testing and prescription*. Seventh Edition. Philadelphia: Lippincott Williams & Wilkins.

American College of Sports Medicine. (2009). *ACSM's exercise management for persons with chronic diseases and disabilities*. Third Edition. Champaign, IL: Human Kinetics.

American Geriatrics Society. (2001). British Geriatrics Society American Academy of orthopaedic surgeons panel on falls prevention, guidelines for the prevention of falls in older persons. *Journal of the American Geriatrics Society*, *49*, 664–672.

Back, J.H., & Lee, Y. (2010). Gender differences in the association between socioeconomic status (SES) and depressive symptoms in older adults. *Archives of Gerontology and Geriatrics*, [Epub ahead of print].

Bouchard, C., Blair S.N., & Haskell W.L. (2007). *Physical Activity and Health*. Champaign, IL: Human Kinetics.

Brennan, S.L., Henry, M.J., Wluka, A.E., Nicholson, G.C., Kotowicz, M.A., & Pasco, J.A. (2010). Socioeconomic status and bone mineral density in a population-based sample of men. *Bone, 46*(4), 993-9

Brill, P.A. (2004). *Functional fitness for older adults*. Champaign, IL: Human Kinetics.

Brockstedt, H., Kassem, M., Eriksen, E.F., Mosekilde, L., & Melsen, F. (1993). Age- and sex-related changes in iliac cortical bone mass and remodeling. *Bone, 14*, 681-91.

Casperson, C.J., Powell, K.E., & Christenson, G.M. (1985). Physical activity, exercise, and physical fitness: definition and distinctions for health-related research. *Public Health Reports, 100*, 126-131.

Chodzko-Zajko, W., & Schwingel, A. (2010). *Active Aging History*. Retrieved Jan 2, 2011, from http://www.humankinetics.com/active-aging-history.

Cohen, U., & Cohen, R. (2006). Environment. Culture, and Physical Activity of Older Persons. In Zhu, W. & Chodzko-Zajko, W. (Eds.), *Measurement Issues in Aging and Physical Activity. Proceedings of the 10th Measurement and Evaluation Symposium* (pp. 49-54). Champaign, IL: Humans Kinetics.

Cooper, C., Campion, G., & Melton, L.J. (1992). Hip fractures in the elderly: a world-wide projection. *Osteoporosis International, 2*, 285-9.

Cromwell, R., & Newton, R. (2004). Relationship between balance and gait stability in healthy older adults. *Journal of Aging and Physical Activity*, 12, 90-100.

Daly, R.M., Ahlborg, H.G., Ringsberg, K., Gardsell, P., Sernbo, I., & Karlsson, M.K. (2008). Association between changes in habitual physical activity and changes in bone density, muscle strength, and functional performance in elderly men and women. *Journal of the American Geriatrics Society, 56*, 2252-60.

Davidovic, M., Sevo, G., Svorcan, P., Milosevic, D.P., Despotovic, N., & Erceg, P. (2010). Old age as a privilege of the "selfish ones". *Aging and Disease,1(2),* 139–146.

Dishman, R.K., Washburn, R.A., & Heath, G.W. (2004). *Physical Activity Epidemiology*. Champaign, IL. Human Kinetics.

Ebersole, P., Hess, P., Touhy, T., & Jett, K. (2005). *Gerontology Nursing Healthy Aging*. Second edition. United States of American: Elsevier Mosby.

Faggiano, F., Partanen, T., Kogevinas, M., & Boffetta, P. (1997). Socioeconomic differences in cancer incidence and mortality. *IARC Scientific Publication, 138*, 65-176.

Fried, L.P., Kronmal, R.A., Newman, A.B., Bild, D.E., Mittelmark, M.B., Polak, J.F., et al. (1998). Risk factors for 5-year mortality in older adults: the Cardiovascular Health Study. *The Journal of the American Medical Association, 279*(8), 585-92

Hedrick, S.C. (1995). Assessment of Functional Status. Activities of Daily Living. In Rubenstein, L.Z., Wieland, D., & Benabei, R., (Eds), *Geriatric Assessment Technology: The State of the Art* (pp. 51-58). Editrice Kurtis – Milano: Editrice Kurtis.

Instituto Nacional de Estatística. (2002). *Censos 2001: resultados definitivos: XIV recenseamento geral da população: IV recenseamento geral da habitação.* Lisboa: Instituto Nacional de Estatística.

Instituto Nacional de Estatística. (2009). *População Residente - Portugal - 2008 – 2060*. Lisboa: Instituto Nacional de Estatística, Departamento de Estatísticas Demográficas e Sociais.

International Osteoporosis Foundation. (2001). *Osteoporosis in the European Community: a call to action*. *An audit of policy developments since 1998*. Retrieved Jan 15, 2010, from www.osteofound.org/advocacy_policy/eu_ calltoaction_ report.html.

International Osteoporosis Foundation. (2008). *Osteoporosis in the European Union in 2008: Ten years of progress and ongoing challenges*. Retrieved Feb. 10, 2010, from www.iofbonehealth.org.

Janssen, I., Heymsfield, S.B., & Ross, R. (2002). Low relative skeletal muscle mass (Sarcopenia) in older persons is associated with functional impairment and physical disability. *Journal of the American Geriatrics Society, 50*, 889-96.

Janssen, I., Heymsfield, S.B., Wang, Z.M., & Ross, R. (2000). Skeletal muscle mass and distribution in 468 men and women aged 18-88 yr. *Journal of Applied Physiology, 89*(1), 81-8.

Jin, K. (2010). Modern Biological Theories of Aging. *Aging and Disease*, *1*(2), 72-74.

Jones, C.J. (2005). Predictors of Successful Aging. In Jones C.J., & Rose D.J. (Eds), *Physical Activity Instruction of Older Adults* (pp.11-21). Champaign, IL: Human Kinetics.

Jones, C.J., & Rose, D.J. (2005). *Physical Activity Instruction of Older Adults.* Champaign, IL: Human Kinetics.

Jones, G.J., & Rose, D.J. (2005). The field of Gerokinesiology. In Jones C.J., & Rose D.J. (Eds), *Physical Activity Instruction of Older Adults* (pp.3-10). Champaign, IL: Human Kinetics.

Kane, R.A. (1995). Assessment of Social Functioning: Recommendations for Comprehensive Geriatric Assessment. In Rubenstein, L.Z., Wieland, D., & Benabei, R., (Eds), *Geriatric Assessment Technology: The State of the Art* (pp. 91-110). Editrice Kurtis – Milano: Editrice Kurtis.

Kanis, J.A., & Johnell, O. (2005). Requirements for DXA for the management of osteoporosis in Europe. *Osteoporosis International, 16*, 229-38.

Kanis, J.A., Burlet, N., Cooper, C., Delmas, P.D., Reginster, J.Y., Borgstrom, F., et al. (2008). European guidance for the diagnosis and management of osteoporosis in postmenopausal women. *Osteoporosis International, 19*, 399-428.

Kinsella, K., & Velkoff, V.A. (2001). *An aging world: 2001* (U.S. Census Bureau Series P95/01-1). Washington, DC: U.S. Government Printing Office.

Lord, S., Sherrington, C., Menz, H., & Close, J. (2007). *Falls in Older People. Risk factors and strategies for Prevention*. UK: Cambridge University Press.

Malina, R., Bouchard, C., & Bar-Or, O. (2004). *Growth, Maturation, and Physical Activity*. Second edition. Champaign, IL: Human Kinetics.

Moore, G.E., Mars, A.P., & Durstine, J.L. (2009). Approach to exercise and Disease Management. In Durstine, J.L., Moore, G.E., Painter, P.L., & Roberts, S.O. (Eds), *ACSM's Exercise Management for Persons with Chronic Diseases and Disabilities*. Third edition. American College of Sport Medicine. Champaign, IL: Human Kinetics.

Morrow, J.R., & Mood, D.P. (2006). Measuring the Ever-Changing "Environments" for Physical Activity in Older Adults. In Zhu, W., & Chodzko-Zajko, W. (Eds), *Measurement Issues in Aging and Physical Activity. Proceedings of the 10th Measurement and Evaluation Symposium* (pp. 81-88). Champaign, IL: Humans Kinetics.

Nelson, M.E., Fiatarone, M.A., Morganti, C.M., Trice, I., Greenberg, RA., & Evans, W.J. (1994). Effects of high-intensity strength training on multiple risk factors for osteoporotic fractures. A randomized controlled trial. *The Journal of the American Medical Association*, *272*(24), 1909-14.

Portuguese Eurostat. (2004). *Portrait of the Regions - Portugal - Madeira – Economy*. Retrieved Dec. 28, 2010 from http://circa.europa.eu/irc/dsis/regportraits /info/data/en/pt3_eco.htm.

Quintal, R. (2001). Levadas e Veredas da Madeira. 3ª Edição. Funchal: Francisco Ribeiro & Filhos Edições.

Quintal, R., & Vieira, M.J. (1985). *Ilha da Madeira. Esboço de Geografia Física*. Funchal: Região Autónoma da Madeira Secretaria Regional do Turismo e Cultura.

Rikli, R.E., & Jones, C.J. (2001). *Senior fitness test manual. Development and validation of a functional fitness test for community-residing older adults*. Champaign, IL: Human Kinetics.

Rose, D.J. (2010). *Fall proof: a comprehensive balance and mobility training program, Second edition*. Champaign IL: Human Kinetics.

Roubenoff, R. (2000). Sarcopenia and its implications for the elderly. *European Journal of Clinical Nutrition, 54*(suppl 3), S40-47.

Rubenstein, L. (2006). Falls in older people: epidemiology, risk factors and strategies for prevention. *Age Ageing*, 35 (Suppl 2), ii37-ii4.

Shepard, R.J. (1994). *Aerobic Fitness and Health*. Champaign, IL. Human Kinetics.

Spirduso, W.W., Francis, K.L., & MacRae, P.G. (2005). *Physical dimensions of aging*. Second edition. Champaign, IL:Human Kinetics.

Stenderup, K., Justesen, J., Clausen, C., & Kassem, M. (2003). Aging is associated with decreased maximal life span and accelerated senescence of bone marrow stromal cells. *Bone, 33*, 919-26.

Taylor, A.W., & Johnson, M.J. (2008). *Physiology of Exercise and Healthy Aging. Champaign*, IL: Human Kinetics.

Tinetti, M. (2003). Clinical practice. Preventing falls in elderly persons. *The New England Journal of Medicine, 348*(1), 42-9.

Tinetti, M., & Kumar, C. (2010). The patient who falls: "It's always a trade-off". *The Journal of the American Medical Association*, *303*(3), 258-66.

U.S. Census Bureau. (2001). International database. Table 094. Midyear population, by age and sex. Retrieved Jun. 5, 2010 from http://www.census.gov/population /www/projections/ natdet-D1A.html.

U.S. Department of Health and Human Services. (2004). *Bone health and osteoporosis: a report of the surgeon general*. Rockville, MD: U.S. Department of Health and Human Services, Office of the Surgeon General.

Williams, J. (2003). Dementia and Genetics. In Plomin, R., Defries, J.C., Craig, I.W., Mcguffin, P. (Eds), Be*havioral Genetics in the Postgenomic Era*. Washington: American Psychological Association.

World Health Organization. (2002). *Active Ageing: A Policy Framework*. Retrieved Nov. 21, 2010, from http://whqlibdoc.who.int/hq/2002/WHO_NMH_NPH_02.8. pdf.

Chapter 2

General Methodology

2.1 Study design, sampling procedures and participants

Participants are part of the research project entitled ‘Health and quality of life of older adults from Autonomous Region of Madeira, Portugal’. This cross-sectional study included 802 participants (401 males and 401 females) distributed similarly over four age-cohorts (60-64, 65-69, 70-74, and 75-79 years). The sampling criteria were the following: geographic area (11 districts of ARM), the number of participants in each age cohort, functional independence, and no medical contraindications to sub-maximum exercises according to the guidelines of the American College of Sports Medicine (ACSM), (2006). Participants were sufficiently mobile and independent to visit our laboratory at the UMa on their own. Data was collected between September of 2008 and September of 2009.

In each birth cohort, approximately 100 men and 100 women were proportionally included in the sample, i.e., given the number of participants by age and sex in each district. An initial prediction of the proportional regional (geographic) representation was determined by stratified sampling procedures based on Census 2001 (Portuguese Statistics [INE], 2002). This procedure was similar to one described by Freitas et al. (2002) in the Madeira Growth Study, more precisely:

- The total dimension of the sample was established in 800 participants, with 100 participants each one age cohort and sex (60-64, 65-69, 70-74, 75-79 years old);
- For each age cohort the allocation of the sample size for each district was similar to the allocation of population studied;
- The calculation of the number of participants to include in each district was based in the following formula:

$$n_{ij} = n_j \frac{N_{ij}}{N_j}$$

where:

j	age cohort ($j = 1, 2, 3$ and 4)
i	district index ($i = 1, \ldots, 11$)
$n_j = 100$	allocation of the sample for each age cohort j
n_{ij}	dimension of the sample by district (i) and age cohort j
N_j	total of participants of ARM by age cohort j
N_{ij}	total of participants of ARM in district (i) and age cohort j

The distribution of total sample by district on Madeira and Porto Santo Islands and the total number of participants effectively measured are presented in Figure 2.1.

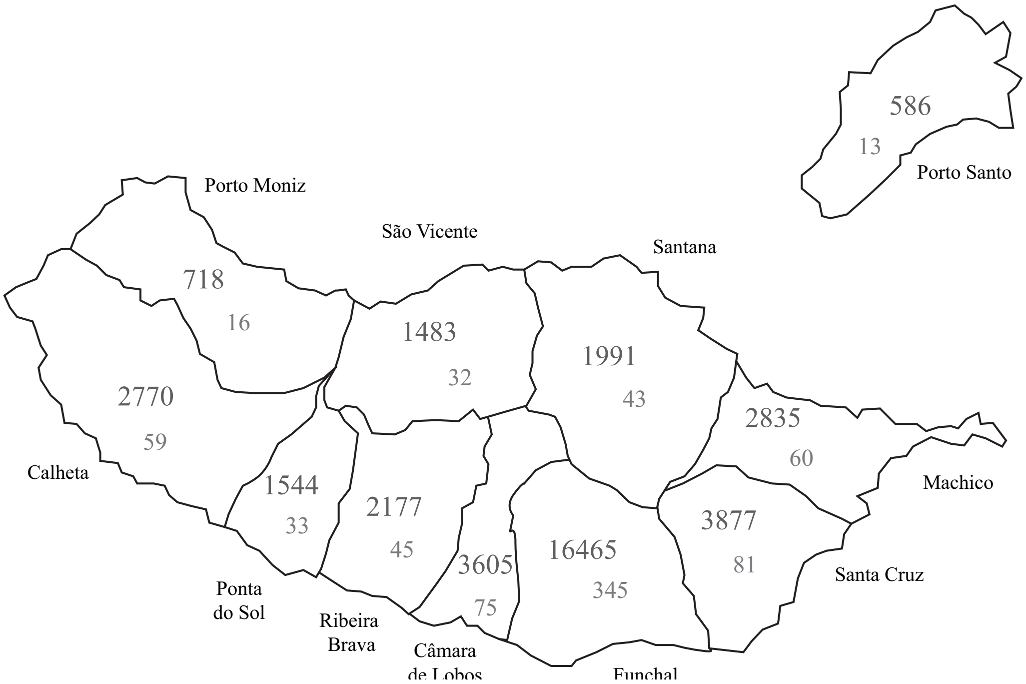

Figure 2.1 Distribution of the sample by region on Madeira and Porto Santo Islands and the number of participants effectively measured.

Participation was voluntary and participants were recruited through direct contacts carried out by the principal investigator of this study in day care centers, nursing homes, cultural and sport clubs associations, and residential and public places (e.g., open markets, municipal gardens and churches). The study was disclosed in the daily news, radio and television. Table 2.1 provides the total number of measured participants in each district of ARM according to sex and age cohort.

The study was approved by the UMa, the Regional Secretary of Education and Culture (SREC), and the Regional Secretary of Social Affairs. All participants were informed about the nature and purposes of the study and written informed consent was obtained from each subject (see appendix A). Additionally, all participants filled the Physical Activity Readiness Questionnaire (PAR-Q) (Thomas, Reading, & Shephard, 1992) (see appendix B).

Table 2.1 Number of participants measured by district and age group.

	60-64 yr		65-69 yr		70-74 yr		75-79 yr		Total	
Districts	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
Calheta	6	7	7	7	8	9	9	6	30	29
C^a de Lobos	11	10	11	10	8	10	8	7	38	37
Funchal	47	44	41	45	49	40	36	43	173	172
Machico	8	8	7	8	7	7	8	7	30	30
Ponta do Sol	4	4	4	5	5	4	3	4	16	17
Porto Moniz	1	2	2	3	2	2	2	2	7	9
Porto Santo	2	2	2	2	2	1	1	1	7	6
Ribeira Brava	4	6	4	6	6	7	6	6	20	25
Santa Cruz	12	11	12	10	9	10	10	7	43	38
Santana	5	5	5	6	7	5	5	5	22	21
São Vicente	3	3	4	6	4	3	4	5	15	17
Total	103	102	99	108	107	98	92	93	401	401

♂ Males; ♀ Females

2.2 Measurements and protocols

2.2.1 Physical activity

PA was assessed during face-to-face interviews using the Baecke questionnaire developed in the Netherlands (Baecke, Burema, & Frijters, 1992) (see appendix C). This questionnaire includes a total of 16 questions classified into three specific domains: PA at work, sport and leisure time, the latter excluding sports. The questionnaire also provides a measure of total PA which is the sum of these three specific domains. Numerical coding for most response categories varied from 1 to 5 (Likert scale) ranging from never to always or very often. Questions 1 and 9 require a written response and dial with to main occupation and types of sports played, respectively. PA indices were calculated according to a specific formulas for work (questions 1- 8), sport (questions 9-12) and leisure time (questions 13-16).

If the participants were not employed or if they were retired, their occupation was coded as homemaker. The work index includes information about sitting, standing, walking, lifting and, if sweating at work was elicited, as well as information about fatigue after work or household activities (HS). Additionally, each subject was asked how they perceived their activity at work or during HS in relationship to that of others their own age. A sport score (one or two main sports) was also calculated from a combination of the intensity, amount of time per week and proportion of the year in which the sport was practiced. Sports were subdivided into three levels of PA: the low level (average energy expenditure 0.76 MJ/h), the middle level (average energy expenditure 1.26 MJ/h) and the high level (average energy expenditure 1.76 MJ/h). The leisure-time activity index was based on the frequency of walking and cycling either for leisure and /or to work or shopping. This index included the amount of time spent watching television. Participants were classified separately by age-cohort and sex into tertiles of high, moderate or low PA levels, based on their responses to this questionnaire.

The questions on HS have four to five possible answers, classifying the activity levels from inactive to very active. Questions about sport and leisure time activities include the type, frequency and the number of months per year that the activity is performed. All items give a separate score that incorporates duration, frequency and intensity. The sum of the household score, sport score and leisure time activity score, gives a continuous activity score.

2.2.2 Functional fitness

FF was assessed with the Senior Fitness Test (SFT) (Rikli & Jones, 2001). All participants received the same instructions about the procedures of each test and they completed one or two trials to become familiarized with the task. To minimize the effects of fatigue, stations were arranged in the following order: chair stand test (lower body strength), arm curl test (upper body strength), chair sit and reach test (lower body flexibility), back scratch test (upper body flexibility), 8-foot up-and-go test and (agility/ dynamic balance). The 6-minute walk test (aerobic endurance) was administered after all other tests and questionnaires had been completed. The 2-minute step test was performed on another day. A detailed description of the evaluation procedures, namely, equipment, procedure, scoring and safety precautions can be found in the SFT manual (Rikli & Jones, 2001). The registration form of the motor tests is presented in appendix D.

2.2.3 Balance scales

2.2.3.1 Fullerton Advance Balance scale

The FAB is designed to measure changes in multiple dimensions of balance in higher functioning community-dwelling older adults. The 10-item FAB scale comprises 10 items, namely: standing with feet together and eyes closed (item 1), reaching forward to retrieve an object (pencil) held at shoulder height with outstretched arm (item 2), turning 360 degrees in right and left direction in a circle (item 3), stepping up and over a 15 cm bench (item 4), tandem walking (item 5), standing on one leg (item 6), standing on foam with eyes closed (item 7), jumping for distance (item 8), walking with head turns (item 9), and recovering from an unexpected loss of balance (item 10). The performance on each of the 10 individual test items is scored using a 4-point ordinal scale (0–4), with a maximum score of 40 possible points. Details referring to the protocols of administration, equipment and an explanation about static and dynamic balance activities are described in Rose (2003). The registration form of the FAB is presented in appendix E.

2.2.3.2 50-foot walk test

Participants were required to walk a total distance of 70 feet (first with a preferred speed and then with maximal speed), with the distance between 10 and 60 feet being timed for the purpose of calculating gait velocity (GV) and other measures of gait. The number of steps is counted over the same 50 feet distance, in order to calculate cadence (steps per second) and stride length (SL) (number of steps divided by 2 (Rose, 2010). The gait stability ratio (GSR) is calculated from cadence (steps per sec) and velocity (ff/sec) and was expressed in units of steps per feet (Cromwell, & Newton, 2004). A full description of test administration instructions for 50-foot walk test at preferred and maximum speed is reported by Rose (2003). The 50-foot walk test is a useful measure of gait speed and the indication of whether an older adult is able to adapt their gait speed to accommodate a change in task demands. The registration form of the 50-foot walk test is presented in appendix F.

2.2.4 Human somatic dimensions

The anthropometric measurements were obtained according to the standardized procedures described by Claessens et al. (1990). Height and sitting height were measured with a harpenden stadiometer and a harpenden sitting height table (Holtain Ltd., Crymych. United Kingdom), respectively. The measures were recorded to the nearest millimetre. BM was measured on a balance-beam scale accurate to 0.1 kg (Seca Optima 760, Hamburg, Germany). Skeletal breadths (biacromial, bicristal, biepicondylar femur and biepicondylar humerus) were assessed with a spreading caliper with an accuracy of 1mm (Siber-Hegner, GPM). Girths measurements (arm flexed and relaxed, calf, forearm, hip, thigh, and waist) were taken with a flexible steel tape (Holtain, Crymych, UK) accurate to 1 mm. Skinfold thickness (biceps, calf, subscapular, suprailiac and triceps) was measured using a skinfold caliper and recorded to the nearest 0.2 mm (Siber-Hegner, GPM).

All one-sided measurements were taken on the left side of the body. Participants were measured in the Laboratory of Human Physical Growth and Motor Development of UMa. Participants wore light, indoor clothing without shoes and jewelry during the measurements. Measurements were performed twice and a third measurement was carried out in case of excessive difference. The scores of the two or the two closest measurements were averaged to reduce measurement error. The registration form of the anthropometric measurements is presented in appendix G.

2.2.5 Bone mineral density

BMD (g/cm^2) was determined by dual-energy x-ray absorptiometry-DXA (Lunar Prodigy Primo, with technologic fan beam – GE Healthcare, Encore 2007 software version 11.40.004). This instrument uses a constant potential X-ray source and a K-edge filter to achieve an X-ray beam of stable energy radiation of 38 and 70 KeV. The x-rays are emitted from a source below the subject and pass through the subject, who lies in a supine position on a table (Lohman, & Chen, 2005). After removing all objects suspected or known to contain metal, participants were positioned by the technician according to the manufacturer's recommended protocol. Participants were in a supine position and the following sites were investigated: total body, LS (anterior-posterior), and femur (FN, trochanter, Ward's triangle and total femur).

In addition to the conventional densitometry measurements, structural variables were also determined using the Hip Strength Analysis program (HAS), including hip axis length and cross-sectional moment of inertia (CSMI). These bone geometry variables were used to calculate the FSI, the ratio of estimated compressive yield strength of the FN to the expected compressive stress of a fall on the greater trochanter adjusted for each subject's age, height and BM (Yoshikawa et al., 1994).

Scans were standardized daily against a calibration phantom; the precision error, expressed as the coefficient of variation (CV %), was 0.31%. Scans were taken alternately by four different technicians over the course of data collection. All technicians received an identical 5 days DXA training course before the start the study using the manufacturer's recommended protocol.

2.2.6 Body composition

Total and regional body composition, including the estimation of lean soft tissue mass, fat-free and fat mass for arms, legs and trunk were also assessed by DXA. In addition, TLTM, ALTM, and LLTM were determined. ALST was calculated as the sum of ALTM + LLTM. Furthermore, relative values were calculated, namely, RLTM (LTM / TM), RALTM (ALTM / total arm mass), RLLTM (LLTM / total leg mass), and RALST (ALST / total legs and arms mass) and expressed as a percentage. Relative appendicular lean tissue mass was calculated as ALST (kg) / height^2 (m^2).

2.2.7 General health

Demographic information and a complete health history were obtained by telephone interview. A modified version of the health questionnaire employed in the FallProof! Programme (Rose, 2003) was used to assess behaviour and lifestyle characteristics, including smoking history, history of degenerative diseases and osteoarthritis, fracture history, current and past therapy with specific classes of medications, including hormones (estrogen and thyroid), calcium supplements, aspirin, vitamin D, anxiolytic drugs and sleeping aids. The registration form is presented in appendix H.

2.2.8 Dietary intake

For estimation of dietary intake we used a semi-quantitative food frequency questionnaire developed by the Department of Hygiene and Epidemiology of Porto University Medical School, and previously validated (Lopes, 2000). This questionnaire included 86 items, including those with high contribution for the intake of dietary calcium such as dairy products (e.g., milk, cheese, ice cream, yogurts), as well as leafy green vegetables and fish. In addition, this questionnaire assessed caffeine and alcohol intake (combination of consumption of wine, beer and liquor drinks). Food consumption was converted into nutrients using the software Food Processor Plus® (ESHA Research, Salem-Oregon, 1997), which has been adapted to Portuguese traditional food and dishes (Lopes, 2000). The registration form of the semi-quantitative food frequency questionnaire is present in appendix I.

2.3 Organization and preparation of the study

All the assessments took place in the Laboratory of Human Physical Growth and Motor Development of UMa, Social Sciences Competence Centre, Department of Physical Education and Sport. To maximize the consistency of assessment procedures, measurements were conducted by five graduates in Physical Education and Sport, one in Nursing and 3 in Senior Education. At the baseline, all the measurements and protocols were theoretically presented. In the second phase, all the measurements and questionnaires were applied between the member of the field team. In addition, training sessions were extended to a group of older adults belonging to a PA program. A pilot study was conducted involving 50 older adults from the named group, aged between 60 and 79 years. A pilot study was carried in UMa and all participants were measured twice with a 1 week interval.

2.4 References

American College of Sports Medicine. (2006). *ACSM's guidelines for exercise testing and prescription*. Seventh Edition. Philadelphia: Lippincott Williams & Wilkins.

Baecke, J.A., Burema, J., & Frijters, J.E. (1992). A short questionnaire for the measurement of habitual physical activity in epidemiological studies. *The American Journal of Clinical Nutrition, 36*, 936-42.

Claessens, A., Vanden Eynde, B., Renson, R., & Van Gerven, D. (1990). The description of tests and measurements. In Simons J, Beunen G, Renson R, Claessens A, Vanreusel B, Lefevre J (Eds). *Sport Science Monograph Series* (pp.21-39). Champaign, IL: Human Kinetics.

Cromwell, R., & Newton, R. (2004). Relationship between balance and gait stability in healthy older adults. *Journal of Aging and Physical Activity*, 12, 90-100.

Freitas, D.L., Maia, J.A., Beunen, G.P., Lefevre, J.A., Claessens, A.L., Marques, A.T., et al. (2002). *Crescimento somático, maturação biológica, aptidão física, actividade física e estatuto sócio-económico de crianças e adolescentes madeirenses*. O estudo de crescimento da Madeira. Funchal: Universidade da Madeira.

Instituto Nacional de Estatística. (2002). *Censos 2001: resultados definitivos: XIV recenseamento geral da população: IV recenseamento geral da habitação.* Lisboa: Instituto Nacional de Estatística.

Lohman, T.G., & Chen, Z. (2005). Dual Energy X-Ray Absorptiometry. In Heymsfield, S.B., Lohman, T.G., Wang, Z., Going, S.B., (Eds). *Human body composition*. Second Edition. Champaign, IL: Human Kinetics.

Lopes, C. (2000). *Diet and acute myocardial infarction: a population based case-control study. Reproducibility and validity of a semi-quantitative food frequency questionnaire*. Unpublished doctoral dissertation, University of Porto – Portugal.

Rikli, R.E., & Jones, C.J. (2001). *Senior fitness test manual. Development and validation of a functional fitness test for community-residing older adults*. Champaign, IL: Human Kinetics

Rose, D.J. (2003). Fallproof: *A comprehensive balance and mobility training program*. Champaign, IL. Human Kinetics.

Rose, D.J. (2010). *Fall proof: a comprehensive balance and mobility training program, Second edition*. Champaign IL: Human Kinetics.

Thomas, S., Reading, J., & Shephard, R.J. (1992). Revision of the Physical Activity Readiness Questionnaire (PAR-Q). *Canadian Journal of Sport Sciences*, *17*(4), 338-45.

Yoshikawa, T., Turner, C.H., Peacock, M., Slemenda, C.W., Weaver, C.M., Teegarden, D., et al. (1994). Geometric structure of the femoral neck measured using dual-energy x-ray absorptiometry. *Journal of Bone and Mineral Research*, *9*,1053-64.

Chapter 3

Physical activity, fitness and bone health: a state of art

3.1 Physical activity, fitness and bone health

The association between PF and PA is a reciprocal one; PF provides the individual with the capability to engage in physical activities, whereas PA helps to maintain and in some cases improve PF (Rimmer, 2006). This association, coupled with the high prevalence of physical inactivity among older adults, has profound implications for several physiological systems, especially those related with musculoskeletal and cardiorespiratory health. In addition, the substantial change in PA patterns is typically seen in individuals as they get older (Dishman, Washburn, & Heath, 2004). The decrease of PA levels in older adults is related to chronic health conditions, disease or age. A negative spiral of deterioration leads to loss of autonomy and, consecutively, to a reduction in quality of life (Dishman et al., 2004).

A basic model linking PA, PF, and health was developed by Bouchard & Shephard (1994). An increase of PA may be expected to increase various components of the individual's fitness and any improvements in the aerobic component are in turn likely to improve general health. However, other lifestyle behaviours, environmental conditions, personal attributes and genetic characteristics could affect the three major components of the model and their interrelationships (Bouchard & Shephard; 1994; Shephard, 1994). The American College of Sport Medicine (ACSM) (2006) distinguished physiological fitness and health related fitness. Physiological fitness includes non-performance components that relate to biological systems (metabolic fitness, morphologic fitness and bone integrity). Health-related PF is associated with the ability to perform daily activities with vigour and the presence of traits and capacities that are associated with a low risk of premature development of hypokinetics diseases. Both, health-related and physiological fitness are linked with health promotion and disease prevention and can be modified through regular PA and exercise (ACSM, 2006).

Many epidemiological studies have suggested a dose–response pattern for PA that is associated with a lower risk of physical limitations (Leveille, Guralnik, Ferrucci, & Langlois, 1999; He & Baker, 2004; Hillsdon, Brunner, Guralnik, & Marmot, 2005). A classic study developed by Paffenbarger, Hyde, Wing, & Hsieh (1986) investigated the PA and lifestyle characteristics of 16 936 Harvard alumni, aged 35 to 74 years old. In older men, adequate PA was associated with an increase in lifetime of one to two years compared to men with sedentary lifestyles.

More recently, others studies strengthened that the high levels of PA and PF and other modifiable lifestyle characteristics may influence the risk of chronic disease and premature death. It seems that change in lifestyle may therefore promote optimal health and longevity (Paffenbarger et al., 1993; Kampert, Blair, Barlow, & Kohl, 1996). Similarly, Kushi et al. (1997) analyzed the association between PA and all-cause mortality in postmenopausal women. The results showed an inverse association between PA and all-cause mortality.

Aging has been clearly associated with deterioration in a majority physiological systems that culminates in limited or lost physical capacity (Shephard, 1997; Paterson & Stathokostas, 2002). In the last decades, research has shown that many of the age-related physiology decrements that older adults experience are not inevitable. The primary components of FF (aerobic endurance, flexibility, body composition, power, balance/coordination, muscular endurance and muscular strength) have an effective role in preserving physical function, reducing the risk for chronic health conditions and averting disability with age (Brown, Sinacore, Binder & Kohrt, 2000; Foldvari et al., 2000; Rikli & Jones, 2001).

There are considerable age-related losses on physiological capacity and function, including losses of cardiorespiratory fitness, muscle mass, oxidative capacity, strength, shoulder flexibility and self-selected speed of walking. On the other hand, the reduction of cardiorespiratory fitness, several times induced by cardiovascular disease, is the leading cause of morbidity and mortality among older adults (Schulman, 1999). In fact, cardiovascular disease is so prevalent among the older adult population, that it is often difficult to separate cardiovascular changes that occur with increasing age from effects of the disease process (Paterson & Stathokostas, 2002).

Recognizing the importance of PA and FF for older adults is the basis of gerokinesiology (an area of study that focuses on understanding how PA influences health and well-being in older adult population and the aging process in general) (Jones & Rose, 2005). Physical inactivity has been considered as one of the strongest predictors of physical disability among older adults. Paterson & Stathokostas (2002) presented physical inactivity or a low level of PF, namely, cardiorespiratory fitness and muscle strength as the major risk factors for the loss of functional capacity, disability and dependence.

PA and exercise have an important role in allowing individuals to attain peak bone mass, reducing subsequent rates of bone loss and reducing the risk of fall-related fractures (Lane, 2006). It is important to note that fractures due to skeletal disorders are common. One in three women and one in five men, over age 50 are estimated to suffer a fracture in their lifetime, (U.S. Department of Health and Human Services, [U.S.DHHS], 2004).

Longitudinal studies reveal that regular PA and exercise not only extend longevity, but also reduce the risk of physical disability in later life (LaCroix, Guralnik, Berkman, Wallace, & Satterfield, 1996; Strawbridge Cohen, Shema, & Kaplan, 1996; Ferrucci et al., 1999; Leveille et al., 1999; Wu, Leu, & Li, 1999). In parallel, a body of evidence reinforces that moderate or high intensity PA appears to exert site-specific beneficial effects on bone health/strength (Schmitt, Schmitt, & Dören, 2009).

Data from the Leisure World Study showed that women with an activity level >1 hour a day had a reduced risk of hip fracture, but the beneficial effect was lost if the activity level was reduced (Paganini-Hill, Chao, Ross & Henderson, 1991). The Osteoporotic Fracture Study, a longitudinal study including 9704 women >65 years of age and followed for about 8 years, women in the highest quintile of PA had a reduction of 42% in the risk for hip fracture when compared the least active quintile of women. The same study found that self-reported walking time was associated to a 30% reduction in hip fracture risk during a 4.1-year follow-up (Cummings et al., 1995).

In an extensive review Guadalupe-Grau, Fuentes, Guerra, & Calbet, (2009) concluded, that bone mass can be increased by some specific exercise programs, and attenuate the losses in bone mass with age. It is important to note that not all, but individually tailored, intense and high impact exercise programs may be more effective in maximizing the goals of public health to prevent osteoporosis and consecutive adverse outcomes (Schmitt et al., 2009; Kemmler et al., 2004).

Nelson et al. (1994) examined how multiple risk factors for osteoporotic fractures could be modified by high-intensity strength training exercises in postmenopausal women. They concluded that high-intensity strength training exercises were an effective and feasible mean to preserve bone density, while improving muscle mass, strength and balance in this population. Exercise may be of critical importance in increasing bone formation, because the effect of weight-bearing loading is essential for bone formation, whereas calcium supplements and estrogen treatment only slow down bone resorption (Franck, Beuker, & Gurk, 1991). The benefits of engaging in PA programs, and the positive association between exercise and bone mass, has encouraged many physicians and public health officials to recommend that people engage in daily exercise, with the goal of reducing the incidence of osteoporotic fracture and the morbidity/mortality (Turner & Robling, 2005).

According to Wilcox, Tudor-Locke, & Ainsworth (2002) exercise self-efficacy, social support for exercise, perceived benefits of exercise, positive attitudes toward exercise, and a fewer perceived barriers to exercise, are the major predictors for PA among older adults. It is important to note that men and women do not react in the same way. Older women have lower exercise self-efficacy, report greater health barriers to exercise, especially musculoskeletal pain, perceive greater health risk that results from exercise, receive less social support for exercise, have greater fear of falling and may hold more negative attitudes toward exercise (Wilcox et al., 2002).

On the other hand, the protective effect of regular exercise, particularly in bone health/strength is more pronounced in men than women, possibly because of their higher testosterone levels (U.S.DHHS, 2004). This gender difference could be attributable to the fact that women possess less initial bone calcium content and have reduced calcium intake during menopause (Shephard, 1997; Spirduso, Francis, & MacRae, 2005). In general, older men have been less studied than women and, although it seems that men may respond better than their female counterparts, the evidence for a sexual dimorphism in the osteogenic response to exercise in the elderly is weak (Guadalupe-Grau et al., 2009).

The lower osteoporotic fracture incidence in men could be another reason for this group to be less studied (Mackey et al., 2007). In biological terms, women tend to begin losing bone mass between 30 and 35 years of age at a rate of 0.75% to 1% per year, and they lose approximately more 6g of BMD per decade when compared with men (Shephard, 1997). Bone loss in men generally commences later, between 50 to 55 years of age, at an initial rate of 0.4% per year (Taylor & Johnson, 2008; Spirduso et al., 2005; Shephard, 1997).

An important function of bone tissue is to withstand and transmit forces without breaking. Bone health/strength depends on the amount of tissue, its material composition and how bone material is organized microarchitecturally and geometrically (shape and size) (Bouxsein & Karasik, 2006; Viguet-Carrin, Garnero & Delmas, 2006). Bouxsein & Seeman (2009) referred that the ability of a bone to resist to a fracture depends on the amount of bone, the spatial distribution of the bone mass as cortical and trabecular bone and the intrinsic properties of the bone material. Bone is a living tissue that undergoes a continuous cycle of bone building by osteoblasts and bone resorption by osteoclasts. The balance between resorption (osteoclasts) and formation (osteoblasts) of bone differs substantially not only in different bones (e.g., weight-bearing or non- weight-bearing) but also in different bone tissue (Pearson & Lieberman, 2004; Sommerfeldt & Rubin, 2001).

Sabolinski, Alvarez, Auletta, Mulder & Parenteau, (1996) consider the bone tissue as a "smart" material, given its ability to (1) adapt its mass and morphology to functional demands; (2) repair itself without leaving a scar; and (3) rapidly mobilize mineral stores on metabolic demand. Measures of bone health/strength include bone mass (the amount of bone), bone mineral content (BMC) (the grams of bone mineral as hydroxyapatite within a measure bone region), bone mineral density (BMD) (the grams of bone mineral per unit of bone area scanned), bone geometry (internal structure of bone) and rate of bone loss (Crabtree & Ward, 2009; Spirduso et al., 2005; Khan et al., 2001).

The maintenance of bone health throughout the life span is essential to human being. A decline in skeletal integrity increases the risk of osteoporosis and bone fracture (Spidurso et al., 2005). Shephard, (1997) refer that lifestyle factors, such as PA level, calcium intake and nutritional status, play a major role making it difficult to determine the intrinsic contribution of aging itself on bone loss. Khan et al. (2001) state that PA accounts for only 10% of bone minerals, at the population level. The determinants that account for 90% are genetics, gender, age, soft tissue composition (TLM, TFM), lifestyle choices (smoking, alcohol intake), medication, hormones, and nutrition. The same authors add that these factors are interrelated and their degree of influence varies at different stages of the lifespan and at different skeletal sites. Recently, Spirduso et al. (2005) summarized two types of factors affecting bone health with aging: non-modifiable factors, such as gender and ethnicity (genetic factors), and modifiable factors such as hormones, diet exercise and body weight (environmental factors).

The gradual decline in LTM or skeletal muscle mass leads to sarcopenia results in impaired functional performance and increased risk for falls. Remains uncertain whether the age-related decrease in muscle size and strength is related to the age-related decrease in bone health/strength, or whether both contribute to increased fracture risk independently. However, it seems unequivocal that muscle mass and strength losses with age can increase the individual's risk for developing musculoskeletal disease and osteoporosis (Roubenoff & Hughes, 2000; Crepaldi & Maggi, 2005).

There is scientific consensus that the magnitude of the peak skeletal mass in the first three decades of life probably accounts for the variability in bone mass in elderly persons, (Hui, Slemenda & Johnston, 1990;

Heaney et al., 2000). Heaney et al. (2000) presented the peak bone mass and the rate of bone loss with advancing age as two principal mechanisms that determine adult bone health. A combination of good nutrition and exercise produces healthy bones in youth, and higher peak bone density is associated with a reduced risk of bone fracture in later life (Boot et al., 2010). In the same line, Karlsson (2001) suggested that exercise during childhood and adolescence may be associated with lower risk of sustaining fragility fractures during old age in men. These results are not so clear for women (Guadalupe-Grau et al., 2009). However, more knowledge is needed to prove or disprove this theory.

Some the most common skeletal disorders in the elderly are osteoarthritis, rheumatoid arthritis and osteoporosis. Osteoporosis results from a chronic excess of resorption of bone by osteoclasts in comparison to the amount of bone deposition by osteoblasts. Changes in hormone levels (estrogen in women and testosterone in men) appear to be the prime cause of the imbalance between resorption and deposition, but the senescence of osteoblasts and of osteo-progenitor cells also plays a role (Pearson & Lieberman, 2004). Osteoporosis is characterized by compromised bone mass and strength, resulting in an increase in bone fragility and thus to a predisposition for bone fractures in response to a traumatic stresses (Kanis et al., 2008; World Health Organization [WHO], 1994).

Osteoporosis has a debilitating effect on independence and quality of life. Risk factors for osteoporosis are the family history, female gender, estrogen deficiency, low weight, dietary factors, prolonged use of corticosteroids, smoking and physical inactivity (U.S.DHHS, 2004). Within the risk factors, the PA level arises as a way to prevent osteoporosis, based on evidence that PA can regulate bone maintenance, stimulate bone formation, including the accumulation of mineral, strengthen muscles, improve balance and reduce the overall risk of falls and fractures (Borer, 2005). Both, muscular contraction and gravity, apply force to bones that influences the structure and integrity of the bone. However, the understanding of how to use exercise effectively in the prevention of osteoporosis is incomplete and the effectiveness of exercise to increase bone mass, or at least, arrest the bone mass loss after menopause, is an open question (Borer, 2005).

3.2 References

American College of Sports Medicine. (2006). *ACSM's guidelines for exercise testing and prescription*. Seventh Edition. Philadelphia: Lippincott Williams & Wilkins.

Boot, A.M., de Ridder, M.A., van der Sluis, I.M., van Slobbe, I., Krenning, E.P., & Keizer-Schrama, S.M. (2010). Peak bone mineral density, lean body mass and fractures. *Bone*, *46*(2), 336-41.

Borer, K.T. (2005). Physical activity in the prevention and amelioration of osteoporosis in women: interaction of mechanical, hormonal and dietary factors. *Sports Medicine, 35*(9), 779-830.

Bouchard, C. & Shephard, R.J. (1994). Physical activity, fitness, and health: the model and key concepts. In Bouchard C, Shephard RJ, & Stephens, T., (Eds.), *Physical Activity, Fitness, and health: international proceedings and consensus statement* (pp. 77-88). Champaign IL: Human kinetics.

Bouxsein, M.L., & Karasik, D. (2006). Bone geometry and skeletal fragility. *Current Osteoporosis Reports, 4*(2), 49-56.

Bouxsein, M.L., & Seeman, E. (2009). Quantifying the material and structural determinants of bone strength. *Best Practice & Research*. *Clinical Rheumatology, 23*(6), 741-53.

Brown, M., Sinacore, D.R., Binder, E.F., & Kohrt, W.M. (2000). Physical and performance measures for the identification of mild to moderate frailty. *Journal of Gerontology: Biological Sciences, 55*(6), 350-5.

Crabtree, N., & Ward, K. (2009). Bone densitometry: current status and future perspectives. *Endocrine Development, 16*, 58-72.

Crepaldi, G., & Maggi, S. (2005). Sarcopenia and osteoporosis: A hazardous duet. *Journal of Endocrinological Investigation, 28*(10 Suppl), 66-8.

Cummings, S.R., Nevitt, M.C., Browner, W.S., Stone, K., Fox, K.M., Ensrud. K.E et al., (1995). Risk factors for hip fracture in white women: Study of Osteoporotic Fractures Research Group. *The New England Journal of Medicine*, *332*(12), 767-73.

Dishman, R.K., Washburn, R.A., & Heath, G.W. (2004). *Physical Activity Epidemiology*. Champaign, IL: Human Kinetics.

Ferrucci, L., Izmirlian, G., Leveille, S., Phillips, C.L., Corti, M.C., Brock, D.B., & Guralnik, J.M. (1999). Smoking, physical activity, and active life expectancy. *American Journal of Epidemiology, 149*(7), 645-53.

Foldvari, M., Clark, M., Laviolette, L.C., Bernstein, M.A., Kaliton, D., Castaneda, et al., (2000). Association of muscle power with functional status in community-dwelling elderly women.

Journal of Gerontology: Biological Sciences, 55(4), 192-9.

Franck, H., Beuker, F., & Gurk, S. (1991). The effect of physical activity on bone turnover in young adults. *Experimental and Clinical Endocrinology*, *98*(1), 42-6.

Guadalupe-Grau, A., Fuentes, T., Guerra, B., & Calbet, J.A. (2009). Exercise and bone mass in adults. *Sports Medicine, 39*(6), 439-68.

He, X.Z., & Baker, D.W. (2004). Body mass index, physical activity, and the risk of decline in overall health and physical functioning in late middle age. *American Journal of Public Health, 94*, 1567 –73.

Heaney, R.P., Abrams, S., Dawson-Hughes, B., Looker, A., Marcus, R., Matkovic, V., Weaver, C. (2000). Peak bone mass. *Osteoporosis International, 11*(12), 985-1009.

Hillsdon, M.M., Brunner, E.J., Guralnik, J.M., & Marmot, M.G. (2005). Prospective study of physical activity and physical function in early old age. *The American Journal of Preventive Medicine*, *28*, 245–50.

Hui, S.L., Slemenda, C.W., & Johnston, C.C. (1990). The contribution of bone loss to postmenopausal osteoporosis. *Osteoporosis International, 1*(1), 30-4.

Jones, C.J., & Rose, D.J. (2005). *Physical Activity Instruction of Older Adults.* Champaign, IL: Human Kinetics.

Kampert, J.B., Blair, S.N., Barlow, C.E., & Kohl, H.W. (1996). Physical activity, physical fitness, and all-cause and cancer mortality: a prospective study of men and women. *Annals of Epidemiology, 6*(5), 452-7.

Kanis, J.A., Burlet, N., Cooper, C., Delmas, P.D., Reginster, J.Y., Borgstrom, F., et al., (2008). European guidance for the diagnosis and management of osteoporosis in postmenopausal women. *Osteoporosis International, 19*, 399–428. Karlsson, M.K. (2001). Skeletal effects of exercise in men. *Calcified Tissue International, 69*(4), 196-9.

Kemmler, W., Lauber, D., Weineck, J., Hensen, J., Kalender, W., & Engelke, K. (2004). Benefits of 2 years of intense exercise on bone density, physical fitness, and blood lipids in early postmenopausal osteopenic women: results of the Erlangen Fitness Osteoporosis Prevention Study (EFOPS). *Archives of Internal Medicine*, *164*, 1084–9.

Khan, K., McKay. H., Kannus, P., Bailey, D., Wark, J., & Bennell, K. (2001). *Physical Activity and Bone Health*. Champaign, IL: Human Kinetics.

Kushi, L.H., Fee, R.M., Folsom, A.R., Mink, P.J., Anderson, K.E., & Sellers, T.A. (1997). Physical activity and mortality in postmenopausal women. *The Journal of the American Medical Association*, *277*(16), 1287-92.

LaCroix, A.Z., Guralnik, J.M., Berkman, L.F., Wallace, R.B., & Satterfield, S. (1993). Maintaining mobility in late life. II. Smoking, alcohol consumption, physical activity, and body mass index. *American Journal of Epidemiology, 137*(8), 858-69.

Lane, N.E. (2006). Epidemiology, etiology, and diagnosis of osteoporosis. *American Journal of Obstetrics and Gynecology, 194*, S3–11.

Leveille, S.G., Guralnik, J.M., Ferrucci, L., & Langlois, J.A. (1999). Aging successfully until death in old age: opportunities for increasing active life expectancy. *American Journal of Epidemiology, 149*, 654–64.

Mackey, D.C., Lui, L.Y., Cawthon, P.M., Bauer D.C., Nevitt, M.C., Cauley, J.A. et al., (2007). High-trauma fractures and low bone mineral density in older women and men. *The Journal of the American Medical Association*, *298* (20), 2381-8.

Nelson, M.E., Fiatarone, M.A., Morganti, C.M., Trice, I., Greenberg, RA., & Evans, W.J. (1994). Effects of high-intensity strength training on multiple risk factors for osteoporotic fractures. A randomized controlled trial. *The Journal of the American Medical Association*, *272*(24), 1909-14.

Paffenbarger, R.S., Hyde, R.T., Wing, A.L., & Hsieh, C.C. (1986). Physical activity, all-cause mortality, and longevity of college alumni. *The New England Journal of Medicine, 314*(10), 605-13.

Paffenbarger, R.S., Hyde, R.T., Wing, A.L., Lee, I.M., Jung, D.L., & Kampert, J.B. (1993). The association of changes in physical-activity level and other lifestyle characteristics with mortality among men. *The New England Journal of Medicine, 328*(8), 538-45.

Paganini-Hill, A., Chao, A., Ross, R.K., & Henderson, B.E. (1991). Exercise and other factors in the prevention of hip fracture: the Leisure World study. *Epidemiology*, *2*(1), 16-25.

Paterson, D.H., & Stathokostas, L. (2002). Physical Activity, Fitness, and Gender in Relation to Mortality, Survival, Quality of Life, and Independence in Older Age. In Shephard, R.J. (Eds.), *Gender, Physical Activity, And Aging* (pp. 99-120). United States of America: CRS Press.

Pearson, O.M., & Lieberman, D.E. (2004). The aging of Wolff's "law": ontogeny and responses to mechanical loading in cortical bone. *American Journal of Physical Anthropology, Suppl 39*, 63-99.

Rikli, R.E., & Jones, C.J. (2001). *Senior Fitness Test Manual. Development and validation of a functional fitness test for community-residing older adults*. Champaign, IL: Human Kinetics.

Rimmer, J.H. (2006). Assessment Issues Related to Physical Activity and Disability, In Zhu, W., & Chodzko-Zajko, W. (Eds.), *Measurement Issues in Aging and Physical Activity. Proceedings of the 10th Measurement and Evaluation Symposium* (pp. 69-79). Champaign, IL: Human

Kinetics.

Roubenoff, R., & Hughes, V.A. (2000). Sarcopenia: current concepts. *The Journals of Gerontology.* Series A, Biological Sciences and Medical Sciences*, 55*(12), 716-24.

Sabolinski, M.L., Alvarez, O., Auletta, M., Mulder, G., & Parenteau, N.L. (1996). Cultured skin as a 'smart material' for healing wounds: experience in venous ulcers. *Biomaterials, 17*, 311-320.

Schmitt, N.M., Schmitt, J., & Dören, M. (2009). The role of physical activity in the prevention of osteoporosis in postmenopausal women-An update. *Maturitas, 63*(1), 34-8.

Schulman, S.P. (1999). Cardiovascular consequences of the aging process. *Cardiology Clinics, 17*(1), 35-49.

Shephard, R.J. (1994). *Aerobic Fitness and Health*. Champaign IL: Human kinetics.

Shephard, R.J. (1997). *Aging Physical Activity, and Health.* Champaign, IL: Human Kinetics.

Sommerfeldt, D.W., & Rubin, C.T. (2001). Biology of bone and how it orchestrates the form and function of the skeleton. *European Spine Journal, 10*Suppl, 2, S86-95.

Spirduso, W.W., Francis, K.L., & MacRae, P.G. (2005). *Physical dimensions of aging*. Second Edition. Champaign, IL: Human Kinetics.

Strawbridge, W.J., Cohen, R.D., Shema, S.J., & Kaplan, G.A. (1996). Successful aging: predictors and associated activities. *American Journal of Epidemiology, 144*(2), 135-41.

Taylor, A.W., & Johnson, M.J. (2008). *Physiology of Exercise and Healthy Aging.* Champaign, Illinois: Human Kinetics.

Turner, C.H., & Robling, A.G. (2005). Exercises for improving bone strength. *British Journal of Sports Medicine, 39*(4), 188-9.

U.S. Department of Health and Human Services. (2004). *Bone health and osteoporosis: a report of the surgeon general*. Rockville, MD: U.S. Department of Health and Human Services, Office of the Surgeon General.

Viguet-Carrin, S., Garnero, P., & Delmas, P.D. (2006). The role of collagen in bone strength. *Osteoporosis International, 17*(3), 319-36.

Wilcox, S., Tudor-Locke, C.E., & Ainsworth, B.E. (2002). Physical Activity Patterns, Assessment, and Motivation in Older Adults. In Shephard, R.J. (Eds.), *Gender, Physical Activity, And Aging* (pp. 13-40). United States of America: CRS Press.

World Health Organization. (1994). *Assessment of fracture risk and its application to screening for* *postmenopausal osteoporosis: report of a WHO Study Group.* Geneva: World Health Organization.

Wu, S.C., Leu, S.Y., & Li, C.Y. (1999). Incidence of and predictors for chronic disability in activities of daily living among older people in Taiwan. *The Journal of the American Geriatrics Society, 47*(9), 1082-6.

Chapter 4

Functional fitness and physical activity of Portuguese community-residing older adults

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4.1 Abstract

The purposes of this study were to generate reference data for Portuguese older adults, to verify age and sex differences, and to analyse the physical activity-associated variation in functional fitness.

The sample comprised 802 older adults, 401 men and 401 women, aged between 60 to 79 years. Functional fitness was assessed using the Senior Fitness Test. Physical activity was estimated via the Baecke questionnaire.

The P50 values decreased from 60-64 to 75-79 years of age. A significant main effect for age-group was found in all motor tests. Men scored significantly better than women in the chair stand, 8-foot up-and-go and 6-min walk. Women scored significantly better than men in chair sit and reach and back scratch. Active participants scored better in functional fitness tests than their average and non-active peers.

This study showed a decline in functional fitness with age, better performance of men and increased proficiency in active participants.

4.2 Introduction

Portugal, like other countries of southern Europe, has recently experienced a shift toward an increasingly elderly population as a result of low birth rates and increased life expectancy. According to World Health Organization [WHO] (2008), life expectancy at birth was 76.0 years in men and 83.0 years in women. The proportion of people aged 65 years or more doubled over the past forty years, from 8% in 1960 to 16% in 2001. In agreement to the demographic projections of Statistics Portugal (INE) this percentage will double in the next 40 years, representing 32% of the total population in 2050 (Carrilho & Gonçalves, 2004).

The aging process leads to profound changes in the cardiopulmonary, musculoskeletal, and nervous and immune systems. At rest, stroke volume decreased about 30% from 25 to 85 years of age. Similarly, there is a progressive reduction of ventilatory peak flow and lung capacity in adulthood (Taylor & Johnson, 2008). Aging is also characterized by increased bone loss resulting in reduced bone mineral density. About 25% of muscle function, defined as the highest lifetime force-generating capacity, is lost by around 65 years of age. Negative changes of the central nervous system are observed in neurotransmitters, nerve conduction and fine motor control, and resistance to infection agents decreases, by about 5% to 30% through the lifespan (Taylor & Johnson, 2008; Graves et al., 2006; Spirduso, Francis & MacRae, 2005).

The net effect of these changes is a decrease in autonomy and quality of life of older adults. Although environmental and genetic factors may partially explain this decline, physical activity plays a prominent role in healthy aging. The benefits of physical activity and/or exercise are reflected in an improvement of cardiovascular and respiratory functions, reduction of risk factors of coronary heart diseases and a decreased morbidity and mortality (American College of Sports Medicine [ACSM], 2006).

Rikli & Jones (1999) published normative scores for older adults, aged 60-94. Results revealed a pattern of decline across most age groups for all variables. The total decrease in muscular strength, cardiorespiratory endurance and agility/balance was about 30% to 45% between 60 and 94 years of age. Whereas the pattern of decrease over age was similar in men and women. Men scored better on muscular strength, aerobic endurance and agility/balance, and women better on flexibility (Rikli & Jones, 1999).

Very little is known about the functional fitness of Portuguese older adults. To our knowledge has been only a single study and that was performed in the Autonomous Region of Azores (ARA) (Santos et al., 2008). The assessment of functional fitness in the Autonomous Region of Madeira (ARM) would provide insight into the effects of aging on characteristics that can directly impact self efficacy and personal independence, while also informing research and community programs development for elderly. The central purposes of this study were threefold: (1) to generate normative functional fitness values for older adults living in the ARM, Portugal, (2) to identify age and gender differences and (3) to analyse physical activity-associated variation in functional fitness.

4.3 Methods

4.3.1 Sample

Participants are part of a research project entitled ‘Health and quality of life of older adults from ARM, Portugal’. In total, 802 participants (401 men and 401 women), aged between 60 and 79 years, were assessed in 2008/2009. This study used a cross-sectional design. The distribution of the participants by age interval and sex is shown in Table 4.1.

Table 4.1 Sample size of Madeira older adults by age interval and sex.

	Age interval (years)				
Sex	60-64	65-69	70-74	75-79	Total
Male	103	99	107	92	401
Female	102	108	98	93	401
Total	205	207	205	185	802

The sampling criteria were the following: geographic area (11 districts of ARM), age, functional independence, and no medical contraindications to sub-maximum exercises, according to the guidelines of the ACSM (2006). In each birth cohort, approximately 100 men and 100 women were included in the sample in a geographically proportionate way, i.e., weighted samples by age and sex in each district. The proportionate stratified sampling procedure was based on information gathered from Census 2001 (INE, 2002).

Participation was voluntary and participants were recruited through direct contacts carried out by the principal investigator of this study in day care centers, nursing homes, cultural and sport clubs associations, and residential and public places (e.g., open markets, municipal gardens and churches). The study was disclosed in the daily news, radio and television.

All participants signed an informed consent and filled out three questionnaires related to health status and readiness for physical activity: ‘FallProof health and activity questionnaire’ (Rose, 2003) and ‘Physical activity readiness questionnaire’ (PAR-Q) (Canadian Society for exercise physiology, 2002).

The study was approved by the University of Madeira (UMa), the Regional Secretary of Education and Culture, and the Regional Secretary of Social Affairs.

4.3.2 Protocols

4.3.2.1 Functional fitness and human somatic dimensions

Functional fitness was assessed with the SFT (Rikli & Jones, 2001). The SFT battery was developed in the United States of America and was previously applied in the ARA (Santos et al., 2008). The test battery includes five functional parameters and seven motor tests. In this study, aerobic endurance was assessed via the 6-minute walk test. A detailed description of the evaluation procedures, namely, equipment, procedures, scoring and safety precautions can be found in the SFT manual (Rikli & Jones, 2001). Height was measured with a Harpenden Stadiometer (Holtain, Ltd) to the nearest millimetre. Body mass was measured on a balance-beam scale accurate to 100 g (Seca Optima 760, Germany).

4.3.2.2 Physical activity

The Baecke questionnaire (Baecke, Burema & Frijters, 1982) was used in the present research. The questionnaire comprises sixteen questions, eight related to physical activity at work and eight related to physical activity in sports and leisure-time. Item 9 is about regular and systematic practice of sports, and is formulated in terms of intensity, time and proportion. Items responses are quantified in a Likert scale. The questionnaire is operationalised through three indexes: work, sport and leisure-time. Members of the field team administered the questionnaire through a face-to-face interview.

4.3.2.3 Preparation of the field team and pilot study

The assessments took place in the Laboratory of Human Physical Growth and Motor Development of the UMa. To maximize the consistency of assessment procedures, training sessions were conducted with five graduates in Physical Education and Sport, one in Nursing and 3 in Senior Education. First, a theoretical explanation of the protocols was done for all research and field team members. Second, motor tests and questionnaires were self-administered among team members. Third, training sessions were organized with older adults.

The preparation of the field team and procedures was pre-tested with a pilot study of 50 older adults, aged between 60 and 79 years. The motor tests were administered according the instructions of the authors of the SFT (Rikli & Jones, 2001), i.e., the stations were arranged in the following order: (1) chair stand test, (2) arm curl test, (3) chair sit and reach test, (4) back scratch test, (5) 8-foot up-and-go test and (6) 6-minute walk test. Height and body mass followed standardized procedures described by Claessens, Vanden Eynde, Renson & Van Gerven (1990). Test-retest correlations coefficients are presented in Table 4.2.

Table 4.2 Sample (n), mean (M), standard deviation (SD), intraclass correlation coefficient (R) and 95% confidence interval between test and retest: pilot study.

Variables	n	Test	Retest	R	CI 95%
		M±SD	M±SD		
Chair stand (n)	49	17.6±4.6	18.5±3.9	0.772	0.596-0.871
Arm curl (n)	50	22.8±5.7	24.2±5.3	0.895	0.815-0.940
6-Minute walk (m)	49	567.4±116.9	575.6±95.1	0.784	0.617-0.878
Chair sit and reach (cm)	47	9.8±10.7	7.9±9.2	0.903	0.825-0.946
Back scratch (cm)	50	-7.1±10.6	-6.1±10.5	0.749	0.558-0.858
8-Foot up and go (sec)	50	4.9±1.0	4.8±1.1	0.858	0.749-0.919
Height (cm)	50	155.9±6.5	155.9±6.5	0.999	0.998-0.999
Body mass (kg)	50	74.3±12.2	74.7±12.2	0.999	0.999-1.000

The values of the test-retest correlation (R) for motor tests are between 0.749 and 0.903, indicating acceptable levels of reliability, according to the cut-off point of 0.70 suggested by Safrit (1990). Intraclass correlation coefficients for height and body mass are also high (0.999). For physical activity, intra-class correlation-coefficients were calculated to determine the test-retest reliability of the Baecke questionnaire in a pilot study involving 32 males and 59 females (68.3± 7.6 years). Over an interval of 1 week, correlations were 0.83, 0.85 and 0.85 for the work, sport and leisure-time indices, respectively.

4.3.2.4 Statistical and smoothing procedures

Data were entered twice in the computer by two different people, and crossed in specific software to detect input errors. Variables were presented as basic descriptive measures: mean, standard deviation and percentiles. Exploratory analysis of data took place through the usual procedures for identifying outliers and normality of distributions. Test-retest reliability was estimated from the intraclass correlation coefficient. Two-way ANOVA was used to look at the individual and joint effect of gender and age-group on each motor test. The smoothing procedure for the 10th, 25th, 50th, 75th and 90th percentile curves was carried out in two steps. First, the raw values were smoothed by eye with a graphical fitting procedure and using a flexible ruler. Second, Adobe Illustrator CS5 software tools (Adobe Systems Incorporated, 2011) were used to fit the final curves. The analysis of covariance (ANCOVA) was used to assess differences in mean scores of functional fitness tests according to three levels of physical activity: non-active, average active and active, with height and body mass serving as covariates. The Tukey post-hoc test was used to detect differences among activity groups. The calculations were made in STATA 11 (Stata Statistical Software, 2009) and SPSS 17 (Statistical Package for Social Sciences, 2010). Statistical significance was maintained at p <0.05.

4.4 Results

Table 4.3 presents the scores for each functional fitness test by gender and age group. Results from the Two-way ANOVA revealed no significant interaction effects (sex*age groups) for any of the motor tests, i.e., there was no significant difference in the effect of age on functional fitness tests for men and women. A main effect of sex, with all age groups collapsed, was found for the chair stand [F (1, 794) = 14.04, $p <$ 0.001], chair sit and reach [F (1, 794) = 25.56, $p < 0.001$], back scratch [F (1, 794) = 111.05, $p < 0.001$], 8-foot up-and-go [F (1, 794) = 13.96, $p < 0.001$] and the 6-min walk [F (1, 794) = 72.71, $p < 0.001$]. Men scored significantly better than women for the chair stand ($p < 0.001$), 8-foot up-and-go ($p < 0.001$) and 6-min walk ($p < 0.001$) tests. Women scored significantly better than men for the chair sit and reach ($p <$ 0.001) and back scratch ($p < 0.001$) tests. There was no significant main effect of sex for the arm curl test [F (1, 749) = 37.94, $p = 0.127$]. In other words, men and women had similar arm curl test performances.

Significant main effects for age-group were found for the chair stand [F (3, 794) = 22.95, $p < 0.001$], arm curl [F (3, 794) = 13.27, $p < 0.001$], chair sit and reach [F (3, 794) = 5.97, $p < 0.001$], back scratch [F (3, 794) = 8.84, $p < 0.001$], 8-foot up-and-go [F (3, 794) = 33.55, $p < 0.001$] and 6-min walk [F (13, 794) = 37.90, $p < 0.001$] tests. This means that performances became poorer with advancing age, regardless of sex.

Table 4.3 Mean (M) and standard deviation (SD) for functional fitness tests by gender and age-groups.

Motor tests	Age intervals (years)				
	60-64	65-69	70-74	75-79	Combined
	M±DP	M±DP	M±DP	M±DP	M±DP
Men					
Chair stand (n)	15,7±4,1	14,8±4,0	13,4±4,0	12,6±3,1	14,2±4,0
Arm curl (n)	17,7±3,7	17,3±4,1	15,8±3,9	14,9±2,8	16,5±3,8
6-Minute walk (m)	577,9±93,7	526,9±115,7	512,3±105,9	461,8±108,6	521,2±113,3
Chair sit and reach (cm)	-0,7±11,8	-6,1±15,2	-4,3±12,0	-4,3±12,0	-4,6±13,1
Back scratch (cm)	-17,8±12,2	-22,6±12,9	-24,9±11,7	-26,0±13,4	-22,8±12,9
8-Foot up and go (sec)	4,8±1,5	5,4±2,1	5,9±2,1	6,9±3,2	5,7±2,4
Women					
Chair stand (n)	14,8±4,7	13,2±4,2	12,8±3,7	11,5±3,4	13,2±4,2
Arm curl (n)	16,8±4,3	16,3±4,8	16,0±4,3	14,8±4,0	16,0±4,4
6-Minute walk (m)	502,6±97,0	474,8±110,1	452,7±98,1	392,8±118,2	457,5±112,9
Chair sit and reach (cm)	1,2±12,6	0,2±11,2	0,6±10,5	-2,8±11,3	-0,3±11,7
Back scratch (cm)	-12,0±12,1	-12,8±10,9	-13,3±10,5	-16,8±11,1	-13,8±11,5
8-Foot up and go (sec)	5,3±1,3	6,0±1,7	6,5±2,4	7,7±3,6	6,3±2,5

Post-hoc comparisons indicated that group 1 (60-64 years) scored better than groups 2 (65-69 years), 3 (70-74 years) and 4 (75-79 years) for the chair stand, 8-foot up-and-go and 6-minute walk tests. Group1 also scored better than group 3 and/or 4 for the arm curl, chair sit and reach and back scratch tests. Groups 2 and/or 3 performed better than group 4 for the chair stand, arm curl, back scratch, 8-foot up-and-go and 6-minute walk tests.

4.4.1 Developmental growth curves

Age and sex differences described earlier are clearly seen in the developmental curves (P50 values) for the different tests (Figures 4.1 and 4.2, a-f). For muscular strength (chair stand and arm curl tests), inter-individual variability, i.e., the absolute range between the 10th and 90th percentiles, is larger at 60-64 than at 75-79 years of age in men and women, respectively (Figure 4.1, a-d). The variability for aerobic endurance, as measured by the 6-minute walk test is higher in the oldest (75-79) compared to the youngest age (60-64) cohort. Women demonstrate somewhat greater variability on this test than men at 60-64 (219 m *versus* 210 m) and 75-79 years of age (340,2 m *versus* 277 m), respectively (Figure 4.1, e-f). For lower-body flexibility (sit and reach test), the range of variability is larger in the older (75-79 years of age) than younger age cohorts, whereas the performance on this test was much more consistent and less variable across age cohorts for the women: 33,84 cm (60-64 years) and 27,12 cm (75-79 years) (Figure 4.2, a-b).

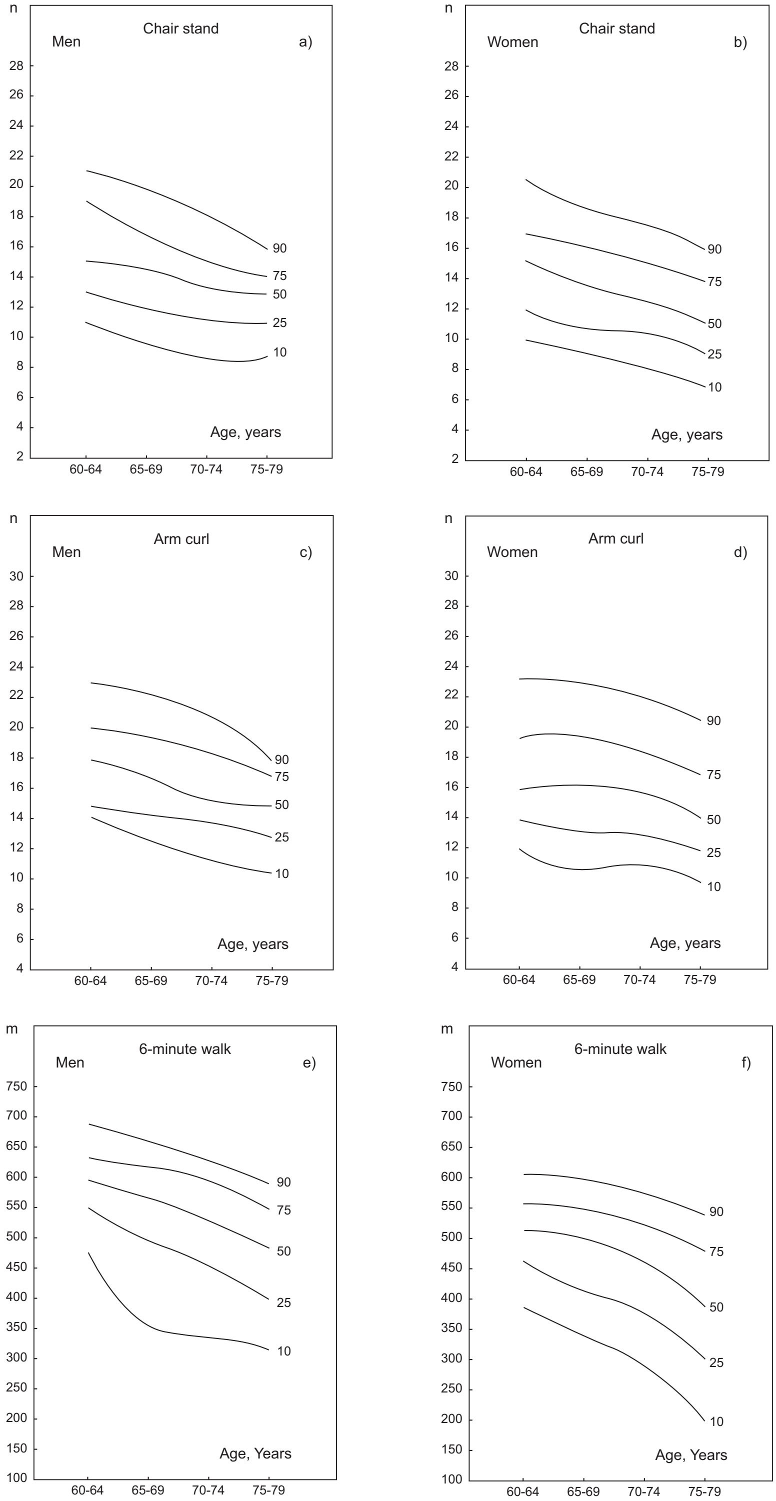

Figure 4.1 Percentiles 10th, 25th, 50th, 75th and 90th for older Portuguese men and women: chair stand (a-b), arm curl (b-c) and 6-minute walk (e-d) tests.

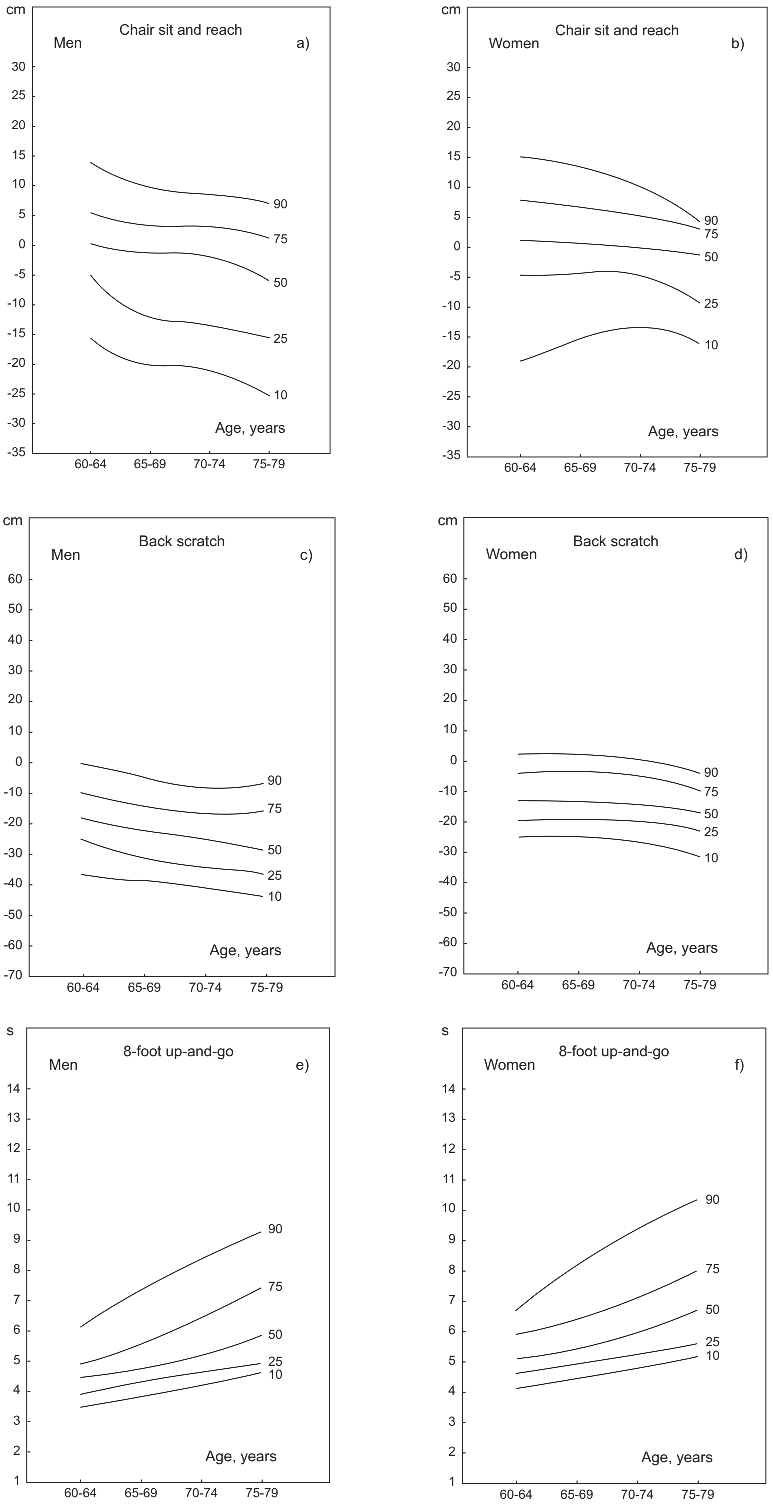

Figure 4.2 Percentiles 10th, 25th, 50th, 75th and 90th for older Portuguese men and women: chair sit and reach (a-b), back scratch (c-d) and 8-foot up-and-go (e-f) tests.

For upper-body flexibility (back scratch test), variability increases with ages for men [from 25 cm to 30.4 cm between the youngest and oldest cohorts) and decreases for women [from 21,85 cm to 17,5 cm) (Figure 4.2, c-d). The performance in agility/dynamic balance (8-foot up-and-go) is shown in Figure 4.2, e-f. Inter-individual variability increases with age.

4.4.2 Physical activity-associated variation in functional fitness

Means and standard deviations for the functional fitness tests, by level of physical activity, are presented in Table 4.4. Active participants have better performances than average active and non-active participants in the chair stand, arm curl, 6-minute walk and 8-foot up-and-go tests, in both men and women. Similar results are observed for the chair sit and reach and back scratch tests, in women. An analogous pattern is observed when we compare the average active with non-active participants, i.e., the average active group score better than the non-active group.

Table 4.4 Mean, standard deviation and *p* values for the difference of means in functional fitness test according to levels of physical activity: non-active, average active and active.

	Physical activity				
Motor tests	Non-active (1)	Average (2)	Active (3)	*p*	Contrast[†]
Men					
Chair stand (n)	12.9±3.7	14.2±3.8	15.5±4.2	0.001	1 < 2 and 3; 2 < 3
Arm curl (n)	15.6±3.6	16.2±3.6	17.7±4.0	0.001	1 and 2 < 3
6-Minute walk (m)	484.7±129.4	533.9±92.9	550.0±100.5	0.001	1 < 2 and 3; 2 < 3
Chair sit and reach (cm)	-6.8±12.5	-2.9±11.6	-3.6±14.1	0.028	1 < 2
Back scratch (cm)	-24.1±12.7	-23.4±13.2	-20.8±12.7	0.082	n.s.
8-Foot up and go (sec)	6.6±3.3	5.4±1.4	5.0±1.6	0.001	1 < 2 and 3
Women					
Chair stand (n)	44.1±32.9	59.0±31.7	76.5±29.8	0.001	1 < 2 and 3; 2 < 3
Arm curl (n)	14.3±3.9	16.0±4.4	18.0±4.1	0.001	1 < 2 and 3; 2 < 3
6-Minute walk (m)	397.3±122.6	458.6±88.9	523.8±87.8	0.001	1 < 2 and 3; 2 < 3
Chair sit and reach (cm)	-4.1±12.9	0.4±10.2	3.6±9.9	0.001	1 < 2 and 3
Back scratch (cm)	-16.6±1.8	-12.8±11.8	-11.4±10.5	0.001	1 < 2 and 3
8-Foot up and go (sec)	7.6±3.5	6.0±1.8	5.3±1.1	0.001	1 < 2 and 3; 2 < 3

[†] Tukey test – post hoc procedure; n.s. non-significant.

4.5 Discussion

Older adults from ARM showed, on average, lower functional fitness compared to younger seniors and men were fitter than women, with the exception of flexibility. Variability increased or decreased with age depending on the motor test and sex. The active participants performed better than their average and/or non-active peers.

It is difficult to compare the present results with other studies due to differences among participants (i.e., birth cohort, race/ethnicity, lifestyle, physical activity levels and culture) and methodological aspects related to sampling (i.e., active *versus* passive recruitment; stratified *versus* non-stratified, etc...). However, a decline with age in muscle strength/endurance, aerobic endurance, flexibility and agility/balance was observed in Brazilian (Krause et al., 2009), Japanese (Demura et al., 2003) and North-American older adults (Rikli & Jones, 1999). The decrease in functional fitness with the age seems to be associated to degenerative processes in conjunction with physical inactivity (Graves et al., 2006; Spirduso et al., 2005). Among the deleterious effects of aging, the most important in relation to quality of life and functional independence of older adults seems to be a reduction in aerobic capacity and muscle strength (Fleg et al., 2005).

The difference between sexes observed in the Madeira sample parallels other studies. In Japanese older adults (60-89 years), Demura et al. (2003) observed that men had better performance than women in muscle strength and aerobic capacity. In contrast, women were more flexible than men. In a North-American sample, Rikli & Jones (1999) found that men outperformed women in strength, aerobic endurance and agility/balance. Women scored better in flexibility tests. The higher values for men in muscular strength can be explained by higher gains during puberty (Malina, Bouchard & Bar-Or, 2004) and smaller losses from 65 years onwards compared to women (Shephard, 2002). Moreover, the superiority of women in flexibility seems to result from differences in tissue architecture and morphology of the skeletal tissue (Holland, Tanaka, Shigematsu & Nakagaichi, 2002).

Compared to older adults from the USA (USA national sample 89.1 % of Caucasian origin) (Rikli & Jones, 1999) the elderly in our study performed poorer in all the motor tests (data not shown). Results for the two studies were more similar for the chair stand test (women), the 6-minute walk test (women) and the 8-foot up and go test (men and women). There was a large difference in the back scratch test performance between Portuguese and North-American participants, favouring the North-Americans.

The positive association between physical activity and functional fitness in our Madeira elderly was consistent with other studies. In older Dutch adults, Voorrips, Lemmink, Heuvelen, Bult & Staveren (1993) observed higher mean values for flexibility and walking in active, compared to non-active participants. In Canada, Sawatzky & Naimark (2002) found that older women, especially those with moderate or vigorous physical activity, have a healthier cardiovascular profile than their less active peers. Similarly, Tanaka et al. (2000) found a positive association between physical activity and functional fitness in older Japanese adults. Also, in Finland, active participants (75 years or more) performed better than sedentary peers (Laukkanen, Kauppinen & Heikkinen, 1998). In the scope of the 'Baltimore Longitudinal Study of Aging', Fleg et al. (2005) found that higher average values of physical activity were accompanied by higher levels of VO_2 and this relationship was maintained across all age intervals. In ARA, Santos et al. (2008) found that active men performed better than non-active peers on the chair stand, 8-foot up-and-go, chair sit and reach and back scratch tests.

The association between physical activity and functional fitness may be obscured by human somatic dimensions characteristics such as height and body mass. In an attempt to eliminate these effects, height and body mass were used as covariates in our study. The results were similar to the initial analysis, i.e., a better performance in favour of active older adults compared to the non-active elderly in functional fitness tests, with the exception of back scratch, in men.

The results of our research corroborate the idea that part of the functional decline that occurs with aging can be 'attenuated' by regular exercise (Rikli & Jones, 2001). The positive association between physical activity and functional fitness is crucial to the functionality, mobility, autonomy, health and welfare of elderly adults (Fleg et al., 2005). For example, high values of functional fitness, especially cardiorespiratory endurance, have been associated with a lower risk of mortality from all causes and cardiovascular events (Kodama et al., 2009; Sui et al., 2009). Likewise, high levels of physical activity in older adults are associated with a more favourable profile of cardiovascular biomarkers (Mora, Lee, I-Min, Buring & Ridker, 2006) and a lower risk for Alzheimer's disease (Scarmeas et al., 2009) and diabetes mellitus (Weinstein et al., 2004).

Data from the Cardiovascular Health Study (Hirsch et al., 2010) also suggest gains in survival and years of healthy life in older adults who are active. Compared with being sedentary, the most active men (75 years and over) had 1.49 more years of healthy life (95% CI: 0.79, 2.19), and the most active women (75 years and over) had 1.06 years of healthy life (95% CI: 0.44, 1.68). Similar results were found by Baker, Meisner, Logan, Kungl & Weir (2009) in older Canadians adults. Active participants were more than twice as likely to be rated as aging successfully, even after removing variance associated with demographic covariates.

Although there was a clear positive association between functional fitness and physical activity in this study, the validity of this association may be impacted by the questionnaire approach that are used to quantify physical activity levels. In older adults, there is no consensus regarding the most valid and accurate way of assessing physical activity and there is little information about how well old people are able to evaluate their activity levels (Sihvonen, Rantanen & Heikkinen, 1998). To minimize problems of perception, encoding, storage and retrieval of information, the questionnaire was administered by a face-to-face interview.

Our findings may also be limited by two other factors, namely sample characteristics and study design. Even though our study has a reasonable sample size, data from older adults (80 years and over) are lacking. In addition, we used media announcements (passively recruited) and personal contact (actively recruited) sampling procedures. Heuvelen, Stevens & Kemper (2002) observed that the performance of a passively recruited sample was significantly better on several motor tests, compared with an actively recruited sample. As for the latter potential limitation, the cross-sectional design is inadequate to capture the temporal relations that occur throughout life, and this approach precludes inference of causality between physical activity and functional ability.

Our research approach also has substantive strength. First, the sample includes older adults from the Madeira and Porto Santo Islands. Second, the data were collected by 9 well-trained team members graduated in Physical Education and Sports, Nursing and Senior Education ensuring protocol consistency and minimizing data collection error. Third, we gathered information about physical activity and explored the variation in functional fitness according to physical activity levels: this has not been examined extensively in the elderly. Lastly, the measurement protocols were first implemented in a pilot study and reported high reliabilities.

In sum, this research provides cross-sectional information about the variation in functional fitness according to age, sex and level of physical activity. Muscular strength, aerobic endurance, flexibility and agility/dynamic balance declined over age and men generally performed better on tests of functional fitness than women. Furthermore and importantly, the active participants scored better on functional fitness tests than their non-active peers. Thus, any intervention in older adults should take into account the loss of functionality and sexual dimorphism in fitness performance. Our findings suggest that the deleterious effects of aging may be partially ‘suppressed’ by physical activity. More research, particularly longitudinal studies including adults over 80 years of age, is needed in ARM for a more thorough understanding of these relations.

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4.7 References

American College of Sports Medicine. (2006). *ACSM's guidelines for exercise testing and prescription.* 7th Ed. Philadelphia: Lippincott Williams & Wilkins.

Baecke, J.A., Burema, J., & Frijters, J.E. (1982). A short questionnaire for the measurement of habitual physical activity in epidemiological studies. *The American Journal of Clinical Nutrition, 36*, 936-942.

Baker, J., Meisner, BA., Logan, A.J., Kungl, A-M., & Weir, P. (2009). Physical activity and sucessful aging in Canadian older adults. *Journal of Aging and Physical Activity, 17*, 223-235.

Canadian Society for Exercise Physiology. (2002). Physical Activity Readiness Questionnaire – PAR-Q. Revised version. Ottawa, ON: *Expert Advisory Committee of the Canadian Society for Exercise Physiology.*

Carrilho, M.J. & Gonçalves, C. (2004). Dinâmicas territoriais do envelhecimento: análise exploratória dos resultados dos Censos 91 e 2001. *Revista de Estudos Demográficos, 36*, 175-191.

Claessens, A., Vanden Eynde, B., Renson, R. & Van Gerven, D. (1990). The description of tests and measurements. In J. Simons, G. Beunen, R. Renson, A. Claessens, B. Vanreusel & J. Lefevre, (Eds.), *Growth and fitness of Flemish girls – The Leuven Growth Study.* Vol. 3. HKP Sport Science Monograph Series (chap. 4, pp 21-39). Champaign: Human Kinetics Books.

Demura, S., Minami, M., Nagasawa, Y., Tada, N., Matsuzawa, J., & Sato, S. (2003). Physical-fitness declines in older Japanese adults. *Journal of Aging and Physical Activity, 11*, 112-122.

Fleg, J.L., Morrell, C.H., Bos, A.G., Brant, L.J., Talbot, L.A., Wright, J.G., et al. (2005). Accelerated longitudinal decline of aerobic capacity in healthy older adults. *Circulation, 112*, 674-682.

Graves, E.W., Cauley, J.A., Stone, K., Thompson, T.J., Bauer, D.C., Cummings, S.R., et al. (2006). Relationship of changes in physical activity and mortality among older women. *The Journal of the American Medical Association, 289*(18), 2379-2386.

Heuvelen, M., Stevens, M., & Kemper, G.I. (2002). Differences in physical-fitness test scores between actively and passively recruited older adults: consequences for norm-based classification. *Journal of Aging and Physical Activity, 10*, 143-159.

Hirsch,C.H., Diehr, P., Newman, A.B., Gerrior, S.A., Pratt, C., Lebowitz, M.D., et al. (2010). Physical activity and years of healthy life in older adults: results from the Cardiovascular Health Study. *Journal of Aging and Physical Activity, 18*, 313-334.

Holland, G.J., Tanaka, K., Shigematsu, R., & Nakagaichi, M. (2002). Flexibility and physical functions of older adults: a review. *Journal of Aging and Physical Activity, 10*, 169-206.

Instituto Nacional de Estatística. (2002). *Censos 2001: resultados definitivos: XIV recenseamento geral da população: IV recenseamento geral da habitação*. Lisboa: Instituto Nacional de Estatística.

Kodama, S., Saito, K., Tanaka, S., Maki, M., Yachi, Y., Asumi, M., et al. (2009). Cardiorespiratory fitness as a quantitative predictor of all-cause mortality and cardiovascular events in healthy men and women. A meta-analysis. *The Journal of the American Medical Association, 301*(19), 2024-2035.

Krause, M.P., Januário, R.S., Hallage, T., Haile, L.; Miculis, C.P., Gama, M.P., et al. (2009). A comparison of functional fitness of older Brazilian and American women. *Journal of Aging and Physical Activity, 17*, 387-397.

Laukkanen, P., Kauppinen, M., & Heikkinen, E. (1998). Physical activity as a predictor of health and disability in 75- and 80-year-old men and women: a five-year longitudinal study. *Journal of Aging and Physical Activity, 6*, 141-156.

Malina, R.M., Bouchard, C., & Bar-Or O. (2004). *Growth, Maturation, and Physical Activity*. Champaign, IL: Human Kinetics, Inc.

Mora, S., Lee, I-Min., Buring, J.E., & Ridker, P.M. (2006). Association of physical activity and body mass index with novel and traditional cardiovascular biomarkers in women. *The Journal of the American Medical Association, 295*(12), 1412-1419.

Rikli, R.E., & Jones. (1999). Functional fitness normative scores for community-residing older adults, ages 60-94. *Journal of Aging and Physical Activity, 7*, 162-181.

Rikli, R.E., & Jones. (2001). *Senior fitness test manual. Development and validation of a functional fitness test for community-residing older adults*. Champaign, IL: Human Kinetics.

Rose, D.J. (2003). *FallProof! A comprehensive balance and mobility training program*. Champaign, IL: Human Kinetics, Inc.

Safrit, M. (1990). The validity and reliability of fitness tests for children: a review. *Pediatric Exercise Science, 2*(1), 9-28.

Santos, R., Moreira, P., Mota., Ribeiro, J.C., Carvalho, J., Santos, M.P., et al. (2008). *Carta da condição física dos cidadãos da Região Autónoma dos Açores. Centro de Investigação em Actividade, Saúde e Lazer*. Faculdade de Desporto da Universidade do Porto. Direcção Regional do Desporto da Região Autónoma dos Açores. Porto: Multitema.

Sawatzky, J.A., & Naimark, B.J. (2002). Physical activity and cardiovascular health in aging women: a health-promotion perspective. *Journal of Aging and Physical Activity, 10*, 396-412.

Scarmeas, N., Luchsinger, J.A., Schupf, N., Brickman, A.M., Cosentino, S., Tang, M.X., et al. (2009). Physical activity, diet, and risk of Alzheimer disease. *The Journal of the American Medical Association, 302*(6), 627-637.

Shephard, R.J. (Eds.), *Gender, Physical Activity, And Aging* (pp. 99-120). United States of America: CRS Press.

Sihvonen, S., Rantanen, T., & Heikkinen, E. (1998). Physical activity and survival in elderly people: a five-year follow-up study. *Journal of Aging and Physical Activity, 6*, 133-140.

Spirduso, W.W., Francis, K.L., & MacRae, P.G. (2005). *Physical dimensions of aging*. 2nd ed. Champaign, IL: Human Kinetics, Inc.

SPSS. (2010). *Statistical Package for the Social Sciences*. Version 17.0. Chicago, IL:SPSS, Inc.

StataCorp. (2009). *Stata Statistical Software: Release 11*. College Station, TX: StataCorp LP.

Sui, X., LaMonte, M.J., Laditka, J.N., Hardin, J.W., Chase, N., Hooker, S.P., et al. (2009). Cardiorespiratory fitness and adiposity as mortality predictors in older adults. *The Journal of the American Medical Association, 298*(21), 2507-2516.

Tanaka, K., Shigematsu, R., Nakagaichi, M., Kim, H., & Takeshima, N. (2000). The relationship between functional fitness and coronary heart disease risk factors in older Japanese adults. *Journal of Aging and Physical Activity, 8*, 162-174.

Taylor, A.W., & Johnson, M.J. (Eds). (2008). *Physiology of exercise and healthy aging*. Champaign, IL: Human Kinetics, Inc.

Voorrips, L.E., Lemmink, K.a., Heuvelen, M.J., Bult, P., & Staveren, W.A. (1993). The physical condition of elderly women differing in habitual physical activity. *Medicine and Science in Sports and Exercise, 25*(10), 1152-1157.

Weinstein, A.R., Sesso, H.D., Lee, I.M., Cook, N.R., Manson, J.E., Buring, J.E., et al. (2004). Relationship of physical activity vs body mass index with type 2 diabetes in women. *The Journal of the American Medical Association, 292*(10), 1188-1194.

World Health Organization. (2008). *Health topics. Life expectation*. Portugal. Retrieved February 11, 2011, from http://www.who.int/gho/countries/prt.pdf

Chapter 5

Physical Activity and Bone Mineral Density in Elderly Men and Women

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5.1 Abstract

This study describes the association between level of physical activity (PA), other lifestyle and constitutive factors and bone health/strength in a large sample of elderly men and women from Madeira, Portugal.

This cross-sectional study included 401 males and 401 females aged 60-79 years old. Femoral strength index (FSI) and bone mineral density (BMD) of the whole body, lumbar spine (LS), hip (femoral neck (FN), trochanter, Ward's triangle and total hip) and total lean tissue mass (TLTM) and total fat mass (TFM) were determined by dual-energy x-ray absorptiometry-DXA. PA was assessed during face-to-face interviews using the Baecke questionnaire. Demographic and health history information were obtained by telephone interview through questionnaire.

Women in the 65-69 year old cohort only, with the highest tertile of total PA had significantly higher FN BMD than females in the lowest tertile, whereas there were no other significant cohort specific differences among PA tertiles at any of the other sites for women or at any of the sites for males. Likewise, PA was not a significant determinant of FSI for any age-cohort in either sex. Total PA was positively associated with BMD at some body sites. In the multiple regression analysis (MLRA) age, TLTM and TFM entered as the most significant contributors for FN BMD in both genders, and TFM in men and TFM and age in women were the most significant predictors for LS BMD and FSI.

This study suggests that PA is minimally but positively associated with BMD and FSI among elderly males and females and that constitutive factors like TLTM and TFM are stronger determinants of BMD and FSI in this population.

Key words: Aging, Bone Mineral Density, Femur Strength Index, Physical Activity

5.2 Introduction

Bone mass, strength and quality in the elderly have been associated with genetic factors (Eisman, 1999) and several environmental influences, one of the most important of which is PA (Moayyeri, 2008). Bone-formation declines with advancing age (Stenderup, Justesen, Clausen, & Kassem, 2003) as does the levels of total PA (Daly et al., 2008); therefore, in both genders, but particularly in women, there is an increased loss of bone mass with ageing (Jones, Nguyen, Sambrook, Kelly, & Eisman, 1994). The enhanced bone fragility and consequent increase in fracture risk among the elderly has been linked to changes in BMD, bone material properties and bone geometry (that is the overall bone size and shape), including microarchitectural deterioration of cancellous bone (Kanis, et al., 2008).

In Europe, the number of all osteoporotic fractures in 2000 was estimated at 3.79 million, of which 0.89 million were hip fractures (179 000 hip fractures in men and 711 000 in women) (Kanis & Johnell, 2005). The incidence of hip fractures/year in women and men over 65 years was 67.9/10 000 and 26.1/10 000, respectively (International Osteoporosis Foundation [IOTF], 2001). The total direct cost of this disease was estimated at 31.7 billion Euros, which is expected to increase to 76.7 billion Euros in 2050, based on projected demographics in Europe (Kanis, et al., 2008). In Portugal, the number of hip fractures increased from 8500 in 2000 (rate: 8.24 per 10 000 population) to 9 821 in 2007 (rate: 9.26 per 10 000 population); the direct hospital costs were 51 321 300 Euros and 53 433 131 Euros, respectively in 2000 and 2007 (IOF, 2008).

Portugal is considered one of the most aged countries of Europe with 17.1% of its total population older than 65 years of age in 2008 (Statistics Portugal [INE], 2009). With its relatively low fertility rate and rapidly expanding population of elderly, Portugal has been recognized as a high risk country for the development of hip fracture (Kanis et al., 2008; Johnell, 2005). Particularly in the Portuguese Autonomous Region of Madeira, the elderly (65 years and older) are projected to comprise approximately 57.4% of the total population by 2050. The main occupations in this region are farming and construction work. There are almost as many female (47%) as male farmers (53%) in Madeira, with an average age of 64 years (Census 2001) (INE, 2009), the highest of all regions of Portugal.

PA, one of the key putative environmental determinants of bone health has been associated with increases in bone mass (Hagberg et al., 2001; Pluijm et al., 2001) and improvements in muscle mass, muscle strength, balance and bone strength, all of which mitigate falls and fractures among the elderly (U.S. Department of Health and Human Services [U.S.DHHS], 2004). The evidence in support of the benefits of PA for bone health promotion is so compelling that many physicians and public health officials now recommend increased PA and regular exercise programmes regardless of age (Rutherford, 1997).

Besides PA, constitutive factors may also influence bone health status (Daly et al., 2008; Lane, 2006; Hannan et al., 2000). Age-related changes in body composition have been considered potential determinants of bone health/density with ageing. Although, their relative importance remains equivocal, changes in body mass (BM), TLTM and TFM have each been identified as having important (Felson, Zhang, Hannan, & Anderson, 1993; Dargent-Molina, Poitiers, Bréart, & EPIDOS Group, 2000), independent roles in determining skeletal integrity in the elderly (Ho-Pham, Nguyen, Lai, & Nguyen, 2010). Lean mass is postulated to be a determinant on bone mass because of the structural and functional relationships between muscle and bone (Looker et al., 2009). BM and fat mass could exert protective effects on bone by increasing the mechanical loading forces acting on the skeleton during weight-bearing, with fat mass having an additional potential influence through the conversion of steroids to estrogen (Reid, Plank & Evans, 1992). Age-related changes in general health and socio-economic status (Booth, Owen, Bauman, Clavisi, & Leslie, 2000; Lim & Taylor, 2005), and in smoking, calcium intake, alcohol consumption, nutrition status and prescriptive medications (Hannan et al., 2000; Felson et al., 1993) have also been identified as equivocal yet potential determinants of bone health in the elderly.

While fragility fractures may be an inevitable consequence of ageing, the morbidity, mortality and financial burden of osteoporosis may be mitigated by management of known risk factors. No attempt has been made in either Portugal or the Autonomous Region of Madeira, to identify or characterize relationships between potential determinants of bone health/strength in elderly Portuguese people. The main purpose of this study was to describe the association between level of total PA, other lifestyle and constitutive factors and bone health/strength (assessed as multi-site BMD and FSI) in a large Portuguese sample of active community dwelling elderly men and women (60-79 y), controlling for many of the known important confounding and covariate influences among potential determinants. Anticipating high occupational participation rates from the Census data, we hypothesized that constitutive factors rather than PA levels per se, would be stronger determinants of bone density and strength in this population.

5.3 Methods

5.3.1 Study design and participants

This cross-sectional study included 802 participants (401 males and 401 females) distributed similarly over four age-cohorts (60-64, 65-69, 70-74, and 75-79 years). Participants were sufficiently mobile and independent to visit our laboratory at the University of Madeira on their own. Proportional regional (geographic) representation was determined by stratified sampling based on Census 2001 data from the Portuguese Statistics National Institute (INE, 2002) with the number of participants per age cohort and sex serving as stratification factors. Participants were volunteers recruited via advertisements for a large study on bone health and PA distributed via newspapers and through churches, senior groups and senior centres throughout the island of Madeira.

The study was approved by the University of Madeira, the Regional Secretary of Education and Culture, and the Regional Secretary of Social Affairs. All participants were informed about the nature and purposes of the study and written informed consent was obtained from each subject.

5.3.2 Anthropometry and bone densitometry

BM (kg) was measured with a balance scale accurate to 0.1kg (Seca alpha digital scales model 770, Germany) and standing height (cm) with a Holtain stadiometer (Holtain Ltd., Crymych. United Kingdom) accurate to 0.1cm. Participants wore light, indoor clothing without shoes during the measurements.

BMD (g/cm^2) was determined by dual-energy x-ray absorptiometry-DXA (Lunar Prodigy Primo, with technologic fan beam – GE Healthcare, Encore 2007 software version 11.40.004). After removing all objects suspected or known to contain metal, participants were positioned by the technician according to the manufacturer's recommended protocol. Participants were in a supine position and the following sites were investigated: whole body, LS (anterior-posterior), and hip (FN, trochanter, Ward's triangle and total hip). Furthermore, the scans yielded information on body composition, including total lean mass (TLTM) and total fat mass (TFM).

In addition to the conventional densitometry measurements, structural variables were also determined using the Hip Strength Analysis program, including hip axis length and cross-sectional moment of inertia (CSMI). These bone geometry variables were used to calculate the FSI, the ratio of estimated compressive yield strength of the FN to the expected compressive stress of a fall on the greater trochanter adjusted for each subject's age, height and BM (Yoshikawa et al., 1994).

Scans were standardized daily against a calibration phantom; the precision error expressed as the coefficient of variation (CV %) was 0.31%. Scans were taken alternately by four different technicians over the course of data collection. All technicians received an identical 5 days DXA training course before the start the study using the manufacturer's recommended protocol. Reliability of our DXA measurements was determined on a sub-sample of 17 males and females aged 69.3 ± 5 years. Technicians were paired and members of each pair performed separate LS and hip scans on half the participants each (9 and 8 participants, respectively, per pair). Participants were repositioned after every scan. Results from both pairs of assessors were pooled and the technical error of the measurements (TEM) were determined. TEM was used to determine inter-observer error, as occurs when two technicians independently measure the same thing. The values ranged from 0.19% for total hip to 0.50% for the LS. Inter-observer reliability was also determined using the CV. The CV% was 1.72% for LS, 2.10% for the FN, 2.53% for Ward's triangle and 0.88% for the total hip.

5.3.3 Physical activity measures

Total PA was assessed during face-to-face interviews using the Baecke questionnaire developed in the Netherlands (Baecke, Burema, & Frijters, 1992). This questionnaire includes a total of 16 questions classified into three specific domains: PA at work, sport and leisure time, the latter excluding sports. The questionnaire also provides a measure of total PA which is the sum of these three specific domains. Numerical coding for most response categories varied from 1 to 5 (Likert scale) ranging from never to always or very often. A detailed description of the scoring procedures for calculation of total PA and its subcomponent categories (PA at work, sport and leisure time) is provided by Baecke et al. (1982).

Participants were classified separately by age-cohort and sex into tertiles of high, moderate, or low PA levels based on their responses to this questionnaire. Intra-class correlation-coefficients were calculated to determine the test-retest reliability of the questionnaire in a pilot study involving 32 males and 59 females (68.3± 7.6 years). Over an interval of 1 week, correlations ranged between 0.83, 0.85 and 0.85 for the work, sport and leisure-time indices, respectively. Our reliability scores for work and sport PA were similar to those obtained by Baecke et al. (1982) in a sample of Dutch adult men and women (0.88, 0.81) and with a more recent study by Ono et al. (2007) of middle aged women (0.84, 0.83). However, our correlations were higher for leisure time index than those reported by either Baecke et al. (1982) or Ono et al. (2007) 0.74 and 0.78, respectively. The validity of the Baecke questionnaire has also been established by Ono et al. (2007) for this population against the more objective measure of movement counts using digital pedometry and uniaxial accelerometry (Lifecorder, Suzuken Co., Nagoya, Japan);

correlations ranged from (0.30-0.49) for the 3 dimensions of PA assessed with the Baecke questionnaire in this study.

5.3.4 Health questionnaire and dietary intake

Demographic information and a complete health history were obtained by telephone interview. A modified version of the health questionnaire employed in the FallProof! Programme (Rose, 2003), was used to assess smoking history, and medication.

Dietary intake was estimated using a semi-quantitative food frequency questionnaire developed by the Department of Hygiene and Epidemiology of Porto University Medical School, and previously validated (Lopes, 2000).This questionnaire was used to quantify calcium and alcohol using the software Food Processor Plus® (ESHA Research, Salem-Oregon, 1997), adapted to Portuguese traditional foods and dishes.

5.3.5 Statistical analysis

Descriptive characteristics of participants were reported as means ± SDs. All data were tested for normality by the Kolmogorov-Smirnov statistic. If required, characteristics were appropriately transformed.

Sex specific two-way ANOVAs were conducted to test for mean differences in BMD and FSI, between age-cohorts and total PA categories. Sex specific bivariate associations between the bone health indicators (BMD and FSI) and putative predictors of bone health (age, BM, TLTM, total calcium intake, alcohol consumption and total PA in women and sports related PA in men) were calculated for all age-cohorts combined using Pearson correlations. Sex-specific MLRA was then used to identify the independent contribution of the individual and combined predictors for BMD at the different skeletal sites. Betas, namely standardized regression coefficients, were used to assess the relative independent contributions of each predictor or combination of predictors, and the adjusted R^2s indicated the percentage of explained variance in the bone health outcomes. The level of significance was set at $P < 0.05$. All analyses were performed using SPSS (version 18.0).

5.4 Results

As summarized in Table 5.1, height, BM and TLTM, respectively, decreased across age-cohorts in both males (1.8%, 6.6%, 3.1% and 5.7%) and females (2.7%, 6.1%, 1.6% and 4.3%). Age-related declines were significant ($p < 0.05$) for height and TLTM for both males and females. BM declined significantly across age only in women and TFM was unchanged across age in males and females.

Likewise, sports related PA for men and total PA for women, decreased significantly across age-groups by 13.6% and 8.0%, respectively. There were no significant age related declines for any of the other PA variables for men or women. Only men demonstrated a significant age-related reduction in alcohol consumption and there were no significant age-related differences in calcium intake for either sex.

Table 5.1 Age and sex-specific descriptive characteristics (Means and SD).

	Age groups (years)			
	60 – 64	65 – 69	70 – 74	75 – 79
Men	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
Height (cm)	166.9 ± 5.2^{a}	165.9 ± 6.2$^{a\,b}$	164.5 ± 6.1^{b}	164.6 ± 6.2^{b}
BM (kg)	80.3 ± 12.1^{a}	79.7 ± 13.1^{a}	79.9 ± 13.3^{a}	75.8 ± 13.0^{a}
TLTM (kg)	54.3 ± 5.9^{a}	53.3 ± 5.8^{a}	52.8 ± 5.5^{a}	51.2 ± 6.3^{b}
TFM (kg)	22.6 ± 8.1^{a}	23.3 ± 7.9^{a}	23.6 ± 8.6^{a}	21.5 ± 8.2^{a}
PA work (1-5 units)	2.8 ± 0.6^{a}	2.6 ± 0.5^{a}	2.6 ± 0.6^{a}	2.7 ± 0.5^{a}
PA leisure (1-5 units)	2.6 ± 0.6^{a}	2.5 ± 0.6^{a}	2.5 ± 0.7^{a}	2.5 ± 0.5^{a}
PA sport (1-5 units)	2.2 ± 0.6^{a}	2.2 ± 0.6^{a}	2.0 ± 0.6$^{a\,b}$	1.9 ± 0.5^{b}
Total PA (3-15 units)	7.6 ± 1.3^{a}	7.3 ± 1.2^{a}	7.1 ± 1.4^{a}	7.2 ± 1.2^{a}
Dietary Calcium (mg/day)	721.7 ± 321.7^{a}	743.7 ± 365.2^{a}	723.9 ± 350.6^{a}	734.5 ± 384.9^{a}
Alcohol (dl/day)	16.7 ± 20.5^{a}	13.1 ± 17.3^{a}	11.6 ± 18.2^{a}	9.2 ±15.3^{b}
Women				
Height (cm)	154.2 ± 5.4^{a}	153.8 ± 5.5$^{a\,b}$	152.0 ± 5.8$^{b\,c}$	150.1 ± 5.4^{c}
BM (kg)	72.2 ± 11.7^{a}	71.2 ± 12.7^{a}	70.6 ± 10.6^{a}	67.8 ± 11.5^{b}
TLTM (kg)	39.9 ± 4.9$^{a\,b}$	40.0 ± 5.5^{a}	39.3 ± 3.9$^{a\,b}$	38.2 ± 4.3$^{b\,c}$
TFM (kg)	29.7 ± 7.8^{a}	28.7 ± 8.0^{a}	28.2 ± 7.3^{a}	27.1 ± 7.8^{a}
PA work (1-5)	2.8 ± 0.6^{a}	2.8 ± 0.4^{a}	2.7 ± 0.4^{a}	2.5 ± 0.4^{a}
PA leisure (1-5)	2.5 ± 0.7^{a}	2.5 ± 0.5^{a}	2.4 ± 0.5^{a}	2.4 ± 0.6^{a}
PA sport (1-5)	2.2 ± 0.6^{a}	2.3 ± 0.6^{a}	2.3 ± 0.6^{a}	2.1 ± 0.6^{a}
Total PA (3-15)	7.5 ± 1.3^{a}	7.5 ± 1.1^{a}	7.3 ± 1.1$^{a\,b}$	6.9 ± 1.2^{b}
Dietary Calcium (mg/day)	906.5 ± 387.3^{a}	817.9 ± 381.2^{a}	821.8 ± 398.6^{a}	796.5 ± 384.5^{a}
Alcohol (dl/day)	2.1 ± 3.9^{a}	1.5 ± 4.1^{a}	1.2 ± 2.7^{a}	1.3 ± 2.9^{a}

SD, standard deviation; BM, body mass; PA, physical activity; TLTM, total lean tissue mass; TFM, total fat mass; Descriptive characteristics with dissimilar alphabetic suprascripts indicate significant differences ($p< .05$) among age groups.

BMD for all sites and for both sexes was, with one exception (LS males 65-69 y), highest in the youngest age-cohort and for the most part decreased progressively with advancing age-cohort (Table 5.2) for both sexes. BMD declined significantly (9.6 % to 21.1 %) with age at all sites for women whereas significant age-reductions were observed only for the FN (9.8%), trochanter (7.5%), Ward's triangle (11.5%) and total hip (8.2 %) for males.

FSI was highest in the youngest age-cohort in both sexes, did not change significantly across ages for males, but decreased progressively and significantly with increasing age-cohort in females.

Table 5.2 Age and sex-specific descriptive characteristics for BMD and FSI.

	Age groups (years)			
	60 – 64	65 – 69	70 – 74	75 – 79
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
Men				
Total body	1.23 ± 0.10 ^{a}	1.22 ± 0.11 ^{a}	1.22 ± 0.11 ^{a}	1.19 ± 0.09 ^{a}
LS	1.19 ± 0.18 ^{a}	1.21 ± 0.21 ^{a}	1.18 ± 0.24 ^{a}	1.14 ± 0.19 ^{a}
FN	1.02 ± 0.15 ^{a}	0.99 ± 0.14 $^{a\,b}$	0.95 ±0.14 $^{b\,c}$	0.92 ± 0.13 ^{c}
Trochanter	0.93 ± 0.12 ^{a}	0.91 ± 0.14 $^{a\,b}$	0.89 ± 0.13 $^{a\,b}$	0.86 ± 0.13 ^{b}
Ward’s triangle	0.78 ± 0.15 ^{a}	0.75 ± 0.15 $^{a\,b}$	0.71 ± 0.13 $^{a\,b}$	0.69 ± 0.14 ^{b}
Total hip	1.10 ± 0.14 ^{a}	1.07 ± 0.16 ^{a}	1.05 ± 0.14 $^{a\,b}$	1.01 ± 0.14 ^{b}
FSI	1.86 ± 0.45 ^{a}	1.74 ± 0.52 ^{a}	1.76 ± 0.51 ^{a}	1.83 ± 0.57 ^{a}
Women				
Total body	1.14 ± 0.09 ^{a}	1.10 ± 0.10 ^{b}	1.07 ± 0.09 ^{b}	1.03 ± 0.08 ^{c}
LS	1.06 ± 0.18 ^{a}	1.01 ± 0.16 $^{a\,b}$	0.96 ± 0.18 ^{b}	0.95 ± 0.16 ^{b}
FN	0.92 ± 0.13 ^{a}	0.88 ± 0.12 ^{b}	0.83 ± 0.10 ^{c}	0.78 ± 0.10 ^{d}
Trochanter	0.81 ± 0.13 ^{a}	0.77 ± 0.12 ^{a}	0.73 ± 0.11 ^{b}	0.68 ± 0.11 ^{c}
Ward’s triangle	0.71 ± 0.14 ^{a}	0.67 ± 0.13 ^{a}	0.61 ± 0.11 ^{b}	0.56 ± 0.10 ^{c}
Total hip	1.01 ± 0.13 ^{a}	0.96 ± 0.13 ^{b}	0.91 ± 0.11 ^{c}	0.86 ± 0.12 ^{d}
FSI	1.61 ± 0.47 ^{a}	1.53 ± 0.39 $^{a\,b}$	1.48 ± 0.38 $^{a\,b}$	1.44 ± 0.37 ^{b}

SD, standard deviation; FN, femoral neck; LS, lumbar spine; FSI, femur strength index. BMD values with dissimilar alphabetic suprascripts indicate significant differences ($p< 0.05$) among age groups.

There were no significant age-cohort or sex specific effects of total PA level in women and sport related PA level in men on LS BMD (Figure 5.1, a and b) or FSI (data not shown). Likewise there were no significant age-cohort effects of PA on FN BMD for males (Figure 5.1, c).

In females, however, (Figure 5.1, d) FN BMD was significantly higher in the high activity group compared to the low activity group for the 65-70 year old cohort, with no other evident statistically significant differences among activity groups for the other age-cohorts.

With the exception of the LS for males, BMD at multiple sites were significantly negatively correlated with age in both genders (Table 5.3). All BMD measures were significantly positively correlated with height, BM, TLTM and TFM for both males and females. Sport related PA was the only activity category to relate significantly with BMD for males, correlating weakly, but nonetheless positively, with LS and Ward’s triangle BMD.

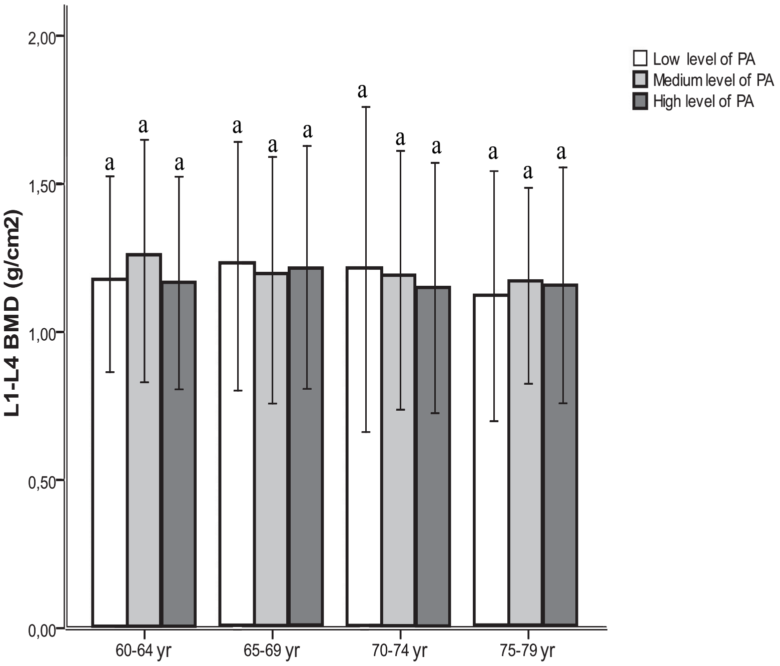
Table 5.3 Sex-specific Pearson correlations between BMD indicators, FSI and selected descriptive characteristics.

	Total body	LS	FN	Trochanter	Ward's Triang.	Total Hip	FSI
Men							
Age (years)	-0.110‡	-	-0.259†	- 0.158†	- 0.243†	- 0.203†	-
Height (cm)	0.279†	0.158†	0.262†	0.195†	0.178†	0.185†	- 0.147†
BM (kg)	0.425†	0.293†	0.309†	0.329†	0.243†	0.323†	- 0.343†
TLTM (kg)	0.389†	0.179†	0.308†	0.311†	0.238†	0.300†	- 0.165†
TFM (kg)	0.319†	0.292†	0.228†	0.249†	0.190†	0.256†	- 0.383†
PA work (1-5 units)	-	-	-	-	-	-	0.105‡
PA leisure (1-5 units)	-	-	-	-	-	-	-
PA sport (1-5units)	-	0.104‡	-	-	0.112‡	-	-
Total PA(3-15units)	-	-	-	-	-	-	-
Dietary Calcium (mg/day)	-	-	-	-	-	-	-
Smoking (units)	-0.147‡	-0.124‡	-	-0.116‡	-	-0.119‡	-
Alcohol (dl/day)	-	-	-	-	-	-	-
Medication (units)	-	0.123‡	-	-	-	-	-
Women							
Age (years)	- 0.394†	- 0.248†	- 0.443†	- 0.386†	- 0.442†	- 0.427†	- 0.164†
Height (cm)	0.396†	0.314†	0.426†	0.363†	0.380†	0.350†	-
BM (kg)	0.530†	0.395†	0.352†	0.512†	0.260†	0.472†	- 0.334†
TLTM (kg)	0.477†	0.323†	0.336†	0.455†	0.221†	0.409†	- 0.220†
TFM (kg)	0.486†	0.334†	0.314†	0.485†	0.245†	0.441†	- 0.326†
PA work (1-5 units)	0.098‡	-	0.164†	0.133†	0.137†	0.144†	0.099‡
PA leisure (1-5 units)	0.127‡	-	0.100‡	-	0.122‡	-	0.108‡
PA sport (1-5units)	-	-	0.140†	0.120‡	0.102‡	0.116‡	-
Total PA(3-15units)	0.117‡	-	0.189†	0.130†	0.169†	0.155†	-
Dietary Calcium (mg/day)	0.108‡	-	-	-	-	-	0.108‡
Smoking (units)	0.150†	0.150†	0.192†	0.120‡	0.129‡	0.133‡	-
Alcohol (dl/day)	-	-	-	-	-	-	-
Medication (units)	-	-	-	-	-	-	0.115‡

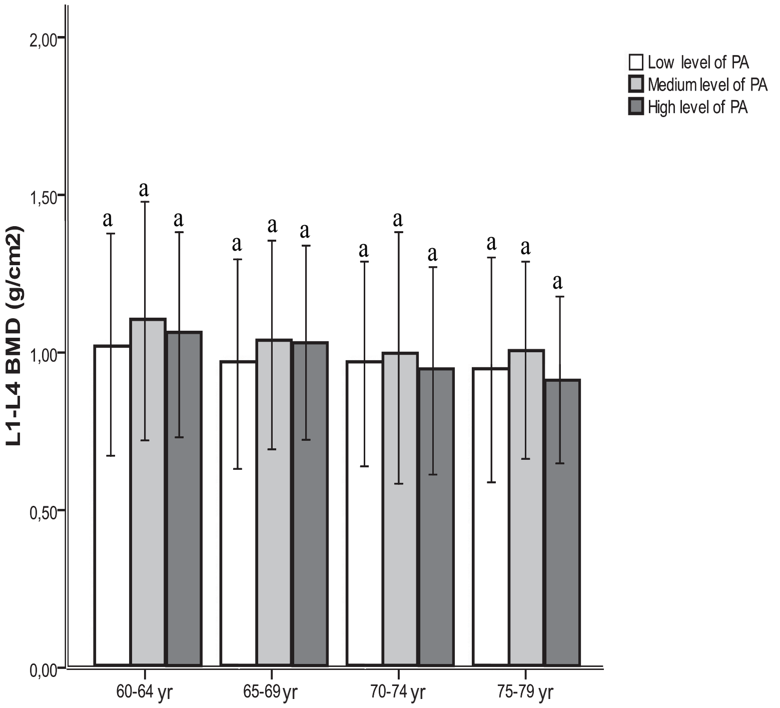
Only correlations that were statistically significant were included; ‡ correlation is significant at the 0.05 level (2-tailed); † Correlation is significant at the 0.01 level (2-tailed); FN, femoral neck; LS, lumbar spine; FSI, femur strength index; BM, body mass; PA, physical activity; TLTM, total lean tissue mass; TFM, total fat mass.

The relationship between PA and BMD in females was generally more pervasive than for males, with several significant, but similarly weak correlations between PA variables and the various measures of BMD (Table 5.3). FSI was significantly negatively correlated with age in females but not males, with height in males but not females, and with BM, TLTM and TFM in both sexes. FSI was significantly negatively correlated with work related PA in males but positively correlated in females, whereas the association with leisure time PA was significant, positive and weak for both sexes. Dietary calcium intake was significantly positively correlated with FSI in females only.

a)



b)



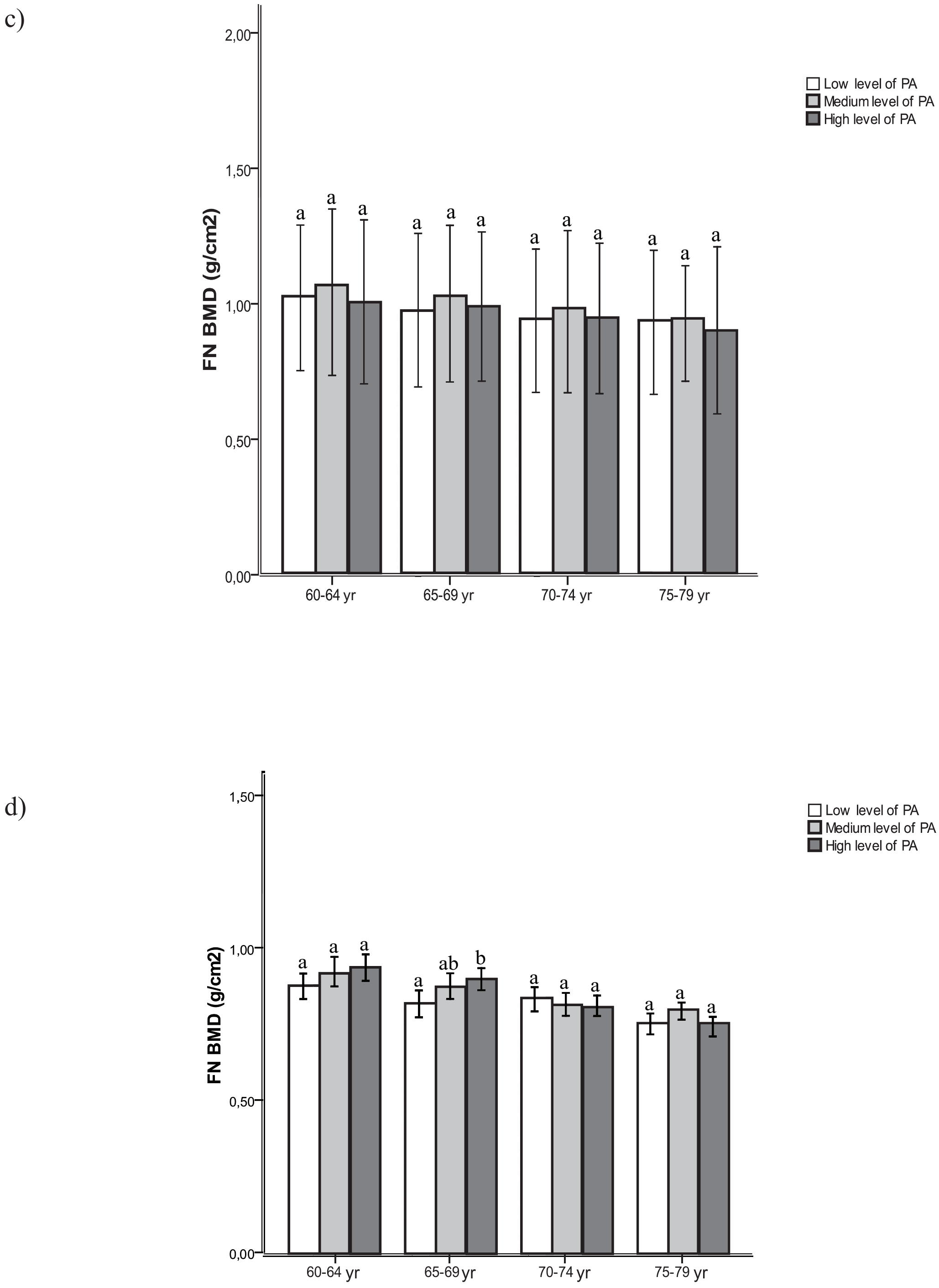


Figure 5.1 Age related differences LS BMD (g/cm^2) (a - males; b - females – b) and in FN BMD (g/cm^2) (c – males; d – females) in relation to total PA levels classified as tertiles. Bars with dissimilar alphabetic suprascripts indicate PA groups that are significantly different ($p< 0.05$) from each other within a given age cohort. Values are mean ± SD.

Results from MLRA modelling containing TLTM, TFM, Total PA, age and total calcium intake are presented in Table 5.4 for the FN, LS and FSI measures only. Similar modelling was done for the remaining bone measures but these findings are not reported in the figures or tables. Age, TLTM, TFM for FN BMD in both sexes, TFM in men and TFM, age and TLTM in female for LS BMD, entered as the primary and most significant contributors. Total PA contributed significantly to variation in FN BMD in females. In men, PA did not significantly contribute to the variation in BMD at any bone site. Also, dietary calcium intake did not contribute to the variation in BMD of FN or LS in either sex.

Our regression model explained 14.2 and 29.6 percent of the total variance in the FN BMD in males and females, respectively. For LS BMD, the total variance explained by the model was 8.3% in males and 14.8% in females. The regression model explained 13.7 and 14.6 percent of the total variation in mechanical FSI in males and females, respectively. In both sexes, age was the most significant predictor for FN BMD, and TFM for LS BMD and for FSI.

Table 5.4 Standard MLR between FN, LS and FSI and putative predictors (TLTM, TFM, total PA and total calcium intake).

Panel A: FN BMD (R^2_{adj}= 0.142) for men
FN BMD (R^2_{adj}= 0.296) for women

Predictors	Crude B±Std. Error	Adjusted B±Std. Error	*Beta*†	*p*	95 % CI*
Men					
TLTM (kg)	0.007±0.001	0.005±0.001	0.210	<0.001	0.003; 0.008
TFM (kg)	0.004±0.001	0.002±0.001	0.130	0.016	0.000; 0.004
Total PA (units)	0.004±0.006	0.003±0.005	0.028	0.551	-0.007; 0.014
Age (years)	-0.007±0.001	-0.005±0.001	-0.211	<0.001	-0.008; -0.003
Calcium intake	2.386^{-5}±0.000	2.326^{-5}±0.000	0.057	0.220	0.000; 0.000
Women					
TLTM (kg)	0.009±0.001	0.004±0.001	0.162	0.002	0.002; 0.007
TFM (kg)	0.005±0.001	0.003±0.001	0.182	<0.001	0.001; 0.005
Total PA (units)	0.020±0.005	0.013±0.005	0.124	0.004	0.004; 0.022
Age (years)	-0.010±0.001	-0.008±0.001	-0.369	<0.001	-0.010; -0.006
Calcium intake	4.037^{-5}±0.001	1.585^{-5}±0.000	0.049	0.253	0.000; 0.000

† Significant contribution by an independent variable to the total explained variation in the model (p < .05); * 95.0% confidence interval for B-values. TLTM, total lean tissue mass; TFM, total fat mass; PA, Physical activity.

Panel B: LS BMD (R^2_{adj}= 0.083) for men
LS BMD (R^2_{adj}= 0.148) for women

Predictors	Crude B±Std. Error	Adjusted B±Std. Error	*Beta*†	*p*	95 % CI*
Men					
TLTM (kg)	0.006±0.002	0.001±0.002	0.041	0.460	-0.002; 0.005
TFM (kg)	0.008±0.001	0.007±0.001	0.282	<0.001	0.005; 0.010
Total PA (units)	0.001±0.008	0.008±0.008	0.049	0.319	-0.008; 0.025
Age (years)	-0.003±0.002	-0.002±0.002	-0.044	0.374	-0.005; 0.002
Calcium intake	1.880^{-5}±0.000	2.645^{-5}±0.000	0.043	0.369	0.000; 0.000
Women					
TLTM (kg)	0.011±0.002	0.005±0.002	0.118	0.042	0.000; 0.009
TFM (kg)	0.008±0.001	0.006±0.001	0.244	<0.001	0.003; 0.008
Total PA (units)	0.006±0.008	0.003±0.007	0.018	0.704	-0.012; 0.017
Age (years)	0.007±0.002	-0.006±0.002	-0.176	<0.001	-0.009; -0.003
Calcium intake	3.267^{-5}±0.000	1.304^{-5}±0.000	0.028	0.558	0.000; 0.000

† Significant contribution by an independent variable to the total explained variation in the model ($p < .05$); * 95.0% confidence interval for B-values. TLTM, total lean tissue mass; TFM, total fat mass; PA, Physical activity.

5.5 Discussion

The contrasts between PA tertiles, the bivariate correlations and the MLRA revealed only minor associations between PA and BMD. Moreover, associations tended to be sex- and site-specific.
Additional information about FSI, a derived measure that provides an estimate of hip fracture risk, was also assessed in our study. FSI is not only dependent on femoral BMD, but it is also a function of the spatial distribution of bone mass and bone's intrinsic structural geometric properties such as its diameter, area, length, and angle at the FN. FSI has been recognized as a significant independent predictor of hip fracture risk (Faulkner et al., 2006).

In our study there were no significant sex specific age-cohort effects of total PA tertiles on this index, and total PA was not a significant predictor of FSI in our MLRA. However, work related PA was significantly correlated with FSI in males and females, whereas the association with leisure time PA was significant only in females. As with our findings for BMD, these results also suggest that PA in general, is only weakly-moderately associated with FSI in the elderly men and women of our study.

Panel C: FSI (R^2_{adj}= 0.137) for men
FSI (R^2_{adj}= 0.146) for women

Predictors	Crude B±Std. Error	Adjusted B±Std. Error	*Beta*†	*p*	95 % CI*
Men					
TLTM (kg)	-0.014±0.004	0.000±0.005	0.005	0.931	-0.009; 0.009
TFM (kg)	-0.024±0.003	-0.024±0.003	-0.383	<0.001	-0.031; -0.018
Total PA (units)	0.030±0.020	0.005±0.019	0.012	0.803	-0.033; 0.043
Age (years)	-0.002±0.005	-0.002±0.004	-0.025	0.600	-0.011; 0.006
Calcium intake	5.725^{-5}±0.000	3.820^{-5}±0.000	0.027	0.570	0.000; 0.000
Women					
TLTM (kg)	-0.019±0.004	-0.007±0.005	-0.085	0.141	-0.017; 0.002
TFM (kg)	-0.017±0.003	-0.016±0.003	-0.301	<0.001	-0.022; -0.010
Total PA (units)	0.033±0.017	0.014±0.016	0.041	0.392	-0.018; 0.046
Age (years)	-0.012±0.004	-0.015±0.003	-0.203	<0.001	-0.021; -0.008
Calcium intake	6.106^{-5}±0.000	4.959^{-5}±0.000	0.047	0.315	0.000; 0.000

† Significant contribution by an independent variable to the total explained variation in the model (p < .05); * 95.0% confidence interval for B-values. TLTM, total lean tissue mass; TFM, total fat mass; PA, Physical activity.

The association between current PA and BMD in the elderly has not been extensively studied and collectively the findings are equivocal at best. Our findings for BMD are in partial agreement with previous select cross-sectional and longitudinal studies of similarly aged populations. Hannan et al. (2000) and Stewart et al. (2005) failed to find any association between PA score and BMD change in elderly males within the age range of our study, whereas Nguyen, Center, & Eisman (2000) found a significant positive relationship between PA and FN, but not LS BMD in similarly aged males. A few additional studies, reported positive associations between sport related PA with FN and hip BMD in elderly males (Pluijm et al., 2001; Vuillemin, Guillemin, Jouanny, Denis, & Jeandel, 2001), and as in our study, positive associations between PA and BMD using simple univariate analyses, which became weaker or non-significant with more stringent multivariate approaches that adjusted for putative BMD covariates Cauley et al., 2005; Lau et al., 2006).

There is more abundant comparative research for elderly women than men, but the results are no less equivocal. Previous studies (Nguyen, Sambrook & Eisman, 1998) have shown a modest favourable effect of PA on the rate of bone loss at the FN and significant positive associations with FN but not LS BMD in elderly females (Hagberg et al., 2001; Pluijm et al., 2001; Nguyen et al., 2000). Likewise, Mavroeidi, Stewart, Reid & Macdonald (2009) recently reported significant interactions between PA tertiles, classified according to metabolic (energy expended in carrying out activities expressed in MET.h/week) and mechanical components of PA (from ground reaction forces on the skeleton expressed in peak scores), and left and right hip BMD in a large population of older women living in the community. Others have reported no relationship between PA level and BMD in elderly females (Gerdhem, Dencker, Ringsberg & Akesson, 2008; Nahas et al., 2011) or insignificant relationships with proxy measures of habitual PA after adjustment for covariates (Schoffl et al., 2008), whereas some have reported specific positive associations with walking (Pluijm et al., 2001) and sports related PA (Vuillemin et al., 2001).

There are few published reports of the association between geometric or derived biomechanical and functional (e.g. bone strength index) measures of bone strength and PA in elderly populations. However, similar to our findings, Nurzenski et al. (2007) and Uusi-Rasi, Sievänen, Pasanen, Beck & Kannus, (2008) recently reported significant positive associations between aspects of femoral bone geometry and PA in elderly females, whereas there is only one report to our knowledge (Semanick et al., 2005), which likewise, indicated a weak positive relationship between walking and FN section modulus in elderly men.

Discrepancies among findings regarding PA may be attributed to a variety of factors. Studies often include different measures of PA and its sub-classifications, different age ranges, differing cut points defining age-specific cohorts, variable health status and levels of social independence and co-morbidities, different degrees of statistical sophistication in data analysis, differing levels of historical and current PA and variable measures of bone health. Notwithstanding these limitations, our findings and the cumulative literature to date suggest that "current" levels of PA contribute only minimally in explaining variation in BMD and FSI among elderly males, with perhaps a slightly stronger influence among elderly females and for certain geometric measures reflecting bone strength in both sexes. Our findings regarding PA were not altogether unexpected, as we anticipated, based on the National Survey (Census 2001) (INE, 2002), a relatively high level of occupational engagement among our participants, which we hypothesized would reduce variability in PA levels, thereby accentuating broader differences in constitutive factors. In our study, however, only 35.2% of the men and 11.5% of the women were active in farming. This differs markedly from the percentage found in the National Census, suggesting that participants in our study were less occupationally engaged than the regional population at large. Notwithstanding this difference in occupational engagement, our findings nevertheless suggest reduced variability in general levels of PA among our participants compared to constitutive factors.

In the present study, as hypothesized, constitutive factors like age, height, BM, TLTM and TFM were consistently more strongly correlated with BMD and FSI than any of our measures of PA. Further, these constitutive factors, specifically age, TLTM and TFM for FN BMD in both genders and TFM in men and TFM and age in women for LS BMD and FSI, persisted as the most important predictors. Other studies have shown that age (Hannan et al., 2000), BM (Felson et al., 1993; Dargent-Molina, et al., 2000), TLTM (Travison, Araujo, Esche, Beck & McKinlay, 2008; Ho-Pham et al., 2010) and TFM (Ho-Pham et al., 2010) are important predictors of BMD in elderly males and females, corroborating our findings. Results from MLRA in our study, showed that age, TLTM and TFM entered as the primary and most significant contributors for FN BMD in our study, accounting for between 13-21.1 % and 16.2-36.9% of the explained variation in these measures in males and females, respectively. For LS BMD, TFM entered as the primary and most significant predictor accounting for 28.2 % of the variation in males and 24.4 % in females.

Our study is unique in several respects; it included relatively large populations of both elderly men and women, these elderly individuals were living freely and independently among the general community, and the population had a high degree of occupational engagement. There were, however, several limitations associated with this study. First, the cross-sectional design does not allow conclusions about the cause-and-effect relationship between PA and BMD. Second, although the Baecke questionnaire has been shown to have acceptable reproducibility (r=0.71-0.82), the limited ability of some participants to accurately recall past sport and leisure activities could introduce bias and lead to misclassification. The data were obtained from independently living elderly men and women from Madeira, Portugal, a geographically isolated region where the cultural backgrounds, living and working conditions and environmental influences are generally homogeneous. The homogeneity of these environmental influences, especially with regards to working history, would minimize the apparent importance of PA as a determinant of BMD and bone strength in this study. Further, the participants were essentially volunteers, who could have been generally healthier than those who did not participate, and survivor bias, especially among males in the older age-cohorts cannot be ruled out as a potential confounding factor particularly for between sex comparisons in our study. Lastly, ours was a very unique elderly population as witnessed by their lower rates of retirement, high prevalence of gainful employment in farming and reduced dependency on social assistance.

In conclusion, our findings point to the importance of age, TLTM and TFM in both sexes, as predominant determinants of bone health in older Portuguese men and women. Total PA showed significant, although weak, positive correlations with LS and Ward's triangle BMD in men and BMD for the total body and all femur sites in women, but was either not important or relatively less important than constitutive factors in explaining variation in BMD or FSI. Neither dietary calcium intake nor alcohol consumption appeared as important determinants of bone health in this study. Our findings suggest that bone health promotion and preservation might be enhanced among the elderly by encouraging dietary practices and PA behaviours aimed at body composition stabilization with advancing age.

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Author's Contribution: ERG, DLF and JAM conceived the study design, sampling procedures, selection of measurements/protocols and performed the statistical analysis. CJRB and GPB were responsible for the quality control of the data. ERG and CJRB drafted the manuscript. ALR supervised the DEXA measurements and CML estimated dietary and alcohol intakes. All the authors contributed to the writing of the manuscript and accepted the final version.

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5.7 References

Baecke, J.A., Burema, J., & Frijters, J.E. (1982). A short questionnaire for the measurement of habitual physical activity in epidemiological studies. *The American Journal of Clinical Nutrition, 36*, 936-42.

Booth, M.L., Owen, N., Bauman, A., Clavisi, O., & Leslie, E. (2000). Social-cognitive and perceived environment influences associated with physical activity in older Australians. *Preventive Medicine, 31*, 15-22.

Cauley, J.A., Fullman, R.L., Stone, K.L., Zmuda, J.M., Bauer, D.C., & Barrett-Connor, E. (2005). Factors associated with the lumbar spine and proximal femur bone mineral density in older men. *Osteoporosis International*, *16*(12), 1525-37.

Daly, R.M., Ahlborg, H.G., Ringsberg, K., Gardsell, P., Sernbo, I., & Karlsson, M.K. (2008). Association between changes in habitual physical activity and changes in bone density, muscle strength, and functional performance in elderly men and women. *Journal of the American Geriatrics Society, 56*, 2252-60.

Dargent-Molina, P., Poitiers, F., Bréart, G., & EPIDOS Group. (2000). In elderly women weight is the best predictor of a very low bone mineral density: evidence from the EPIDOS study. *Osteoporosis International, 11*(10), 881-8.

Eisman, J.A. (1999). Genetics of Osteoporosis. *Endocrine Reviews, 20,* 788-804.

Faulkner, K.G., Wacker, W.K., Barden, H.S, Simonelli, C., Burke, P.K., Ragi, S., et al., (2006). Femur strength index predicts hip fracture independent of bone density and hip axis length. *Osteoporosis International*, *17*, 593-9.

Felson, D.T., Zhang, Y., Hannan, M.T., & Anderson, J.J. (1993). Effects of weight and body mass index on bone mineral density in men and women: the Framingham study. *Journal of Bone and Mineral Research, 8,* 567-73.

Gerdhem, P., Dencker, M., Ringsberg, K., & Akesson, K. (2008) Accelerometer-measured daily PA among octogenerians: results and associations to other indices of physical performance and bone density. *European Journal of Applied Physiology, 102*(2), 173-80.

Hagberg, J.M., Zmuda, J.M., McCole, S.D., Rodgers, K.S., Ferrell, R.E., Wilund, K.R., et al., (2001). Moderate physical activity is associated with higher bone mineral density in postmenopausal women. *Journal of the American Geriatrics Society, 49*, 1411-7.

Hannan, M.T., Felson, D.T., Dawson-Hughes, B., Tucker, K.L., Cupples, L.A., et al., (2000). Risk factors for longitudinal bone loss in elderly men and women: the Framingham Osteoporosis Study. *Journal of Bone and Mineral Research, 15*,710-20.

Ho-Pham, L.T., Nguyen, N.D., Lai, T.Q, & Nguyen, T.V. (2010). Contributions of lean mass and fat mass to bone mineral density: a study in postmenopausal women. *BMC Musculoskeletal Disorders, 26,* 11:59.

Instituto Nacional de Estatística. (2002). *Censos 2001: resultados definitivos: XIV recenseamento geral da população: IV recenseamento geral da habitação.* Lisboa: Instituto Nacional de Estatística.

Instituto Nacional de Estatística. (2009). *População Residente - Portugal - 2008 – 2060*. Lisboa: Instituto Nacional de Estatística, Departamento de Estatísticas Demográficas e Sociais.

International Osteoporosis Foundation. (2001). *Osteoporosis in the European Community: a call to action*. *An audit of policy developments since 1998*. Retrieved Jan 15, 2010, from www.osteofound.org/advocacy_policy/eu_calltoaction_ report.html.

International Osteoporosis Foundation. (2008). *Osteoporosis in the European Union in 2008: Ten years of progress and ongoing challenges*. Retrieved Feb. 10, 2010, from www.iofbonehealth.org.

Jones, G., Nguyen, T., Sambrook, P. Kelly PJ, & Eisman, J.A. (1994). Progressive loss of bone in the femoral neck in elderly people: longitudinal findings from the Dubbo osteoporosis epidemiology study. *British Medical Journal, 309*, 691-695.

Kanis, J.A., & Johnell, O. (2005). Requirements for DXA for the management of osteoporosis in Europe. *Osteoporosis International, 16*, 229-38.

Kanis, J.A., Burlet, N., Cooper, C., Delmas, P.D., Reginster, J.Y., Borgstrom, F., et al. (2008). European guidance for the diagnosis and management of osteoporosis in postmenopausal women. *Osteoporosis International, 19*, 399-428.

Lane, N.E. (2006). Epidemiology, etiology, and diagnosis of osteoporosis. *American Journal of Obstetrics and Gynecology, 194*, S3-11.

Lau, E.M., Leung, P.C., Kwok, T., Woo, J., Lynn, H., Orwoll, E., et al., (2006). The determinants of bone mineral density in Chinese men-results from Mr. Os (Hong Kong), the first cohort study on osteoporosis in Asian men. *Osteoporosis International, 17*(2), 297-303.

Lim, K., & Taylor, L. (2000). Factors associated with physical activity among older people a population-based study. *Preventive Medicine, 40*, 33-40.

Looker, A.C., Melton, L.J., Harris, T., Borrud, L., Shepherd, J., & McGowan, J. (2009). Age, gender, and race/ethnic differences in total body and subregional bone density. *Osteoporosis International*, *20*, 1141-9.

Lopes, C. (2000). *Diet and acute myocardial infarction: a population based case-control study. Reproducibility and validity of a semi-quantitative food frequency questionnaire*. Unpublished doctoral dissertation, University of Porto – Portugal.

Mavroeidi, A., Stewart, A.D., Reid, D.M., & Macdonald, H.M. (2009). Physical activity and dietary calcium interactions in bone mass in Scottish postmenopausal women. *Osteoporosis International, 20*, 409-16.

Moayyeri, A. (2008). The association between physical activity and osteoporotic fractures: a review of the evidence and implications for future research. *Annals of Epidemiology, 18,* 827-35.

Nahas, E.A., Kawakami, M.S., Nahas-Neto, J., Buttros, D.D., Cangussu, L., & Rodrigues, A.B. (2011). Assessment of risk factors for low bone mineral density in Brazilian postmenopausal women. *Climacteric, 14 (2)*, 220-227.

Nguyen, T.V., Center, J.R., & Eisman, J.A. (2000). Osteoporosis in elderly men and women: effects of dietary calcium, physical activity, and body mass index. *Journal of Bone and Mineral Research, 15*, 322-3.

Nguyen, T.V., Sambrook, P.N., & Eisman, J.A. (1998). Bone loss, physical activity, and weight change in elderly women: the Dubbo Osteoporosis Epidemiology Study. *Journal of Bone and Mineral Research*, *13*, 1458-67.

Nurzenski, M.K., Briffa, N.K., Price, R.I., Khoo, B.C., Devine, A., Beck, T.J., et al., (2007) Geometric indices of bone strength are associated with physical activity and dietary calcium intake in healthy older women. *Journal of Bone and Mineral Research*, *22*, 416-24.

Ono, R., Hirata, S., Yamada, M., Nishiyama, T., Kurosaka, M., & Tamura, Y. (2007). Reliability and validity of the Baecke physical activity questionnaire in adult women with hip disorders. *BioMed Central Musculoskeletal Disorders, 8*, 61.

Pluijm, S.M., Visser, M., Smit, J.H., Popp-Snijders, C., Roos, J.C., & Lips, P. (2001). Determinants of bone mineral density in older men and women: body composition as mediator. *Journal of Bone and Mineral Research, 16*, 2142-51.

Reid, I.R., Plank, L.D., & Evans, M.C. (1992). Fat mass is an important determinant of whole body bone density in premenopausal women but not in men. *The Journal of Clinical Endocrinology and Metabolism, 75*, 779-82.

Rose, D. (2003). *Fall proof: a comprehensive balance and mobility training program*. Champaign IL: Human Kinetics.

Rutherford, O.M. (1997). Bone density and physical activity. *The Proceedings of the Nutrition Society, 56*, 967-75.

Schoffl, I., Kemmler, W., Kladny, B., von Stengel, S., Kalender, W.A., & Engelk, K. (2008). In healthy elderly postmenopausal women variations in BMD and BMC at various skeletal sites are associated with differences in weight and lean body mass rather than by variations inhabitual physical activity, strength or VO2 max. *Journal of Musculoskeletal & Neuronal Interactions, 8*(4), 363-374.

Semanick, L.M., Beck, T.J., Cauley, J.A., Wheeler, V.W., Patrick, A.L., Bunker, C.H., et al., (2005). Association of body composition and PA with proximal femur geometry in middle-aged and elderly Afro-Caribbean men: the Tobago bone health study. *Calcified Tissue International, 77*(3), 160-6.

Stenderup, K., Justesen, J., Clausen, C., & Kassem, M. (2003). Aging is associated with decreased maximal life span and accelerated senescence of bone marrow stromal cells. *Bone, 33,* 919-26.

Stewart, K.J., Bacher, A.C., Hees, P.S., Tayback, M., Ouyang, P., & Jan de Beur, S. (2005). Exercise effects on bone mineral density relationships to changes in fitness and fatness. *American Journal of Preventive Medicine, 28,* 453-60.

Travison, T.G., Araujo, A.B., Esche, G.R., Beck TJ, & McKinlay, J.B. (2008). Lean mass and not fat mass is associated with male proximal femur strength. *Journal of Bone and Mineral Research, 23*, 189-98.

U.S. Department of Health and Human Services. (2004). *Bone health and osteoporosis: a report of the surgeon general*. Rockville, MD: U.S. Department of Health and Human Services, Office of the Surgeon General.

Uusi-Rasi, K., Sievänen, H., Pasanen, M., Beck, T.J., & Kannus, P. (2008). Influence of calcium intake and PA on proximal femur bone mass and structure among pre- and postmenopausal women. A 10-year prospective study. *Calcified Tissue International, 82*(3), 171-81.

Vuillemin, A., Guillemin, F., Jouanny, P., Denis, G., & Jeandel. C. (2001). Differential influence of PA on lumbar spine and femoral neck bone mineral density in the elderly population. *The Journals of Gerontology. Series A, Biological Sciences and Medical Sciences, 56*(6), 248-53.

Yoshikawa, T., & Turner, C.H., Peacock, M., Slemenda, C.W., Weaver, C.M., Teegarden, D., et al., (1994). Geometric structure of the femoral neck measured using dual-energy x-ray absorptiometry. *Journal of Bone and Mineral Research*, *9*, 1053-64.

Chapter 6

Functional Fitness and Bone Mineral Density in the Elderly

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6.1 Abstract

The main purpose of this study was to describe the association between Functional Fitness (FF) and bone health/strength in a large Portuguese sample of active elderly community-dwelling.

This cross-sectional study included 401 males and 401 females aged 60-79 years old. Bone mineral density (BMD) of the total body, lumbar spine (LS) and hip region was determined by dual-energy x-ray absorptiometry-DXA. In addition, femur strength index (FSI) was determined. FF was assessed using the Senior Fitness Test (SFT). Demographic information and a health history were obtained by telephone interview through questionnaire.

Aerobic endurance and body strength were positively related with hip BMD region in males ($0.10 < r < 0.16$; $p<0.01$-0.05) and females ($0.13 < r < 0.27$; $p<0.01$). No significant correlation was found between any FF test and LS BMD, except for upper-body strength in females. After controlling for other constitutive predictors (sex, age, height, body mass (BM), total fat mass (TFM) and total lean tissue mass (TLTM)), FF had a minor contribution only in prediction of BMD at multi- sites and FSI. The total explained variance was moderate ($R^2 = 0.346$ for FN BMD; $R^2 = 0.274$ for LS BMD; $R^2 = 0.486$ total body BMD and ($R^2 = 0.215$ for FSI).

Sex, age, height, BM, TLTM and TFM entered as most significant contributors for BMD and FSI. Although FF parameters are typically considered in clinical assessments of bone health in older people, body composition appears to have a higher relevance in the explanation of BMD in our study.

Key words: Aging, Bone Mineral Density, Functional Fitness, Femur Strength Index

6.2 Introduction

Osteoporosis is a disease characterized by low BMD, microarchitectural bone tissue deterioration and increased fracture risk (Stock, Schneider, & Strauss, 2004). Bone fractures resulting from osteoporosis seem to be a major worldwide health concern. In fact, demographic patterns and secular trends suggest that this problem will increase in the next few years (U.S. Department of Health and Human Services [U.S. DHHS], 2004).

Bone mass is mainly genetically determined (Kelly, Eisman, & Sambrook, 1990). However, because bones adapt to the forces they support (Heinonen, 2001), bone quality also depends on environmental and lifestyle factors (Slemenda, Miller, Hui, Reister, & Johnston, 1991) such as physical activity (PA) and nutrition, e.g., calcium intake (Babaroutsi, Magkos, Manios, & Sidossis, 2005). Currently, most clinicians, dealing with established vertebral and hip osteoporosis, focus their attention on BMD, and rarely consider fall prediction or prevention. However, the treatment of osteoporosis is moving forward and nowadays its prevention seems to be gaining importance (U.S. DHHS, 2004). Indeed, the risk of fracture is influenced by both bone strength and falls. Measures of FF and performance are predictors of falls, and both BMD and physical performance are independent predictors of fracture risk (Schott et al., 1998; Nguyen et al., 1993).

The evidence relating variations in PA and fitness levels to BMD in healthy older people is inconclusive. Theoretically, it has been postulated that skeletal muscle contraction forces generate large reaction forces during normal activity and such forces are thought to have local trophic or adaptive effects on bone mass. Recently, it has been shown that physical fitness is associated with BMD in older population (Aoyagi, et al., 2000; Taaffe et al., 2003). However, others have confirmed the association between physical fitness and BMD only in women (Hughes et al., 1995; Stewart et al., 2002) whereas other authors failed to find any association either in women Hughes et al., 1995; Lindsey, Brownbill, Bohannon, & Ilich, 2005) or in men (Miller et al., 2009). Generally, there are relatively limited published data about this issue in men. Evidence suggests that reduced body weight (Harris, Dallal, & Dawson-Hughes, 1992; Edelstein & Barrett-Connor, 1993), TLTM and TFM (Edelstein & Barrett-Connor, 1993; Visser, et al., 1998), reduced levels of PA (Hagberg et al., 2001; Pluijm et al., 2001), general frailty and poor balance (Taaffe et al., 2003; Cawthon et al., 2008), low body strength (Cawthon et al., 2008; Blain et al., 2001) and low aerobic endurance (Vico et al., 1995; Pocock et al., 1989) are risk factors for lower levels BMD and increased fractures.

The main purpose of this study was to describe the association between muscular strength, aerobic endurance, balance and bone health/strength in a large Portuguese sample of active community dwelling elderly men and women. We hypothesize that FF tests are associated with BMD at the total body, LS, FN, Ward's triangle and total hip, and with FSI even after controlling for constitutive factors (age, sex, height, body mass and body composition).

6.3 Methods

6.3.1 Study design and participants

Participants are part of the research project entitled 'Health and quality of life of older adults from ARM, Portugal'. In total, 802 community-dwelling, 401 men and 401 women, aged between 60 and 79 years were evaluated in 2008/2009. Participants were sufficiently independent to visit the Laboratory of Human Physical Growth and Motor Development at the University of Madeira (UMa) on their own. Proportional regional (geographic) representation was determined by stratified sampling, based on Census 2001 data (Statistics Portugal [INE], 2002), with the number of participants per age cohort and sex serving as stratification factors. Participants were volunteers recruited via advertisements for a large study on bone health and FF in newspapers, churches, senior groups and senior centers throughout the ARM.

The study was approved by the University of Madeira (UMa), the Regional Secretary of Education and Culture, and the Regional Secretary of Health. All participants were informed about the nature and purposes of the study and written informed consent was obtained from each subject.

6.3.2 Anthropometry and bone densitometry

BM (kg) was measured with a balance scale accurate to 0.1kg (Seca alpha digital scales model 770, Germany) and standing height (cm) with a Holtain stadiometer (Holtain Ltd., Crymych. United Kingdom) accurate to 0.1cm. Participants wore light, indoor clothing without shoes during the measurements.

BMD (g/cm^2) was determined by dual-energy x-ray absorptiometry-DXA (Lunar Prodigy Primo, with technologic fan beam – GE Healthcare, Encore 2007 software version 11.40.004). After removing all objects suspected or known to contain metal, participants were positioned by the technician according to the manufacturer's recommended protocol. Participants were in a supine position and the following sites were investigated: total body, LS (anterior-posterior), and left femur (FN, trochanter, Ward's triangle and total femur). In addition, the scans yielded information on body composition, including TLTM and TFM.

In addition to the conventional densitometry measurements, structural variables were also determined using the Hip Strength Analysis program, including hip axis length and cross-sectional moment of inertia (CSMI). These bone geometry variables were used to calculate the FSI, the ratio of estimated compressive yield strength of the FN to the expected compressive stress of a fall on the greater trochanter adjusted for each subject's age, height and BM (Yoshikawa et al., 1994).

Scans were standardized daily against a calibration phantom; the precision error expressed as the coefficient of variation (CV %) was 0.31%. Scans were taken alternately by four different technicians over the course of data collection. All technicians received an identical 5 day DXA training course before the start the study using the manufacturer's recommended protocol. Reliability of our DXA measurements was determined on a sub-sample of 17 males and females aged 69.3 ± 5 years. Technicians were paired and members of each pair performed separate LS and hip scans on half the participants each (9 and 8 participants, respectively, per pair). Participants were repositioned after every scan. Results from both pairs of assessors were pooled and the technical error of the measurements (TEM) were determined. These values ranged from 0.19% for total hip to 0.50% for the LS. Inter-observer reliability using the CV% was 1.72%, 2.10%, 2.53% and 0.88% for LS, FN, Ward's triangle and total hip, respectively.

6.3.3 Functional fitness

FF was assessed with the SFT (Rikli & Jones, 2001). To maximize the consistency of assessment procedures, training sessions were conducted with five graduates in Physical Education and Sport, one in Nursing and three in Senior Education. First, a theoretical explanation of the protocols was provided for all research and field team members based on a standard testing manual and a videotape describing all test procedures (Rikli & Jones, 2001). Second, FF tests were self-administered among team members. Third, training sessions was done with older adults. The preparation of the field team was completed with a pilot study in 50 older adults from the training group, aged between 60 and 79 years.

The pilot study was carried out in UMa and all participants were measured twice with an interval of 1 week. The test-retest reliability for each test item in the pilot study was established by calculating the intra-class correlation coefficient (R). Correlation coefficients were between 0.75 for the 8-foot up-and-go test (95% CI: 0.56; 0.86) and 0.88 for the 6-minute walk test (95% CI: 0.79; 0.93), indicating acceptable levels of reliability for all FF tests.

All participants received the same instructions about the procedures for each test and completed one or two trials to become familiarized with the task. Testing stations were arranged in the following order to minimize the effects of fatigue: the chair stand test (lower body strength), arm curl test (upper body strength), chair sit and reach test (lower body flexibility), back scratch test (upper body flexibility) and 8-foot up-and-go test (agility/dynamic balance). The 6-minute walk test (aerobic endurance) was administered after all other tests and questionnaires had been completed. The flexibility tests were not included in the statistical analysis. A detailed description of the evaluation procedures, namely, equipment, procedure, scoring and safety precautions can be found in the SFT manual (Rikli & Jones, 2001).

6.3.4 Health questionnaire and nutritional habits

Demographic information and a health history were obtained by telephone interview. A modified version of the health questionnaire employed in the FallProof! Programme (Rose, 2003), was used to assess behaviour and lifestyle characteristics, including smoking history, history of degenerative diseases and osteoarthritis, fracture history, current and past therapy with specific classes of medications including hormones (estrogen and thyroid), calcium supplements, aspirin, vitamin D, anxiolytic drugs and sleeping aids.

Dietary intake was estimated using a semi-quantitative food frequency questionnaire developed by the Department of Hygiene and Epidemiology of Porto University Medical School, and previously validated (Lopes, 2000). This questionnaire included 86 food items, including those with high contribution for the intake of dietary calcium such as dairy products (e.g., milk, cheese, ice cream, yogurts), as well as leafy green vegetables and fish. In addition, this questionnaire assessed caffeine and alcohol intake (combination of consumption of wine, beer and liquor drinks). Food consumption was converted into nutrients by the software Food Processor Plus® (ESHA Research, Salem-Oregon, 1997), which has been adapted to Portuguese traditional food and dishes (Lopes, 2000).

6.3.5 Statistical analysis

Descriptive characteristics of participants were reported as means ± SDs. Exploratory analysis of the data took place through the usual procedures for identifying outliers and tested for normality by the Kolmogorov-Smirnov statistic. If required, non-normal distributed characteristics were appropriately transformed using log10, square root or inverse transform functions. Differences of means, within each sex and across age intervals, were performed with analysis of variance (ANOVA).

Sex specific bivariate associations between bone health indicators (BMD and FSI) and putative predictors of bone health (age, height, BM, BMI, TLTM, TFM, PA, FF parameters, fracture history, dietary calcium, medication consumption and smoking) were calculated for all age-cohorts combined, using Pearson product-moment correlation coefficient.

Multiple linear regression (MLR) analysis was then used to identify the contribution of the predictors for BMD (FN, LS and total body) and FSI. Betas, namely standardized regression coefficients, were used to assess the relative independent contributions of each predictor, and the R^2s to indicate the percentage of variance accounted for by the predictors for each BMD site and FSI separately. The standard MLR was used, with all predictors entered in the equation simultaneously. The selection of the putative predictors sex, age, height, BM, TLTM, TFM and FF tests (chair stand test, arm curl test, 6-minute walk test and 8-foot up-and-go test) was based on known key important predictors previously identified in the literature, and the strength and significance of the zero-order correlations in the preliminary analysis. The level of significance was set at $p< 0.05$. Analyses were performed using SPSS, version 18.0 (Statistical Package for the Social Sciences [SPSS], 2010).

6.4 Results

Table 6.1 contains a summary of the participants' characteristics by sex and age cohort. Results from the ANOVA's revealed that differences between age-cohorts were significant ($p<0.05$) for height, TLTM, upper and lower body strength, aerobic endurance, and balance, in both genders.

Medication consumption showed significant age-cohort differences only in men. Sex-specific correlations for all age cohorts combined between FSI, BMD at multiple body site and participants' characteristics are presented in Table 6.2. With the exception of LS BMD and FSI for males, all BMD sites were significantly negatively correlated with age, in men and women (Table 6.2).

BMD at all sites was significantly positively correlated at the $p<0.01$ level, with height ($0.158< r <0.279$ and $0.314< r <0.426$), BM ($0.158< r <0.279$ and $0.314< r <0.426$), TFM ($0.190< r <0.319$ and $0.245< r <0.486$) and TLTM ($0.179< r <0.389$ and $0.221< r <0.477$) in men and women, respectively. The relationship between FF parameters and BMD in females was positive and consistently stronger than for males. Aerobic endurance and upper and lower body strength in both men and women, and balance, only in women, were positively correlated with BMD at all sites for the femur (FN, trochanter, Ward's triangle and total hip). No significant correlation was found between FF parameters and LS BMD.

Table 6.1 Age and sex-specific descriptive characteristics (means and SD).

	Age groups (years)			
	60-64	65-69	70-74	75-79
Variables	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
Men				
Height (cm)	166.9 ± 5.2 ^{a}	165.9 ± 6.2 $^{a b}$	164.5 ± 6.1 ^{b}	164.6 ± 6.2 ^{b}
BM (kg)	80.3 ± 12.1 ^{a}	79.7 ± 13.1 ^{a}	79.9 ± 13.3 ^{a}	75.8 ± 13.0 ^{a}
TFM (kg)	22.6 ± 8.1 ^{a}	23.3 ± 7.9 ^{a}	23.6 ± 8.6 ^{a}	21.5 ± 8.2 ^{a}
TLTM (kg)	54.3 ± 5.9 ^{a}	53.3 ± 5.8 ^{a}	52.8 ± 5.5 ^{a}	51.2 ± 6.3 ^{b}
Chair stand test (n)	15.7±4.1 ^{a}	14.8±4.0 ^{a}	13.4±4.0 ^{b}	12.6 ± 3.1 ^{b}
Arm curl test (n)	17.7±3.7 ^{a}	17.3±4.1 ^{a}	15.8±3.9 ^{b}	14.9±2.8 ^{b}
6-minute walk test (m)	577.9±93.7 ^{a}	526.9±115.7 ^{b}	512.3±105.9 ^{b}	461.8±108.6 ^{c}
8-foot up-and-go test (sec)	4.8±1.5 ^{a}	5.4±2.1 ^{ab}	5.9±2.1 ^{b}	6.9±3.2 ^{c}
Dietary Calcium (mg/day)	721.7 ± 321.7 ^{a}	743.7 ± 365.2 ^{a}	723.9 ± 350.6 ^{a}	734.5 ± 384.9 ^{a}
Medication (units)	2.3±2.1 ^{a}	3.0±2.4 ^{ab}	3.6±2.7 ^{b}	3.1±2.2 ^{ab}
Fracture history (%)	28.9	32.9	21.6	18.5
Smoking (%)	17.8	6.7	10.8	7.6
Women				
Height (cm)	154.2 ± 5.4 ^{a}	153.8 ± 5.5 $^{a b}$	152.0 ± 5.8 $^{b c}$	150.1 ± 5.4 ^{c}
BM (kg)	72.2 ± 11.7 ^{a}	71.2 ± 12.7 ^{a}	70.6 ± 10.6 ^{a}	67.8 ± 11.5 ^{b}
TFM (kg)	29.7 ± 7.8 ^{a}	28.7 ± 8.0 ^{a}	28.2 ± 7.3 ^{a}	27.1 ± 7.8 ^{a}
TLTM (kg)	39.9 ± 4.9 $^{a b}$	40.0 ± 5.5 ^{a}	39.3 ± 3.9 $^{a b}$	38.2 ± 4.3 $^{b c}$
Chair stand test (n)	14.8±4.7 ^{a}	13.2±4.2 ^{b}	12.8±3.7 ^{bc}	11.5±3.4 ^{c}
Arm curl test (n)	16.8±4.3 ^{a}	16.3±4.8 ^{ab}	16.0±4.3 ^{ab}	14.8±4.0 ^{b}
6-minute walk test (m)	502.6±97.0 ^{a}	474.8±110.1 ^{ab}	452.7±98.1 ^{b}	392.8±118.2 ^{c}
8-foot up-and-go test (sec)	5.2±1.4 ^{a}	6.0±1.7 ^{ab}	6.5±2.4 ^{b}	7.7±3.6 ^{c}
Dietary Calcium (mg/day)	906.5 ± 387.3 ^{a}	817.9 ± 381.2 ^{a}	821.8 ± 398.6 ^{a}	796.5 ± 384.5 ^{a}
Medication (units)	3.5 ± 2.8 ^{a}	4.5 ± 2.8 ^{a}	4.3 ± 2.3 ^{a}	4.3 ± 2.4 ^{a}
Fracture history (%)	26.5	24.7	39.0	36.9
Smoking (%)	3.6	-	1.2	-

SD, standard deviation; BM, body mass; TFM, total fat mass; TLTM, total lean tissue mass. Descriptive characteristics with dissimilar alphabetic superscripts indicate statistical significant differences ($p < .05$) among age groups.

Table 6.2 Sex-specific Pearson correlations between BMD indicators, FSI and selected descriptive characteristics.

Variables	Total body	LS	FN	Trochanter	Ward's Triang.	Total Hip	FSI
Men							
Age (years)	-0.110‡	-	-0.259†	- 0.158†	- 0.243†	- 0.203†	-
Height (cm)	0.279†	0.158†	0.262†	0.195†	0.178†	0.185†	- 0.147†
BM (kg)	0.425†	0.293†	0.309†	0.329†	0.243†	0.323†	- 0.343†
TFM (kg)	0.319†	0.291†	0.228†	0.249†	0.190†	0.256†	- 0.386†
TLTM (kg)	0.389†	0.179†	0.308†	0.311†	0.238†	0.300†	- 0.165†
Chair stand test (n)	-	-	0.113‡	0.144†	0.153†	0.112‡	0.129‡
Arm curl test (n)	-	-	0.158†	0.111‡	0.161†	0.125‡	-
6-minute walk test (m)	-	-	0.111‡	0.114‡	0.144†	0.101‡	-
8-foot up-and-go test (sec)	-	-	-	-	-	-	-
Fracture history (y/n)	-0.193†	-0.184†	-0.153†	-0.184†	-0.143‡	-0.201†	-
Dietary Calcium (mg/day)	-	-	-	-	-	-	-
Smoking (units)	-0.154†	-0.125‡	-	-	-0.120‡	-0.114‡	-
Medication (units)	-	-0.124‡	-	-	-	-	-
Women							
Age (years)	- 0.394†	- 0.248†	- 0.443†	- 0.386†	- 0.442†	- 0.427†	- 0.164†
Height (cm)	0.396†	0.314†	0.426†	0.363†	0.380†	0.350†	-
BM (kg)	0.530†	0.395†	0.352†	0.512†	0.260†	0.472†	- 0.334†
TFM (kg)	0.486†	0.358†	0.314†	0.485†	0.245†	0.441†	- 0.326†
TLTM (kg)	0.477†	0.323†	0.336†	0.455†	0.221†	0.409†	- 0.220†
Chair stand test (n)	0.121‡	-	0.156†	0.129†	0.171†	0.150†	0.119‡
Arm curl test (n)	0.230†	0.156†	0.278†	0.242†	0.256†	0.259†	-
6-minute walk test (m)	0.145†	-	0.251†	0.234†	0.272†	0.225†	0.159†
8-foot up-and-go test (sec)	-0.124‡	-	-0.218†	-0.138†	-0.224†	-0.173†	-0.184†
Fracture history (y/n)	-0.220†	-0.184†	-0.173†	-0.167†	-0.166†	-0.203†	-0.152†
Dietary Calcium (mg/day)	0.108‡	-	-	-	-	-	0.108‡
Smoking (units)	-	-	-	-	-	-	-
Medication (units)	-	-	-	-	-	-	-0.115‡

Only correlations that were statistically significant were included; ‡ correlation is significant at 0.05 level (2-tailed); † correlation is significant at 0.01 level (2-tailed); FN, femoral neck; LS, lumbar spine; BM, body mass; TLTM, total lean tissue mass; TFM, total fat mass; Y/N, yes/no.

There was a significant negative correlation between FSI and age, in women but not men, between FSI and height, in men but not in women, and between FSI and BM, TFM and TLTM, in both genders. FSI was significantly positively correlated with endurance and balance in women and with lower body strength in both genders. Fracture history and BMD at all sites, were negatively correlated ($-0.201 < r < -0.143$, and $-0.220 < r < -0.166$; $p<0.01$) in men and women, respectively. Fracture history and FSI, were negatively correlated, only in women ($r = -152$; $p<0.01$).

In the MLR analyses, the contributions of sex, age, height, BM, TLTM, TFM, and FF tests in explaining variation in BMD at multiple sites and FSI was investigated. The contributions of the putative predictors of BMD and FSI are provided in Table 6.3 (Panel A to Panel D).

For FN, LS, and total body BMD and FSI, sex, BM and height were the most important predictors, followed by TLTM (for LS BMD), age (for FN and total body BMD) and TFM (for FSI). With the exception of upper body strength for FN BMD, and lower body strength for FSI, none of the FF tests were associated with BMD at any other site or with FSI.

Table 6.3 Standard MLR between FN (Panel A), LS (Panel B), Total body (Panel C) and FSI (Panel D) and putative predictors (sex, age, BM, Height, TLTM, TFM, 6-minute walk test, Arm curl test, Chair stand test, 8-foot up-and-go test).

Panel A: FN BMD ($R^2_{adj} = 0.346$)

Predictors	Crude B±Std. Error	Adjusted B±Std. Error	*Beta*	*p* †	95 % CI
Sex (0 men, 1 women)	-0.116±0.010	-0.045±0,017	-0.153	0.008	-0.078;-0.012
Height (cm)	0.008±0.001	0.003±0,001	0.203	<0.001	0.002; 0.005
TLTM (kg)	0.008±0.001	0.000±0,001	0.027	0.741	-0.002; 0.003
BM (kg)	0.005±0.000	0.002±0,001	0.191	<0.001	0.001; 0.003
Age (years)	-0.008±0.001	-0.006±0,001	-0.233	<0.001	-0.008; -0.004
6-minute walk test (m)	0.000±0.000	4.197^{-5}±0,000	0.033	0.422	0.000; 0.000
Arm curl test (n)	0.008±0.001	0.004±0,001	0.101	0.012	0.001; 0.006
Chair stand test (n)	0.006±0.001	0.000±0,002	-0.006	0.893	-0.003; 0.003
8-foot up-and-go test (sec)	-0.010±0.002	0.001±0,002	0.017	0.658	-0.004; 0.006

† Significant contribution by an independent variable to the total explained variation in the model ($p < .05$); BM, body mass; TLTM, total lean tissue mass.

Panel B: LS BMD (R^2_{adj}= 0.274)

Predictors	Crude B±Std. Error	Adjusted B±Std. Error	*Beta*	*p* †	95 % CI
Sex (0 men, 1 women)	-0.19±0.02	-0.16±0.03	-0.360	<0.001	-0.21; -0.12
TLTM (kg)	0.01±0.00	-0.01±0.00	-0.205	0.016	-0.01; -0.00
Height (cm)	0.01±0.00	0.00±0.00	0.157	0.007	0.00; 0.01
BM (kg)	0.01±0.00	0.00±0.00	0.342	<0.001	0.00; 0.01
6-minute walk test (m)	0.00±0.00	-8.83^{-5}±0.00	-0.047	0.245	0.00; 0.00
Age (years)	0.01±0.00	-0.00±0.00	-0.081	0.015	-0.01; -0.00
Arm curl test (n)	0.01±0.00	0.00±0.00	0.028	0.500	-0.00; 0.01
Chair stand test (n)	0.01±0.00	0.00±0.00	0.049	0.296	-0.00; 0.01

† Significant contribution by an independent variable to the total explained variation in the model (p < .05); BM, body mass; TLTM, total lean tissue mass.

Betas were negative for sex and age, indicating that women and older people had lower BMD and FSI. The total explained variance was moderate $R^2 = 0.346$, $R^2 = 0.274$ and $R^2 = 0.486$ for FN BMD, LS BMD and total body BMD, respectively. The total explained variance of FSI was lower ($R^2 = 0.215$).

6.5 Discussion

This study was conducted to assess the association between muscular strength, aerobic endurance, balance and bone health/strength in a large Portuguese sample of active community dwelling elderly men and women. Our findings indicate that almost all FF tests are associated with most BMD body sites and FSI. However, these associations vanish mostly, with few exceptions, when size and body composition are taken into account in MLR analysis.

Our findings in part, agree with previous cross-sectional and longitudinal studies of similar aged populations. Blain et al. found, that high FN and LS BMD were significantly associated with higher values of quadriceps strength (r=0.55; p<0.001 and r=0.36; p<0.01), respectively in women aged 60 years and over. Data from a relatively large study by Taaffe et al. (2003) of black and white men and women with an approximate sample size similar to ours corroborate our findings, and reported a weak, but positive correlation between chair-rise performance and FN BMD.

Opposite results were found by Lindsey et al. (2005) in older women (68.3±6.8yr). The timed sit-to-stand test did not correlate significantly with BMD of the total body, LS, FN, Ward’s triangle, trochanter, shaft or total hip. Recently, Marin et al. (2010) confirmed these results by failing to find an association between

30-s chair stand and LS, FN or total body BMD. In older men, Miller et al. (2009) concluded that total body, LS, pelvis, arm and leg BMD did not correlate with lower body strength, measured as knee extensor strength. Similar results were reported by Stewart et al. (2002) in older men and women for LS BMD.

Panel C: Total body BMD (R^2_{adj}= 0.486)

Predictors	Crude B±Std. Error	Adjusted B±Std. Error	*Beta*	*p* †	95 % CI
Sex (0 men, 1 women)	-0.14±0.01	-0.07±0.01	-0.296	<0.001	-0.10; -0.05
TLTM (kg)	0.01±0.00	0.00±0.00	0.076	0.283	-0.00; 0.00
Height (cm)	0.01±0.00	0.00±0.00	0.103	0.032	0.00; 0.00
BM (kg)	0.01±0.00	0.00±0.00	0.332	<0.001	0.00; 0.00
Age (years)	-0.00±0.00	-0.00±0.00	-0.127	<0.001	-0.00; -0.00
6-minute walk test (m)	0.00±0.00	1.05^{-6}±0.00	0.001	0.978	0.00; 0.00
Chair stand test (n)	0.00±0.00	0.00±0.001	0.045	0.178	-0.00; 0.00
8-foot up-and-go test (sec)	-0.01±0.00	-0.00±0.00	-0.020	0.566	-0.00; 0.00

† Significant contribution by an independent variable to the total explained variation in the model (p < .05); BM, body mass; TLTM, total lean tissue mass.

Panel D: FSI (R^2_{adj}= 0.215)

Predictors	Crude B±Std. Error	Adjusted B±Std. Error	*Beta*	*p* †	95 % CI
Sex (0 men, 1 women)	-0.28±0.33	-0.18±0.06	-0.189	0.003	-0.30; -0.06
TFM (kg)	-0.02±0.00	-0.01±0.01	-0.189	0.021	-0.02; -0.00
BM (kg)	-0.01±0.00	-0.01±0.00	-0.232	0.009	-0.02; -0.00
Height (cm)	0.01±0.00	0.01±0.00	0.142	0.016	0.00; 0.01
6-minute walk test (m)	0.00±0.00	-1.01^{-5}±0.00	-0.002	0.957	0.00; 0.00
Chair stand test (n)	0.02±0.00	0.01±0.01	0.083	0.042	0.00; 0.02
8-foot up-and-go test (sec)	-0.02±0.01	0.01±0.01	0.035	0.419	-0.01; 0.02
Age (years)	-0.01±0.00	-0.01±0.00	-0.088	0.012	-0.01; -0.00

† Significant contribution by an independent variable to the total explained variation in the model (p < .05); BM, body mass; TFM, total fat mass.

Our study found a site-specific association between lower muscular strength and BMD at the hip.

Reduced lower body strength has been strongly associated with hip fracture risk. Cawthon et al. (2008) in a MLR analyses, showed that men who were unable to complete five consecutive chair stands were much more likely to suffer a hip fracture, than those who completed the measure in the fastest time. The association between FSI, a derived measure that provides an estimative of hip fracture risk, and lower body strength, was only moderate in our study. We found a small negative correlation between FSI and fracture history, but only in women ($r=-0.16$; $p<0.01$). On the other hand, our MLR analyses confirmed that among FF tests, lower body strength contributed most to the explained variation in FSI ($\beta=0.083$; $p< 0.042$), after controlling for the variance explained by all other variables in the model.

Previous studies among postmenopausal women, have shown an association between upper-body strength and LS (Stewart et al., 2002; Kröger, Tuppurainen, Honkanen, Alhava, & Saarikoski, 1994), hip (Stewart et al., 2002; Kritz-Silverstein & Barrett-Connon, 1994) and total body BMD (Stewart et al., 2002; Proctor et al., 2000). Some studies have considered biologically plausible, the association between upper-body strength and BMD at more distant sites like the hip and LS. Snow-Harter et a1. (1990) have proposed that muscle groups more distant to the LS, proximal femur and total body may contribute to increased BMD in those areas because arm activity is linked to the simultaneous contraction of trunk-stabilizing muscles that directly exert forces on the hip and LS. In our study, results from the MLR analysis indicated that of the FF parameters, upper-body strength made the strongest contribution to the explained variation in FN BMD ($\beta=0.10$; $p< 0.012$), when the variance explained by all other variables in the model was controlled for. However, no other contribution from upper-body strength was evident for LS and total body BMD or for FSI.

The association between aerobic endurance and bone health/strength seems to be equivocal. In contrast to our results, Stewart et al. (2002) did not find any significant correlation between aerobic fitness, measured directly as VO2 max, and BMD at total body, FN or LS in men or women. Bevier et al. (1989), found a significant correlation between aerobic fitness (evaluated directly as VO2 max) and BMD at the LS in men, but not in women. The lack of significant correlation between aerobic fitness and FN, trochanter, Ward's triangle and LS BMD was also confirmed by Huuskonen et al. (2000) and Miller et al. (2009) for total body BMD.

Our results agree, however, with those of Pocock et al. (1989), who found a positive correlation between cardiorespiratory endurance (measured as VO_2max consumption) and BMD at the femur ($0.40 < r < 0.56$; $p<0.001$). Vico et al. (1995) in a sample of 55 women aged 73.54 ±5.9 years old, found that cardiorespiratory endurance was a major determinant of FN BMD. In our study, although aerobic endurance was associated with BMD at multiple body sites and FSI, these associations vanished when other putative determinants were taken into account in the MLR analysis.

The relationship between balance and BMD has been studied mostly in older women (Lindsey et al., 2005; Marin et al., 2010; Kärkkäinen et al., 2009; Khazzani et al., 2009; Sakai et al., 2009) and, to our knowledge, few studies have investigated this relationship in men. Corroborating our data, Taaffe et al. (2003) did not find any association between balance and hip BMD in elderly men. The association between balance and BMD found in our women agrees with the results found by Lindsey et al. (2005), but are counter to those reported by Taaffe et al. (2003) for elderly women. Lindsey et al. (2005) also report a positive relationship between balance and BMD at the hip ($r=0.21$; $p<0.02$) and total body ($r=0.21$; $p<0.02$). Similarly, Khanzzani et al. (2009) identified positive associations between BMD at multiple body sties and the get-up-an-go test ($-0.13 < r < 0.20$; $p< 0.005-0.001$), whereas Marin et al. (2010) reported a specific positive association between static balance (measured as unipedal balance test) and LS BMD ($r=0.24$, $p<0.005$) in older women. Additionally, Kärkkäinen et al. (2009) even after controlling for other putative determinants, showed that the standing-one-foot was associated with LS BMD ($r^2=0.16$, $p=0.004$) and BMD at the femoral regions ($0.17< r^2 <0.23$; $p<0.001$). As FF tests are related to falls, those with poorer performance scores on these tests may be at a greater risk of falls. Further, if BMD is compromised, they would be at an increased risk of fracture once a fall takes place. Since older women seem to be a group with enhanced risk for falls, a targeted intervention aimed at improving balance, muscular strength and aerobic endurance should be considered in a preventive perspective for enhancement of health care in this specific sub group of elderly.

In the present study, as hypothesized, FF tests are associated with BMD at multiple body sites and with FSI, even after controlling for constitutive factors (age, sex, height, body mass and body composition). In agreement with our findings, other studies have shown that age (Hannan et al., 2000), height (Bunout et al., 2007), BM (Marin et al., 2010), TFM (Pluijm et al., 2001; Taaffe et al., 2001) and TLTM (Bevier et al., 1989; Travison, Araujo, Esche, Beck & McKinlay, 2008) are important predictors of BMD in the elderly. Results from MLR analyses, in our study, showed that sex, age, height, BM and TLTM entered as the primary and most significant contributors to the variability in bone health/strength variables, with their relative importance varying by specific bone site: e.g. FN BMD (3% - 23%), LS BMD (8% -36%) and total body BMD (8% - 33%).

Some limitations of our study should be noted. Our's was a cross-sectional study design, reflecting associations but not revealing causality. In addition, all participants must have been able to walk without assistance or aid of other persons and were therefore in good overall health. Generalization of our findings to less mobile populations of ARM and less healthy or institutionalized groups is limited. The strengths of our study are grounded on a large population based sample and extensive bone and physical measurements.

In sum, all BMD body sites were significantly negatively correlated with age, and fracture history in men and women. The MLR analyses confirmed that women and older people had lower BMD and FSI. Lower body strength made the strongest contribution to explaining FSI, when the influence of all other variables in the model were controlled. Sex, age, height, BM, TLTM and TFM entered as the primary and most significant contributors for BMD at the multiple body sites and for FSI. Although, body strength, endurance and balance should be considered in clinical assessments of bone health in older people, our findings suggest that body composition has a higher relevance in the explanation of BMD in older people.

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6.7 References

Aoyagi, K., Ross, P.D., Hayashi, T., Okano, K., Moji, K., Sasayama, H., et al., (2000). Calcaneus bone mineral density is lower among men and women with lower physical performance. *Calcified Tissue International, 67*, 106–110.

Babaroutsi, E., Magkos, F., Manios, Y., & Sidossis, L.S. (2005). Body mass index, calcium intake, and physical activity affect calcaneal ultrasound in healthy Greek males in an age-dependent and parameter specific manner. *Journal of Bone and Mineral Metabolism, 23*, 157–166.

Bevier, W.C., Wiswell, R.A., Pyka, G., Kozak, K.C., Newhall, K.M., & Marcus, R. (1989). Relationship of body composition, muscle strength, and aerobic capacity to bone mineral density in older men and women. *Journal of Bone and Mineral Research*, *4*(3), 421-32.

Blain, H., Vuillemin, A., Teissier, A., Hanesse, B., Guillemin, F., & Jeandel, C. (2001). Influence of muscle strength and body weight and composition on regional bone mineral density in healthy women aged 60 years and over. *Gerontology, 47*(4), 207-12.

Bunout, D., Barrera, G., de la Maza, M.P., Leiva, L., Gattas, V., & Hirsch, S. (2007). Height reduction, determined using knee height measurement as a risk factor or predictive sign for osteoporosis in elderly women. *Nutrition, 23*(11-12), 794-7.

Cawthon, P.M., Fullman, R.L., Marshall, L., Mackey, D.C., Fink, H.A., Cauley, et al., (2008). Physical performance and risk of hip fractures in older men. *Journal of Bone and Mineral Research, 23*(7), 1037-44.

Edelstein, S.L., & Barrett-Connor, E. (1993). Relation between body size and bone mineral density in elderly men and women. *American Journal of Epidemiology, 138*, 160–169.

Hagberg, J.M., Zmuda, J.M., McCole, S.D., Rodgers, K.S., Ferrell, R.E., Wilund, K.R., et al., (2001). Moderate physical activity is associated with higher bone mineral density in postmenopausal women. *Journal of the American Geriatrics Society*, *49*, 1411-7.

Hannan, M.T., Felson, D.T., Dawson-Hughes, B., Tucker, K.L., Cupples, L.A., Wilson, P.W., et al., (2000). Risk factors for longitudinal bone loss in elderly men and women: the Framingham Osteoporosis Study. *Journal of Bone and Mineral Research*, *15*, 710-20.

Harris, S., Dallal, G.E., & Dawson-Hughes, B. (1992). Influence of body weight on rates of change in bone density of the spine, hip and radius of postmenopausal women. *Calcified Tissue International*, *50*, 19-23.

Heinonen, A. (2001). Biomechanics. In: Khan K, McKay H, Kannus P, Bailey D, Wark J, Bennell K (eds) *Physical Activity and Bone Health* (pp 23–34). Champaign, IL: Human Kinetics.

Hughes, V.A., Frontera, W.R., Dallal, G.E., Lutz, K.J., Fisher, E.C., & Evans, W.J. (1995). Muscle strength and body composition: associations with bone density in older subjects. *Medicine and Science in Sports and Exercise, 27*, 967-974.

Huuskonen, J., Vaisanen, S.B., Kroger, H., Jurvelin, C., Bouchard, C., Alhava, E., et al., (2002). Determinants of bone mineral density in middle aged men: a population-based study. *Osteoporosis International, 11*, 702-708.

Instituto Nacional de Estatística. (2002). *Censos 2001: resultados definitivos: XIV recenseamento geral da população: IV recenseamento geral da habitação.* Lisboa: Instituto Nacional de Estatística.

Kärkkäinen, M., Rikkonen, T., Kröger, H., Sirola, J., Tuppurainen, M., Salovaara, K., et al., (2009). Physical tests for patient selection for bone mineral density measurements in postmenopausal women. *Bone, 44*(4), 660-5.

Kelly, P.J., Eisman, J.A., & Sambrook, P.N. (1990). Interaction of genetic and environmental influences on peak bone density. *Osteoporosis International*, *1*, 56–60.

Khazzani, H., Allali, F., Bennani, L., Ichchou, L., El Mansouri, L., Abourazzak, F.E., et al., (2009). The relationship between physical performance measures, bone mineral density, falls, and the risk of peripheral fracture: a cross-sectional analysis. *BMC Public Health, 18*, 9, 297.

Kritz-Silverstein, D., & Barrett-Connon, E. (1994). Grip strength and bone mineral density in older women. *Journal of Bone and Mineral Research*, *9*, 45–51.

Kröger, H., Tuppurainen, M., Honkanen, R., Alhava, E., & Saarikoski, S. (1994). Bone mineral density and risk factors for osteoporosis a population-based study of 1600 perimenopausal women. *Calcified Tissue International*, *55*(1), 1-7.

Lindsey, C., Brownbill, R.A., Bohannon, R.A., & Ilich, J.Z. (2005). Association of physical performance measures with bone mineral density in postmenopausal women. *Archives of Physical Medicine and Rehabilitation, 86*(6), 1102-7.

Lopes, C. (2000). *Diet and acute myocardial infarction: a population based case-control study. Reproducibility and validity of a semi-quantitative food frequency questionnaire*. Unpublished doctoral dissertation, University of Porto – Portugal.

Marin, R.V., Pedrosa, M.A., Moreira-Pfrimer, L.D., Matsudo, S.M., & Lazaretti-Castro, M. (2010). Association between lean mass and handgrip strength with bone mineral density in physically active postmenopausal women. *Journal of Clinical Densitometry, 13*(1), 96-101.

Miller, L.E., Pierson, L.M., Pierson, M.E., Kiebzak, G.M., Ramp, W.K., Herbert, W.G., et al., (2009). Age influences anthropometric and fitness-related predictors of bone mineral in men. *Aging Male*, *12*(2-3), 47-53.

Nguyen, T., Sambrook, P., Kelly, P., Jones, G., Lord, S., Freund, J., & Eisman, J. (1993). Prediction of osteoporotic fractures by postural instability and bone density. *British Medical Journal, 307*, 1111-1115.

Pluijm, S.M., Visser, M., Smit, J.H., Popp-Snijders, C., Roos, J.C., & Lips, P. (2001). Determinants of bone mineral density in older men and women: body composition as mediator. *Journal of Bone and Mineral Research, 16*, 2142-51.

Pocock, N., Eisman, J., Gwinn, T., Sambrook, P., Kelly, P., Freund, J., & Yeates M. (1989). Muscle strength, physical fitness, and weight but not age predict femoral neck bone mass. *Journal of Bone and Mineral Research*, *4*(3), 441-8.

Proctor, D.N., Melton, L.J., Khosla, S., Crowson, C.S., O'Connor. M.K., & Riggs, B.L. (2000). Relative influence of physical activity, muscle mass and strength on bone density. *Osteoporosis International, 11,* 944–52.

Rikli, R.E., & Jones, C.J. (2001). *Senior fitness test manual. Development and validation of a functional fitness test for community-residing older adults*. Champaign, IL: Human Kinetics.

Rose, D. (2003). *Fall proof: a comprehensive balance and mobility training program*. Champaign IL: Human Kinetics.

Sakai, A., Toba, N., Takeda, M., Suzuki, M., Abe, Y., Aoyagi, K., et al., (2009). Association of unipedal standing time and bone mineral density in community-dwelling Japanese women. *Osteoporosis International*, *20*(5), 731-6.

Schott, A.M., Cormier, C., Hans, D., Favier, F., Hausherr, E., Dargent-Molina, P., et al., (1998). How hip and whole body bone mineral density predict hip fracture in elderly women. The EPIDOS prospective study. *Osteoporosis International*, *8*, 247-254.

Slemenda, C.W., Miller, J.Z., Hui, S.L., Reister, T.K., & Johnston, C.C. (1991). Role of physical activity in the development of skeletal mass in children. *Journal of Bone and Mineral Research*, *6*, 1227-1233.

Snow-Harter, C., Bouxsein, M., Lewis, B., Charette, S., Weinstein, P., & Marcus, R. (1990). Muscle strength as a predictor of bone mineral density in young women. *Journal of Bone and Mineral Research*, *5*, 589-95.

Statistical Package for the Social Sciences. (2010). *Version 18.0*, Chicago IL, USA: SPSS Inc.

Stewart, K.J., Deregis, J.R., Turner, K.L., Bacher, A.C., Sung, J., Hees, P.S., et al., (2002). Fitness, fatness and activity as predictors of bone mineral density in older persons. *Internal Medicine Journal, 252*, 381-388.

Stock, H., Schneider, A., & Strauss, E. (2004). Osteoporosis: a disease in men. *Clinical orthopaedics, 425*, 143–151.

Taaffe, D.R., Cauley, J.A., Danielson, M., Nevitt, M.C., Lang, T.F., Bauer, D.C., et al., (2001). Race and sex effects on the association between muscle strength, soft tissue, and bone mineral density in healthy elders: the Health, Aging, and Body Composition Study. *Journal of Bone and Mineral Research*, *16*(7), 1343-52.

Taaffe, D.R., Simonsick, E.M., Visser, M., Volpato, S., Nevitt, M.C., Cauley, J.A., et al., (2003). Lower extremity physical performance and hip bone mineral density in elderly black and white men and women: cross-sectional associations in the Health ABC Study. *The Journals of Gerontology*, *Series A: Medical Sciences, 58*, 934–M942.

Travison, T.G., Araujo, A.B., Esche, G.R., Beck TJ, & McKinlay, J.B. (2008). Lean mass and not fat mass is associated with male proximal femur strength. *Journal of Bone and Mineral Research, 23*, 189-98.

U.S. Department of Health and Human Services. (2004). *Bone health and osteoporosis: a report of the surgeon general*. Rockville, MD: U.S. Department of Health and Human Services, Office of the Surgeon General.

Vico, L., Pouget, J.F., Calmels, P., Chatard, J.C., Rehailia, M., Minaire, P., et al., (1995). The relations between physical ability and bone mass in women aged over 65 years. *Journal of Bone and Mineral Research*, *10*(3), 374-83.

Visser, M., Kiel, D.P., Langlois, J., Hannan, M.T., Felson, D.T., Wilson, P.W., et al., (1998). Muscle mass and fat mass in relation to bone mineral density in very old men and women: The Framingham Heart Study. *Applied Radiation and Isotopes, 49*, 745-747.

Yoshikawa, T., & Turner, C.H., Peacock, M., Slemenda, C.W., Weaver, C.M., Teegarden, D., et al., (1994). Geometric structure of the femoral neck measured using dual-energy x-ray absorptiometry. *Journal of Bone and Mineral Research*, *9*, 1053-64.

Chapter 7

Balance, Mobility and Physical Activity in Community-dwelling Elderly Men and Women

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7.1 Abstract

The purpose of this study was to describe gender- and age-related differences in balance and gait and their association with physical activity (PA) in a sample of older adults residing in Madeira, Portugal.

This cross-sectional study included 401 males and 401 females (60-79 yr). Balance was assessed using the Fullerton Advanced Balance (FAB) scale and multiple parameters of gait (i.e., gait velocity (GV), stride length (SL), cadence, and gait stability ratio (GSR) were calculated using the 50-foot walk test). PA was assessed by the Baecke Questionnaire.

Males demonstrated significantly higher total scores on the FAB scale and in some gait measures in comparison to females. The 60-64 age cohort also performed significantly better on all measures when compared to the oldest age cohort (75-79 yr). Finally, higher levels of total PA were associated with better balance scores and higher gait speeds.

This study supports current PA recommendations for older adults in order to maintain balance and mobility.

7.2 Introduction

Age-related declines in balance and gait are well documented and lead to reduced physical function, lower physical activity levels, and impaired activities of daily living, which are important contributors to falls (Cromwell & Newton, 2004; Gill et al., 2001; Rose, Lucchese, & Wiersma, 2006). Large epidemiological studies have identified many risk factors for falling in older adults. Socio-demographic factors, medical diagnoses, muscle weakness, deficits in balance, gait or vision, mobility limitation, cognitive impairment, impaired functional status, and postural hypotension have all been shown to be moderately to strongly associated with falls (Rubenstein, 2006; Lord, Sherrington, & Menz, 2007; Tinetti & Kumar, 2010).

Epidemiological information about the incidence of falls worldwide reveals that approximately 28-35% of older adults over 65 years old fall each year, increasing to 32-42% for those over 70 years of age (World Health Organization [WHO], 2007). Falls are also the leading cause of injury-related hospitalization in people aged ≥65 years and constitute a condition requiring considerable healthcare expenditure (Lord et al., 2007). In Portugal, the estimated incidence of deaths attributed to falls is 6.3 per 100,000 persons (WHO, 2007). In particular, accidents among older adults account for 15% of all domestic and leisure accidents registered in Portugal. Moreover, falls account for 76.4% of all accidents reported in people aged 65-74 years old, and 89.7% in people over 75 years old (Rabiais, Nunes, & Contreiras, 2006). Clearly, falls in the older adult population represent a major health-care problem that lead to high rates of morbidity and mortality (Rose, 2010).

Older adults are the fastest growing segment of the Portuguese population which, when coupled with its relatively low fertility rate, makes Portugal one of the most aged countries in Europe (17.1% of the total population was older than 65 years in 2008) (Statistics Portugal [INE], 2009). Particularly, in the Portuguese Autonomous Region of Madeira, the older adult segment (≥65 years old) is projected to comprise approximately 57.4% of the total population by 2050 (Regional Secretary of Social Affairs [SRAS], 2009).

Many studies have investigated gender-related differences in functional mobility in older adults (Duncan, Weiner, Chandler, & Studenski, 1990; Demura, Yamaji, & Kitabayashi, 2005; Butler, Menant, Tiedemann, & Lord, 2009; Doyo, Kozakai, Kim, Ando, & Shimokata, 2011). Even though the majority of fallers are women (Campbell, Spears, & Borrie, 1990), the influence of gender differences in balance and mobility remains uncertain. Some authors argue that postural ability is associated with gender-specific physical fitness characteristics (Campbell et al., 1997; Butler et al., 2009), while others have postulated that gender differences in physical performance (including balance) are eliminated when anthropometric differences are considered (Duncan et al., 1990; Bryant, Trew, Bruce, Kuisma, & Smith, 2005).

Age-related changes in temporo-spatial gait parameters have generally been interpreted as indicators of specific adaptive gait strategies to maintain dynamic balance in older adults (Winter, Patla, Frank, & Walt, 1990; Rosengren, McAuley, & Mihalko, 1998; Cromwell, & Newton, 2004). Multiple studies have shown that older adults tend to walk more slowly, have a shorter stride length (SL), and spend a greater proportion of the gait cycle in double-leg support (DLS) (Elble, Thomas, Higgins, & Colliver, 1991; Barak, Wagenaar, & Holt, 2006). A shorter SL contributes to a decreased risk of falling because of a shorter forward progression per step and increased time spent in DLS (Elble et al., 1991). The Gait Stability Ratio (GSR) provides information about walking stability, with increases in GSR indicating that older adults take more steps per unit of distance in order to maintain balance (Cromwell & Newton, 2004).

The role of physical activity (PA) in preventing falls and maintaining physical functioning in older adults is still unclear, primarily due to the different methods of measuring PA, the many and varied types of PA, and the difficulties associated with tracking long-term adherence to unsupervised activity (Feder, Cryer, Donovan, & Carter, 2000; Skelton, 2001; Chan et al., 2007; Li et al., 2006; Lawton et al., 2009). Several studies have identified physical inactivity as a behavioural risk factor that adversely affects balance and mobility among older adults (Stevens, Powell, Smith, Wingo, & Sattin, 1997; Gillespie et al., 2003; Heesch, Byles, & Brown, 2008; Mertz, Lee, Sui, Powell, & Blair, 2010; Kenny et al., 2011). Declines in postural control, muscle strength, gait, and physical function are influenced by physical inactivity, (Hindmarsh, & Estes, 1989; Michael et al., 2009). It is well documented that PA and structured exercise help to maintain postural stability, strength, endurance, bone density, and functional ability; thereby reducing the incidence of falls (Province et al., 1995; Campbell et al., 1997; Perrin, Gauchard, Perrot, & Jeandel, 1999; Skelton, 2001).

The aims of this study were as follows: (1) to investigate the age-related changes in balance and gait parameters, (2) to document gender differences in balance and gait parameters, and (3) to identify the associations between PA and balance and gait parameters in older adults 60 to 79 years of age living in Madeira, Portugal.

7.3 Methods

7.3.1 Study design and participants

This cross-sectional study included 802 participants (401 males and 401 females) distributed approximately equally over four age-cohorts (60-64, 65-69, 70-74, and 75-79 years). Participants were sufficiently mobile and independent enough to visit our laboratory at the University of Madeira for all testing. Proportional regional (geographic) representation was determined by stratified sampling based on Census 2001 data from the Portuguese Statistics National Institute (INE, 2002), with the number of participants per age cohort and gender serving as stratification factors.

Participants were volunteers recruited for a large clinical research study investigating bone health and PA via newspapers, and communication with churches, senior groups, and senior centers throughout the Madeira region. The study was approved by the Scientific Commission of the Physical Education and Sports of the University of Madeira, the Regional Secretary of Education and Culture, and the Regional Secretary of Social Affairs. All participants were informed about the nature and purposes of the study and written informed consent was obtained from each participant prior to the start of testing.

7.3.2 Preparation of the field team and pilot study

All assessments were conducted in the Human Physical Growth and Motor Development Laboratory at the University of Madeira. To maximize the consistency of the assessment procedures, training sessions were conducted with five graduate students in Physical Education and Sport, one in Nursing, and three in Senior Education. First, a theoretical explanation of the protocols and tests to be performed was provided to all research and field team members. Second, the physical assessments (Fullerton Advanced Balance (FAB) scale, and 50-Foot walk test) and questionnaires were self-administered among team members during preliminary training (5 days, 2 training sessions per day, with a duration of 2 hours). Third, two training sessions were conducted with a group of older adults (6 men and 14 women) belonging to a regular PA program. The purposes of these additional training sessions were to: (1) evaluate the field team in a realistic testing situation; and (2) to calculate the mean time of a complete evaluation. The final preparation of the field team was completed with a pilot study that included a sample of 8 men and 23 women with a mean age of 67.02 years (±6.6 years).

The FAB scale was administered according to the published test administration instructions (Rose, 2003). Test-retest reliability was established based on two testing sessions conducted one week apart. Each of the five graduates in Physical Education and Sport independently administered the FAB scale and the 50-Foot walk test in older adults on two separate occasions (6-7 participants per administrator). The results from both tests administered twice by each administrator were pooled and the intra-class correlation (R) and its confidence intervals determined. Test-retest reliability was determined for the total FAB scale score only and four parameters of gait at preferred and maximum speed (i.e., GV, SL, cadence, and GSR). The correlation value for the total FAB scale score was 0.96 (95% CI: 0.92; 0.98) while correlations for the gait parameters measured at maximum and preferred speed ranged from 0.73 to 0.92, indicating acceptable levels of reliability according to the cut-off point of 0.70 recommended by Safrit (1990).

Similar procedures were followed to establish the test-retest reliability of the Baecke questionnaire. The resulting correlations were 0.83, 0.85, and 0.85 for the work, sport, and leisure-time indices, respectively. Our reliability scores for work and sport PA were similar to those obtained by Baecke, Burema, & Frijters, (1982) in a sample of Dutch adult men and women (0.88, 0.81) and by Ono et al. (2007) in a sample of middle aged women (0.84, 0.83).

7.3.3 Instruments

The FAB scale was used to measure balance. This 10-item scale is used to measure the multiple dimensions of balance in higher functioning older adults (Rose, Lucchese, & Wiersma, 2006). The scale has previously been shown to be a valid and reliable measure of balance. The predictive validity of the scale relative to fall risk has also been demonstrated (Hernandez & Rose, 2008). Each test item is scored using a 4-point ordinal scale (0–4), with a maximum score of 40 possible points. The FAB scale includes the following items: standing with feet together and eyes closed (item 1), reaching forward to retrieve an object (pencil) held at shoulder height with outstretched arm (item 2), turning 360 degrees in a right and left direction (item 3), stepping up and over a 15 cm bench (item 4), tandem walking (item 5), standing on one leg (item 6), standing on foam with eyes closed (item 7), jumping for distance (item 8), walking with head turns (item 9), and recovering from an unexpected loss of balance (item 10). A detailed description of the test administration protocol, equipment needed, and instructional video is provided elsewhere (Rose, 2010).

Limitations in functional mobility were measured using the 50-foot walk test (Rose, 2003). Participants were required to walk a total distance of 70 feet (first at preferred speed and then at maximal speed), with the distance between 10 and 60 feet being timed for the purpose of calculating GV and other measures of gait. The number of steps taken over the same 50-foot distance were counted in order to calculate cadence (steps per second) and SL (feet) (Rose, 2010). The GSR was calculated from cadence (steps/sec) and velocity (ft/sec) and was expressed in units of steps per foot (Cromwell, & Newton, 2004). A full description of the test administration instructions for the 50-foot walk test at preferred and maximum speed is reported in Rose (2003).

7.3.4 Physical activity measures

Total PA was assessed during face-to-face interviews using a Portuguese version of the Baecke questionnaire that was originally developed in the Netherlands (Baecke et al., 1982). This questionnaire includes a total of 16 questions classified into three specific domains: PA at work, sport, and leisure time PA, the latter domain excluding sports. The questionnaire also provides a measure of total PA which is the sum of these three specific domains. Numerical coding for most response categories varied from 1 to 5 (Likert scale) ranging from never to always or very often. Questions 1 and 9 pertaining to main occupation and types of sports played, respectively, required a written response. PA indices were calculated according to specific formulae for work (questions 1- 8), sport (questions 9-12), and leisure time (questions 13-16).

If the participants were not employed or if they were retired, their occupation was coded as homemaker. The work index includes information about sitting, standing, walking, lifting, and if sweating at work was elicited, as well as information about fatigue after work or household activities (HS). Additionally, each participant was asked how they perceived their activity at work or during HS in relationship to that of others their own age. A sport score (one or two main sports) was also calculated from a combination of the intensity, amount of time per week, and proportion of the year the sport was practiced. The leisure-time activity index was based on the frequency of walking and cycling, either for leisure and /or to work or shopping. This index also included the amount of time spent watching television. Participants were classified separately by age-cohort and gender into tertiles of high, moderate, or low PA levels based on their responses to this questionnaire.

7.3.5 Statistical analyses

Descriptive characteristics of all participants were reported as Means ± SDs. All data were tested for normality using the Kolmogorov-Smirnov statistic. If required, non-normally distributed characteristics were appropriately transformed using log10, square root, or inverse transform functions. Mean differences in the total score for the FAB scale and four gait measures (i.e., GV; SL, cadence, GSR) calculated for the maximal and preferred speed condition of the 50-foot walk as a function of age cohort and gender were analysed using a t-test for independent groups. Gender specific two-way ANOVAs were conducted to test for mean differences in total score for the FAB scale and GV, SL, cadence, GSR (at maximum speed) between age-cohorts and total PA tertiles (low, medium and high level).

Multiple ANOVAs, with post-hoc Tukey comparisons to identify the source(s) of the differences, were calculated to test for mean differences between age groups and gender- specific mean differences between PA tertiles in total score for the FAB scale, GV, SL, Cadence, and GSR (at preferred and maximum speed). All data were analysed using the Statistical Package for Social Sciences (SPSS), version 18 (SPSS, 2010). Statistical significance was set at *p* <0.05 for all analyses.

7.4 Results

Gender differences for total score for the FAB scale, GV, SL, cadence, and GSR (at preferred and maximum speed) are summarized in Table 7.1. Males demonstrated significantly higher total scores on the FAB scale, GV and SL in both speeds (preferred and maximal) in comparison to females (*p* <0.001). Contrarily, females presented higher values than males in GSR in both speeds (preferred and maximal) and cadence at preferred speed only. No significant difference between males and females was found in cadence at maximal speed.

Table 7.1 Gender differences based on total FAB scale score and selected gait measures (GV; SL, cadence, GSR).

	Men		Women			
Balance and Gait	n	Mean±SD	n	Mean±SD	*p*	Contrast[‡]
FAB	400	31.94±6.73	400	29.09±7.92	<0.001	1> 2
GV/PS [†] (ft/sec)	398	1.28±0.25	399	1.22±0.25	<0.001	1> 2
GV/MS [†] (ft/sec)	399	1.81±0.36	399	1.59±0.33	<0.001	1> 2
C/PS [†] (steps/sec)	398	1.89±0.21	399	1.94±0.23	<0.001	1< 2
C/MS [†] (steps/sec)	399	2.25±0.29	399	2.22±0.28	0.184	n.s
SL/PS [†] (ft/stride)	399	1.35±0.18	399	1.25±0.17	<0.001	1> 2
SL/MS [†] (ft/stride)	399	1.60±0.22	399	1.43±0.23	<0.001	1> 2
GSR/PS [†] (step/ft)	398	1.51±0.23	399	1.64±0.25	<0.001	1< 2
GSR/MS [†] (step/ft)	399	1.28±0.21	399	1.44±0.25	<0.001	1< 2

[‡] t-test; n.s. non-significant; 1> 2 or 1< 2 differences between men and women; [†] 50-foot walk; GV/MS = Gait Velocity at maximum speed; GV/PS = Gait Velocity at preferred speed; C/PS = Cadence at preferred speed; C/MS = Cadence at maximum speed; SL/PS = Stride Length at preferred speed; SL/PS = Stride Length at maximum speed; GSR/PS = Gait Stability Ratio at preferred speed; GSR/MS = Gait Stability Ratio at maximum speed.

Table 7.2 contains a gender- specific summary of the total score for the FAB scale and the four gait measures (i.e., GV, SL, cadence, GSR) derived from the 50-foot walk test performed at maximal speed.

One-way between-groups analyses of variance (ANOVAs) revealed statistically significant differences ($p < 0.001$) for the total FAB scale score as well as GV, SL, cadence, and GSR (at maximal and preferred speed) across the four age-cohorts, and within each gender. The total FAB scale score declined by 17.4% and 25.4% between the youngest (60-64 yr) and oldest cohort (75-79 yr) for males and females, respectively.

Table 7.2 Age and gender-specific characteristics on total FAB scale score and selected gait measures (GV; SL, cadence, GSR).

	Age groups (years)				
	60-64	65-69	70-74	75-79	
Balance and Gait	Mean±SD	Mean±SD	Mean±SD	Mean±SD	*p*
Men					
FAB	34.45±6.54^{a}	33.24±6.83^{ab}	31.28±6.27^{b}	28.47±5.78^{c}	<0.001
GV/PS [†] (ft/sec)	1.36±0.22^{a}	1.32±0.22^{a}	1.28±0.25^{a}	1.15±0.26^{b}	<0.001
GV/MS [†] (ft/sec)	1.94±0.31^{a}	1.83±0.34^{ab}	1.79±0.35^{b}	1.64±0.38^{c}	<0.001
C/PS [†] (steps/sec)	1.94±0.18^{a}	1.91±0.19^{a}	1.90±0.20^{a}	1.79±0.23^{b}	<0.001
C/MS [†] (steps/sec)	2.32±0.25^{a}	2.24±0.32^{ab}	2.26±0.26^{ab}	2.15±0.30^{b}	<0.001
SL/PS [†] (ft/stride)	1.40±0.14^{a}	1.39±0.20^{a}	1.34±0.17^{a}	1.27±0.19^{b}	<0.001
SL/MS [†] (ft/stride)	1.67±0.15^{a}	1.63±0.25^{ab}	1.58±0.21^{b}	1.50±0.22^{c}	<0.001
GSR/PS [†] (step/ft)	1.44±0.15^{a}	1.47±0.22^{a}	1.52±0.23^{a}	1.62±0.27^{b}	<0.001
GSR/MS [†] (step/ft)	1.21±0.12^{a}	1.25±0.20^{ab}	1.29±0.22^{bc}	1.37±0.26^{c}	<0.001
Women					
FAB	32.45±6.24^{a}	31.08±6.76^{a}	27.69±7.84^{b}	24.22±8.13^{c}	<0.001
GV/PS [†] (ft/sec)	1.33±0.21^{a}	1.27±0.23^{ab}	1.19±0.22^{b}	1.06±0.25^{c}	<0.001
GV/MS [†] (ft/sec)	1.74±0.29^{a}	1.67±0.30^{ab}	1.56±0.29^{b}	1.38±0.33^{c}	<0.001
C/PS [†] (steps/sec)	2.04±0.20^{a}	1.97±0.18^{ab}	1.91±0.25^{b}	1.83±0.24^{c}	<0.001
C/MS [†] (steps/sec)	2.31±0.25^{a}	2.26±0.28^{ab}	2.19±0.26^{bc}	2.11±0.29^{c}	<0.001
SL/PS [†] (ft/stride)	1.30±0.13^{a}	1.28±0.16^{a}	1.24±0.19^{a}	1.15±0.18^{b}	<0.001
SL/MS [†] (ft/stride)	1.50±0.20^{a}	1.48±0.25^{ab}	1.42±0.21^{b}	1.30±0.21^{c}	<0.001
GSR/PS [†] (step/ft)	1.56±0.18^{a}	1.59±0.22^{a}	1.64±0.22^{a}	1.78±0.32^{b}	<0.001
GSR/MS [†] (step/ft)	1.35±0.18^{a}	1.39±0.21^{a}	1.44±0.23^{a}	1.58±0.31^{b}	<0.001

Descriptive characteristics with dissimilar alphabetic suprascripts indicate significant differences ($p < 0.05$) among age groups; [†] 50-foot walk; GV/MS = Gait Velocity at maximum speed; GV/PS = Gait Velocity at preferred speed; C/PS = Cadence at preferred speed; C/MS = Cadence at maximum speed; SL/PS = Stride Length at preferred speed; SL/PS = Stride Length at maximum speed; GSR/PS = Gait Stability Ratio at preferred speed; GSR/MS = Gait Stability Ratio at maximum speed.

Among the four gait measures derived from the 50-foot walk test, GV at maximum speed showed the biggest differences between younger and older participants with a decline of 15.5% and 20.7% observed in males and females, respectively.

With no exceptions, statistically significant differences ($p < 0.001$) for total FAB scale score, GV, SL, Cadence, and GSR (at maximal and preferred speed) were observed when within-gender activity groups (low, medium and high level) were contrasted (Table 7.3). Significant differences between medium and high activity groups were seen in women for total FAB score, GV, SL, GSR at maximal and preferred speed and Cadence at maximal speed only. In men these differences were only found in GV at preferred speed.

There were significant age-cohort and gender-specific effects of total PA level on total score for the FAB scale (Figure 7.1), and each of the four gait measures at maximum speed (figures not presented). The mean performance differences were much higher for women than men. Higher total scores on the FAB scale and lower values on GSR were observed for women in the high activity group when compared to the low activity group, across all age cohorts. With the exception in the 70 to 74 years old cohort, similar results were seen for GV at maximum speed. For males, aged 60-69 years old, no significant age-cohort effects of total PA on GSR were evident. The same was true for GV in the 60 to 74 years old cohort. No statistically significant differences among activity groups were observed for the total FAB scale score, except for the 70-74 years old cohort.

7.5 Discussion

This report in community-dwelling men and women aged 60-79 years old, living in Madeira, Portugal, focused on balance and gait parameters, and their association with overall PA levels. Our data confirm gender differences in overall balance performance and selected parameters of gait. Males scored significantly better than women on the FAB scale, and on three of the four gait measures (i.e., GV; SL, GSR) calculated for the maximal and preferred speed condition of the 50-foot walk test. In both genders, the youngest cohort (60-64 yr) performed significantly better on both tests when compared to the oldest age cohort (75-79 yr). In addition, our data confirm that higher levels of total PA, measured as the sum of three specific domains (PA at work, sport, and leisure time), were associated with significantly better performance on the total score FAB scale and four gait measures (i.e., GV; SL, cadence, GSR) in males and females for all age-cohorts combined (60-79 yr).

While several studies have investigated gender-related differences in dynamic balance and gait patterns of community-living older adults (Demura et al., 2005; Doyo et al., 2011), the findings regarding the nature of these gender differences have not been consistent. Era et al. (1997) reported significantly better standing balance, as measured by center of foot pressure, in 75-year old females when compared to their male counterparts in both eyes open and closed standing conditions. Considering the functional reach test as measure of dynamic balance, Duncan et al. (1990) evaluated 58 males and 70 females (21-87 years), and revealed that females had shorter reach than males. However, when controlling for height, the differences between genders were not significant.

Table 7.3 Gender related differences on total FAB scale score and selected gait measures (GV; SL, cadence, GSR) in relation to total PA tertiles.

	Physical activity groups			
	Low	Medium	High	p
Balance and Gait	Mean±SD	Mean±SD	Mean±SD	
Men				
FAB	29.86±7.44^{a}	32.24±5.52^{b}	32.97 ±6.27^{b}	<0.001
GV/PS † (ft/sec)	1.19±0.27^{a}	1.30±0.21^{b}	1.37±0.23^{c}	<0.001
GV/MS † (ft/sec)	1.70±0.43^{a}	1.82±0.26^{b}	1.92±0.32^{b}	<0.001
C/PS † (steps/sec)	1.83±0.22^{a}	1.90±0.17^{b}	1.95±0.20^{b}	<0.001
C/MS † (steps/sec)	2.18±0.33^{a}	2.23±0.20^{b}	2.33±0.28^{b}	<0.001
SL/PS † (ft/stride)	1.29±0.22^{a}	1.36±0.15^{b}	1.40±0.14^{b}	<0.001
SL/MS † (ft/stride)	1.54±0.27^{a}	1.62±0.16^{b}	1.64±0.17^{b}	<0.001
GSR/PS † (step/ft)	1.59±0.29^{a}	1.49±0.18^{b}	1.44±0.16^{b}	<0.001
GSR/MS † (step/ft)	1.34±0.28^{a}	1.25±0.14^{b}	1.24±0.16^{b}	<0.001
Women				
FAB	25.18±8.92^{a}	30.01±6.90^{b}	32.33±5.88^{c}	<0.001
GV/PS † (ft/sec)	1.09±0.26^{a}	1.23±0.22^{b}	1.33±0.21^{c}	<0.001
GV/MS † (ft/sec)	1.43±0.35^{a}	1.60±0.29^{b}	1.76±0.25^{c}	<0.001
C/PS † (steps/sec)	1.86±0.26^{a}	1.96±0.21^{b}	2.01±0.21^{b}	<0.001
C/MS † (steps/sec)	2.13±0.29^{a}	2.22±0.27^{b}	2.32±0.24^{c}	<0.001
SL/PS † (ft/stride)	1.17±0.19^{a}	1.25±0.14^{b}	1.32±0.16^{c}	<0.001
SL/MS † (ft/stride)	1.34±0.25^{a}	1.44±0.22^{b}	1.52±0.18^{c}	<0.001
GSR/PS † (step/ft)	1.76±0.32^{a}	1.62±0.18^{b}	1.53±0.18^{c}	<0.001
GSR/MS † (step/ft)	1.55±0.32^{a}	1.41±0.19^{b}	1.33±0.14^{c}	<0.001

Descriptive characteristics with dissimilar alphabetic suprascripts indicate significant differences ($p< 0.05$) among age groups; † 50-foot walk; GV/MS = Gait Velocity at maximum speed; GV/PS = Gait Velocity at preferred speed; C/PS = Cadence at preferred speed; C/MS = Cadence at maximum speed; SL/PS = Stride Length at preferred speed; SL/PS = Stride Length at maximum speed; GSR/PS = Gait Stability Ratio at preferred speed; GSR/MS = Gait Stability Ratio at maximum speed.

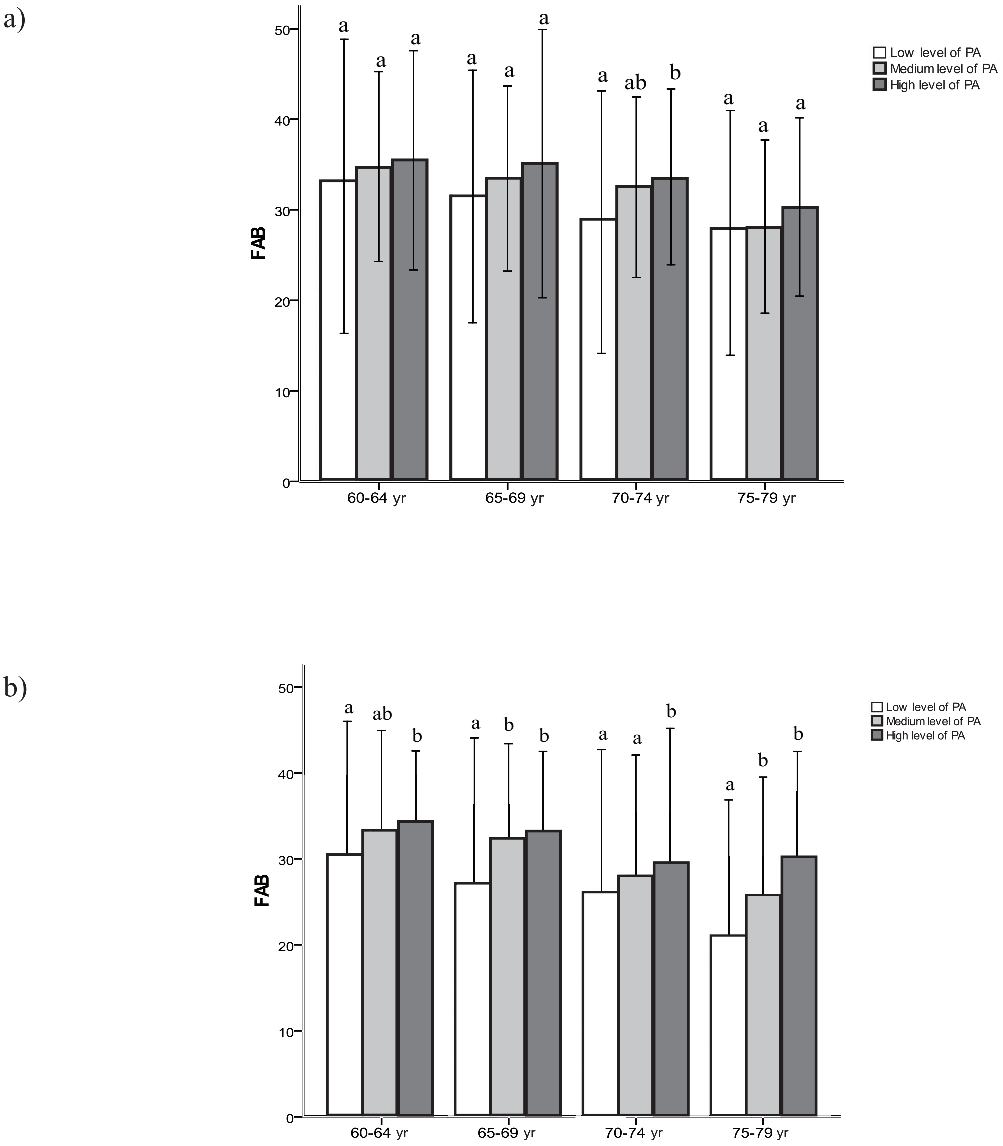

Figure 7.1 Age related differences on Total FAB scale score (a - males; b - females) in relation to total PA levels classified as tertiles. Bars with dissimilar alphabetic suprascripts indicate PA groups that are significantly different ($p < .05$) from each other within a given age cohort. Values are mean ± SD.

Our results are in line with those reported by Duncan et al. (1990) who measured dynamic balance, and Bryant et al. (2005) who measured standing balance performance. Although they used different tests to assess different dimensions of balance, overall, men performed significantly better when compared to women.

Of the many parameters of gait that have been studied, GV is considered to be the most valid and practical measure of mobility and a good predictor of impairments in activities of daily living (Montero-Odasso et al., 2005). Oberg, Karsznia, & Oberg (1993) found that GV and step length were lower, and step frequency was higher in women than in men in a sample of 233 healthy participants (116 men and 117 women), spanning an age range from 10-79 years. Our results partly corroborate these findings. Overall, men walked at significantly higher speeds (GV), demonstrated longer strides (SL) and spent less time in double support phase (GSR) during gait when compared to women.

Our results for GV, GSR, and total FAB scale score are consistent with those of previous studies (Oberg et al., 1993; Cromwell & Newton, 2004) that demonstrated significant age differences in measures of balance and gait. Elble et al. (1991) concluded that healthy older adults (74.7±6.6 years) take shorter steps at a greater frequency for a given gait velocity. When compared to young adults, older adults exhibited GV and SL values that were17-20% lower than their younger counterparts. Our study results further indicated that the most significant age-associated changes were observed for the total FAB scale score (17.4% and 25.4%) and GV at maximum speed (15.5% and 20.7%) in males and females, respectively.

In the present study, GSR also proved to be a useful measure for identifying changes in gait stability (Cromwell, & Newton, 2004). GSR was significantly higher in the oldest age cohort (75-79 years) when compared to the youngest group (60-64 years), for both males and females. The older adults in our sample spent a higher proportion of the gait cycle in DLS, thereby increasing the stability of their walking pattern. Increased stability during walking allows older adults to compensate for disturbances in balance. Our results are in accord with Cromwell & Newton (2004) who have suggested that GSR is a better indicator of balance impairments during gait than GV alone. They further suggested that "by maximizing walking stability, older adults create a movement pattern that is more resistant to perturbations and serves as a mechanism to protect against falls" (p. 96).

Physical inactivity has been identified as an important risk factor for the onset of disability and increased fall risk (Nelson, et al., 2007). The association between balance, gait and total PA observed in our study sample is consistent with the findings of other studies that have investigated changes in balance and gait as a function of age (Mertz et al., 2010; Michael et al., 2009; Rosengren et al., 1998). Our results confirmed that better balance performance was associated with higher levels of PA. These results also provide support for the findings of Era et al. (1997) who studied postural balance in relation to self-reported functional ability and general PA in men and women aged 75 years. Their results indicated that standing balance, with eyes open or closed, was significantly better among the more physically active participants than in their less active counterparts.

With the objective of clarifying the effect PA has on the maintenance of mobility in older men and women aged 65-84 years, Kubota, Ishikawa-Takata, & Ohta (2005) demonstrated in a longitudinal study that participants who walked ≥ 30 minutes per day, exercised ≥ 30 minutes per day, worked for ≥30 minutes per day and walked more quickly, were less likely to experience a decline in their mobility with age. In addition, they concluded that those participants who walked, exercised, or worked less than three times a week, demonstrated lower levels of mobility than their more active counterparts. It was also shown that older adults who could walk faster were able to retain their mobility longer than those who walked more slowly. Our cross-sectional findings are in agreement with the findings of Kubota et al. (2005) in that males and females classified as more physically active (higher tertile of PA), walked faster, exhibited a longer SL and had a lower GSR (spent less time in DLS) than those participants classified in the lowest tertile of PA.

In a similar vein, Stevens et al. (1997) studied the association between vigorous and mild PA and fall-related fractures in a sample of community-dwelling older adults aged 65 years and older. In their study, vigorous levels of PA were associated with a lower risk of experiencing a fall at home, resulting in a serious fracture. However, among the subgroup of older adults without limitations in their activities daily living, vigorous physical activity was associated with a higher risk of serious fracture. Heesch et al. (2008), in a sample of 8188 healthy older women aged 70-75 years, also demonstrated that very high PA levels were associated with a decreased risk of reporting a fall. Still more recently, Mertz et al. (2010) examined whether an association existed between PA and walking-related falls in a sample of 2110 men and women divided in three age cohorts (40-44, 45-64, ≥65yrs). They concluded that for men, and to some degree, for women, PA appears to protect against walking-related falls. These results suggest that engaging in daily moderate to vigorous-intensity PA could serve as an effective way to prevent falls among older adults.

Although our study did not specifically investigate the association between overall PA levels and fall risk, we did examine the association between changes in multiple dimensions of balance and gait, known to be important risk factors for falls, and overall PA level. Not surprisingly, the results of our study indicated that the more physically active men and women demonstrated significantly better balance and gait when compared to the less active group across all age cohorts studied.

Factors that influence gait adjustments were examined by Rosengren et al. (1998) in a group of 55 active and sedentary older adults, aged 60-85 years. Their results showed that sedentary older adults adopted a more cautious walking style than active adults, exhibiting shorter step lengths and slower step velocities. Age and PA level were found to be significantly correlated with gait speed. These findings reiterate the importance of PA as a behavioural risk factor for declines in balance and mobility and increased risk of falls among older adults.

As with most studies, there were several limitations associated with this study. First, the cross-sectional design does not allow us to draw any conclusions about the cause-and-effect relationship between balance, gait impairments, and PA. Second, although the Baecke questionnaire has been shown to have acceptable reproducibility, the limited ability of some participants to accurately recall past sport and leisure activities could introduce bias and lead to misclassification. The data were obtained from independently living older adult men and women from Madeira, Portugal, a geographically isolated region where the cultural backgrounds, living and working conditions, and environmental influences are generally homogeneous. Further, the participants who volunteered to participate in the study could have been generally healthier than those who did not participate. Survivor bias, especially among males in the older age-cohorts also cannot be ruled out as a potential confounding factor, particularly for the between gender comparisons made in our study. Finally, our sample was characterized by a very unique older adult population as witnessed by their lower rates of retirement, high prevalence of gainful employment in farming, and reduced dependency on social assistance.

In summary, this study provides additional cross-sectional information about gender- and age-related differences in balance and gait measures in relation to total PA levels in community-dwelling older adults aged 60-79 years, living in Madeira, Portugal. We found that high levels of total PA were associated with better performances on the FAB scale and select gait parameters analysed (GV, SL, GSR and cadence). In males and females, balance and mobility performance was significantly higher in the youngest cohort when compared to the oldest cohort, with females performing at a lower level than males. Our findings have important practical implications for understanding the role of PA in balance and mobility among the older adult population and provide additional support for the recommendations to increase total PA levels in order to maintain mobility and physical independence as we age.

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7.7 References

Baecke, J., Burema, J., & Frijters, J. (1982). A short questionnaire for the measurement of habitual physical activity in epidemiological studies. *The American Journal of Clinical Nutrition*, *36*, 936-42.

Barak, Y., Wagenaar, R.C., & Holt, K.G. (2006). Gait characteristics of elderly people with a history of falls: a dynamic approach. *Physical Therapy, 86*(11), 1501-10.

Bryant, E., Trew, M., Bruce, A., Kuisma, R., & Smith, A. (2005). Gender differences in balance performance at the time of retirement. *Clinical Biomechanics, 20*(3), 330-5.

Butler, A.A., Menant, J.C., Tiedemann, A.C., & Lord, S.R. (2009). Age and gender differences in seven tests of functional mobility. *Journal of Neuro Engineering and Rehabilitation, 30*, 6:31.

Campbell, A., Robertson, M., Gardner, M., Norton, R., Tilyard, M., & Buchner, D. (1997). Randomised controlled trial of a general practice programme of home based exercise to prevent falls in elderly women. *British Medical Journal*, *315*(7115), 1065-9.

Campbell, A.J., Spears, G.F., & Borrie, M.J. (1990). Examination by logistic regression modelling of the variables which increase the relative risk of elderly women falling compared to elderly men. *Journal of Clinical Epidemiology*, *43*(12), 1415-20.

Chan, B., Marshall, L., Winters, M., Faulkner, A., Schwartz, V., & Orwoll, S. (2007). Incident fall risk and physical activity and physical performance among older men: the Osteoporotic Fractures in Men Study. *American Journal of Epidemiology, 165*(6), 696-703.

Cromwell, R., & Newton, R. (2004). Relationship between balance and gait stability in healthy older adults. *Journal of Aging and Physical Activity*, *12*, 90-100.

Demura, S., & Yamada, T. (2007). Simple and easy assessment of falling risk in the elderly by functional reach test using elastic stick. *The Tohoku Journal of Experimental Medicine*, *213*(2), 105-11.

Demura, S., Yamaji, S., & Kitabayashi, T. (2005). Gender and age-related differences of dynamic balancing ability based on various stepping motions in the healthy elderly. *Journal of Human Ergology*, *34*(1-2), 1-11.

Doyo, W., Kozakai, R., Kim, H., & Ando, F. (2011). Shimokata H. Spatiotemporal components of the 3-D gait analysis of community-dwelling middle-aged and elderly Japanese: Age- and sex-related differences. *Geriatrics & Gerontology International*, *11*(1), 39-49.

Duncan, W., Weiner, K., Chandler, J., & Studenski, S. (1990). Functional reach: a new clinical measure of balance. *Journal of Gerontology, 45(6)*, 192–7.

Elble, R., Thomas, S., Higgins, C., & Colliver, J. (1991). Stride-dependent changes in gait of older people. *Journal of Neurology*, *238*(1), 1-5.

Era, P., Avlund, K., Jokela, J., Gause-Nilsson, I., Heikkinen, E., Steen, B., et al. (1997). Postural balance and self-reported functional ability in 75-year-old men and women: a cross cross-national comparative study. *Journal of the American Geriatrics Society*, *45*, 21-29.

Feder, G., Cryer, C., Donovan, S., & Carter, Y. (2000). Guidelines for the prevention of falls in people over 65. The Guidelines' Development Group. *British Medical Journal*, *321*(7267), 1007-11.

Gill, J., Allum, J., Carpenter, M., Held-Ziolkowska, M., Adkin, A., Honegger, F., et al. (2001). Trunk sway measures of postural stability during clinical balance tests: effects of age. *The Journals of Gerontology. Series A, Biological Sciences and Medical Sciences*, *56*(7), 438-47.

Gillespie, D., Gillespie, J., Robertson, C., Lamb, E., Cumming, G., & Rowe, H. (2003) Interventions for preventing falls in elderly people. *Cochrane Database of Systematic Reviews*, *4*, CD000340.

Heesch, C., Byles, E., & Brown, J. (2008). Prospective association between physical activity and falls in community-dwelling older women. *Journal of Epidemiology and Community Health*, *62*(5), 421-6.

Hernandez, D., & Rose, D.J. (2008). Predicting which older adults will or will not fall using the Fullerton Advanced Balance scale. *Archives of Physical Medicine and Rehabilitation, 89*(12), 2309-15.

Hindmarsh, J., & Estes, E. (1989). Falls in older persons. Causes and interventions. *Archives of Internal Medicine*, *149*(10), 2217-22.

Instituto Nacional de Estatística. (2002). *Censos 2001: resultados definitivos: XIV recenseamento geral da população: IV recenseamento geral da habitação*. Lisboa: Instituto Nacional de Estatística.

Instituto Nacional de Estatística. (2009). *População Residente - Portugal - 2008 – 2060*. Lisboa: Instituto Nacional de Estatística, Departamento de Estatísticas Demográficas e Sociais.

Kenny, R.A., Rubenstein, L.Z., Tinetti, M.E., Brewer, K., Cameron, K.A., et al., (2011). Summary of the Updated American Geriatrics Society/British Geriatrics Society clinical practice guideline for prevention of falls in older persons. *Journal of the American Geriatrics Society, 59*(1), 148-57.

Kubota, A., Ishikawa-Takata, I., & Ohta, T. (2005). Effect of Daily Physical Activity on Mobility Maintenance in the Elderly. *International Journal of Sport and Health Science*, *3*, 83-90.

Lawton, A., Rose, B., Raina Elley, C., Dowell, C., Fenton, A., & Moyes, A. (2009). Exercise on prescription for women aged 40-74 recruited through primary care: two year randomised controlled trial. *British Journal of Sports Medicine*, *43*(2), 120-3.

Li, W., Keegan, H., Sternfeld, B., Sidney, S., Quesenberry, Jr., & Kelsey, L. (2006). Outdoor falls among middle-aged and older adults: a neglected public health problem. *American Journal of Public Health, 96*(7), 1192-200.

Lord, S., Sherrington, C., Menz, H., & Close, J. (2007). *Falls in Older People. Risk factors and strategies for Prevention*. UK. Cambridge University Press.

Mertz, J., Lee, C., Sui, X., Powell, E., & Blair, N. (2010). Falls among adults: the association of cardiorespiratory fitness and physical activity with walking-related falls. *American Journal of Preventive Medicine*, *39*(1), 15-24.

Michael, K., Goldberg, A., Treuth, M., Beans, J., Normandt, P., & Macko, R. (2009). Progressive adaptive physical activity in stroke improves balance, gait, and fitness: preliminary results. *Topics in Stroke Rehabilitation*, *16*(2), 133-9.

Montero-Odasso, M., Schapira, M., Soriano, E.R., Varela, M., Kaplan, R., Camera, L.A., et al., (2005). Gait velocity as a single predictor of adverse events in healthy seniors aged 75 years and older. *The Journals of Gerontology. Series A, Biological Sciences and Medical Sciences*, *60*(10), 1304-9.

Nelson, M.E., Rejeski, W.J., Blair, S.N., Duncan, P.W., Judge, J.O., King, A.C., et al., (2007). Physical activity and public health in older adults: Recommendation from the American College of Sports Medicine and the American Heart Association. *Medicine and Science in Sports and Exercise, 39* (8), 1435-1445.

Oberg, T., Karsznia, A., & Oberg, K. (1993). Basic gait parameters: reference data for normal subjects, 10-79 years of age. *Journal of Rehabilitation Research and Development*, *30*(2), 210-23.

Ono, R., Hirata, S., Yamada, M., Nishiyama, T., Kurosaka, M., & Tamura, Y. (2007). Reliability and validity of the Baecke physical activity questionnaire in adult women with hip disorders. *BMC Musculoskeletal Disorders*, *8*, 61.

Perrin, P., Gauchard, G., Perrot, C., & Jeandel, C. (1999). Effects of physical and sporting activities on balance control in elderly people. *British Journal of Sports Medicine*, *33*(2), 121-6.

Province, M., Hadley, E., Hornbrook, M., Lipsitz, L., Miller, J., Mulrow, C., et al., (1995). The effects of exercise on falls in elderly patients. A preplanned meta-analysis of the FICSIT Trials. Frailty and Injuries: Cooperative Studies of Intervention Techniques. *The Journal of the American Medical Association*, *273*(17), 1341-7.

Rabiais, S., Nunes, B., Contreiras, T. (2006). *ADELIA 2005 – Acidentes Domésticos e de Lazer: Informação Adequada*. Lisboa: Instituto Nacional de Saúde Dr. Ricardo Jorge. Retrieved Nov. 1, 2010, from https://webgate.ec.europa.eu/idb/ documents/PT_proj_adelia_relat-final-2005_ onsa.pdf. Rose D.J. (2010). *Fall proof: a comprehensive balance and mobility training program, 2nd Ed*. Champaign IL: Human Kinetics.

Rose, D.J. (2003). *Fall proof: a comprehensive balance and mobility training program*. Champaign IL: Human Kinetics.

Rose, D.J., Lucchese, N., & Wiersma, L. (2006). Development of a multidimensional balance scale for use with functionally independent older adults. *Archives of Physical Medicine and Rehabilitation*, *87*(11), 1478-85.

Rosengren, K., McAuley, E., & Mihalko, S. (1998). Gait adjustments in older adults: activity and efficacy influences. *Psychology and Aging, 13*(3), 375-86.

Rubenstein, L. (2006). Falls in older people: epidemiology, risk factors and strategies for prevention. *Age Ageing*, 35 (2), 37-4.

Safrit, M. (1990). The validity and reliability of fitness tests for children: a review. *Pediatric Exercise Science*, *2*(1), 9-28.

Secretaria Regional dos Assuntos Sociais. (2009). *Plano Gerontológico da RAM: Viver mais, Viver Melhor 2009-2013*. Região Autónoma da Madeira.

Skelton, D. (2001). Effects of physical activity on postural stability. *Age Ageing*, *30* (4), 33-9.

SPSS. (2010). Statistical Package for the Social Sciences. *Version 18.0*. Chicago, IL: SPSS, Inc.

Stevens, A., Powell, E., Smith, M., Wingo, A., & Sattin, W. (1997). Physical activity, functional limitations, and the risk of fall-related fractures in community-dwelling elderly. *Annals of Epidemiology*, *7*(1), 54-61.

Tinetti, M., & Kumar, C. (2010). The patient who falls: “It’s always a trade-off”. *The Journal of the American Medical Association*, *303*(3), 258-66.

Winter, D., Patla, A., Frank, J., & Walt, S. (1990). Biomechanical walking pattern changes in the fit and healthy elderly. *Physical Therapy*, *70*(6), 340-7.

World Health Organization. (2007). *WHO global report on falls prevention in older age*. Retrieved Nov. 21, 2010, from http://www.who.int/ageing/publications/ Falls_prevention7March.pdf.

Chapter 8

Non-bone Lean Tissue Mass and Physical Activity in Elderly Portuguese Men and Women.

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8.1 Abstract

Background: Associations between physical activity (PA) and lean tissue mass are complex, gender, age and body segment dependent.

Objective: The aims of this study are therefore: (1) to study the age-related decline in total body non-bone lean tissue mass and appendicular lean tissue mass (2) to document gender differences in non-bone lean tissue mass and appendicular lean tissue mass, (3) to identify the associations between daily PA and lean tissue mass and appendicular non-bone lean tissue mass in older adults 60 to 79 years of age from Madeira.

Design: This cross-sectional study included 802 participants (401 males) aged 60-79 years old. Non-bone lean soft tissue (further called lean tissue) of the total body, and appendicular body segments (arm and legs) was determined by dual-energy x-ray absorptiometry-DXA. PA was assessed during face-to-face interviews using the Baecke questionnaire.

Results: In Madeira's elderly, lean tissue tended to decline with age and men had greater absolute and mass relative lean tissue mass. In contrasting age- and sex-specific PA groups, only a few differences were observed in favour of the more active. Correlation and multivariate analyses showed a positive but small contribution (Betas vary between 0.041 and 0.074) of PA to the variation in lean tissue mass. Sex, height and fat mass explained most of the variation in lean tissue mass. Conclusion: This study suggests that PA exerts only a minor role in differentiation of lean tissue mass among elderly Portuguese males and females but that fat mass is positively associated with higher lean tissue.

Key words: Elderly, Non-bone Soft Tissue, Physical Activity, Skeletal Muscle.

8.2 Introduction

Sarcopenia or the gradual loss of muscle mass that happens to everyone with age is associated with increased mortality, even after adjusting for major clinical variables. In addition, it is accompanied with functional decline and disability (Janssen, Heymsfield, & Ross, 2002; Roubenoff & Castaneda, 2001; Roubenoff, 2003; Aagaard, Suetta, Caserotti, Magnusson, & Kjaer, 2010). With increasing age and starting from about 40-45 years onwards lean tissue mass as well as skeletal muscle mass progressively decline, but longitudinal data over extended periods of time are lacking (Baumgartner, 2005; Mazess, Hanson, & Barden, 2000). The gradual decline in lean tissue mass or skeletal muscle mass leads ultimately to sarcopenia, often defined as lean tissue mass lower than 2SD below the average of young (25-30 years) healthy adults (Janssen et al., 2002; Baumgartner et al.,1998). The prevalence of sarcopenia below the age of 70 is about 10 to 20% in white and Hispanic men and women of New Mexico, USA, but, in persons above 80 years the prevalence is >50% (Baumgartner et al., 1998). The loss of skeletal muscle mass is associated with a loss in muscular strength, power and functional ability

(Akima et al., 2001; Frändin & Grimby, 1994; Häkkinen et al., 1998; Izquierdo et al., 1999; Visser et al., 2002). Parallel to the age-related decline in skeletal muscle mass and function, PA volume and intensity also decline with age (Kruger, Yore, Kohl, 2007; ACSM et al., 2009; Speakman & Westerterp, 2010). Since PA is most likely related to the maintenance of body mass (BM) it is also of interest to note that less than half the people who tried to maintain weight were regularly active during leisure-time (Kruger et al., 2007).

Since the 80s, several randomized controlled trials provided ample evidence that high intensity resistance training improves strength, power, functional performance and even muscle cross sectional area and muscle mass also in the elderly (Häkkinen et al., 2002; Porter, 2001; Roth, Ferrell, Hurley, 2000; Steib, Schoene, Pfeifer, 2010; Toth, Beckett, Poehlman, 1993; Whiteford et al., 2010). Resistance training (2-3 days/week for the major muscle groups) is considered as an important intervention in the combat of the decline in muscle strength, power, performance function and sarcopenia, and is recommended as part of a healthy and physically active lifestyle for older adults (Aagaard, et al., 2010; ACSM et al., (2009); Nelson et al., 2007; Lynch, 2004). The types of most popular physical activities in older non-agrarian adults are walking, gardening, golf and low-impact aerobic activities (ACSM et al., 2009). However, currently, only 10-15% of older adults perform muscle-strengthening exercises at least twice a week (Nelson et al., 2007; Winett, Williams, Davy, 2009).

There is a paucity of data concerning the impact of daily PA on the age-related decline in skeletal muscle, lean tissue mass, and non-bone lean tissue mass in the elderly. Recently, it was demonstrated that in elderly habitual walkers and those who walked at higher speeds had muscle mass above the sarcopenia threshold or had higher lean body mass (Fiser et al., 2010; Park, Park, Shephard, & Aoyagi, 2010). Step counts were also associated with increased leg strength and muscle quality in older women, but in men and women no associations were found with lean leg mass (Scott, Blizzard, Fell, & Jones, 2009). However, it is still uncertain whether and which types of PA provide benefit to muscle preservation in older populations.

The aims of this study are therefore: (1) to study the age-related decline in whole body non-bone lean tissue mass and non-bone appendicular lean tissue mass, (2) to document gender differences in non-bone lean tissue mass and (3) to identify the associations between daily PA and non-bone tissue mass in older adults 60-80 years of age, a large proportion of whom maintain a fairly active agrarian lifestyle well into their 6th decade.

8.3 Methods

8.3.1 Study design and participants

This cross-sectional study included 802 participants (401 males and 401 females) distributed similarly over four age-cohorts (60-64, 65-69, 70-74, and 75-79 years). Participants were sufficiently mobile and independent to visit the laboratory of Human Physical Growth and Motor Development of the University of Madeira on their own. Proportional regional (geographic) representation was determined by stratified sampling based on Census 2001 data from Statistics Portugal (INE, 2002) with the number of participants per age cohort and sex serving as stratification factors. Participants were volunteers recruited via advertisements for a large population study on bone health and PA distributed via newspapers and through churches, senior groups and senior centres throughout the island of Madeira and Porto Santo.

The study was approved by the University of Madeira, the Regional Secretary of Education and Culture, and the Regional Secretary of Social Affairs. All participants were informed about the nature and purposes of the study and written informed consent was obtained from each subject.

8.3.2 Anthropometry and non-bone lean tissue mass

BM (kg) was measured with a balance scale accurate to 0.1kg (Seca alpha digital scales model 770, Germany) and standing height (cm) with a Holtain stadiometer (Holtain Ltd., Crymych. United Kingdom), accurate to 0.1cm. Participants wore light, indoor clothing without shoes during the measurements. Body mass index [weight (kg)/height (m^2)] was calculated as an indicator of overweight and obesity.

As previously demonstrated (Kim, Heymsfield, Baumgartner, & Gallagher, 2002; Dorsey, Thornton, Heymsfield, Gallagher, 2010), total non-bone lean soft tissue mass (TLTM), non-bone lean tissue mass of arms (ALTM), and legs (LLTM) were measured by

Dual Energy x-ray absorptiometry-DXA (Lunar Prodigy Primo, with technologic fan beam – GE Healthcare, Encore 2007 software version 11.40.004). After removing all objects suspected or known to contain metal, participants were positioned by the technician according to the manufacturer's recommended protocol. Participants were in a supine position. Appendicular lean soft tissue (ALST) was calculated as the sum of ALTM + LLTM. Furthermore, relative values were calculated, similar to the calculation of percent fat mass, namely RTLTM (TLTM / total mass), RALTM (ALTM / total arm mass), RLLTM (LLTM / total leg mass), and RALST (ALST / total legs and arms mass). The relative values were expressed as a percentage. In addition, the scans yielded information on bone mineral density (BMD g/cm^2) of the total body, total body fat mass (TFM) and fat mass of the arms (AFM) and legs (LFM). Following Baumgartner et al. (1998), and for comparative reasons, an additional relative appendicular lean tissue mass was calculated as ALST (kg) / height^2 (m^2), and sarcopenia was defined as values two standard deviations below the sex-specific means of the Rosetta Study reference data for young adults aged 18-40 years. Cut-off values of the RALST for men were 7.26 kg/m^2 and for women 5.45 kg/m^2.

Scans were standardized daily against a calibration phantom; the precision error for BMD expressed as the coefficient of variation (CV %) was 0.31%. Scans were taken alternately by four different technicians over the course of data collection. All technicians received an identical 5 days DXA training course before the start the study using the manufacturer's recommended protocol. Reliability of the DXA measurements was determined on a sub-sample of 17 males and females aged 69.3 ± 5 years. Technicians were paired and members of each pair performed separate lumbar spine (LS) and hip scans on half the participants each (9 and 8 participants, respectively, per pair). Participants were repositioned after every scan. Results from both pairs of assessors were pooled and the technical error of the measurements (TEM) was determined. TEM was used to determine inter-observer error, as occurs when two technicians independently measure the same thing. The TEM for BMD ranged from 0.19% for total hip to 0.50% for the LS. Inter-observer reliability was also determined using the CV, that expresses sample variability relative to the mean of the sample, derived from the duplicate scans on each subject from both pairs of technicians. The CV% was 1.72% for LS, 2.10% for the femoral neck (FN), 2.53% for Ward's triangle and 0.88% for the total femur. Intra-class correlations (R) for repeated measurements of the non-bone lean tissue mass (TLTM, ALTM, LLTM, ALST) of 27 Madeira's elderly varied between 0.946 (LLTM) and 0.990 (TLTM).

8.3.3 Physical activity measures

Total PA was assessed during face-to-face interviews using the Baecke questionnaire developed in the Netherlands (Baecke, Burema, & Frijters, 1982). This questionnaire includes a total of 16 questions classified into three specific domains: PA at work, sport and leisure time, the latter excluding sports. Numerical coding for most response categories varied from 1 to 5 (Likert scale) ranging from never to always or very often. Questions 1 and 9 pertaining to main occupation and types of sports played, respectively, required a written response. PA indices were calculated according to specific formulae for work (questions 1- 8), sport (questions 9-12) and leisure time (questions 13-16).

If the participants were not employed or if they were retired, their occupation was coded as homemaker. The work index includes information about sitting, standing, walking, lifting, and if sweating at work was elicited, as well as information about fatigue after work or household activities (HS). Additionally, each subject was asked how they perceived their activity at work or during HS in relationship to that of others their own age. A sport score (one or two main sports) was also calculated from a combination of the intensity, amount of time per week, and proportion of the year the sport was practiced. The leisure-time activity index was based on the frequency of walking and cycling either for leisure and /or to work or shopping. In all other analysis, PA categories were calculated based on the questionnaire's total score. Intra-class correlation-coefficients were calculated to determine the test-retest reliability of the questionnaire in a pilot study involving 32 males and 59 females (68.3± 7.6 years). Over an interval of 1 week, correlations were 0.83, 0.85 and 0.85 for the work, sport and leisure-time indices, respectively. Our reliability scores for work and sport PA were similar to those obtained by Baecke et al. (1982) in a sample of Dutch adult men and women (0.88, 0.81) and with a more recent study by Ono et al. (2007) of middle aged women (0.84, 0.83). However, our correlations were higher for leisure time index than those reported by either Baecke et al. (1982) or Ono et al. (2007) 0.74 and 0.78, respectively. The validity of the Baecke questionnaire has also been established by Ono et al. (2007) for this population against the more objective measure of movement counts using digital pedometer and uniaxial accelerometer (Lifecorder, Suzuken Co., Nagoya, Japan); correlations ranged from (0.30-0.49) for the 3 dimensions of PA assessed with the Baecke questionnaire in this study.

8.3.4 Health questionnaire and nutritional habits

Demographic information and a complete health history were obtained by telephone interview. A modified version of the health questionnaire employed in the FallProof! Programme (Rose, 2003), was used to assess behaviour and lifestyle characteristics, including smoking history, history of degenerative diseases and osteoarthritis, fracture history, current and past therapy with specific classes of medications including hormones (estrogens and thyroid), calcium supplements, aspirin, vitamin D, anxiolytic drugs and sleeping aids.

Dietary intake was estimated using a semi-quantitative food frequency questionnaire developed by the Epidemiology and Hygiene Service of Porto University (Lopes, 2000). This questionnaire included the amount of dietary calcium from the consumption of dairy products (e.g., milk, cheese, ice cream, yogurts), as well as leafy green vegetables and fish. In addition, this questionnaire assessed caffeine and alcohol intake (combination of consumption of wine, beer and liquor drinks). In this manuscript only alcohol consumption was included as confounding characteristic.

8.3.5 Statistical analysis

Descriptive characteristics of participants were reported as means ± SDs. All data were tested for normality by the Kolmogorov-Smirnov statistic. If required, non-normal distributed characteristics were appropriately transformed using log10, square root or inverse transform functions. ANOVAs were calculated to test for mean differences between age groups and sex- and age-specific mean differences between PA-tertiles in lean tissue mass measurements (TLTM, ALTM, LLTM, ALST, RTLTM, RALTM, RLLTM, RALST). Mean differences in lean tissue mass between men and women were tested with a t-test for independent groups.

Sex specific univariate associations between the lean soft tissue mass measurements and putative predictors of lean tissue mass (age, age^2, height, BM, BMI, fat mass, alcohol consumption, total PA and sports related PA) were calculated for all age-cohorts combined using Pearson correlations. Multiple regression (MLR) analysis was then used to identify the contribution of the predictors for total body non-bone lean soft tissue mass and the lean soft tissue mass of arms and legs and the appendicular (sum of arms and legs) lean soft tissue mass. Betas, namely standardized regression coefficients, were used to assess the independent contributions of each predictor, and the R^2s indicated the percentage of explained variance by the predictors for each non-bone lean soft tissue mass separately. The standard MLR was used, with all predictors entered into the equation simultaneously. The selection of the putative predictors (sex, age, height, fat mass and physical activity) was based on known key important predictors previously identified in the literature, and the strength and significance of the zero-order correlations in the preliminary analysis. Since body dimensions were introduced as putative predictors, the MLR was done only with the absolute lean tissue masses (TLTM, ALTM, LLTM, and ALST). The level of significance was set at $P < 0.05$. Analyses were performed using SPSS, version 17.0 (SPSS, 2010) and SYSTAT 13 (SYSTAT, 2010).

8.4 Results

Age related changes in lean tissue mass are reported in Table 8.1. On average, absolute lean mass (TLTM, ALTM, LLTM, ALST) declined with age in both, men and women, although there was no significant decline between successive age groups. In contrast, relative lean tissue mass (RLTM, RLLTM, RALTM and RALST) and fat measurements remained fairly constant.

In men, total PA was similar in all age groups, whereas sports related PA (PA sport) was similar in the youngest age groups (60-64 and 65-69 years), but declined thereafter. The opposite was observed in women, where total PA was similar in the two youngest age groups but declined thereafter, and there were no age-related differences for sport related PA.

Sex differences for absolute and relative lean tissue mass for the total age group are summarized in Table 8.2. For all characteristics men had higher absolute and relative lean tissue mass compared to women.

With few exceptions, no significant differences for absolute or relative lean tissue mass were observed when age-specific activity groups (low, medium and high level) were contrasted (results not shown). Of interest, however, the relative lean tissue mass (RTLM, RALTM, RLLTM, and RALST) of the high active group was higher compared to the low active group in men 70 to 74 years (Figure 8.1, panel a-d). No consistent other differences were observed.

Sex-specific correlations, calculated over the entire age span, between the absolute lean tissue mass and age or age^2 were negative, confirming the decline with age in lean soft tissue (Table 8.3). Height, BM, BMI, and fat mass were positively related to absolute lean soft tissue mass, but negatively to relative lean tissue mass in both sexes. In men, total PA was positively associated with relative lean tissue mass, but correlations were rather low (0.112 to 0.216) and negative with RALTM. In women, absolute and relative lean tissue mass were related to total PA and absolute lean tissue to sports related PA. Again, negative associations were observed for RALTM. In women, alcohol consumption showed low positive associations with RTLTM and RALST, but low negative associations with RALTM.

Table 8.1 Age and sex-specific descriptive characteristics (Mean and SD).

	Age groups (years)			
	60 – 64	65 – 69	70 – 74	75 – 79
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
Men				
Age (years)	62.7±1.5^{a}	67.6±1.5^{b}	72.6±1.6^{c}	77.2±1.4^{d}
Height (cm)	166.9±5.2^{a}	165.9±6.2^{ab}	164.5±6.1^{b}	164.6±6.2^{b}
BM (kg)	80.3±12.1^{a}	79.7±13.1^{a}	79.9±13.3^{a}	75.8±13.0^{a}
BMI (kg/m^{2})	28.8±3.8^{ab}	29.0±4.0^{ab}	29.5±4.0^{a}	27.9±4.1^{b}
TLTM (kg)	54.3±5.9^{a}	53.3±5.8^{ab}	52.8±5.5^{ab}	51.2±6.3^{b}
RLTM (%)	68.6±6.7^{a}	67.6±6.1^{a}	67.2±6.7^{a}	68.5±6.4^{a}
TFM (kg)	22.5±8.1^{a}	23.3±7.9^{a}	23.6±8.6^{a}	21.5±8.2^{a}
LLTM (kg)	17.2±2.5^{a}	17.0±2.3^{a}	16.5±2.2^{ab}	16.1±2.3^{b}
RLLTM (%)	72.9±6.4^{a}	71.8±5.4^{a}	71.0±6.1^{a}	71.4±5.8^{a}
LTFM (kg)	5.5±2.4^{a}	5.7±2.3^{a}	5.8±2.3^{a}	5.5±2.3^{a}
ALTM (kg)	6.6±1.1^{a}	6.5±0.9^{ab}	6.1±1.0^{bc}	5.8±1.0^{c}
RALTM (%)	74.4±6.6^{a}	3.0±5.7^{a}	72.1±7.3^{a}	73.2±6.9^{a}
ATFM (kg)	1.9±0.9^{a}	2.1±1.0^{a}	2.0±0.9^{a}	1.8±0.8^{a}
ALST (kg)	23.8±3.4^{a}	23.4±3.1^{ab}	22.6±3.0^{bc}	21.8±3.1^{c}
RALST (%)	73.3±6.3^{a}	72.1±5.3^{a}	71.3±6.2^{a}	71.9±5.8^{a}
Total PA (3-15)	7.6±1.3^{a}	7.3±1.2^{a}	7.1±1.4^{a}	7.2±1.2^{a}
PA sport (1-5)	2.2±0.6^{a}	2.2±0.6^{a}	2.0±0.6^{ab}	1.9±0.5^{b}
Alcohol (dl/day)	16.7±20.5^{a}	13.1±17.3^{a}	11.6±18.2^{a}	9.2±15.3^{b}
Women				
Age (years)	62.5±1.3^{a}	67.7±1.5^{b}	72.4±1.4^{c}	77.3±1.5^{d}
Height (cm)	154.2±5.4^{a}	153.8±5.5^{ab}	152.0±5.8^{bc}	150.1±5.4^{c}
BM (kg)	72.2±11.7^{a}	71.2±12.7^{a}	70.6±10.6^{a}	67.8±11.5^{b}
BMI (kg/m^{2})	30.5±4.6^{a}	30.2±5.2^{a}	30.3±4.0^{a}	30.0±4.4^{a}
TLTM (kg)	39.9±4.9^{ab}	40.0±5.5^{a}	39.3±3.9^{ab}	38.2±4.3^{b}
RLTM (%)	56.0±5.4^{a}	57.0±5.6^{a}	57.1±5.5^{a}	57.6±5.9^{a}
TFM (kg)	29.7±7.8^{a}	28.7±8.0^{a}	28.2±7.3^{a}	27.1±7.8^{a}
LLTM (kg)	12.6±1.7^{a}	12.5±1.9^{ab}	12.2±1.6^{bc}	11.8±1.8^{c}
RLLTM (%)	56.7±6.7^{a}	57.1±6.5^{a}	57.5±6.7^{a}	57.4±6.4^{a}
LTFM (kg)	9.1±3.0^{a}	8.8±2.7^{a}	8.5±2.6^{a}	8.4±2.8^{a}
ALTM (kg)	4.2±0.7^{a}	4.1±0.7^{a}	3.8±0.6^{b}	3.8±0.7^{b}
RALTM (%)	55.2±5.9^{a}	55.6±6.2^{a}	55.7±6.0^{a}	55.4±8.7^{a}
ATFM (kg)	3.2±1.1^{a}	3.1±1.1^{a}	2.9±0.9^{a}	2.9±1.0^{a}
ALST (kg)	16.8±2.3^{a}	16.6±2.5^{a}	16.0±2.0^{ab}	15.6±2.3^{b}
RALST (%)	56.3±6.2^{a}	56.6±6.0^{a}	57.0±6.1^{a}	56.5±6.6^{a}
Total PA (3-15)	7.5±1.3^{a}	7.5±1.1^{ab}	7.3±1.1^{bc}	6.9±1.2^{c}
PA sport (1-5)	2.2±0.6^{a}	2.3±0.6^{a}	2.3±0.6^{a}	2.1±0.6^{a}
Alcohol (dl/day)	2.1±3.9^{a}	1.5±4.1^{a}	1.2±2.7^{a}	1.3±2.9^{a}

SD, standard deviation; BM, body mass; BMI (kg/m^{2}), body mass index; TLTM, total soft lean tissue mass; RLTM, relative soft lean tissue mass; TFM, total fat mass; LLTM, legs soft lean tissue mass; RLLTM, relative legs soft lean tissue mass; LTFM, Legs total fat mass; ALTM, arms soft lean tissue mass; RALTM, relative arms soft lean tissue mass; ATFM, arms total fat mass; ALST, appendicular lean tissue mass; RALST, relative appendicular lean tissue; PA, physical activity; descriptive characteristics with dissimilar alphabetic superscripts indicate significant differences ($p < .05$) among age groups.

Table 8.2 Sex differences in muscle tissue.

	Men M±SD	Women M±SD	*p*	Contrast†
TLTM (kg)	52.9±6.0	39.4±4.8	<0.001	1> 2
RLTM (%)	68.0±6.5	56.9±5.6	<0.001	1> 2
ALTM (kg)	6.2±1.0	4.0±0.7	<0.001	1> 2
RALTM (%)	73.2±6.7	55.5±6.7	<0.001	1> 2
LLTM (kg)	16.7±2.4	12.3±1.8	<0.001	1> 2
RLLTM (%)	71.8±6.0	57.2±6.5	<0.001	1> 2
ALST (kg)	22.9±3.2	16.3±2.3	<0.001	1> 2
RALST (%)	72.1±6.0	56.6±6.2	<0.001	1> 2

† t-test student; $p < .05$; SD, standard deviation; TLTM, total soft lean tissue mass; RLTM, relative soft lean tissue mass; ALTM, arms soft lean tissue mass; RALTM, relative arms soft lean tissue mass; LLTM, legs soft lean tissue mass; RLLTM, relative legs soft lean tissue mass; ALST, appendicular lean tissue mass; RALST, relative appendicular lean tissue mass.

In the MLR analysis, the contributions of sex, age, height, fat mass and total PA in explaining variation in absolute lean tissue mass was investigated. The contributions of the putative predictors for TLTM and ALST are provided in Table 8.4. For TLTM and ALST, sex, height and fat mass were the most important predictors, followed by total PA and age. For TLTM, age was not a significant predictor. Betas were negative for sex and age indicating that women and older people had lower lean tissue mass. Height, fat mass and total PA were positively associated to TLTM and ALST. The total explained variance of lean tissue mass was very high ($r^2 = 0.79$ for TLTM and $R^2 = 0.76$ for ALST). The Beta's for total PA indicated that for each increase by 1 SD (SD varies between 1.1 and 1.4 units on the Baecke scale) in total PA, TLTM will increase by 0.041 SD and ALST by 0.074 SD. Very similar associations were found for ALTM and LLTM (results not shown).

For comparative reasons the prevalence of sarcopenia in each of the age categories for women and men were calculated using the same procedures as in Baumgartner et al. (1998). Prevalence's of sarcopenia increased from 5.8 % to 21.7 % in men and from 2.9 % to 6.5 % in women. In the total sample of men, those with sarcopenia had significantly lower PA-scores for the Baecke work-, leisure time- and total-PA index. In women no significant PA-differences were found between women with and without sarcopenia.

Table 8.3 Sex-specific Pearson correlations between body composition components and selected descriptive characteristics.

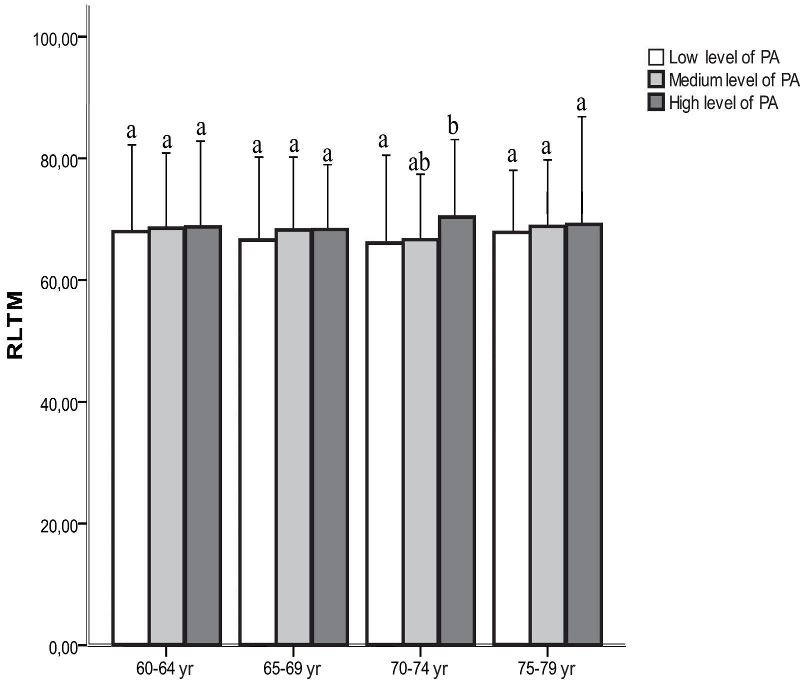
	TLTM (kg)	RLTM (%)	LLTM (kg)	RLLTM (%)	ALTM (kg)	RALTM (%)	ALST (kg)	RALST (%)
Men								
Age (years)	-0.181†	-	-0.187†	-	-0.288†	-	-0.230†	-
Age^2	-0.183†	-	-0.188†	-	-0.289†	-	-0.231†	-
Height (cm)	0.635†	-0.184†	0.613†	-0.145†	0.448†	-0.135†	0.592†	-0.147†
BM (kg)	0.774†	-0.706†	0.628†	-0.627†	0.517†	-0.615†	0.626†	-0.644†
BMI (kg/m^2)	0.599†	-0.754†	0.431†	-0.673†	0.383†	-0.664†	0.438†	-0.693†
TFM (kg)	0.469†	-0.925†	0.365†	-0.855†	0.232†	-0.833†	0.342†	-0.877†
ATFM (kg)	0.357†	-0.738†	0.301†	-0.727†	0.249†	-0.823†	0.300†	-0.779†
LTFM (kg)	0.397†	-0.809†	0.406†	-0.907†	0.211†	-0.765†	0.364†	-0.895†
PA sport (1-5units)	-	-	-	-	-	-	-	-
Total PA(3-15units)	-	0.173†	-	0.209†	0.112‡	-0.203†	-	0.216†
Alcohol (dl/day)	-	-	-	-	-	-	-	-
Women								
Age (years)	-0.149†	-	-0.193†	-	-0.245†	-	-0.221†	-
Age^2	-0.151†	-	-0.194†	-	-0.245†	-	-0.222†	-
Height (cm)	0.511†	-0.121‡	0.561†	-	0.453†	-	0.565†	-
BM (kg)	0.799†	-0.664†	0.644†	-0.506†	0.600†	-0.489†	0.672†	-0.499†
BMI (kg/m^2)	0.635†	-0.704†	0.443†	-0.551†	0.442†	-0.533†	0.471†	-0.556†
TFM (kg)	0.574†	-0.885†	0.461†	-0.733†	0.461†	-0.652†	0.491†	-0.724†
ATFM (kg)	0.487†	-0.711†	0.423†	-0.558†	0.607†	-0.760†	0.505†	-0.644†
LTFM (kg)	0.396†	-0.797†	0.461†	-0.864†	0.389†	-0.538†	0.469†	-0.799†
PA sport (1-5units)	0.114‡	-	0.180†	-	0.100‡	-	0.168†	-
Total PA(3-15units)	-	0.106‡	0.184†	0.123‡	0.123‡	-0.157†	0.178†	0.154†
Alcohol (dl/day)	-	0.110‡	-	-	-	-0.137†	-	0.117‡

Only correlations that were statistically significant were included; ‡ correlation is significant at the 0.05 level (2-tailed); † Correlation is significant at the 0.01 level (2-tailed); BMI, body mass index; TLTM, total soft lean tissue mass; RLTM, relative soft lean tissue mass; TFM, total fat mass; LLTM, legs soft lean tissue mass; RLLTM, relative legs soft lean tissue mass; LTFM, Legs total fat mass; ALTM, arms soft lean tissue mass; RALTM, relative arms soft lean tissue mass; ATFM, arms total fat mass; ALST, appendicular lean tissue mass; RALST, relative appendicular lean soft tissue mass; PA, physical activity.

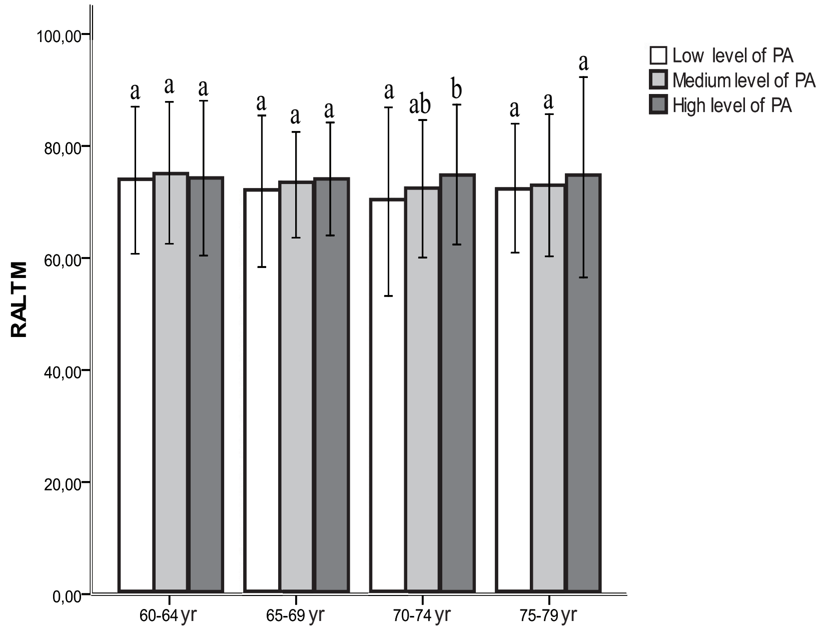
8.5 Discussion

The association between daily physical activity and non-bone lean soft tissue mass among the elderly is equivocal. In our study, only a few age specific significant differences were observed for lean tissue mass outcomes across differing PA levels. Only in men aged 70 to 74 years was the relative lean tissue mass greater in the high active group compared to the low active group.

Panel A

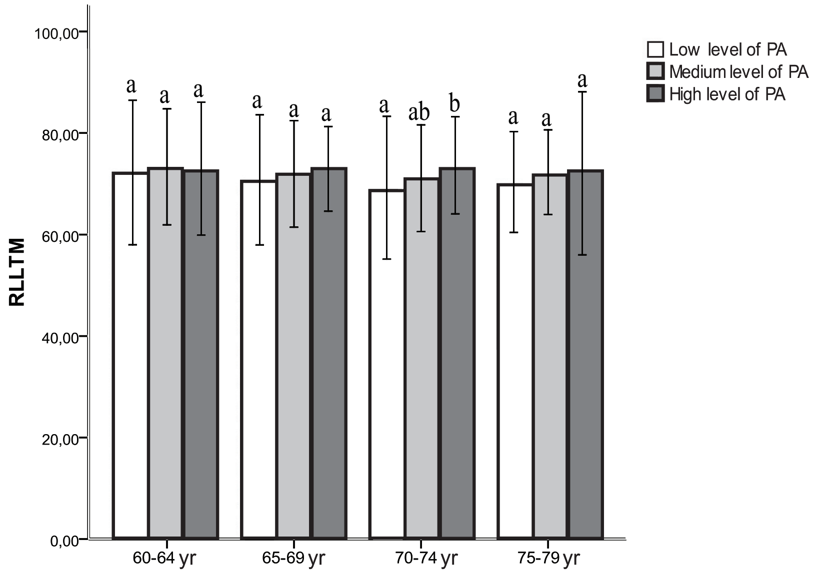


Panel B



Low but positive correlations were found between total PA and relative tissue mass in men and, in women, between absolute and relative lean tissue mass and total PA, as well as sports related PA. Furthermore, total PA contributed to the variation in TLTM and ALST. In addition, men with sarcopenia had lower PA-scores compared with those without sarcopenia. These observations partly confirm previous findings. Scott et al. (2009) found that pedometer counts were associated with maintenance of leg strength and muscle quality in older women (50 to 79 years).

Panel C



Panel D

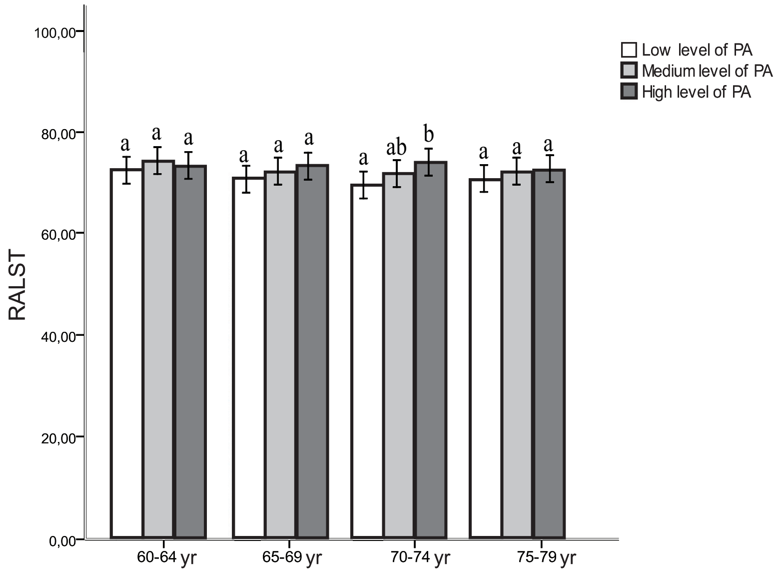


Figure 8.1 Age related differences in relative lean tissue mass of total body (RTLTM-Panel A), arms (RALTM-Panel B), legs (RLLTM-Panel C), and appendicular (RALST-Panel D) in males of contrasting total PA-tertiles. Bars with dissimilar alphabetic superscripts indicate PA groups that are significantly different (p < .05) from each other within a given age cohort. Values are mean ± SD.

Table 8.4 Standard MLR between TLTM (Panel A) and ALST (Panel B) and putative predictors (age, sex, height, fat mass and PA).

Panel A: TLTM (R^2_{adj}= 0.79)

Predictors in order of importance	β	*p*	95 % CI*
Sex (0 men, 1 women)	-0.555	<0.001	- 10.529;-8.650
Height (cm)	0.418	<0.001	0.365; 0.468
TFM (kg)	0.244	<0.001	0.212; 0.286
Total PA (3-15 units)	0.041	0.014	0.058; 0.518
Age (years)	-0.014	0.417	-0.073; 0.030

† Significant contribution by an independent variable to the total explained variation in the model (p < .05); * 95.0% confidence interval for beta-values; TFM, total body fat mass; PA, physical activity;

Panel B: ALST (R^2_{adj} = 0.75)

Predictors in order of importance	β	*p*	95 % CI*
Sex (0 men, 1 women)	-0.544	<0.001	-5.291; -4.193
Height (cm)	0.448	<0.001	0.197; 0.253
Appendicular fat mass (kg)	0.208	<0.001	0.184; 0.280
Total PA (3-15 units)	0.074	<0.001	0.139; 0.387
Age (years)	-0.049	0.007	- 0.066; -0.010

† Significant contribution by an independent variable to the total explained variation in the model (p < .05); * 95.0% confidence interval for beta-values; TFM, total body fat mass; PA, physical activity;

Furthermore, energetics of walking (gait speed and number of steps/day) were associated with higher lean body mass in 65 to 84 year-old Japanese elderly (Park et al., 2010) and in 60 to 88 year-old elderly in the USA (Fiser et al., 2010). In addition, above 52 years of age, fat free mass, daily energy expenditure and activity energy expenditure measured by the doubly labelled water technique were negatively associated with age (Speakman & Westerterp, 2010). However, pedometer counts were not associated with LLTM in community dwelling 50-79 year old Australians (Scott et al., 2009). There is obviously a need to further elucidate these associations, since only a minority of elderly individuals participate in strength training programmes (Nelson et al., 2007; Lynch, 2004) notwithstanding that it has been shown to have a positive impact on muscle mass and muscle function in this population (Häkkinen et al., 2002; Porter, 2001; Roth, Ferrell, & Hurley, 2000; Steib, Schoene, & Pfeifer, 2010; Toth, Beckett, & Poehlman, 1999; Whiteford, et al., 2010)).

Associations between measures of PA and lean tissue mass are more consistent when wider age ranges were considered. This could be explained by the simultaneous decline in lean soft tissue and PA over longer periods. In our study, height declined with age but BMI, fat mass, relative fat mass and relative lean tissue mass remained fairly constant between 60 and 79 years. In both genders, absolute lean tissue mass was lowest in the oldest age group (75 to 79 years). Furthermore, the prevalence of sarcopenia, as defined by Baumgartner et al. (1998), increased with age, especially in men. Total PA was constant in men, but declined in women and sport PA declined in men but was constant in women. Precise measurements of energy expenditure by the doubly labelled water technique indicated that above the age of 52, daily energy expenditure and activity energy expenditure were negatively associated with age (Speakman & Westerterp, 2010). Our findings in a relatively large sample of Madeira's elderly add to the present knowledge about changes with age in skeletal muscle mass and non-bone lean tissue mass, confirming a definitive reduction in non-bone lean tissue mass with ageing in both sexes that appears to be influenced, to a small extend, by current levels of physical activity.

Baumgartner (2005) reviewed the available evidence and concluded that "The relationships between changes with age in muscle strength and size continues to be a controversial issue" (p.266). Part of the controversy lies in the methods used to estimate skeletal muscle mass or non-bone lean tissue mass (Baumgartner, 2005). Magnetic resonance imaging (MRI) estimates of muscle mass indicated relative stability up to 45 years after which accelerated loss of muscle mass was found in both sexes (Janssen, Heymsfield, Wang & Ross, 2000). The non-bone lean tissue mass (TLTM, LLTM, ALTM, ALST) obtained or derived from DXA-scans comprises not only skeletal muscle mass, the largest fraction, but also skin, organ and connective tissue, the smaller fraction. However, Kim et al. (2002) demonstrated that non-bone appendicular lean tissue mass (ALST), as measured in our study, was highly associated with skeletal muscle mass (r^2 =0.96, SEE=1.63 kg). The prediction improved somewhat when age and sex were added as covariates. For comparative reasons, total-body skeletal muscle mass in our study was estimated according to the prediction equation validated by Kim et al.: Total-body SM = (1.13 x ALST) – (0.02 x age) + 0.61 x sex) +0.97 in which sex = 0 for females and sex = 1 for males). If these predictions are valid for our population and applied to our sex- and age-specific ALST-values; the average total-body skeletal muscle mass in men declines from 27.20 kg to 24.72 kg between 60-64 years and 75-79 years. The decline is less pronounced (0.52 kg) between 60-64 years and 65-69 years compared to the other age categories (about 1.0 kg between successive age groups). In women the total-body skeletal muscle mass declines from 18.40 kg at 60 to 64 years to 17.10 kg at 75 to 79 years. As for men, the decline is less pronounced (0.38 kg) between 60-64 and 65-69 years compared to the older age groups (0.56 to 0.72 kg). The average ALST = 22.6 (3.0) kg in men 70-74 years corresponds closely with the New Mexico Elder Health Survey ALST = 22.5 (2.6) kg (Baumgartner et al., 1998) and to the more recent values reported by Hairi et al. (2010) ALST =22.8 (3.0) kg in men aged 70-74 years and 22.1 (3.0) in men aged 75 to 79 years (ALST = 21.8 (3.1) kg in men 75 to 79 years in this sample). ALST-values for women 70 to 74 years are higher (ALST = 16.0 (2.0)) for Madeira women compared to the New Mexico Elder Health Survey (ALST = 14.5 (2.2) kg) (Baumgartner et al., 1998). In addition, total lean soft tissue mass is higher in this sample compared to the values reported by Mazess et al. (2000).

Compared to elderly men Madeira's women have less absolute and relative non-bone lean tissue mass in the total body (TLTM and RLTM) and the appendicular body segments (ALTM, RALTM, LLTM, RLLTM, ALST, RALST) (Table 8.2). This sexual dimorphism which is accentuated during the adolescent growth spurt (Malina, 2005) appears to remain over the entire lifespan. Surprisingly, in all age groups, women (2.9 % to 6.5 %) showed less sarcopenia than men (5.8 % to 21.7 %). This is in contrast to the findings of Baumgartner et al. (1998) who found prevalence's between 13.5% and 26.7 % in Non-Hispanic white men and between 23.1 % and 35.9 % in non-Hispanic white women 60-80 years. Janssen et al. (2000) used bioelectrical estimates of skeletal muscle mass and NHANES III reference data to define sarcopenia cut-off points. According to their definition prevalence's were 6% to 7% in men 60-79 years and 9% to 11% in women.

It can be argued that our sample of community dwelling volunteers was very active for their age. However, the total PA [PA = 7.5 (SD = 1.3)], and sport PA [sport PA = 2.2 (SD = 0.6)] of women 60 to 64 years from our study was somewhat lower than those of healthy post-menopausal volunteers 57 years of age total PA = 7.7 (SD = 2.1) and sport PA = 2.7 (SD = 1.1) (Walsh, Hunter, Livingstone, 2006) both obtained with the Baecke questionnaire. For Madeira's men, total PA (total PA ranged between 7.1 and 7.6 (SD =1.2 to 1.4)) was lower in our study than that of healthy adult Belgians 30 to 40 years of age (PA = 7.9 to 8.8 (SD = 1.4 to 1.8)), (Philippaerts & Lefevre, 1998). Also, the sport PA (sport PA ranges between 1.9 and 2.2) of Madeira's elderly men was lower in our study than that of adult Belgians (sport PA ranges between 2.8 and 3.0) (Philippaerts & Lefevre, 1998). Apart from the PA-levels, the elderly in our sample are small and heavy and their average BMI is high (Table 8.1). But, according to national demographics, there are almost as many female farmers (47 %) as male farmers (53 %) in Madeira (INE, 2002). We verified these percentages in the present sample; in men 35, 2 % and in women 11, 5 % were actively farming, markedly lower than in the national demographics. But, 47,4 % of the men and 38,9 % of the women report to walk at least 30'/day. Furthermore, there was a low association between farming and walking ($r_t = 0.157$). Considering the above we would characterise this sample of Madeira's elderly as small, heavy and fairly active (slightly above average).

The multivariate analyses indicates that, in elderly 60 to 79 years, sex, height and fat mass and to a lesser extend total PA and age contribute to the explained variance in total body and appendicular lean tissue mass ($R^2 = 0.76$ to 0.79). This study suggests that PA exerts only a minor role in differentiation of non-bone lean soft tissue mass among elderly Portuguese males and females and that fat mass is positively associated with higher non-bone lean soft tissue. Suggesting that the higher fat mass might be protecting muscle mass by increased loading during weight supported activities.

Associations between non-bone lean soft tissue and BMD have been reported and discussed previously (Gouveia et al., 2011). Age, BM and LTM entered as the primary and most significant contributors for BMD of total body, LS, FN and Ward's triangle, in both sexes (Gouveia et al., 2011). In conclusion, this study provides some evidence for a positive association between daily PA and TLTM, ALTM and LLTM in elderly Portuguese men and women. Longitudinal studies are badly needed, however, to confirm these associations and to verify if elderly who decline in PA also show more marked loss in skeletal muscle mass. If these associations can be studied in more detail, with objective measurements of PA, this would greatly enhance the promotion of daily PA in the elderly not only for cardiovascular health, obesity, type 2 diabetes and related morbidities, but also for the combat of the age-related decline in muscle mass and associated loss in muscle function and risk of disability. This study also confirmed the persistence of adolescent onset sexual dimorphism in muscle mass into old age. Finally, evidence is provided for a decline in TLTM and ALST, especially after 75 years. However, in both sexes, relative non-bone lean soft tissue remains fairly constant over the 60 to 79 years period.

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Author's Contribution: ERG, DLF and JAM conceived the study design, sampling procedures, selection of measurements/protocols and performed the statistical analysis. CJRB and GPB were responsible for the quality control of the data and drafted the manuscript. ALR supervised the DEXA measurements and CML estimated dietary and alcohol intakes. All the authors contributed to the writing of the manuscript and accepted the final version. The authors had no personal or financial conflict of interest.

8.7 References

Aagaard, P., Suetta, C., Caserotti, P., Magnusson, S.P., & Kjaer, M. (2010). Role of the nervous system in sarcopenia and muscle atrophy with aging: strength training as a countermeasure. *Scandinavian Journal of Medicine & Science in Sports, 20*, 49-64.

Akima, H., Kano, Y., Enomoto, Ishizu, M., Okada, M., Oishi, Y., et al., (2001). Muscle function in 164 men and women aged 20-84 yr. *Medicine and Science in Sports and Exercise, 33*, 220-26.

Baecke, J.A., Burema, J., & Frijters, J.E. (1982). A short questionnaire for the measurement of habitual physical activity in epidemiological studies. *The American Journal of Clinical Nutrition, 36*, 936-42.

Baumgartner, R.N. (2005). Age. In: Heymsfield, S.B., Lohman, T.G., Wang, Z,M., & Going, S.B., eds. *Human body composition* (pp-259-69). Champaign, ILL: Human Kinetics.

Baumgartner, R.N., Koehler, K.M., Gallagher, D., Romero, L., Heymsfield, S.B., Ross, R.R., et al. (1998). Epidemiology of sarcopenia among elderly in New Mexico. *American Journal of Epidemiology*, *147*, 755-63.

American College of Sports Medicine (ACSM), Chodzko-Zajko, W.J., Proctor, D.N., Fiatarone Singh M,A., Minson, C.T., Nigg, C.R, Salem, G.J., et al., (2009). American College of Sports Medicine position stand. Exercise and physical activity for older adults. American College of Sports Medicine position stand. Exercise and physical activity for older adults. *Medicine and Science in Sports and Exercise, 41*(7), 1510-30.

Dorsey, K.B., Thornton, J.C., Heymsfield, S.B., & Gallagher, D. (2010). Greater lean tissue and skeletal muscle mass are associated with higher bone mineral content in children. *Nutrition and Metabolism, 7,* 41-50.

Fiser, W.M., Hays, N.P., Rogers, S.C., Kajkenova, O., Williams, A.E., Evans, C.M., et al., (2010). Energetics of walking in elderly people: factors related to gait speed. *The Journals of Gerontology. Series A, Biological Sciences and Medical Sciences, 65*(12), 1332-7.

Frändin, K., & Grimby, G. (1994). Assessment of physical activity, fitness and performance in 76-year-olds. *Scandinavian Journal of Medicine & Science in Sports*, *4*, 41-46.

Gouveia, E.R., Blimkie, C.J., Freitas, D.L., Maia, J.A., Rodrigues, A.L., Lopes, et al., (2011). Physical Activity and Bone Mineral Density in Elderly Portuguese Men and Women. *(submitted for publication)*.

Hairi, N.N., Cumming, R.G., Naganathan, V., Handelsman, D.J., Le Couteur, D.G., Creasey, H. et al., (2010). Loss of muscle strength, mass (Sarcopenia), and quality (sepcific force) and its relationship with functional limitation and phsyical disability: The Concord Health and Ageing in Men Project. *The Journal of the American Geriatrics Society, 58,* 2055-2062.

Häkkinen, K., Alen, M., Kallinen, M., Izquierdo, M., Jokelainen, K., Lassila, H., et al., (1998). Muscle CSA, force production, and activation of leg extensors during isometric and dynamic actions in middle-aged and elderly men and women. *Journal of Aging and Physical Activity*, *6*, 232-47.

Häkkinen, K., Kraemer, W.J., Pakarinen, A. Triplett-McBride, T., McBride, J.M., Häkkinen, A., et al., (2002). Effects of heavy resistance training on maximal strength, muscle morphology, and hormonal response patterns in 60-75-year-old men and women. *Canadian Journal of Applied Physiology, 27*, 213-31.

Instituto Nacional de Estatística. (2002). *Censos 2001: resultados definitivos: XIV recenseamento geral da população: IV recenseamento geral da habitação.* Lisboa: Instituto Nacional de Estatística.

Izquierdo, M., Ibanez, J., Gorostiaga, E. Garrues, M., Zúñiga, A., Antón, A., et al., (1999). Maximal strength and power characteristics in isometric and dynamic actions of upper and lower extremities in middle-aged and older men. *Acta Physiologica Scandinavica, 167*, 57-68.

Janssen, I., Heymsfield, S.B., & Ross, R. (2002). Low relative skeletal muscle mass (Sarcopenia) in older persons is associated with functional impairment and physical disability. *The Journal of the American Geriatrics Society*, *50*, 889-96.

Janssen, I., Heymsfield, S.B., Wang, Z.M., & Ross, R. (2000). Skeletal muscle mass and distribution in 468 men and women aged 18-88 yr. *American Physiological Society, 89*, 81-88.

Kim, J., Heymsfield, S.B., Baumgartner, R.N., & Gallagher, D. (2002) Total-body skeletal muscle mass: estimation by a new dual-energy X-ray absorptiometry method. *The American Journal of Clinical Nutrition, 76*, 378-83.

Kruger, J., Yore, M.M., & Kohl, H.W. (2007). Leisure-time physical activity patterns by weight control status: 1999-2002 NHANS. *Medicine and Science in Sports and Exercise*, *39*, 788-95.

Lopes, C. (2000). *Diet and acute myocardial infarction: a population based case-control study. Reproducibility and validity of a semi-quantitative food frequency questionnaire*. Unpublished doctoral dissertation, University of Porto – Portugal.

Lynch, G.S. (2004). Tackling Australia’s health problems: developing strategies to combat sarcopenia – age-related muscle wasting and weakness. *Internal Medicine Journal, 34*, 294-96.

Malina, R.M. (2005). Variation in body composition associated with sex and ethnicity. In: Heymsfield, S.B., Lohman, T.G., Wang, Z.M., & Going, S.B., eds. *Human body composition* (pp. 271-298). Champaign, ILL: Human Kinetics.

Mazess, R.B., Hanson, J.A., & Barden, R.H. (2000). Total body bone and soft tissue composition by dual x-ray absorptiometry. *Journal Bone Mineral Research, 15*(Suppl 1), 520-21.

Nelson, M.E., Rejeski, W.J., Blair, S.N., Duncan, P.W., Judge, J.O., King, A.C. et al., (2007). Physical activity and public health in older adults: Recommendation from the American College of Sports medicine and the American Heart Association. *Medicine and Science in Sports and Exercise, 39,* 1435-45.

Ono, R., Hirata, S., Yamada, M., Nishiyama, T., Kurosaka, M., & Tamura, Y. (2007). Reliability and validity of the Baecke physical activity questionnaire in adult women with hip disorders. *BioMed Central Musculoskeletal Disorders, 8*, 61.

Park, H., Park, S., Shephard, R.J., & Aoyagi, Y. (2010). Yearlong physical activity and sarcopenia in older adults: the Nakanojo Study. *European Journal of Applied Physiology, 109*, 953-61.

Philippaerts, R.M., & Lefevre, J. (2008). Reliability and validity of three phsyical activity questionnaires in Flemish males. *American Journal of Epidemiology, 147*, 982-90.

Porter, M.M. (2001). The effects of strength training on sarcopenia. *Canadian Journal of Applied Physiology*, 26, 123-141.

Rose, D.J. (2003). *Fallproof: A comprehensive balance and mobility training program*. Champaign, IL. Human Kinetics.

Roth, S.M., Ferrell, R.E., & Hurley, B.F. (2000). Strength training for the prevention and treatment of sarcopenia. *The Journal of Nutrition, Health & Aging, 4*, 143-55.

Roubenoff, R., & Castaneda, C. (2001). Sarcopenia-Understanding the dynamics of aging muscle. *The Journal of the American Medical Association, 286*, 1230-31.

Roubenoff, R. (2003). Sarcopenia: Effects on body composition and function. *The Journals of Gerontology.Series A, Biological Sciences and Medical Sciences*, *58*A, 1012-17.

Scott, D., Blizzard, L., Fell, J., & Jones, G. (2009). Ambulatory activity, body composition, and lower-limb muscle strength in older adults. *Medicine and Science in Sports and Exercise*, *41*, 383-89.

Speakman, J.R., & Westerterp, K.R. (2010). Associations between energy demands, physical activity, and body composition in adult humans between 18 and 96 y of age. *The American Journal of Clinical Nutrition*, *98*, 826-34.

SPSS. Statistical Package for the Social Sciences. Version 17.0. Chicago, IL:SPSS, Inc, 2010.

Steib, S., Schoene, D., & Pfeifer, K. (2010). Dose-response relationship of resistance training in older adults: A meta-analysis. *Medicine and Science in Sports and Exercise*, *42*, 902-14.

SYSTAT. (2010). *SYSTAT 13*. Washington: Systat Software, Inc

Toth, M.J., Beckett, T., & Poehlman, E.T. (1999). Physical activity and the progressive change in body composition with aging: current evidence and research issues. *Medicine and Science in Sports* *and Exercise*, *31*(11suppl), 590-S596.

Visser, M., Kritchevsky, S.B., Bret, H., Newman, A.B., Nevitt, M., Stamm, E., et al., (2002). Leg muscle mass and composition in relation to ower extremity perfoprmance in men and women aged 70 to 79: The Health, Aging and Body Composition Study. *The Journal of the American Geriatrics Society, 50*, 897-904.

Walsh, M.C., Hunter, G.R., & Livingstone, M.B. (2006). Sarcopenia in premenopausal and postmenopausal women with osteopenia, osteoporosis and normal bone mineral density. *Osteoporosis International, 17*, 61-67.

Whiteford, J., Ackland, T.R., Dhaliwal, S.S., James, A.P., Woodhouse, J.J., Price, R., et al. (2010). Effect of a 1-year randomozed controlled trial of resistance training on lower limb bone and muscle structure and function. *Osteoporosis International, 21*, 1529-36.

Winett, R.A., Williams, D.M., & Davy, B.M. (2009). Initiating and maintaining resistance training in older adults: a social cognitive theory-based approach. *British Journal of Sports Medicine, 43,* 114-19.

Chapter 9

Summary and Discussion

9.1 Summary

There is a general agreement that regular PA and high levels of FF contribute to a healthier and independent lifestyle in older adults and greatly improve their functional capacity and quality of live (Spirduso, Francis, & MacRae, 2005). In the aging process, all strategies to promote active and successful aging must be integrated into a comprehensive and far-reaching public policy that embraces a multifactorial approach to successful aging (World Health Organization [WHO], 2002).

This study attempts to get a general "picture" of biological and environmental characteristics of Madeira community-residing older adults. To our knowledge, no attempt had been made in ARM in order to generate normative values and to study the associations of human somatic dimensions, PA an FF.

The purpose of this study was threefold: (1) to construct normative values for FF; (2) to describe the associations between levels of PA, FF, other lifestyle, bone health/strength and body composition; and (3) to identify sex- and age-related changes in FF parameters.

In total, 802 participants (401 males and 401 females) distributed similarly over four age-cohorts (60-64, 65-69, 70-74, and 75-79 years old) participated in this cross-sectional study entitled 'Health and quality of life of older adults from Autonomous Region of Madeira, Portugal'. The human somatic dimensions characteristics included body mass, height, sitting height, skeletal breadths, girths and skinfolds thickness. PA was assessed during face-to-face interviews using the Baecke questionnaire. FF was assessed using the Senior Fitness Test. FSI and BMD of the total body, LS, hip (FN, trochanter, Ward's triangle and total hip) and TLTM and TFM were determined by dual-energy x-ray absorptiometry-DXA. Balance was assessed using the FAB scale. Demographic parameters and health history were obtained through questionnaire to all participants.

A brief review about PA, fitness and bone health and five original investigations were performed in this dissertation. Chapter 3, named 'Physical activity, fitness and bone health: a state of art', reviewed the association between PA and PF and their beneficial effects on bone health/strength. Through this, we recognized the importance of PA and FF in musculoskeletal health and general well-being in older adults.

The first original study (Chapter 4), entitled 'Functional fitness and physical activity of Portuguese community-residing older adults' aimed: (1) to generate normative values in older adults from ARM and (2) to analyse PA-associated variation in FF. The P50 values of all tests were lower in older cohorts when compared to younger ones. Men scored significantly better than women in chair stand, 8-foot up-and-go and 6-min walk (lower body strength, balance and aerobic endurance, respectively). Women scored significantly better than men in chair sit and reach and back scratch (upper and lower flexibility). A significant main effect for age-group was found in all motor tests. Active participants scored better in FF tests than the average and non-active peers.

The second study (Chapter 5), entitled 'Physical activity and bone mineral density in elderly men and women' aimed to describe the association between the level of PA, other lifestyle and constitutive factors and bone health/strength. Madeira women's, in the 65-69 year old cohort, in the highest tertile of total PA, had significantly higher FN BMD than females in the lowest tertile, whereas there were no other significant cohort specific differences among PA tertiles at any of the other sites for women or at any of the sites for males. PA was not a significant determinant of FSI for any age-cohort in either sex in this study. Total PA was positively associated with BMD at some body sites. In the multiple regression analysis, age, TLTM, and TFM entered as the most significant contributors for FN BMD in both genders, TFM in men, and TFM and age in women, were the most significant predictors for LS BMD and FSI.

In Chapter 6, entitled 'Functional fitness and bone mineral density in the elderly', addressed the association between muscular strength, aerobic endurance, balance and bone health/strength in our community-dwelling elderly men and women. Aerobic endurance and lower and upper body strength were positively associated to BMD in all measures of hip region in males ($0.10 < r < 0.16$; $p<0.01$-0.05) and females ($0.13 < r < 0.27$; $p<0.01$). This association was extensive to balance, but only in females. No significant correlation was found between any FF parameters and LS BMD, except for upper-body strength in females. After controlling for other constitutive predictors (sex, age, height, BM, TFM and TLTM), FF had a minor contribution in the prediction of BMD at multiple body sites and FSI. The total explained variance was moderate: $R^2 = 0.346$ (FN BMD), $R^2 = 0.274$ (LS BMD), $R^2 = 0.486$ (total body BMD) and $R^2 = 0.215$ (FSI). Similarly, sex, age, height, BM, TLTM and TFM entered as the primary and most significant contributors for BMD at the multiple sites and FSI.

Chapter 7, named 'Balance, mobility and physical activity in a community-dwelling elderly men and women' aimed to describe sex- and age-related differences in balance and gait, and their association with PA. Men showed higher balance scores than women. The most evident age-related difference appeared in FAB (17.4% and 25.4%) and GV (15.5% and 20.7%) for men and women, respectively. Higher levels of total PA were associated to better performances in FAB and all gait parameters. A significant age- and sex-specific difference on balance and gait was found between PA tertiles.

Finally, in Chapter 8, entitled 'Non-bone lean tissue mass and physical activity in elderly Portuguese men and women' aimed (1) to study the sex- and age-related differences in whole body non-bone lean tissue mass and non-bone appendicular lean tissue mass, and (2) to identify the associations between daily PA and non-bone tissue mass. Lean tissue declined with age, and men had greater absolute mass and relative lean tissue mass than women. For age- and sex-specific PA groups, few differences in RTLM, RALTM, RLLTM, and RALST were observed in favour of the more active participants. The correlations and multivariate analyses showed a positive but small contribution of PA to the variation in lean tissue mass (Betas vary between 0.041 and 0.074). Sex, height, and fat mass explained most of the variation in lean tissue mass.

The following conclusions can be derived from the results:

- Older adults from ARM showed a decline in FF with age, better performance of males and increased proficiency in active participants;
- PA is positively associated with BMD and FSI, and constitutive factors, like TLTM and TFM, are stronger determinants of BMD and FSI in this population;
- Body strength, endurance, and balance are associated to BMD. Sex, age, height, BM, TLTM and TFM were the primary and most significant contributors for BMD at the multiple body sites and FSI;
- Our sample presented a decline in balance and gait performances with age, and increased proficiency in balance tasks in active participants;
- Daily PA exerted a minor role in differentiation of LTM among elderly men and women, but that fat mass was positively associated to higher lean tissue.

9.2 Discussion and implications

The decrease of PA levels in older adults has profound implications on several physiological systems, especially those related with musculoskeletal and cardiorespiratory health. Health-related physical fitness is associated with the ability to perform daily activities, and can be modified through regular PA and exercise. The benefits of PA and/or exercise are reflected in an improvement of cardiovascular and respiratory functions, a reduction of risk factors of coronary heart diseases and a decreased morbidity and mortality (American College of Sports Medicine [ACSM], 2006; Shephard, 1997).

The assessment of FF in older adults is justified by the importance of monitoring the changes that occur with aging, identifying older adults with physical limitations and obtaining information on FF for research purposes and practical application (Rikli & Jones, 2001). Our research confirmed a decrease in FF with age and better scores for active participants. These results corroborated the idea that part of the functional decline that occurs with aging can be ‘restrained’ by regular exercise (Rikli & Jones, 2001). Madeira’s elderly showed a decline in muscular strength, aerobic endurance, flexibility and agility/dynamic balance over age, and men were more proficient than women. The active participants scored better in FF tests than their non-active peers. Therefore, any intervention in older adults should take into account the loss of functionality across age and the sexual dimorphism.

The enhanced bone fragility and consequent increase in fracture risk among the elderly has been linked to changes in BMD, bone material properties and bone geometry, including microarchitectural deterioration of cancellous bone (Kanis, Burlet, & Cooper, 2008). PA has been associated with increases in bone mass (Hagberg et al., 2001; Pluijm et al., 2001). The evidence in supporting the benefits of PA for bone health is so compelling that physicians and public health officials recommend the increased in PA and regular exercise programmes in older adults (Rutherford, 1997).

Bone loss is multifactorial in nature (Taylor & Johnson, 2008). Many factors increase the risk of developing osteoporosis and suffering, in consequence, a fracture. Lifestyle factors, such as PA level, calcium intake and nutritional status, play a major role on bone loss (Shephard, 1997). Our data supported that current levels of PA contributed to explain part of the variation in BMD and FSI among elderly men, with a slightly stronger associations among elderly women. In addition, correlations and multiple regression analysis showed that age, TLTM and TFM were the most significant contributors for all BMD measures and FSI. This data supports that bone health promotion and preservation might be enhanced among the elderly by encouraging PA behaviours.

The evidence that PA and fitness levels in older adults are significant predictors of BMD is inconsistent. Theoretically, it has been postulated that skeletal muscle contraction generate reaction forces during normal activity and such forces are thought to have a trophic or adaptive effect on bone mass. Previous studies tried to prove this postulate and showed that physical fitness was closely related to BMD (Aoyagi et al., 2000; Taaffe et al., 2003). Our data emphasize the relevance of mechanical stress, derived from contributions of TLTM in upper and lower body muscle strength, aerobic capacity and balance. Low FF in elderly was associated with greater weight loss and loss of TLTM, which are important predictors of BMD.

FF, measured by the Senior Fitness test, is a useful and convenient screening tool that correlates to bone health/strength in elderly. Our data suggested that body strength, endurance and balance should be considered in clinical assessments of bone health in older people, but body composition appears to have a higher relevance in the explanation of BMD and FSI.

Balance was other central issue in our study. The literature showed that about one-third of the community-dwelling older adults fall each year (Tinetti, 2003). According to WHO (2005), the estimated incidence of deaths caused by falls, in Portugal, was 6.3 per 100.000 population. In particular, elderly account for 15% of all domestic and leisure accidents registered in Portugal, in which falls represent 76.4% of the accidents in people aged 65-74 years old, and 89.7% in people over 75 years old (Rabiais, Nunes, & Contreiras, 2006).

Falls are the leading cause of injury-related hospitalization in people aged ≥65 years (Lord et al., 2007). This situation requires considerable healthcare expenditure. A large body of evidence reported an age-related decline in balance and gait, and their association with impairments in physical function, dependence and reduced quality of life (Cromwell, & Newton, 2004; Gill et al., 2001; Rose, Lucchese, & Wiersma, 2006).

Our findings hold up the recommendations to increase total PA in order to maintain mobility and physical independence. Higher levels of total PA, achieved by the sum of PA at work, sport and leisure time activities, were associated to better scores in balance and gait, namely, GV, SL, cadence and GSR, in elderly men and women. In addition, balance and mobility scores were higher in the youngest (60-64yrs) than in the oldest cohort (75-79 yrs), and women showed a greater risk for falls than men. Women are a group at risk, who needs more attention in the community setting.

Sarcopenia is associated with increased mortality, even after adjusting for major clinical variables. Sarcopenia poses significant health risk for older adults, including impairment in maximal aerobic capacity, slower gait speed and functional dependency (Singh, 1998). The prevalence of sarcopenia below the age of 70 is about 10 to 20% in white and Hispanic men and women from New Mexico, USA, but, in persons above 80 years the prevalence is >50% (Baumgartner et al., 1998). In Madeira, the prevalence's of sarcopenia increased from 5.8 % to 21.7 % in men and from 2.9 % to 6.5 % in women.

The association between PA and lean tissue mass is complex, and gender-, age- and body segment-dependent. In our study, only few age-group differences were observed for lean tissue mass across PA levels. Positive correlations were found between total PA and relative tissue mass in men and between absolute and relative lean tissue mass and total PA in women. Furthermore, total PA was a predictor of TLTM and ALST, and men with sarcopenia had also lower PA-scores. This study suggested that PA exerts only a minor role in differentiation of lean tissue mass among elderly males and females.

Our data were collected from independently living elderly men and women living in ARM, Portugal. This ultraperipheral region has homogeneous working and environmental characteristics. This homogeneity will minimize the apparent importance of several variables that determine the aging process. Further, the participants were essentially volunteers, who could have been generally healthier than those who did not participate, and survivor bias, especially among males in the older age-cohorts cannot be ruled out as a potential confounding factor particularly for between sex comparisons in our study. Lastly, our participants showed low rates of retirement, high prevalence of gainful employment in farming and reduced dependency on social assistance. These characteristics can be unique and obscure the results.

PA and exercise programmes with the focus on balance, upper and lower body strength, aerobic endurance should be conducted in older adults, particularly, in women who showed a higher risk for physical impairments. Body mass and body composition (TLTM and TFM) are important predictors of bone health/strength. The promotion of PA environments targets to increase FF performances and TLTM should be taken into account in osteoporosis prevention.

In sum, this research was based in a comprehensive multifactorial approach of the aging process and, thereby, supports recommendations to define public policies at the community level, that include general strategies to maintain PA, FF and independence targeted to older adults. Our results will help health professionals working with older adults in day care and residential centers, nursing homes, cultural and sport clubs associations, and other public health institutions. A scientific based assessment and intervention is important for the promotion of the health and quality of life in older adults. Furthermore, this research responded to the challenge of establishing and consolidating the infrastructure for research in the elderly population from ARM.

9.3 References

American College of Sports Medicine. (2006). *ACSM's guidelines for exercise testing and prescription*. Seventh Edition. Philadelphia: Lippincott Williams & Wilkins.

Aoyagi, K., Ross, P.D., Hayashi, T., Okano, K., Moji, K., Sasayama, H., et al. (2000) Calcaneus bone mineral density is lower among men and women with lower physical performance. *Calcified Tissue International*, *67*, 106–110.

Baumgartner, R.N., Koehler, K.M., Gallagher, D., Romero, L., Heymsfield, S.B., Ross, R.R., et al. (1998). Epidemiology of sarcopenia among elderly in New Mexico. *American Journal of Epidemiology*, *147*, 755-63.

Cromwell, R., & Newton, R. (2004). Relationship between balance and gait stability in healthy older adults. *Journal of Aging and Physical Activity*, *12*, 90-100.

Gill, J., Allum, J., Carpenter, M., Held-Ziolkowska, M., Adkin, A., Honegger, F., et al. (2001). Trunk sway measures of postural stability during clinical balance tests: effects of age. *The Journals of Gerontology. Series A, Biological Sciences and Medical Sciences*, *56*(7), 438-47.

Hagberg, J.M., Zmuda, J.M., McCole, S.D., Rodgers, K.S., Ferrell, R.E., Wilund, K.R., et al. (2001). Moderate physical activity is associated with higher bone mineral density in postmenopausal women. *Journal of the American Geriatrics Society, 49*, 1411-7.

Rabiais, S., Nunes, B., Contreiras, T. (2006). *ADELIA 2005 – Acidentes Domésticos e de Lazer: Informação Adequada*. Lisboa: Instituto Nacional de Saúde Dr. Ricardo Jorge. Retrieved Nov. 1, 2010, from https://webgate.ec.europa.eu/idb/ documents/PT_proj_adelia_relat-final-2005_onsa.pdf.

Kanis, J.A., Burlet, N., Cooper, C., Delmas, P.D., Reginster, J.Y., Borgstrom, F., et al. (2008). European guidance for the diagnosis and management of osteoporosis in postmenopausal women. *Osteoporosis International, 19*, 399-428.

Khan, K., McKay, H., Kannus, P., Bailey, D., Wark, J., & Bennell, K. (2001). *Physical Activity and Bone Health*. Champaign, IL: Human Kinetics.

Lord, S., Sherrington, C., Menz, H., & Close, J. (2007). *Falls in Older People. Risk factors and strategies for Prevention*. UK: Cambridge University Press.

Pluijm, S.M., Visser, M., Smit, J.H., Popp-Snijders, C., Roos, J.C., & Lips, P. (2001). Determinants of bone mineral density in older men and women: body composition as mediator. *Journal of Bone and Mineral Research, 16*, 2142-51.

Rikli, R.E., & Jones, C.J. (2001). *Senior fitness test manual. Development and validation of a functional fitness test for community-residing older adults*. Champaign, IL: Human Kinetics.

Rose, D., Lucchese, N., & Wiersma, L. (2006). Development of a multidimensional balance scale for use with functionally independent older adults. *Archives of Physical Medicine and Rehabilitation*, *87*(11), 1478-85.

Rutherford, O.M. (1997). Bone density and physical activity. *Proceedings of the Nutrition Society, 56*, 967-75.

Shephard, R.J. (1997). *Aging Physical Activity, and Health*. Champaign, IL: Human Kinetics.

Singh, M.A. (1998). Combined exercise and dietary intervention to optimize body composition in aging. *Annals of the New York Academy of Sciences*, *20*(854), 378-93.

Spirduso, W.W., Francis, K.L., & MacRae, P.G. (2005). *Physical dimensions of aging*. Second Edition. Champaign, IL: Human Kinetics.

Taaffe, D.R., Simonsick, E.M., Visser, M., Volpato, S., Nevitt, M.C., Cauley, J.A., et al. (2003). Lower extremity physical performance and hip bone mineral density in elderly black and white men and women: cross-sectional associations in the Health ABC Study. *The Journals of Gerontology Series A, 58*, 934-942.

Taylor, A.W. & Johnson, M.J. (2008). *Physiology of Exercise and Healthy Aging*. Champaign, IL: Human Kinetics, Inc.

Tinetti, M. (2003). Clinical practice. Preventing falls in elderly persons. *The New England Journal of Medicine, 348*(1), 42-9. World Health Organization. (2002). *Active Ageing: A Policy Framework*. Retrieved Nov. 21, 2010, from http://whqlibdoc.who.int/hq/2002/WHO_NMH_NPH_02.8. pdf.

World Health Organization. (2005). *Causes of death*. Retrieved Sept. 1, 2010, from http://www.who.int/research/en/.

Chapter 10

Appendices

Appendix A

APTIDÃO FÍSICA
SAÚDE E QUALIDADE DE VIDA

UNIVERSIDADE DA MADEIRA

Appendix A

DISTRICT	BIY	NUMBER

Name: ______________________________ Birth Date: __________

Adress: ______________________________

____

Postal Code: __________ ______________ e-mail: ______________

Telephones: ______________ ______________

Profession: ______________________________

Qualifications: ______________________________

Institution (if any): ______________________________

____

Person in charge of the Institution: ______________________________

Institution’s Contact: ______________________ e- mail: ______________

Informed consent

I, ______________________________, was informed that I will do a set of assessments regarding physical fitness (motor tests), physical activity (questionnaires and acelerometery), growth and development (anthropometry, densitometry and body composition) and other health conditions (blood pressure), that will help me understand my health status.

It was explained to me that I have the right to give up the assessments at any time, without any penalty for me. There are minor risks associated to the assessment procedures and my right to privacy will be respected.

I confirm that I have read and accept the terms of participation and I offer as volunteer to participate in the investigation project: health and quality of life of the Madeira’s elderly population. The present document will be signed in duplicate, one for the responsible investigator and other for me.

______________________ ______________________

(Participant’s signature) (Main Investigator’s signature)

Appendix B

APTIDÃO FÍSICA
SAÚDE E QUALIDADE DE VIDA

UNIVERSIDADE DA MADEIRA

Appendix B
Physical Activity Readiness Questionnaire (PAR-Q)[1]

(Thomas et al., 1992)

1. Identification

Identification number - IDNR

DISTRICT			BIY			NUMBER		

Family name ____________________

First and midle name ____________________

Investigation date

Day	Month	Year
IND	INM	INY

Birth date

Day	Month	Year
BID	BIM	BIY

Sex Male ☐ Female ☐

Telephone number (House) ____________________ Mobile phone ____________________

E-mail(s) ____________________

Other contact ____________________

Residence area ☐

Door number ☐☐☐☐☐☐ Floor ☐☐☐☐

Address ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐

Postal Code ☐☐☐☐ – ☐☐☐ ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐

Section/ Subsection ☐☐☐ ☐☐ Edifice number ☐☐☐ Housing number ☐☐☐

District ____________________ ☐☐☐

District ☐☐ Area ☐☐

Physical Activity Readiness Questionnaire (PAR-Q)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

Yes	No		
☐	☐	1	Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?
☐	☐	2	Do you feel pain in your chest when you do physical activity?
☐	☐	3	In the past month, have you had chest pain when you were not doing physical activity?
☐	☐	4	Do you lose your balance because of dizziness or do you ever lose consciousness?
☐	☐	5	Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?
☐	☐	6	Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?
☐	☐	7	Do you know of any other reason why you should not do physical activity?

Signature of Participante

---

[1] Thomas, S., Reading, J., & Shephard, R.J. (1992). Revision of the Physical Activity Readiness Questionnaire (PAR-Q). Canadian Journal of Sport Sciences, 17(4), 338-45.

Appendix C

APTIDÃO FÍSICA
SAÚDE E QUALIDADE DE VIDA

UNIVERSIDADE DA MADEIRA

Appendix C

The Baecke Questionnaire[1]

(Baecke et al., 1982).

1. Identification

Identification number - IDNR

☐☐☐	☐☐☐	☐☐☐
DISTRICT	BIY	NUMBER

Family name ______________________________

First and midle name ______________________________

Investigation date

Day	Month	Year
IND	INM	INY

Birth date

Day	Month	Year
BID	BIM	BIY

Sex Male ☐ Female ☐

Telephone number (House) ______________________ Mobile phone ______________________

E-mail(s) ______________________________

Other contact ______________________________

Residence area ☐

Door number ☐☐☐☐☐☐ Floor ☐☐☐☐

Address ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐

Postal Code ☐☐☐☐ – ☐☐☐ ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐

Section/ Subsection ☐☐☐ ☐☐ Edifice number ☐☐☐ Housing number ☐☐☐

District ______________________________ ☐☐☐

District ☐☐ Area ☐☐

1. What is your main occupation? ____________________

1	3	5
☐	☐	☐

2. At work I sit:

never	seldom	sometimes	often	always
☐	☐	☐	☐	☐
1	2	3	4	5

3. At work I stand:

never	seldom	sometimes	often	always
☐	☐	☐	☐	☐
1	2	3	4	5

4. At work I walk:

never	seldom	sometimes	often	always
☐	☐	☐	☐	☐
1	2	3	4	5

5. At work I lift heavy loads:

never	seldom	sometimes	often	always
☐	☐	☐	☐	☐
1	2	3	4	5

6. After working I am tired:

very often	often	sometimes	seldom	never
☐	☐	☐	☐	☐
5	4	3	2	1

7. At work I sweat:

very often	often	sometimes	seldom	never
☐	☐	☐	☐	☐
5	4	3	2	1

8. In comparison with others of my own age I think my work is physically:

much heavier	heavier	as heavier	lighter	much lighter
☐	☐	☐	☐	☐
5	4	3	2	1

9. Do you play sport? Yes ☐ No ☐

If yes:

- Which sport do you play most frequently ? ____________________ ☐.☐☐

- How many hours a week?

<1	1-2	2-3	3-4	>4
☐	☐	☐	☐	☐
0.5	1.5	2.5	3.5	4.5

- How many months a year?

<1	1-3	4-6	7-9	>9
☐	☐	☐	☐	☐
0.04	0.17	0.42	0.67	0.92

If you play a second sport:

- Which sport is it ? ______________________________ ☐.☐☐

- How many hours a week?

<1	1-2	2-3	3-4	>4
☐	☐	☐	☐	☐
0.5	1.5	2.5	3.5	4.5

- How many months a year?

<1	1-3	4-6	7-9	>9
☐	☐	☐	☐	☐
0.04	0.17	0.42	0.67	0.92

10. In comparison with others of my own age I think my physical activity during leisure time is:

much more	more	the same	less	much less
☐	☐	☐	☐	☐
5	4	3	2	1

11. During leisure time I sweat:

very often	often	sometimes	seldom	never
☐	☐	☐	☐	☐
5	4	3	2	1

12. During leisure time I play sport:

never	seldom	sometimes	often	always
☐	☐	☐	☐	☐
1	2	3	4	5

13. During leisure time I watch television:

never	seldom	sometimes	often	always
☐	☐	☐	☐	☐
1	2	3	4	5

14. During leisure time I walk:

never	seldom	sometimes	often	always
☐	☐	☐	☐	☐
1	2	3	4	5

15. During leisure time I cycle:

never	seldom	sometimes	often	always
☐	☐	☐	☐	☐
1	2	3	4	5

16. How many minutes do you walk and /or cycle per day to and from work, school and shopping?

<5	5-15	15-30	30-45	>45
☐	☐	☐	☐	☐

---

[1] Baecke, J.A., Burema, J., Frijters, J.E. (1992). A short questionnaire for the measurement of habitual physical activity in epidemiological studies. The American Journal of Clinical Nutrition, 36, 936-42.

Appendix D

APTIDÃO FÍSICA
SAÚDE E QUALIDADE DE VIDA

UNIVERSIDADE DA MADEIRA

Appendix D

Senior Fitness Test Manual

(Rikli & Jones, 2001)

1. Identification

Identification number - IDNR

DISTRICT			BIY			NUMBER		

Family name ______________________________

First and midle name ______________________________

Investigation date

Day	Month	Year
IND	INM	INY

Birth date

Day	Month	Year
BID	BIM	BIY

Sex Male ☐ Female ☐

Telephone number (House)______________________ Mobile phone ______________________

E-mail(s) ______________________________

Other contact ______________________________

Residence area ☐

Door number ☐☐☐☐☐☐ Floor ☐☐☐☐

Address ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐

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Section/ Subsection ☐☐☐ ☐☐ Edifice number ☐☐☐ Housing number ☐☐☐

District ______________________________ ☐☐☐

District ☐☐ Area ☐☐

Senior Fitness Test Manual; (Rikli & Jones, 2001)

Chair Stand Test	CST	☐☐		n
Arm Curl Test	ACT	☐☐		n
Chair Sit-And - Reach Test	CSAR	☐☐☐.☐	☐☐☐.☐	cm
Back Scratch Test	BST	☐☐☐.☐	☐☐☐.☐	cm
8 – Foot Up-And-Go Test	FUG	☐☐.☐☐	☐☐.☐☐	seg
6 – Minute Walk Test	6 MWT	☐☐☐☐		m
2 – Minute Step Test	2 MST	☐☐☐		n

Appendix E

APTIDÃO FÍSICA
SAÚDE E QUALIDADE DE VIDA

UNIVERSIDADE DA MADEIRA

Appendix E

Fullerton Advanced Balance (FAB) Scale

(Rose, 2003)

1. Identification

Identification number - IDNR

DISTRICT			BIY			NUMBER		

Family name ______________________________

First and midle name ______________________________

Investigation date

Day	Month	Year
IND	INM	INY

Birth date

Day	Month	Year
BID	BIM	BIY

Sex Male ☐ Female ☐

Telephone number (House) ______________________ Mobile phone ______________________

E-mail(s) ______________________________

Other contact ______________________________

Residence area ☐

Door number ☐☐☐☐☐☐ Floor ☐☐☐☐

Address ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐

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Section/ Subsection ☐☐☐ ☐☐ Edifice number ☐☐☐ Housing number ☐☐☐

District ______________________________ ☐☐☐

District ☐☐ Area ☐☐

Fullerton Advanced Balance (FAB) Scale

1. Standing with Feet Together and Eyes Closed.

( ) 0 - Unable to obtain the correct standing position independently.

( ) 1 - Able to obtain the correct standing position independently but unable to maintain the position or keep the eyes closed for more than 10 seconds.

( ) 2 - Able to maintain the correct standing position with eyes closed for more than 10 seconds but less than 30 seconds.

( ) 3 - Able to maintain the correct standing position with eyes closed for 30 seconds but requires close supervision.

( ) 4 - Able to maintain the correct standing position with eyes closed for 30 seconds safely.

2. Reaching Forward to Retrieve an Object (pencil) Held at Shoulder Height with Outstretched Arm.

( ) 0 - Unable to reach the pencil without taking more than 2 steps.

( ) 1 - Able to reach the pencil but needs to take 2 steps.

( ) 2 - Able to reach the pencil but needs to take 1 step.

( ) 3 - Can reach the pencil without moving the feet but requires supervision.

( ) 4 - Can reach the pencil safely and independently without moving the feet.

3. Turn 360 Degrees in a Right and Left Direction.

( ) 0 - Needs manual assistance while turning.

( ) 1 - Needs close supervision or verbal cueing while turning.

( ) 2 - Able to turn 360 degrees but takes more than 4 steps in both directions.

( ) 3 - Able to turn 360 degrees but unable to complete in 4 steps or less in one direction.

( ) 4 - Able to turn 360 degrees safely and takes 4 steps or less in both directions.

4. Step Up and Over a 6” Bench.

( ) 0 - Unable to step onto the bench without loss of balance or manual assistance.

( ) 1 - Able to step up onto the bench with lead leg but trailing leg contacts bench or swings around the bench during swing-through phase in both directions.

( ) 2 - Able to step up onto the bench with lead leg but trailing leg contacts bench or swings around bench during swing-through phase in one direction.

( ) 3 - Able to correctly complete the step up and over in both directions but requires close supervision in one or both directions.

( ) 4 - Able to correctly complete the step up and over in both directions safely and independently.

5. Tandem Walk.

( ) 0 - Unable to complete 10 steps independently.

( ) 1 - Able to complete the 10 steps with more than 5 interruptions.

( ) 2 - Able to complete the 10 steps with 5 or less interruptions.

( ) 3 - Able to complete the 10 steps with 2 or less interruptions.

( ) 4 - Able to complete the 10 steps independently and with no interruptions.

6. Standing on One Leg.

( ) 0 - Unable to try or needs assistance to prevent falling.

( ) 1 - Able to lift leg independently but unable to maintain position for more than 5 seconds.

( ) 2 - Able to lift leg independently and maintain position for at least 5 but less than 12 seconds.

( ) 3 - Able to lift leg independently and maintain position for at least 12 but less than 20 seconds.

( ) 4 - Able to lift leg independently and maintain position for the full 20 seconds.

7. Standing on Foam with Eyes Closed.

( ) 0 - Unable to step onto foam and/or maintain standing position independently with eyes open.

( ) 1 - Able to step onto foam independently and maintain standing position but unable or unwilling to close eyes.

( ) 2 - Able to step onto foam independently and maintain standing position with eyes closed for 10 seconds or less.

( ) 3 - Able to step onto foam independently and maintain standing position with eyes closed for more than 10 seconds but less than 20 seconds.

( ) 4 - Able to step onto foam independently and maintain standing position with eyes closed for 20 seconds.

8. Two-footed Jump for Distance.

( ) 0 - Unable to attempt or attempts to initiate two-footed jump but one or both feet do not leave the floor.

( ) 1 - Able to initiate two-footed jump but one foot either leaves the floor or lands before the other.

( ) 2 - Able to perform two-footed jump but unable to jump further than the length of their own feet.

( ) 3 - Able to perform two-footed jump and achieve a distance greater than the length of their own feet.

( ) 4 - Able to perform two-footed jump and achieve a distance greater than twice the length of their own feet.

9. Walk with Head Turns.

( ) 0 - Unable to walk 10 steps independently while maintaining 30 degree head turns at an established pace.

( ) 1 - Able to walk 10 steps independently but unable to complete required number of 30 degree head turns at an established pace.

( ) 2 - Able to walk 10 steps but veers from a straight line while performing 30 degree head turns at an established pace.

( ) 3 - Able to walk 10 steps in a straight line while performing 30 degree head turns at an established pace but head turns less than 30 degrees in one or both directions.

( ) 4 - Able to walk 10 steps in a straight line while performing required number of 30 degree head turns at established pacing.

10. Reactive Postural Control.

( ) 0 - Unable to maintain upright balance, no observable attempt to step- requires manual assistance to restore balance.

( ) 1 - Unable to maintain upright balance, takes two or more 2 steps and requires manual assistance to restore balance.

( ) 2 - Unable to maintain upright balance, takes two or more 2 steps but is able to restore balance independently.

( ) 3 - Unable to maintain upright balance, takes 1-2 steps but is able to restore balance independently.

( ) 4 - Unable to maintain upright balance, but is able to restore balance independently with one step only.

Appendix F

APTIDÃO FÍSICA
SAÚDE E QUALIDADE DE VIDA

UNIVERSIDADE DA MADEIRA

Appendix F

50-foot Walk Test

(Rose, 2003)

1. Identification

Identification number - IDNR

DISTRICT			BIY			NUMBER		

Family name ______________________________

First and midle name ______________________________

Investigation date

Day	Month	Year
IND	INM	INY

Birth date

Day	Month	Year
BID	BIM	BIY

Sex Male ☐ Female ☐

Telephone number (House) ______________ Mobile phone ______________

E-mail(s) ______________________________

Other contact ______________________________

Residence area ☐

Door number ☐☐☐☐☐☐ Floor ☐☐☐☐

Address ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐

Postal Code ☐☐☐☐ – ☐☐☐ ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐

Section/ Subsection ☐☐☐ ☐☐ Edifice number ☐☐☐ Housing number ☐☐☐

District ______________________________ ☐☐☐

District ☐☐ Area ☐☐

Walk at preferred speed

Time: ____________________ (in seconds)

Number steps: ____________________ (n)

Gait velocity: ____________________________________ (in feet or meters per second)
(Formula: 50 ft or 15.24 m /time in seconds)

Cadence: ____________________________________ (steps per second)
(Formula: number of steps/time in seconds)

Gait Stability Ratio: ____________________________________ (steps per foot or meter)
(Formula: ratio of cadence to velocity)

Stride Length: ____________________________________ (in feet or meters per stride)
(Formula: divide number of steps by 2 for the number
of strides, then 50 ft or 15.24 m/ number of strides)

Walk at maximum speed

Time: ____________________ (in seconds)

Number steps: ____________________ (n)

Gait velocity: ____________________________________ (in feet or meters per second)
(Formula: 50 ft or 15.24 m /time in seconds)

Cadence: ____________________________________ (steps per second)
(Formula: number of steps/time in seconds)

Gait Stability Ratio: ____________________________________ (steps per foot or meter)
(Formula: ratio of cadence to velocity)

Stride Length: ____________________________________ (in feet or meters per stride)
(Formula: divide number of steps by 2 for the number
of strides, then 50 ft or 15.24 m/ number of strides)

Gait Adaptation: ____________________________________ (in feet or meters per second)

(Formula: subtract preferred velocity from maximum velocity)

Appendix G

APTIDÃO FÍSICA
SAÚDE E QUALIDADE DE VIDA

UNIVERSIDADE DA MADEIRA

Appendix G

Anthropometric Measurements

1. Identification

Identification number - IDNR

DISTRICT			BIY			NUMBER		

Family name ____

First and midle name ____

Investigation date

Day	Month	Year
IND	INM	INY

Birth date

Day	Month	Year
BID	BIM	BIY

Sex Male ☐ Female ☐

Telephone number (House)________________________ Mobile phone ________________________

E-mail(s) ____

Other contact ____

Residence area ☐

Door number ☐☐☐☐☐☐ Floor ☐☐☐☐

Address ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐

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Section/ Subsection ☐☐☐ ☐☐ Edifice number ☐☐☐ Housing number ☐☐☐

District __________________________________ ☐☐☐

District ☐☐ Area ☐☐

Anthropometric Measurements

Lengths / Breadths / Circumferences / Skinfolds

					Limits
Body Weight	WT	☐☐☐.☐	☐☐☐.☐	☐☐☐.☐	100 g
Height	HT	☐☐☐.☐	☐☐☐.☐	☐☐☐.☐	5 mm
Sitting Height	SIHT	☐☐☐.☐	☐☐☐.☐	☐☐☐.☐	5 mm
Breadths					
Biacromial	BADI	☐☐.☐	☐☐.☐	☐☐.☐	5 mm
Bicristal	BCDI	☐☐.☐	☐☐.☐	☐☐.☐	3 mm
Humerus	BEHU	☐☐.☐	☐☐.☐	☐☐.☐	1 mm
Femoral	BIFE	☐☐.☐	☐☐.☐	☐☐.☐	1 mm
Circumferences					
Calf	CACI	☐☐.☐	☐☐.☐	☐☐.☐	2 mm
Thigh	THCI	☐☐.☐	☐☐.☐	☐☐.☐	4 mm
Upperarm relax.	UAEC	☐☐.☐	☐☐.☐	☐☐.☐	2 mm
Forearm	FACI	☐☐.☐	☐☐.☐	☐☐.☐	2 mm
Upperarm flex.	UAFC	☐☐.☐	☐☐.☐	☐☐.☐	5 mm
Waist	WACI	☐☐☐.☐	☐☐☐.☐	☐☐☐.☐	5 mm
Hip	HACI	☐☐☐.☐	☐☐☐.☐	☐☐☐.☐	5 mm
Skinfold Thicknesses					10%
Triceps	TRSK	☐☐.☐	☐☐.☐	☐☐.☐	
Biceps	BISK	☐☐.☐	☐☐.☐	☐☐.☐	
Subscapular	SSSK	☐☐.☐	☐☐.☐	☐☐.☐	
Sprailiac	SISK	☐☐.☐	☐☐.☐	☐☐.☐	
Calf	CASK	☐☐.☐	☐☐.☐	☐☐.☐	
Abdomen	MTSK	☐☐.☐	☐☐.☐	☐☐.☐	
Thigh	ABSK	☐☐.☐	☐☐.☐	☐☐.☐	

Appendix H

APTIDÃO FÍSICA
SAÚDE E QUALIDADE DE VIDA

UNIVERSIDADE DA MADEIRA

Appendix H

Modified Version of Health
Questionnaire Employed in
the FallProof Program

(Rose, 2003)

1. Identification

Identification number - IDNR

DISTRICT			BIY			NUMBER		

Family name ____________________

First and midle name ____________________

Investigation date

Day	Month	Year
IND	INM	INY

Birth date

Day	Month	Year
BID	BIM	BIY

Sex Male ☐ Female ☐

Telephone number (House) ____________________ Mobile phone ____________________

E-mail(s) ____________________

Other contact ____________________

Residence area ☐

Door number ☐☐☐☐☐☐ Floor ☐☐☐☐

Address ☐☐☐

Postal Code ☐☐☐☐ – ☐☐☐ ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐

Section/ Subsection ☐☐☐ ☐☐ Edifice number ☐☐☐ Housing number ☐☐☐

District ____________________ ☐☐☐

District ☐☐ Area ☐☐

1. Have you ever been diagnosed as having any of the following conditions?

	Yes (1)	No (0)
Osteoporosis	☐	☐
Rheumatoid arthritis	☐	☐
Other arthritic conditions	☐	☐
Visual/depth perception problems	☐	☐
Inner ear problems	☐	☐
Cerebellar disorder (ataxia)	☐	☐
Other movement disorders	☐	☐
Chemical dependency (alcohol and/or drugs)	☐	☐
Depression	☐	☐
Bone fracture	☐	☐
	☐	☐

If yes, which bone region did you fracture and how old you had at that time?

Bone region: ______________________ Age: ________ (years)

Bone region: ______________________ Age: ________ (years)

Bone region: ______________________ Age: ________ (years)

Cancer

If yes, localization:

Colon	☐	☐
Prostate	☐	☐
Lung	☐	☐
Breast	☐	☐
Skin	☐	☐

Other (which) ______________________

Arthroplasty

If yes, how many times?

Where? ______________________

Right hip	☐	☐
Left hip	☐	☐
Right knee	☐	☐
Left knee	☐	☐

2. Habits

	Yes (1)	No (0)
Do you smoke?	☐	☐
If yes, type?		
Cigarettes	☐	☐
Cigar	☐	☐
Pipe	☐	☐
If yes, how many per day?		
<0,5 packet	☐	☐
0,5 a 1 packet	☐	☐
1 a 1,5 packet	☐	☐
1,5 a 2 packets	☐	☐
<2 packets	☐	☐

Did you quit smoking?

If yes, how long has it been since you stopped? Years: ______ months: ______

For how long and which quantity did you usually smoke? Years: ______ packets per day: ______

	Yes (1)	No (0)
Do you drink alcohol?	☐	☐

If yes, how much per week?

Beer (bottles) ☐ (number) Wine (glasses) ☐ (number) Others strong drinks (glasses) ☐ (number)

If yes, how much per week? ☐ ☐

Coffe (cups) ☐ Tea (cups) ☐ Sodas (glasses) ☐

Do you usually sunbath? ☐ ☐

If yes, how many months per year? ☐

How many hours per day? ☐

Were you an emigrant? ☐ ☐

If yes, for how long? ______________________________

Localization? ______________________________

3. Medication

	Yes (1)	No (0)
Do you take any medication for the bones?	☐	☐

Type of medication : ______________________________

Do you take any medication for balance? ☐ ☐

Do you take any medication for the thyroid ? ☐ ☐

Type of medication ? ______________________________

Do you take any medication to help you sleep? ☐ ☐

Type of medication ? ______________________________

Do you take any medication for anxiety? ☐ ☐

Type of medication ? ______________________________

Do you take any medication for hypertension? ☐ ☐

Type of medication ? ______________________________

Do you take any medication for hormonal replacement? ☐ ☐

Type of medication ?

Estrogen ☐ ☐

Progesterone ☐ ☐

Do you take any calcium or/and vitamin D Supplements? ☐ ☐

Do you take aspirin? ☐ ☐

Do you take other medications? ☐ ☐

If yes, which?

____

____

____

4. Woman's reproductive history

Age of menopause Age: ☐ (years)

	Yes (1)	No (0)
Natural	☐	☐
Artificial	☐	☐

Postmenopausal hormone treatment

If yes, when did you start? (year) ☐ How many years did you used it? ☐

The first menstruation?

Year ☐☐☐☐

Season:

Winter	Spring	Summer	Autumn
☐	☐	☐	☐

Month:

January	February	March	April	May	June
☐	☐	☐	☐	☐	☐
July	**August**	**September**	**October**	**November**	**December**
☐	☐	☐	☐	☐	☐

If you remember, which day, month and year did you experience your first menstruation?

Day		Month		Year	

5. Falls history

How many times have you fallen in last year? ☐

If yes, describe the accident:

Date: / /

Place (indoor or outdoor): ____________________

Reason /causes: ____________________

Did you need medical assistance? -- ☐ Yes (1) ☐ No (0)

Date: / /

Place (indoor or outdoor): ____________________

Reason /causes: ____________________

Did you need medical assistance? -- ☐ Yes (1) ☐ No (0)

Date: / /

Place (indoor or outdoor): ____________________

Reason /causes: ____________________

Did you need medical assistance? -- ☐ Yes (1) ☐ No (0)

Appendix I

APTIDÃO FÍSICA
SAÚDE E QUALIDADE DE VIDA

UNIVERSIDADE DA MADEIRA

Appendix I

Portuguese Food Frequency Questionnaire

(Lopes, 2000)

1. Identification

Identification number - IDNR

☐☐☐	☐☐☐	☐☐☐
DISTRICT	BIY	NUMBER

Family name ______________________________

First and midle name ______________________________

Investigation date

Day	Month	Year
IND	INM	INY

Birth date

Day	Month	Year
BID	BIM	BIY

Sex Male ☐ Female ☐

Telephone number (House) ____________________ Mobile phone ____________________

E-mail(s) ______________________________

Other contact ______________________________

Residence area ☐

Door number ☐☐☐☐☐☐ Floor ☐☐☐☐

Address ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐

Postal Code ☐☐☐☐ – ☐☐☐ ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐

Section/ Subsection ☐☐☐ ☐☐ Edifice number ☐☐☐ Housing number ☐☐☐

District ______________________________ ☐☐☐

District ☐☐ Area ☐☐

I. Dairy products	Food Frequency									Serving (medium)
	Rarely or < 1 time per month	1-3 times per week	Once a week	2-4 times per week	5-6 per week	Once a day	2-3 per day	4-5 per day	> 6 per day	
1 Whole milk	○	○	○	○	○	○	○	○	○	1 cup (250 ml)
2 Semi-skimmed milk	○	○	○	○	○	○	○	○	○	1 cup (250 ml)
3 Skimmed milk	○	○	○	○	○	○	○	○	○	1 cup (250 ml)
4 I Yogurt (any type)	○	○	○	○	○	○	○	○	○	1/2 cup (125 ml)
5 Cheese, fresh cheese, cream cheese (any)	○	○	○	○	○	○	○	○	○	1 slice (30g)
6 Dairy desserts: flan pudding, milk-cream, chocolate pudding, etc	○	○	○	○	○	○	○	○	○	1 serving (1 dessert dish)
7 Ice-cream	○	○	○	○	○	○	○	○	○	1 unit or 1 cup
II. Meat, seafood and eggs										
8 Eggs	○	○	○	○	○	○	○	○	○	1 unit
9 Chicken	○	○	○	○	○	○	○	○	○	2 pieces (1/4)
10 Turkey, rabbit	○	○	○	○	○	○	○	○	○	2 pieces
11 Red meat, pork meat, young goat	○	○	○	○	○	○	○	○	○	1 medium serving (120g)
12 Liver (meat, pork or chicken)	○	○	○	○	○	○	○	○	○	1 serving (120g)
13 Offal: tongue, tripe, heart, kidney	○	○	○	○	○	○	○	○	○	1 serving (100g)
14 Ham, Portuguese pork sausage, pepperoni, salami, etc	○	○	○	○	○	○	○	○	○	2 slices
15 Sausages	○	○	○	○	○	○	○	○	○	3 units
16 Bacon, pork belly	○	○	○	○	○	○	○	○	○	2 slices
17 Oily fish: sardine, herring, mackerel, horse-mackerel, salmon, ell	○	○	○	○	○	○	○	○	○	1 serving (125g)
18 White fish: whiting, snook, etc	○	○	○	○	○	○	○	○	○	1 serving (125g)
19 Cod	○	○	○	○	○	○	○	○	○	1 medium serving
20 Canned fish: tuna, sardine, etc.	○	○	○	○	○	○	○	○	○	1 can
21 Molluscs (octopus, cuttlefish, squids)	○	○	○	○	○	○	○	○	○	1 serving (100g)
22 Shrimp (1 portion, 100g), cockles, mussel, etc	○	○	○	○	○	○	○	○	○	1 dessert dish
III. Fats and oils										
23 Olive oil	○	○	○	○	○	○	○	○	○	1 tablespoon
24 Vegetable oils: sunflower, maize, soy	○	○	○	○	○	○	○	○	○	1 tablespoon
25 Margarine (any)	○	○	○	○	○	○	○	○	○	1 teaspoon
26 Butter	○	○	○	○	○	○	○	○	○	1 teaspoon
IV. Bread, cereals and starchy roots										
27 White bread or white bread toasted	○	○	○	○	○	○	○	○	○	1 unit (50g) or 2 slices
28 Whole grain bread or toasted, rye bread	○	○	○	○	○	○	○	○	○	1 unit (50g) or 2 slices
29 Portuguese bread	○	○	○	○	○	○	○	○	○	1 slice (80g)
30 Breakfast cereals (corn-flakes, oatmeal/wheat, muesli, chocolate cereals, etc)	○	○	○	○	○	○	○	○	○	1 cup (without milk)

31 Rice	○	○	○	○	○	○	○	○	○	½ dish
32 Spaghetti, pasta (any)	○	○	○	○	○	○	○	○	○	½ dish
33 Chips/ French fried potatoes	○	○	○	○	○	○	○	○	○	½ dish
34 Chips (package)	○	○	○	○	○	○	○	○	○	1 package
35 Potatoes (boiled, roasted, stewed, etc)	○	○	○	○	○	○	○	○	○	2 units
V. Bakery products and sweets										
36 Biscuits (plain) and crackers	○	○	○	○	○	○	○	○	○	3 units
37 Sweet biscuits and cookies	○	○	○	○	○	○	○	○	○	3 units
38 Croissant and other pastries, , doughnuts, chocolate bread, home made cakes	○	○	○	○	○	○	○	○	○	1 unit or slice
39 Chocolate (tablet), cocoa powder	○	○	○	○	○	○	○	○	○	3 squares or 1 tablespoon
40 Chocolate snack bars (e.g. Mars, Twix, etc.)	○	○	○	○	○	○	○	○	○	1 bar
41 Jam, quince-jam, jelly, honey	○	○	○	○	○	○	○	○	○	1 dessert spoon
42 Table sugar	○	○	○	○	○	○	○	○	○	1 dessert spoon or 1 single package (8g)
VI. Vegetables										
43 White-cabbage,	○	○	○	○	○	○	○	○	○	½ cup
44 Cabbage	○	○	○	○	○	○	○	○	○	½ cup
45 Kale	○	○	○	○	○	○	○	○	○	½ cup
46 Broccoli	○	○	○	○	○	○	○	○	○	½ cup
47 Cauliflower, Brussels	○	○	○	○	○	○	○	○	○	½ cup
48 Sprout, spinach	○	○	○	○	○	○	○	○	○	½ cup
49 Green-been	○	○	○	○	○	○	○	○	○	½ cup
50 Lettuce, water-cress	○	○	○	○	○	○	○	○	○	½ cup
51 Onion	○	○	○	○	○	○	○	○	○	1 unit
52 Carrots	○	○	○	○	○	○	○	○	○	1 medium
53 Turnip	○	○	○	○	○	○	○	○	○	1 medium
54 Fresh tomato	○	○	○	○	○	○	○	○	○	½ unit (3 slices)
55 Sweet peppers (red, yellow, green)	○	○	○	○	○	○	○	○	○	½ unit (6 slices)
56 Cucumber	○	○	○	○	○	○	○	○	○	¼ unit
57 Beans, grain	○	○	○	○	○	○	○	○	○	1 cup or ½ dish
58 Green peas, broad bean	○	○	○	○	○	○	○	○	○	½ cup or ¼ dish
VII. Fruit										
59 Apple, pear	○	○	○	○	○	○	○	○	○	1 medium
60 Orange, tangerine	○	○	○	○	○	○	○	○	○	1 medium, 2 pieces
61 Banana	○	○	○	○	○	○	○	○	○	1 medium
62 Kiwi	○	○	○	○	○	○	○	○	○	1 medium
63 Strawberry	○	○	○	○	○	○	○	○	○	1 cup
64 Cherries	○	○	○	○	○	○	○	○	○	1 cup
65 Peach, plums	○	○	○	○	○	○	○	○	○	1 medium, 3 pieces
66 Melon, watermelon	○	○	○	○	○	○	○	○	○	1 medium slice

67 Persimmon	○	○	○	○	○	○	○	○	○	1 medium
68 Figs, apricot	○	○	○	○	○	○	○	○	○	3 pieces
69 Grapes	○	○	○	○	○	○	○	○	○	1 medium
70 Canned fruits (peach, pineapple)	○	○	○	○	○	○	○	○	○	2 slices
71 Nuts (e.g. almonds, hazelnuts, walnuts, peanuts, pistachios)	○	○	○	○	○	○	○	○	○	½ cup
72 Olives	○	○	○	○	○	○	○	○	○	6 units
VIII. Beverages										
73 Wine	○	○	○	○	○	○	○	○	○	1 glass (125 ml)
74 Beer	○	○	○	○	○	○	○	○	○	1 bottle or can
75 Distilled drinks: whisky, brandy, etc.	○	○	○	○	○	○	○	○	○	1 drink
76 Coke	○	○	○	○	○	○	○	○	○	1 bottle or can
77 Ice-tea	○	○	○	○	○	○	○	○	○	1 bottle or can
78 Soft drinks, fruit juice and fruit nectar	○	○	○	○	○	○	○	○	○	1 bottle or glass
79 Coffee (including coffee with milk)	○	○	○	○	○	○	○	○	○	1 coffee cup
80 Tea (black or green)	○	○	○	○	○	○	○	○	○	1 cup
81 Snacks: Croquettes, code cakes, other salty cakes, etc.	○	○	○	○	○	○	○	○	○	3 units
82 Mayonnaise	○	○	○	○	○	○	○	○	○	1 dessert spoon
83 Tomato sauce, ketchup	○	○	○	○	○	○	○	○	○	1 tablespoon
84 Pizza	○	○	○	○	○	○	○	○	○	½ pizza
85 Hamburger	○	○	○	○	○	○	○	○	○	1 medium
86 Vegetables soup	○	○	○	○	○	○	○	○	○	1 dish
X. Others										
Tropical fruits (mango, pineapple, papaw)	○	○	○	○	○	○	○	○	○	
Fruit juice (plain)	○	○	○	○	○	○	○	○	○	
Dried fruit (plums, fig, apricot)	○	○	○	○	○	○	○	○	○	
Soluble Mixture (coffee and barley)	○	○	○	○	○	○	○	○	○	
“Alheira” (Portuguese sauce with meat and bread)	○	○	○	○	○	○	○	○	○	
Sweets	○	○	○	○	○	○	○	○	○	
Distilled spirituous drinks (e.g. liquors, Port wine)	○	○	○	○	○	○	○	○	○	

Appendix J

Table J.1 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: body mass (kg).

				Percentiles				
Age group (years)	N	Mean	SD	10	25	50	75	90
				Men				
60-64	103	80.3	12.1	66.5	72.0	78.3	88.8	99.0
65-69	99	79.7	13.1	64.2	69.9	79.8	87.8	97.1
70-74	107	79.9	13.3	63.4	71.0	79.4	86.7	93.6
75-79	92	75.8	13.0	58.0	66.8	76.3	82.8	93.4
				Women				
60-64	102	72.2	11.7	59.0	64.3	71.8	78.7	86.5
65-69	108	71.2	12.7	55.6	62.3	70.7	80.9	87.6
70-74	98	70.6	10.6	55.9	63.4	69.4	76.1	86.1
75-79	93	67.8	11.5	53.4	60.5	67.2	75.4	85.0

Table J.2 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: height (cm).

				Percentiles				
Age group (years)	N	Mean	SD	10	25	50	75	90
				Men				
60-64	103	166.9	5.2	159.5	162.5	167.2	171.0	172.9
65-69	99	165.9	6.2	158.1	161.7	164.8	169.6	174.5
70-74	107	164.5	6.1	157.4	160.3	164.1	168.0	173.8
75-79	92	164.6	6.2	156.2	160.5	164.8	168.5	172.8
				Women				
60-64	102	154.2	5.4	148.3	150.7	154.4	157.8	160.7
65-69	108	153.8	5.5	147.1	150.8	153.7	157.3	162.0
70-74	98	152.0	5.8	144.7	147.2	152.2	155.8	159.9
75-79	93	150.1	5.4	141.9	146.4	151.0	154.6	157.0

Table J.3 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: sitting height (cm).

Age group (years)	N	Mean	SD	Percentiles 10	25	50	75	90
Men								
60-64	103	88.3	3.3	83.9	86.2	88.6	90.6	92.6
65-69	99	87.9	3.2	83.8	85.9	88.0	90.0	91.9
70-74	107	87.0	3.2	83.0	84.9	86.7	89.4	90.9
75-79	92	86.0	4.3	81.3	84.7	86.3	88.3	91.2
Women								
60-64	102	82.3	3.5	78.0	80.0	83.1	84.7	86.7
65-69	108	81.4	3.9	77.3	79.4	81.9	84.0	85.8
70-74	98	80.4	3.3	76.2	78.3	80.3	82.4	84.6
75-79	93	78.7	3.2	74.1	77.0	79.2	81.0	82.5

Table J.4 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: biacromial breadth (cm).

Age group (years)	N	Mean	SD	Percentiles 10	25	50	75	90
Men								
60-64	103	38.6	1.9	36.1	37.6	38.5	40.0	41.0
65-69	99	38.4	1.9	35.9	37.1	38.4	39.6	40.6
70-74	107	38.3	1.9	35.9	36.6	38.3	39.6	40.6
75-79	92	37.8	2.5	35.4	36.5	38.0	39.5	40.5
Women								
60-64	102	35.5	1.8	33.3	34.4	35.8	36.6	37.5
65-69	108	35.4	1.7	33.5	34.5	35.4	36.5	37.4
70-74	98	34.7	1.7	32.3	33.5	34.9	35.9	36.9
75-79	93	34.3	1.8	32.2	33.1	34.1	35.6	36.8

Table J.5 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: bicristal breadth (cm).

				Percentiles				
Age group (years)	N	Mean	SD	10	25	50	75	90
				Men				
60-64	103	29.6	1.7	27.5	28.4	29.5	30.3	31.9
65-69	99	29.9	1.9	27.7	28.5	29.8	31.2	32.4
70-74	107	30.0	1.8	27.9	28.9	29.7	30.9	32.1
75-79	92	29.8	2.1	27.3	28.3	29.6	30.7	32.3
				Women				
60-64	103	29.6	1.7	27.5	28.4	29.5	30.3	31.9
65-69	99	29.9	1.9	27.7	28.5	29.8	31.2	32.4
70-74	107	30.0	1.8	27.9	28.9	29.7	30.9	32.1
75-79	92	29.8	2.1	27.3	28.3	29.6	30.7	32.3

Table J.6 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: humerus breadth (cm).

				Percentiles				
Age group (years)	N	Mean	SD	10	25	50	75	90
				Men				
60-64	103	7.0	0.4	6.6	6.8	7.0	7.3	7.6
65-69	99	7.1	0.4	6.6	6.8	7.1	7.4	7.5
70-74	107	7.0	0.4	6.5	6.8	7.1	7.3	7.5
75-79	92	7.0	0.4	6.4	6.8	7.0	7.3	7.5
				Women				
60-64	102	6.2	0.4	5.7	6.0	6.2	6.5	6.8
65-69	108	6.2	0.4	5.7	6.0	6.2	6.5	6.8
70-74	98	6.2	0.4	5.7	6.0	6.2	6.5	6.7
75-79	93	6.1	0.4	5.6	5.9	6.1	6.3	6.5

Table J.7 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: femoral breadth (cm).

Age group (years)	N	Mean	SD	Percentiles 10	25	50	75	90
Men								
60-64	103	9.6	0.6	8.9	9.3	9.6	10.0	10.4
65-69	99	9.7	0.5	9.0	9.3	9.8	10.2	10.5
70-74	107	9.8	0.6	9.1	9.2	9.8	10.2	10.5
75-79	92	9.7	0.7	8.9	9.4	9.6	10.1	10.6
Women								
60-64	102	9.0	0.6	8.2	8.6	9.0	9.5	9.9
65-69	108	9.2	0.7	8.3	8.6	9.1	9.6	10.2
70-74	98	9.1	0.6	8.2	8.6	9.0	9.5	10.0
75-79	93	9.2	0.7	8.5	8.7	9.0	9.6	10.3

Table J.8 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: calf circumference (cm)

Age group (years)	N	Mean	SD	Percentiles 10	25	50	75	90
Men								
60-64	103	36.9	2.6	33.5	35.0	36.9	38.3	40.2
65-69	99	36.6	3.0	33.1	34.5	36.7	38.5	40.5
70-74	107	37.0	2.8	33.2	35.1	37.0	39.1	40.3
75-79	92	35.9	3.4	31.4	33.9	35.9	37.9	40.4
Women								
60-64	102	36.7	3.1	33.0	34.5	36.2	38.6	40.6
65-69	108	36.5	3.2	32.5	34.3	36.3	38.6	41.0
70-74	98	36.1	3.8	31.8	34.0	36.0	38.1	40.0
75-79	93	35.2	3.2	31.2	33.5	35.0	36.8	39.1

Table J.9 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: thigh circumference (cm).

				Percentiles				
Age group (years)	N	Mean	SD	10	25	50	75	90
				Men				
60-64	103	54.5	4.8	48.7	51.0	54.4	57.8	60.3
65-69	99	54.7	6.0	48.0	51.1	54.5	57.4	61.0
70-74	107	54.2	4.2	48.2	51.3	54.5	57.2	59.5
75-79	92	53.1	5.6	46.3	49.1	53.2	56.8	59.4
				Women				
60-64	102	59.2	5.6	52.8	55.4	58.9	62.2	65.8
65-69	108	57.9	5.2	51.1	54.2	57.8	61.6	65.2
70-74	98	57.6	5.4	52.1	54.4	58.2	60.9	64.6
75-79	93	56.5	5.6	49.4	53.5	56.5	60.5	62.3

Table J.10 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: upper arm relax circumference (cm).

				Percentiles				
Age group (years)	N	Mean	SD	10	25	50	75	90
				Men				
60-64	103	30.7	2.9	27.3	28.6	30.2	32.4	35.1
65-69	99	30.6	3.1	27.0	28.6	30.5	32.2	34.5
70-74	107	30.3	2.8	26.9	28.5	30.0	32.1	34.0
75-79	92	29.1	3.2	25.1	26.7	29.3	31.4	33.0
				Women				
60-64	102	31.4	3.7	27.4	29.0	31.0	33.6	36.1
65-69	108	31.2	3.8	27.4	28.5	31.1	33.3	36.4
70-74	98	30.9	3.4	26.4	28.5	31.0	33.5	34.9
75-79	93	30.3	3.8	26.2	27.9	30.0	32.8	34.2

Table J.11 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: forearm circumference (cm).

				Percentiles				
Age group (years)	N	Mean	SD	10	25	50	75	90
				Men				
60-64	103	27.4	1.8	25.0	26.2	27.5	28.4	30.0
65-69	99	27.2	1.9	25.0	26.0	27.5	28.5	29.5
70-74	107	27.0	1.7	24.9	26.0	26.9	28.1	29.5
75-79	92	26.3	2.0	23.6	24.6	26.5	27.7	28.6
				Women				
60-64	102	25.5	2.3	22.6	24.1	25.3	27.0	28.4
65-69	108	25.2	2.2	22.5	24.0	25.0	26.6	28.0
70-74	98	25.0	2.0	22.8	23.5	25.0	26.5	27.5
75-79	93	24.4	2.2	21.9	23.2	24.0	25.6	27.0

Table J.12 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: upper arm flexed circumference (cm).

				Percentiles				
Age group (years)	N	Mean	SD	10	25	50	75	90
				Men				
60-64	103	32.3	2.8	28.8	30.5	32.4	34.0	36.3
65-69	99	32.1	2.9	28.6	30.5	32.1	33.8	35.2
70-74	107	31.7	2.7	28.2	29.9	31.5	33.3	35.3
75-79	92	30.3	3.1	26.8	28.1	30.4	32.2	34.1
				Women				
60-64	102	31.8	3.6	27.9	29.2	31.5	33.9	36.8
65-69	108	31.3	4.9	27.5	29.0	31.2	33.6	35.6
70-74	98	31.2	3.3	27.0	29.0	31.3	33.3	35.8
75-79	93	30.8	3.7	26.4	28.0	30.3	33.0	35.3

Table J.13 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: waist circumference (cm).

				Percentiles				
Age group (years)	N	Mean	SD	10	25	50	75	90
Men								
60-64	103	99.7	9.9	86.5	91.4	99.5	106.3	113.2
65-69	99	100.2	10.3	86.0	93.5	99.7	107.8	113.0
70-74	107	102.4	10.7	89.1	94.0	102.6	109.6	115.8
75-79	92	99.6	11.2	83.5	91.2	100.9	106.8	112.5
Women								
60-64	102	92.7	10.6	79.1	86.3	92.1	98.2	107.5
65-69	108	92.7	12.3	78.4	85.0	91.2	99.1	109.7
70-74	98	95.1	9.5	84.2	87.6	95.6	101.4	109.0
75-79	93	95.2	11.2	81.7	87.0	96.4	103.6	110.1

Table J.14 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: hip circumference (cm).

				Percentiles				
Age group (years)	N	Mean	SD	10	25	50	75	90
Men								
60-64	103	98.4	7.3	90.8	93.9	96.9	102.3	108.3
65-69	99	98.7	7.6	91.5	94.1	98.3	103.7	107.6
70-74	107	99.4	7.7	90.5	94.1	98.5	103.5	107.4
75-79	92	98.0	7.3	87.2	93.8	98.1	102.5	107.5
Women								
60-64	102	105.3	9.9	93.6	99.1	104.0	110.0	117.1
65-69	108	103.7	9.9	92.8	96.7	103.5	110.4	114.8
70-74	98	104.2	8.9	93.1	98.1	103.9	109.4	115.1
75-79	93	104.0	9.6	91.2	97.2	103.4	110.0	116.0

Table J.15 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: triceps skinfold (mm).

				Percentiles				
Age group (years)	N	Mean	SD	10	25	50	75	90
				Men				
60-64	103	12.4	5.6	7.0	9.0	11.1	14.4	18.7
65-69	99	12.9	4.6	7.6	9.7	12.2	15.4	18.1
70-74	107	12.6	4.5	8.1	9.9	11.6	15.0	17.9
75-79	92	12.0	4.8	6.9	8.5	11.2	14.0	18.3
				Women				
60-64	102	24.2	6.5	16.6	19.5	24.6	29.1	32.4
65-69	108	23.9	5.7	17.0	19.6	24.1	27.9	30.2
70-74	98	22.9	5.5	16.2	19.0	22.8	26.3	30.5
75-79	93	22.7	6.8	15.3	17.9	22.0	27.8	32.3

Table J.16 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: biceps skinfold (mm).

				Percentiles				
Age group (years)	N	Mean	SD	10	25	50	75	90
				Men				
60-64	103	7.9	4.4	4.2	5.1	6.5	9.4	14.4
65-69	99	7.9	3.2	4.4	6.1	7.2	9.3	11.4
70-74	107	8.3	5.3	4.2	5.2	7.1	9.4	13.9
75-79	92	7.3	4.3	3.7	4.7	6.2	8.2	11.2
				Women				
60-64	102	15.8	5.3	9.9	12.0	15.1	19.8	24.3
65-69	108	14.9	5.7	8.8	10.7	14.2	17.7	22.0
70-74	98	14.0	5.1	7.9	10.5	13.1	16.8	20.6
75-79	93	14.9	6.2	8.2	9.9	13.5	19.7	23.0

Table J.17 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: subscapular skinfold (mm).

				Percentiles				
Age group (years)	N	Mean	SD	10	25	50	75	90
				Men				
60-64	103	24.5	7.9	15.5	19.4	22.7	28.4	36.3
65-69	99	25.8	8.1	15.5	20.6	24.9	31.0	37.5
70-74	107	25.2	7.5	15.9	19.4	25.1	30.5	33.5
75-79	92	22.4	6.6	14.5	17.9	22.0	26.7	31.4
				Women				
60-64	102	27.5	7.5	17.1	22.9	27.1	32.9	37.4
65-69	108	26.4	9.3	16.2	20.3	26.1	31.1	35.8
70-74	98	27.0	8.3	17.9	21.1	26.0	32.0	39.2
75-79	93	24.9	9.1	14.4	18.7	22.6	29.4	37.0

Table J.18 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: suprailiac skinfold (mm).

				Percentiles				
Age group (years)	N	Mean	SD	10	25	50	75	90
				Men				
60-64	103	25.3	12.8	11.7	16.2	23.4	33.6	41.3
65-69	99	26.2	11.4	12.6	18.1	23.6	34.9	40.5
70-74	107	27.0	13.4	10.0	17.7	26.0	36.8	42.1
75-79	92	25.6	11.7	12.3	16.6	23.6	33.7	40.8
				Women				
60-64	102	36.1	13.4	21.3	28.0	36.8	43.5	54.0
65-69	108	34.9	13.4	18.9	26.2	34.6	41.8	52.5
70-74	98	35.5	13.1	22.0	27.0	35.7	42.8	55.2
75-79	93	35.3	13.1	21.0	26.5	34.1	42.4	54.3

Table J.19 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: calf skinfold (mm).

				Percentiles				
Age group (years)	N	Mean	SD	10	25	50	75	90
				Men				
60-64	103	10.5	5.2	5.9	6.7	9.3	13.1	18.3
65-69	99	10.9	5.4	5.9	7.1	10.0	13.0	16.4
70-74	107	11.8	6.1	5.9	8.0	10.2	14.1	18.7
75-79	92	10.6	6.3	4.9	6.1	9.9	12.6	17.3
				Women				
60-64	102	23.6	9.2	13.2	16.9	23.2	29.3	36.4
65-69	108	23.4	8.2	12.7	17.6	23.2	28.4	35.0
70-74	98	24.0	9.0	11.3	17.1	23.9	30.6	35.2
75-79	93	23.5	8.9	10.8	16.3	23.7	28.6	36.2

Table J.20 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: abdomen skinfold (mm).

				Percentiles				
Age group (years)	N	Mean	SD	10	25	50	75	90
				Men				
60-64	103	15.3	9.0	8.0	9.7	11.8	18.5	26.1
65-69	99	15.5	8.4	8.6	10.5	13.2	18.3	25.1
70-74	107	16.5	9.7	7.8	10.3	13.9	19.6	28.4
75-79	92	14.9	8.2	6.9	8.9	12.7	19.8	24.6
				Women				
60-64	102	102	34.7	12.5	17.9	26.9	34.6	42.3
65-69	108	108	33.3	11.0	17.7	26.1	33.8	40.9
70-74	98	98	31.9	12.7	14.3	22.2	32.4	41.8
75-79	93	93	33.0	11.4	17.3	25.1	34.9	40.5

Table J.21 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: thigh skinfold (mm).

Age group (years)	N	Mean	SD	Percentiles 10	25	50	75	90
				Men				
60-64	103	33.1	13.4	20.1	24.4	32.7	39.5	46.3
65-69	99	34.3	12.4	22.2	26.0	34.5	40.1	45.7
70-74	107	33.1	12.9	18.9	25.3	32.7	41.8	45.7
75-79	92	33.6	14.7	18.7	24.6	30.4	40.2	50.3
				Women				
60-64	102	41.7	14.5	28.9	34.5	41.4	47.7	59.6
65-69	108	43.5	14.6	28.3	36.2	41.1	49.2	62.8
70-74	98	42.5	13.4	30.3	35.4	40.2	47.8	60.1
75-79	93	44.8	14.4	30.2	35.7	41.7	53.1	65.8

Table J.22 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: body mass index (BMI) (kg/m^2).

Age group (years)	N	Mean	SD	Percentiles 10	25	50	75	90
				Men				
60-64	103	28.8	3.7	24.4	26.0	28.1	31.3	34.7
65-69	99	28.9	4.0	24.1	26.2	29.0	31.6	34.2
70-74	107	29.4	3.9	24.5	27.1	29.0	31.5	33.5
75-79	92	27.9	4.1	22.5	25.5	28.0	30.4	32.6
				Women				
60-64	102	30.3	4.6	24.4	27.4	30.2	33.3	36.5
65-69	108	30.1	5.1	24.4	26.5	29.7	32.8	36.3
70-74	98	30.6	4.2	24.8	27.8	30.5	33.5	35.7
75-79	93	30.0	4.4	24.8	26.5	30.2	33.0	35.5

Table J.23 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: waist-to-hip ratio (WHR).

				Percentiles				
Age group (years)	N	Mean	SD	10	25	50	75	90
				Men				
60-64	103	1.01	0.06	0.94	0.97	1.01	1.05	1.10
65-69	99	1.01	0.07	0.94	0.97	1.01	1.05	1.12
70-74	107	1.03	0.06	.095	0.99	1.03	1.07	1.12
75-79	92	1.01	0.06	0.93	0.97	1.02	1.06	1.08
				Women				
60-64	102	0.88	0.07	0.80	0.83	0.88	0.92	0.97
65-69	108	0.89	0.07	0.81	0.85	0.89	0.95	0.98
70-74	98	0.91	0.06	0.84	0.87	0.91	0.95	1.01
75-79	93	0.91	0.07	0.83	0.87	0.92	0.96	0.99

Table J.24 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: percent body fat in Madeira elderly women and men from Williams, Going, Lohman, Hewitt & Haber (1992) formula.

				Percentiles				
Age group (years)	N	Mean	SD	10	25	50	75	90
				Men				
60-64	103	23.4	5.4	17.0	19.7	22.5	26.4	31.7
65-69	99	24.8	4.9	17.5	21.9	24.9	27.7	31.3
70-74	107	25.5	5.3	17.9	22.7	25.5	29.4	32.3
75-79	92	24.3	5.6	16.1	20.1	25.0	28.2	31.1
				Women				
60-64	102	37.8	5.1	30.9	34.8	38.5	41.6	43.7
65-69	108	38.0	5.2	30.8	35.1	38.9	41.7	44.2
70-74	98	38.3	5.7	29.8	34.8	38.8	43.0	45.4
75-79	93	38.5	5.6	30.8	34.8	39.1	42.7	46.1

Table J.25 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: total fat mass (TFM) (kg) measured by Dual Energy x-ray absorptiometry-DXA.

				Percentiles				
Age group (years)	N	Mean	SD	10	25	50	75	90
				Men				
60-64	103	22.5	8.1	13.1	16.3	22.1	28.3	32.9
65-69	99	23.3	7.9	12.9	18.6	23.9	28.6	32.6
70-74	107	23.6	8.6	12.9	17.6	23.3	28.5	32.3
75-79	92	21.5	8.2	10.3	15.8	21.6	26.5	30.0
				Women				
60-64	102	29.7	7.8	19.8	24.3	29.4	34.4	39.3
65-69	108	28.7	8.0	18.7	21.4	29.1	34.6	39.0
70-74	98	28.2	7.3	18.5	23.3	28.0	32.8	39.5
75-79	93	27.1	7.8	17.9	20.1	27.2	31.8	36.7

Table J.26 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: legs total fat mass (LTFM) (kg) measured by Dual Energy x-ray absorptiometry-DXA.

				Percentiles				
Age group (years)	N	Mean	SD	10	25	50	75	90
				Men				
60-64	103	5.5	2.4	2.8	4.0	5.0	6.9	8.4
65-69	99	5.7	2.3	3.4	4.3	5.6	6.7	8.3
70-74	107	5.8	2.3	3.5	4.3	5.4	6.8	8.6
75-79	92	5.5	2.3	2.8	4.1	5.4	6.5	8.1
				Women				
60-64	102	9.1	3.0	5.7	6.9	8.6	11.0	13.3
65-69	108	8.8	2.7	5.6	6.7	8.7	10.8	12.2
70-74	98	8.5	2.6	5.0	6.7	8.4	9.8	12.2
75-79	93	8.4	2.8	5.4	6.6	8.1	9.9	11.6

Table J.27 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: arms total fat mass (ATFM) (kg) measured by Dual Energy x-ray absorptiometry-DXA.

Age group (years)	N	Mean	SD	Percentiles				
				10	25	50	75	90
				Men				
60-64	103	1.9	0.9	0.9	1.2	1.7	2.4	3.2
65-69	99	2.1	1.0	1.1	1.5	1.9	2.5	3.2
70-74	107	2.0	0.9	1.2	1.4	1.8	2.4	3.1
75-79	92	1.8	0.8	0.8	1.3	1.7	2.1	2.7
				Women				
60-64	102	3.2	1.1	2.0	2.5	3.1	3.8	4.9
65-69	108	3.1	1.1	1.9	2.2	3.0	3.6	4.4
70-74	98	2.9	0.9	1.6	2.2	2.8	3.4	4.1
75-79	93	2.9	1.0	1.8	2.1	2.6	3.5	4.3

Table J.28 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: appendicular lean tissue mass (ALST) (kg) measured by Dual Energy x-ray absorptiometry-DXA.

Age group (years)	N	Mean	SD	Percentiles				
				10	25	50	75	90
				Men				
60-64	103	6.6	1.1	5.3	5.9	6.5	7.3	7.9
65-69	99	6.5	0.9	5.2	5.8	6.5	7.2	7.5
70-74	107	6.1	1.0	4.9	5.4	6.1	7.0	7.5
75-79	92	5.8	1.0	4.5	5.1	5.9	6.6	7.1
				Women				
60-64	102	4.2	0.7	3.3	3.7	4.2	4.5	5.0
65-69	108	4.1	0.7	3.3	3.6	4.1	4.5	4.9
70-74	98	3.8	0.6	3.0	3.4	3.8	4.3	4.5
75-79	93	3.8	0.7	2.9	3.4	3.8	4.2	4.5

Table J.29 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: total soft lean tissue mass (TLTM) (kg) measured by Dual Energy x-ray absorptiometry-DXA.

				Percentiles				
Age group (years)	N	Mean	SD	10	25	50	75	90
				Men				
60-64	103	54.3	5.9	46.9	49.9	53.9	58.2	62.4
65-69	99	53.3	5.8	46.4	49.5	53.6	57.1	61.3
70-74	107	52.8	5.5	45.7	49.0	52.9	56.4	61.0
75-79	92	51.2	6.3	42.2	46.5	51.4	55.6	59.0
				Women				
60-64	102	39.9	4.9	34.2	36.6	39.6	43.1	46.1
65-69	108	40.0	5.5	33.5	36.2	39.7	43.5	46.3
70-74	98	39.3	3.9	34.8	36.4	38.9	41.9	44.4
75-79	93	38.2	4.3	32.3	35.7	38.4	41.0	43.8

Table J.30 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: legs soft lean tissue mass (LLTM) (kg) measured by Dual Energy x-ray absorptiometry-DXA.

				Percentiles				
Age group (years)	N	Mean	SD	10	25	50	75	90
				Men				
60-64	103	17.2	2.5	14.3	15.9	17.0	18.8	20.4
65-69	99	17.0	2.3	14.3	15.3	16.9	18.6	19.9
70-74	107	16.5	2.2	13.7	15.1	16.5	17.9	19.4
75-79	92	16.1	2.3	12.5	14.7	16.2	17.6	19.0
				Women				
60-64	102	12.6	1.7	10.6	11.5	12.4	13.9	15.1
65-69	108	12.5	1.9	10.2	11.3	12.5	13.6	15.2
70-74	98	12.2	1.6	10.1	11.0	12.1	13.3	14.4
75-79	93	11.8	1.8	9.2	10.8	11.9	13.0	13.9

Table J.31 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: arms soft lean tissue mass (ALTM) (kg) measured by Dual Energy x-ray absorptiometry-DXA.

				Percentiles				
Age group (years)	N	Mean	SD	10	25	50	75	90
				Men				
60-64	103	8.5	1.6	6.6	7.4	8.2	9.4	11.1
65-69	99	8.5	1.5	6.8	7.4	8.5	9.4	10.3
70-74	107	8.1	1.4	6.5	7.1	8.0	9.1	9.8
75-79	92	7.5	1.4	5.8	6.6	7.5	8.5	9.3
				Women				
60-64	102	7.3	1.6	5.6	6.3	7.2	8.1	9.6
65-69	108	7.2	1.6	5.3	6.1	7.2	8.0	9.0
70-74	98	6.7	1.4	4.7	5.8	6.8	7.6	8.6
75-79	93	6.6	1.5	4.9	5.6	6.4	7.5	8.8

Table J.32 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: bone mineral density (g/cm^2) at total body.

				Percentiles				
Age group (years)	N	Mean	SD	10	25	50	75	90
				Men				
60-64	103	1.23	0.10	1.10	1.16	1.25	1.30	1.35
65-69	99	1.22	0.11	1.07	1.14	1.22	1.28	1.35
70-74	107	1.22	0.11	1.08	1.14	1.21	1.30	1.35
75-79	92	1.19	0.09	1.08	1.13	1.18	1.26	1.31
				Women				
60-64	102	1.14	0.09	1.03	1.07	1.13	1.20	1.25
65-69	108	1.10	0.10	0.96	1.02	1.10	1.17	1.21
70-74	98	1.07	0.09	0.97	1.00	1.07	1.14	1.18
75-79	93	1.03	0.08	0.91	0.96	1.03	1.09	1.14

Table J.33 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: bone mineral content (g) at total body.

				Percentiles				
Age group (years)	N	Mean	SD	10	25	50	75	90
				Men				
60-64	103	3082.67	489.68	2378.40	2773.00	3058.00	3420.00	3727.00
65-69	99	3024.57	445.18	2349.00	2783.00	3083.00	3286.00	3516.00
70-74	107	2996.91	471.44	2444.20	2623.00	2946.00	3439.00	3666.00
75-79	92	2864.89	413.49	2356.60	2569.25	2808.50	3162.75	3481.60
				Women				
60-64	102	2387.55	408.07	1954.90	2089.50	2379.00	2600.25	2901.20
65-69	108	2242.56	427.71	1675.50	1955.75	2229.50	2535.25	2891.70
70-74	98	2091.52	378.71	1694.00	1827.75	2076.00	2310.75	2579.50
75-79	93	1959.09	324.51	1556.20	1733.00	1905.00	2170.50	2435.20

Table J.34 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: bone mineral density (g/cm^2) at lumbar spine.

				Percentiles				
Age group (years)	N	Mean	SD	10	25	50	75	90
				Men				
60-64	102	1.22	0.19	0.96	1.11	1.23	1.34	1.45
65-69	99	1.23	0.22	0.96	1.08	1.20	1.34	1.56
70-74	106	1.21	0.25	0.94	1.05	1.15	1.37	1.53
75-79	91	1.17	0.20	0.92	1.03	1.16	1.30	1.43
				Women				
60-64	101	1.09	0.19	0.87	0.94	1.05	1.22	1.33
65-69	108	1.03	0.17	0.82	0.90	1.00	1.17	1.26
70-74	96	0.99	0.19	0.77	0.87	0.99	1.09	1.21
75-79	93	0.97	0.17	0.76	0.84	0.96	1.09	1.19

Table J.35 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: bone mineral content (g) at lumbar spine.

				Percentiles				
Age group (years)	N	Mean	SD	10	25	50	75	90
Men								
60-64	102	59.02	12.07	44.64	50.50	57.18	68.49	74.33
65-69	99	59.14	13.71	43.35	49.35	56.95	66.53	78.53
70-74	106	59.26	17.60	40.55	47.57	55.75	68.48	81.67
75-79	91	57.47	14.97	41.19	46.24	54.47	67.12	75.98
Women								
60-64	101	43.01	10.26	31.15	35.48	41.02	50.24	56.76
65-69	108	40.86	9.30	30.85	34.56	39.80	44.73	53.87
70-74	96	39.36	10.23	28.42	32.00	38.92	45.30	51.62
75-79	93	38.13	9.54	26.40	30.92	37.03	45.34	51.11

Table J.36 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: bone mineral density (g/cm^2) at femoral neck.

				Percentiles				
Age group (years)	N	Mean	SD	10	25	50	75	90
Men								
60-64	102	1.02	0.15	0.84	0.92	0.99	1.10	1.22
65-69	97	0.99	0.14	0.80	0.90	0.97	1.08	1.20
70-74	107	0.95	0.14	0.80	0.85	0.92	1.04	1.16
75-79	92	0.92	0.13	0.76	0.82	0.93	1.00	1.08
Women								
60-64	102	0.92	0.13	0.78	0.84	0.92	1.00	1.08
65-69	107	0.88	0.12	0.71	0.80	0.87	0.97	1.03
70-74	96	0.83	0.10	0.69	0.75	0.83	0.91	0.98
75-79	93	0.78	0.10	0.66	0.71	0.77	0.84	0.90

Table J.37 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: bone mineral content (g) at femoral neck.

Age group (years)	N	Mean	SD	Percentiles 10	25	50	75	90
Men								
60-64	102	5.47	0.96	4.49	4.88	5.33	5.97	6.44
65-69	97	5.22	0.82	4.22	4.67	5.20	5.68	6.37
70-74	107	5.09	0.82	4.14	4.54	4.99	5.52	6.15
75-79	92	5.07	0.92	3.94	4.39	5.00	5.61	6.26
Women								
60-64	102	4.34	0.77	3.55	3.78	4.27	4.68	5.56
65-69	107	4.13	0.74	3.13	3.69	4.07	4.64	5.24
70-74	96	3.89	0.60	3.12	3.48	3.85	4.30	4.53
75-79	93	3.63	0.55	3.00	3.24	3.60	3.95	4.29

Table J.38 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: bone mineral density (g/cm^2) at trochanter.

Age group (years)	N	Mean	SD	Percentiles 10	25	50	75	90
Men								
60-64	102	0.93	0.12	0.75	0.85	0.93	1.01	1.08
65-69	97	0.91	0.14	0.73	0.82	0.90	0.99	1.12
70-74	107	0.89	0.13	0.73	0.80	0.87	0.98	1.08
75-79	92	0.86	0.13	0.67	0.77	0.88	0.95	1.04
Women								
60-64	102	0.81	0.13	0.66	0.73	0.81	0.89	0.96
65-69	107	0.77	0.12	0.60	0.69	0.78	0.85	0.93
70-74	96	0.73	0.11	0.57	0.65	0.73	0.81	0.87
75-79	93	0.68	0.11	0.54	0.61	0.68	0.77	0.82

Table J.39 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: bone mineral content (g) at trochanter.

				Percentiles				
Age group (years)	N	Mean	SD	10	25	50	75	90
				Men				
60-64	102	14.67	3.51	10.56	12.77	14.58	16.68	18.37
65-69	97	14.91	3.59	10.99	12.17	14.75	17.05	18.78
70-74	107	14.37	3.12	10.85	12.17	13.79	16.52	19.03
75-79	92	13.67	3.68	9.08	11.50	13.66	15.78	18.80
				Women				
60-64	102	10.24	2.33	7.45	8.75	10.22	11.67	13.08
65-69	107	10.08	2.57	7.15	8.12	9.78	12.07	13.61
70-74	96	9.36	2.22	6.39	7.56	9.53	10.90	12.12
75-79	93	8.77	1.97	6.14	7.53	8.86	9.93	11.12

Table J.40 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: bone mineral density (g/cm^2) at Ward’s Triangle.

				Percentiles				
Age group (years)	N	Mean	SD	10	25	50	75	90
				Men				
60-64	102	0.78	0.15	0.60	0.68	0.76	0.87	0.99
65-69	97	0.75	0.15	0.58	0.64	0.74	0.84	0.95
70-74	107	0.71	0.13	0.58	0.61	0.68	0.78	0.91
75-79	92	0.69	0.14	0.51	0.58	0.70	0.78	0.86
				Women				
60-64	102	0.71	0.14	0.55	0.61	0.69	0.80	0.92
65-69	107	0.67	0.13	0.48	0.59	0.66	0.75	0.86
70-74	96	0.61	0.11	0.48	0.53	0.61	0.70	0.75
75-79	93	0.56	0.10	0.44	0.47	0.56	0.62	0.69

Table J.41 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: bone mineral content (g) at Ward's Triangle.

				Percentiles				
Age group (years)	N	Mean	SD	10	25	50	75	90
				Men				
60-64	102	1.76	0.56	1.20	1.36	1.66	2.07	2.45
65-69	107	1.65	0.48	0.98	1.36	1.56	1.89	2.32
70-74	96	1.50	0.40	1.08	1.21	1.47	1.74	1.92
75-79	93	1.36	0.35	0.97	1.13	1.29	1.56	1.75
				Women				
60-64	102	1.10	0.14	0.90	1.01	1.08	1.20	1.27
65-69	97	1.07	0.16	0.85	0.97	1.07	1.17	1.30
70-74	106	1.05	0.14	0.88	0.94	1.04	1.15	1.25
75-79	92	1.01	0.14	0.85	0.92	1.01	1.10	1.20

Table J.42 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: bone mineral density (g/cm^2) at total hip.

				Percentiles				
Age group (years)	N	Mean	SD	10	25	50	75	90
				Men				
60-64	102	1.10	0.14	0.90	1.01	1.08	1.20	1.27
65-69	97	1.07	0.16	0.85	0.97	1.07	1.17	1.30
70-74	106	1.05	0.14	0.88	0.94	1.04	1.15	1.25
75-79	92	1.01	0.14	0.85	0.92	1.01	1.10	1.20
				Women				
60-64	101	1.01	0.13	0.85	0.92	1.00	1.10	1.17
65-69	106	0.96	0.13	0.79	0.86	0.95	1.06	1.12
70-74	96	0.91	0.11	0.77	0.84	0.90	1.00	1.08
75-79	92	0.86	0.12	0.69	0.78	0.87	0.95	1.01

Table J.43 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: bone mineral content (g) at total hip.

				Percentiles				
Age group (years)	N	Mean	SD	10	25	50	75	90
				Men				
60-64	102	39.89	6.36	31.64	35.48	40.00	43.70	47.75
65-69	97	39.21	6.55	30.71	35.23	38.62	43.33	46.95
70-74	106	38.55	6.09	31.04	34.51	38.04	42.28	47.28
75-79	92	37.21	6.06	29.94	33.57	36.26	41.48	46.02
				Women				
60-64	101	31.26	4.92	25.03	28.46	30.81	34.08	37.74
65-69	106	30.25	4.93	23.72	26.89	30.63	33.95	36.11
70-74	96	28.49	4.44	22.27	25.20	28.35	31.72	34.63
75-79	92	26.85	4.15	22.32	23.74	26.87	29.91	32.46

Table J.44 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: femur strength index.

				Percentiles				
Age group (years)	N	Mean	SD	10	25	50	75	90
				Men				
60-64	102	1.86	0.45	1.30	1.50	1.80	2.20	2.47
65-69	97	1.74	0.52	1.18	1.35	1.70	2.00	2.40
70-74	106	1.76	0.51	1.20	1.40	1.70	2.00	2.40
75-79	92	1.83	0.57	1.30	1.50	1.80	2.00	2.40
				Women				
60-64	102	1.61	0.47	1.10	1.30	1.50	1.80	2.10
65-69	107	1.53	0.39	1.10	1.30	1.50	1.80	2.02
70-74	96	1.48	0.38	1.00	1.20	1.40	1.70	2.00
75-79	93	1.44	0.37	1.00	1.20	1.40	1.70	1.96

Appendix K

Table K.1 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: chair stand test (n) (lower body strength) – Senior Fitness Test (Rikli & Jones, 2001).

Age group (years)	N	Mean	SD	Percentiles 10	25	50	75	90
Men								
60-64	103	15.7	4.1	11.0	13.0	15.0	19.0	21.0
65-69	99	14.8	4.0	10.0	12.0	15.0	17.0	20.0
70-74	107	13.4	4.0	8.0	11.0	13.0	15.0	18.0
75-79	92	12.6	3.1	8.3	11.0	13.0	14.0	16.0
Women								
60-64	102	14.8	4.7	10.0	12.0	15.0	17.0	20.7
65-69	108	13.2	4.2	8.9	10.3	13.0	16.0	18.1
70-74	98	12.8	3.7	8.0	11.0	13.0	15.0	18.0
75-79	93	11.5	3.4	7.0	9.0	11.0	14.0	16.0

Table K.2 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: arm curl test (n) (upper body strength) – Senior Fitness Test (Rikli & Jones, 2001).

Age group (years)	N	Mean	SD	Percentiles 10	25	50	75	90
Men								
60-64	103	17.7	3.7	14.0	15.0	18.0	20.0	23.0
65-69	99	17.3	4.1	13.0	14.0	17.0	20.0	22.0
70-74	107	15.8	3.9	11.0	14.0	15.0	18.0	21.0
75-79	92	14.9	2.8	11.3	13.0	15.0	17.0	18.0
Women								
60-64	102	16.8	4.3	12.0	14.0	16.0	19.3	23.0
65-69	108	16.3	4.8	10.0	13.0	16.0	20.0	23.0
70-74	98	16.0	4.3	11.0	13.0	16.0	18.0	22.0
75-79	93	14.8	4.0	10.0	12.0	14.0	17.0	20.6

Table K.3 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: chair sit and reach (cm) (lower body flexibility) – Senior Fitness Test (Rikli & Jones, 2001).

				Percentiles				
Age group (years)	N	Mean	SD	10	25	50	75	90
				Men				
60-64	103	-0.7	11.8	-15.9	-5.5	0.0	5.0	13.0
65-69	99	-6.5	15.7	-23.0	-14.0	-2.7	2.0	7.4
70-74	107	-4.3	12.0	-19.1	-12.0	-1.5	3.5	9.0
75-79	92	-7.4	11.4	-25.7	-14.4	-6.0	1.0	6.6
				Women				
60-64	102	0.7	13.6	-18.8	-3.9	1.8	8.1	15.0
65-69	108	0.2	11.2	-15.1	-4.8	1.5	7.4	13.1
70-74	98	0.6	10.4	-9.6	-3.3	0.0	5.0	11.6
75-79	93	-2.8	11.3	-20.0	-8.4	1.0	4.0	7.1

Table K.4 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: back scratch (cm) (lower body flexibility) – Senior Fitness Test (Rikli & Jones, 2001).

				Percentiles				
Age group (years)	N	Mean	SD	10	25	50	75	90
				Men				
60-64	103	-17.8	12.2	-36.3	-25.0	-17.5	-10.0	0.0
65-69	99	-22.6	12.9	-40.0	-33.0	-23.5	-13.0	-3.0
70-74	107	-25.0	11.7	-41.2	-33.0	-25.0	-18.0	-10.4
75-79	92	-26.0	13.4	-43.9	-36.0	-28.0	-16.6	-5.6
				Women				
60-64	102	-12.8	13.1	-25.4	-20.0	-13.8	-5.0	1.9
65-69	108	-12.8	10.9	-25.1	-20.6	-13.8	-0.1	0.0
70-74	98	-13.3	10.5	-25.0	-19.3	-13.6	-7.0	1.0
75-79	93	-16.8	11.1	-31.5	-22.5	-16.0	-9.0	-5.0

Table K.5 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: 8-Foot up and go (sec) (lower body flexibility) – Senior Fitness Test (Rikli & Jones, 2001).

				Percentiles				
Age group (years)	N	Mean	SD	10	25	50	75	90
				Men				
60-64	103	4.8	1.5	5.9	5.1	4.5	4.0	3.6
65-69	99	5.4	2.1	7.9	5.5	4.9	4.4	3.9
70-74	107	5.9	2.1	8.2	6.5	5.2	4.6	4.1
75-79	92	6.9	3.2	10.0	7.4	5.9	5.0	4.7
				Women				
60-64	102	5.2	1.4	6.5	5.8	5.0	4.5	4.1
65-69	108	6.0	1.7	8.7	6.5	5.4	4.9	4.4
70-74	98	6.5	2.4	8.7	6.8	5.9	5.2	4.6
75-79	93	7.7	3.6	11.7	8.0	6.7	5.6	5.3

Table K.6 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: 6-minute walk test (m) (lower body flexibility) – Senior Fitness Test (Rikli & Jones, 2001).

				Percentiles				
Age group (years)	N	Mean	SD	10	25	50	75	90
				Men				
60-64	103	577.9	93.7	462.0	545.0	591.0	623.0	676.6
65-69	99	526.9	115.7	336.4	467.1	545.0	607.0	648.0
70-74	107	512.3	105.9	367.3	467.0	540.0	591.0	620.6
75-79	92	461.8	108.6	311.0	392.3	479.6	545.0	588.0
				Women				
60-64	102	502.6	97.0	389.1	467.0	512.0	555.0	608.0
65-69	108	474.8	110.1	325.0	389.0	502.5	543.8	591.9
70-74	98	452.7	98.1	312.8	409.0	467.0	528.8	555.0
75-79	93	392.8	118.2	204.8	313.7	399.0	477.1	545.0

Table K.7 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: dynamic balance – total score of Fullerton Advanced Balance (FAB) scale (Rose, 2003).

				Percentiles				
Age group (years)	N	Mean	SD	10	25	50	75	90
Men								
60-64	103	34.4	6.5	27.4	32.0	36.0	39.0	40.0
65-69	99	33.2	6.8	22.0	30.0	35.0	39.0	40.0
70-74	106	31.3	6.3	21.0	28.0	33.0	36.0	37.0
75-79	92	28.5	5.8	21.3	25.0	29.5	32.0	35.0
Women								
60-64	101	32.8	6.2	25.2	31.0	34.0	37.0	39.0
65-69	108	31.1	6.8	20.0	29.0	32.5	35.8	38.0
70-74	98	27.7	7.8	15.9	25.0	30.0	33.0	36.0
75-79	93	24.2	8.1	14.0	19.0	24.0	30.0	34.6

Table K.8 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: gait velocity (ff/sec) at preferred speed from 50-foot walk test (Rose, 2003).

				Percentiles				
Age group (years)	N	Mean	SD	10	25	50	75	90
Men								
60-64	103	1.36	0.22	1.10	1.20	1.39	1.51	1.64
65-69	99	1.32	0.22	1.00	1.18	1.34	1.49	1.58
70-74	105	1.28	0.25	0.95	1.13	1.33	1.45	1.57
75-79	91	1.15	0.26	0.82	0.98	1.15	1.35	1.48
Women								
60-64	101	1.33	0.21	1.06	1.20	1.36	1.48	1.56
65-69	107	1.27	0.23	0.93	1.10	1.27	1.44	1.59
70-74	98	1.19	0.22	0.86	1.07	1.18	1.37	1.48
75-79	93	1.06	0.25	0.72	0.92	1.07	1.24	1.36

Table K.9 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: gait velocity (ff/sec) at maximum speed from 50-foot walk test (Rose, 2003).

				Percentiles				
Age group (years)	N	Mean	SD	10	25	50	75	90
				Men				
60-64	103	1.94	0.31	1.56	1.75	1.98	2.10	2.33
65-69	99	1.83	0.34	1.38	1.62	1.87	2.08	2.18
70-74	105	1.79	0.35	1.27	1.63	1.85	2.03	2.18
75-79	92	1.64	0.38	1.18	1.47	1.67	1.89	2.06
				Women				
60-64	101	1.74	0.29	1.37	1.63	1.77	1.92	2.06
65-69	107	1.67	0.30	1.18	1.53	1.68	1.87	2.04
70-74	98	1.56	0.29	1.10	1.43	1.59	1.77	1.88
75-79	93	1.38	0.33	0.93	1.22	1.41	1.61	1.78

Table K.10 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: cadence (steps/sec) at preferred speed from 50-foot walk test (Rose, 2003).

				Percentiles				
Age group (years)	N	Mean	SD	10	25	50	75	90
				Men				
60-64	103	1.94	0.18	1.73	1.85	1.93	2.05	2.15
65-69	99	1.91	0.19	1.65	1.81	1.92	2.04	2.13
70-74	105	1.90	0.20	1.62	1.76	1.93	2.04	2.12
75-79	91	1.79	0.23	1.46	1.69	1.83	1.95	2.04
				Women				
60-64	101	2.04	0.20	1.80	1.94	2.07	2.16	2.28
65-69	107	1.97	0.18	1.74	1.85	1.97	2.11	2.20
70-74	98	1.91	0.25	1.62	1.82	1.95	2.09	2.16
75-79	93	1.83	0.24	1.48	1.73	1.83	2.02	2.10

Table K.11 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: cadence (steps/sec) at maximum speed from 50-foot walk test (Rose, 2003).

				Percentiles				
Age group (years)	N	Mean	SD	10	25	50	75	90
				Men				
60-64	103	2.32	0.25	1.99	2.16	2.32	2.47	2.64
65-69	99	2.24	0.32	1.94	2.07	2.24	2.41	2.55
70-74	105	2.26	0.26	1.88	2.07	2.31	2.43	2.54
75-79	92	2.15	0.30	1.85	2.02	2.19	2.34	2.45
				Women				
60-64	101	2.31	0.25	2.07	2.19	2.32	2.45	2.61
65-69	107	2.26	0.28	1.91	2.11	2.28	2.43	2.54
70-74	98	2.19	0.26	1.87	2.06	2.24	2.35	2.49
75-79	93	2.11	0.29	1.76	1.99	2.16	2.28	2.45

Table K.12 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: stride length (ff/stride) at preferred speed from 50-foot walk test (Rose, 2003).

				Percentiles				
Age group (years)	N	Mean	SD	10	25	50	75	90
				Men				
60-64	103	1.40	0.14	1.22	1.33	1.39	1.52	1.57
65-69	99	1.39	0.20	1.17	1.27	1.39	1.45	1.52
70-74	105	1.34	0.17	1.13	1.22	1.39	1.45	1.52
75-79	92	1.27	0.19	1.05	1.17	1.27	1.39	1.45
				Women				
60-64	101	1.30	0.13	1.14	1.22	1.33	1.39	1.45
65-69	107	1.28	0.16	1.09	1.17	1.27	1.39	1.52
70-74	98	1.24	0.19	1.02	1.13	1.22	1.33	1.45
75-79	93	1.15	0.18	0.95	1.03	1.17	1.27	1.33

Table K.13 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: stride length (ff/stride) at maximum speed from 50-foot walk test (Rose, 2003).

				Percentiles				
Age group (years)	N	Mean	SD	10	25	50	75	90
Men								
60-64	103	1.67	0.15	1.52	1.60	1.69	1.79	1.79
65-69	99	1.63	0.25	1.33	1.52	1.69	1.69	1.91
70-74	105	1.58	0.21	1.25	1.52	1.60	1.69	1.79
75-79	92	1.50	0.22	1.27	1.33	1.52	1.69	1.76
Women								
60-64	101	1.50	0.20	1.28	1.39	1.52	1.60	1.69
65-69	107	1.48	0.25	1.22	1.33	1.45	1.60	1.69
70-74	98	1.42	0.21	1.13	1.33	1.39	1.52	1.69
75-79	93	1.30	0.21	1.02	1.17	1.33	1.45	1.52

Table K.14 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: gait stability ratio (steps/ff) at preferred speed from 50-foot walk test (Rose, 2003).

				Percentiles				
Age group (years)	N	Mean	SD	10	25	50	75	90
Men								
60-64	103	1.44	0.15	1.64	1.51	1.44	1.31	1.27
65-69	99	1.47	0.22	1.71	1.57	1.44	1.38	1.31
70-74	105	1.52	0.23	1.77	1.64	1.44	1.38	1.31
75-79	91	1.62	0.27	1.90	1.71	1.57	1.44	1.38
Women								
60-64	101	1.56	0.18	1.76	1.64	1.51	1.44	1.38
65-69	107	1.59	0.22	1.84	1.71	1.57	1.44	1.31
70-74	98	1.64	0.22	1.97	1.77	1.64	1.51	1.38
75-79	93	1.78	0.32	2.10	1.94	1.71	1.57	1.51

Table K.15 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: gait stability ratio (steps/ff) at maximum speed from 50-foot walk test (Rose, 2003).

				Percentiles				
Age group (years)	N	Mean	SD	10	25	50	75	90
Men								
60-64	103	1.21	0.12	1.31	1.25	1.18	1.12	1.12
65-69	99	1.25	0.20	1.51	1.31	1.18	1.18	1.05
70-74	105	1.29	0.22	1.60	1.31	1.25	1.18	1.12
75-79	92	1.37	0.26	1.57	1.51	1.31	1.18	1.14
Women								
60-64	101	1.35	0.18	1.56	1.44	1.31	1.25	1.18
65-69	107	1.39	0.21	1.64	1.51	1.38	1.25	1.18
70-74	98	1.44	0.23	1.77	1.51	1.44	1.31	1.18
75-79	93	1.58	0.31	1.97	1.71	1.51	1.38	1.31

Appendix L

Table L.1 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: physical activity – Work index (1-5 units).

				Percentiles				
Age group (years)	N	Mean	SD	10	25	50	75	90
				Men				
60-64	103	2.80	0.63	2.05	2.38	2.88	3.25	3.63
65-69	99	2.64	0.48	2.00	2.25	2.63	2.88	3.25
70-74	107	2.61	0.61	1.88	2.13	2.50	3.00	3.38
75-79	92	2.71	0.48	2.13	2.38	2.63	3.00	3.38
				Women				
60-64	102	2.78	0.61	1.95	2.38	2.75	3.25	3.63
65-69	108	2.75	0.45	2.24	2.50	2.75	3.13	3.26
70-74	98	2.67	0.42	2.11	2.38	2.63	2.91	3.25
75-79	93	2.50	0.42	2.00	2.25	2.50	2.75	3.13

Table L.2 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: physical activity – Sports index (1-5 units).

				Percentiles				
Age group (years)	N	Mean	SD	10	25	50	75	90
				Men				
60-64	103	2.16	0.62	1.50	1.75	2.00	2.50	3.00
65-69	99	2.16	0.59	1.50	1.75	2.00	2.50	3.00
70-74	107	2.04	0.57	1.25	1.75	2.00	2.50	3.00
75-79	92	1.92	0.54	1.25	1.50	1.75	2.25	2.75
				Women				
60-64	102	2.17	0.62	1.50	1.75	2.25	2.50	3.00
65-69	108	2.28	0.64	1.50	1.75	2.25	2.75	3.25
70-74	98	2.28	0.60	1.50	1.75	2.25	2.75	3.00
75-79	93	2.08	0.60	1.35	1.75	2.00	2.50	3.00

Table L.3 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: physical activity – Leisure time (1-5 units).

				Percentiles				
Age group (years)	N	Mean	SD	10	25	50	75	90
				Men				
60-64	103	2.60	0.58	1.75	2.25	2.75	3.00	3.25
65-69	99	2.49	0.59	1.75	2.00	2.50	3.00	3.25
70-74	107	2.50	0.66	1.50	2.00	2.50	3.00	3.30
75-79	92	2.52	0.54	1.75	2.25	2.50	3.00	3.25
				Women				
60-64	102	2.55	0.66	1.75	2.00	2.50	3.00	3.50
65-69	108	2.47	0.54	1.75	2.25	2.50	2.94	3.25
70-74	98	2.38	0.50	1.75	2.00	2.25	2.75	3.00
75-79	93	2.36	0.59	1.50	2.00	2.25	2.75	3.25

Table L.4 Sample (N), mean, standard deviation (SD) and percentiles for Madeira men and women aged 60-79 years: physical activity – total physical activity (Work index + Sports index + Leisure time) (3-15 units).

				Percentiles				
Age group (years)	N	Mean	SD	10	25	50	75	90
				Men				
60-64	103	7.56	1.27	5.80	6.63	7.50	8.50	9.25
65-69	99	7.29	1.15	5.75	6.38	7.25	8.13	8.75
70-74	107	7.14	1.42	5.13	6.38	7.13	8.00	9.05
75-79	92	7.15	1.19	5.54	6.25	7.00	8.09	8.96
				Women				
60-64	102	7.50	1.26	5.66	6.63	7.44	8.41	9.25
65-69	108	7.50	1.11	6.00	6.75	7.38	8.34	8.88
70-74	98	7.32	1.06	5.86	6.63	7.25	8.16	8.88
75-79	93	6.94	1.24	5.38	6.13	6.88	7.75	8.50