**Universidade Técnica de Lisboa**

**Faculdade de Motricidade Humana**

# Risk of Falls, Fear of Falling, and Loss of Autonomy on Old Women: Impact of Physical Activity and Fitness in the Performance of Activities of Daily Living

**Dissertation submitted in order to obtain a Ph.D. in the Branch of Human Movement, Specialty in Health and Physical Fitness**

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**To my family, colleagues and friends**

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**ABSTRACT**

This thesis examined the importance of physical activity and fitness, in the performance of daily living activities (ADLs). The research comprised 600 adults over 50 year old and 79 young adults, of whom 106 old adults were followed-up for a 5 years period. Falls and injuries, fear of falling, disability in performing ADLs, usual physical activity, intrinsic (physical fitness, body composition and health status) and extrinsic risk factors (environmental hazards) for these events/behaviors were evaluated. Data were analyzed by using comparisons, correlations and regression analyses. Results showed that frailty regarding intrinsic factors leads to an increase in the risk of extrinsic factors and limit the performance of ADLs. The number of co-morbidities was the main intrinsic risk factor for falls and ADL disability. Fear of falling was found to be a higher risk for ADL disability than falls and injuries. Decreased balance was the physical fitness parameter that contributed most for falls, while reduced aerobic endurance was the most important parameter for ADL disability.

**Key words:** fall; injury; fear of falling; activities of daily living; autonomy; disability; physical fitness; physical activity; environmental hazards; elderly.

## RESUMO

Esta tese analisou a importância da actividade e da aptidão física, na realização das actividades da vida diária (AVDs). Foram incluídos 600 adultos com mais de 50 anos de idade e funcionamento independente e 79 adultos jovens, dos quais 106 adultos idosos foram observados por um período de 5 anos. Foram avaliadas as quedas, as lesões, o medo de cair, a incapacidade na realização das AVDs, a actividade física habitual e os factores de risco intrínsecos (aptidão funcional, composição corporal, estado de saúde) e extrínsecos (perigos do envolvimento) para estes eventos/comportamentos. Os dados foram analisados através de comparações, correlações e regressões. Os resultados evidenciaram que uma maior fragilidade dos factores intrínsecos aumenta o risco dos factores extrínsecos e limita a realização das AVDs. O número de co-morbilidades foi o factor intrínseco que mais contribuiu para a ocorrência de quedas e incapacidade nas AVDs. O medo de cair revelou constituir um risco maior para a incapacidade nas AVDs do que as quedas e as lesões. Um equilíbrio diminuído foi o parâmetro da aptidão funcional que mais contribuiu para as quedas, enquanto uma baixa capacidade aeróbia foi o parâmetro que mais determinou a incapacidade para as AVDs.

**Palavras-chave:** queda; lesão; medo de cair; actividades da vida diária; autonomia; incapacidade; aptidão física; actividade física; riscos do envolvimento; idosos.

**ABBREVIATIONS**

ADL: Activities of daily living

- BADL: Basic activities of daily living
- IADL: Instrumental activities of daily living
- AADL: Advanced activities of daily living

AUC: Area under the ROC curve

BMI: Body mass index

BML: Body lean mass

BMLI: Body lean mass index

BFM: Body fat mass

BMD: Bone mineral density

CI: Confidence interval

CPF: Composite physical function

DXA: Dual energy x-ray absorptiometry

FAB: Fullerton Advanced Balance

FES: Falls Efficacy Scale

FF: Fear of falling

IPAQ: International physical activity questionnaire

MB: Multidimensional balance

MET: Metabolic equivalent of task

OR: Odds ratios

PA: Physical activity

$R^2$: Coefficient of determination

ROC: receiver operating characteristic

SD: standard deviation.

# CHAPTER 1

## GENERAL INTRODUCTION

## INTRODUCTION

Maintaining quality of life throughout the aging process expressed as independent functioning and healthy status is a major concern of each subject. Given the current demographic explosion of the third age [1], it has also become a key issue of modern societies. In the United States, life expectancy at birth rose by 0.4 years from 2003 to 2004, reaching a record 77.8 years [2]; in Germany, life expectancy increased from 75 years, in 1990, to 80 years, in 2008 [3]; in Portugal it is expected that the number of people over 65 years will increase from 17% to 32% between 2008 and 2060 and that the percentage of those over 80 years will rise during the same period from 4% to 13% [4]. Successful aging implies not only more years of life (quantity) but also quality of life: the absence of chronic diseases and the ability to function effectively, both physically and mentally, in old age [5].

The risk of both falls and fall-related injuries, and loss of autonomy coexist and increase with age; with falls in the elderly being pointed as a major reason for lower quality of life, loss of autonomy, institutionalisation or death [6-8]. Not only the most obvious consequences of fall-related injuries but also fear of falling lead to the restriction of normal activities among a large percentage of the elderly [9-12]. Furthermore, this restriction can lead to a further functional decline, depression, feeling of helplessness and social isolation [13]. Moreover, most risk factors for loss of autonomy - as the disability in the performance of activities of daily living (ADL) - such as age [14], reduced physical function/fitness [15], deterioration in gait [16], and poor body composition [17], decreased health status, and the presence of incapacities [18, 19], are also pointed as risk factors for falls and related injuries (reported in Chapter 2). Physical activity is one of the main factors known to help maintain autonomy [14, 18, 20] and to be effective in fall prevention [21].

Therefore it is essential to examine the problem of falls and how it relates to loss of autonomy. To this end, the theoretical approach underlying the investigation is presented below.

**The fall**

A fall is an accident in which a person “suddenly and involuntary comes to rest upon the ground or on a surface lower than the original station” [22, 23]. The phenomenon involves the existence of three interacting elements (or constrains): the individual, the task and the environment (Figure 1).

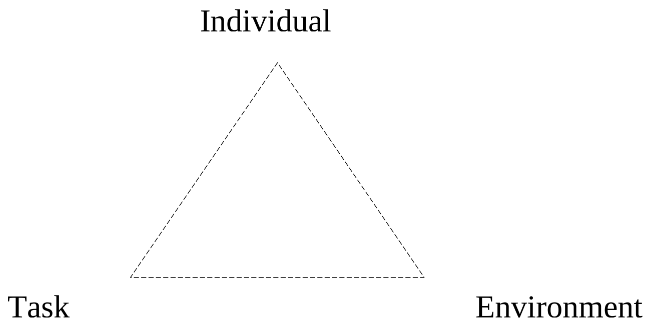


**Figure1.** The three elements involved in the fall.

With their capacity for accomplishment or performance of tasks, able people usually live in a more or less harmonious environment that allows them to carry out everyday tasks without great difficulty and therefore in safety. The occurrence of falls will depend on the capability of the individual to maintain a balance between their ability of performance and the demands of tasks. An accident (fall) will occur when the demands of one particular task exceed the ability of the person to perform that task. These demands are dependent on the difficulty of the task itself and also on the environment: in a hostile environment, the demands of a given task increase [24-26].

A fall may occur when there is an imbalance between the ability of the individual (depending on their function/capacity) and the task and/or environmental demands, namely, when one or several of the following events occur:

- the demand of the task exceed individual ability for performance;
- the environment evolves in an unfavorable way such that the normal ability of the individual for performance is insufficient for confronting environmental difficulties and simultaneously carrying out the task;
- individual ability for performance decreases and does not enable the demands of the task and/or environmental difficulties to be successfully overcome, even in the case of normal/daily tasks.

The fall may not occur when:

- individual function and consequently ability is sufficiently high that it enables them to carry out any task in a normal environment or those with a degree of difficulty or some demands;
- there occurs a reduction in one or more of the functional abilities of the individual; however, this reduction is compensated by other abilities that still allow them to successfully perform the task;
- the demands of the task do not challenge the ability of the individual to perform, in an environment of normal difficulty;
- the environment is so favorable that it enables the task to be successfully carried out;
- there is no task to be carried out, hence there is no difficulty.

Therefore, the variability of functional performance must be considered, since in the performance of functional movement, different degrees of freedom enable different solutions for the successful accomplishment of a given task. The variability of movement helps the individual to adapt to the unique constraints (associated with the individual, the task and the environment) successfully (without falling) [25].

When people age their ability to perform tasks is expected to decrease because, besides demonstrating a higher level of morbidity, functional ability naturally decreases with age [27, 28]. As functionality decreases, people are increasingly less able to deal with less demanding situations [29], either in terms of the environment or the task. Furthermore, as aging advances, human movement systems tend to be characterized by a loss in complexity and also decreasing movement variability resulting in poor adaptation to environmental changes [25, 30]. In fact, the aging process contributes to a progressively precarious balance between the three elements of the system, and, as the probability of the rupture of this balance increases, the probability of the occurrence of falls rises.

When the ability of the elderly in terms of performance is drastically reduced, they may lose even the ability for meeting the demands of everyday tasks [29]. In this case, a fall may occur during the performance of such tasks, which nevertheless present a very low degree of difficulty, and not only during the performance of more demanding tasks [29, 31].

Loss of functionality in the elderly is accompanied by a decrease in their capacity for carrying out tasks in less favorable environments (for example, negotiating toys on the floor constituting an obstacle to reaching the telephone); this is why an understanding of the role of extrinsic risk factors for falling and/or environment hazards with different degrees of functionality is so important [32-34].

Therefore, the ability for accomplishing tasks and, accordingly, the ability for carrying out tasks without falling depends on several ability factors: the somatic, the physical, the sensorial, information analysis and response, among others [31, 35-37]. If the task and/or the environment are not excessively demanding, a high level of ability as regards some factors will probably compensate for a lower level of ability for others, allowing the individual to successfully perform a given task. However, the gradual nature of the aging process means that rupture in the balance between the three elements of the system ends only with death [38].

The main question is which and how the elements involved in this model can be manipulated to counteract or delaying the tendency for rupture and how this can be achieved.

***Task***

The first attempt at avoiding falls and related injuries is inactivity: if the individual does not move, and lies or sits without doing anything, consequently not performing any physical activity or task, the probability of falling will be practically zero. However, if he does not perform any physical activity, his functional level will decline and his ability to perform will decrease drastically [39]. Consequently, any task (e.g. go to the bathroom) may make demands on the elderly person that he may be not able to successfully meet, and a fall may occur during the performance of the task. Current research studies recommend that interventions designed to prevent falls should promote physical activity/exercise [39-41]. However, it is not clear the influence of physical activity on falls, namely which kind and amount of physical activity is required to prevent falls and related injuries, neither are the relationship between physical activity and other risk factors for falls.

***Environment***

Environmental control is always an important factor, because, with advancing age, the elderly tend to neglect their houses, gardens and their general environment, and sometimes live in the midst of very hazardous conditions [42]. In caring for them, an external agent may be required to draw up an inventory of risk situations and find the best solution for each individual [29, 42]. This may involve simply installing supporting bars in the bathtub, replacing the chair stood on to change light bulbs with a small ladder or relocating cooking utensils in a more accessible place. However, it is important to identify the relationships between the different functional abilities, other intrinsic risk factors (like diseases), and the role of environmental hazards, both with regards to falls and fall-related injuries, and loss of autonomy: in some cases, while environmental hazards are known to be extremely high, falls do not occur; by contrast, in some cases where environmental hazards are known to be low, falls still occur.

### *The individual*

Although the aging process cannot be arrested, some measures can be implemented to attenuate its negative effects [43]. Obtaining glasses or a hearing aid can counteract the natural loss of capacity of the visual and auditory systems [44]. At proprioceptive level, it may be more difficult to attenuate the loss of sensory capacity, but the use of suitable foot-ware, for example, with non-slip soles, may be significant in preventing falls [45]. Additionally, medicines and treatments may be prescribed for incapacity caused either by the natural degradation of the organism or illnesses [46]. However, care must be taken to safeguard against the side-effects of both drugs and treatments, such as the effects of anti-depressants that decrease attention and may therefore contribute to a fall [47]. Another level of intervention involves physical exercise for the maintenance of functional abilities, due to the fact that, as mentioned above, physical activity/exercise may prevent the reduction of some functional abilities [43]. A high physical fitness prevents the occurrence of falls, especially a good level of motor coordination, balance, agility, muscle strength, flexibility and aerobic endurance, as does the maintenance of gait pattern and attention capacity for successfully meeting the demands inherent to the performance of specific motor tasks (the dual-task paradigm) [48-51]. Furthermore, physical activity prevents or decreases the effects of illness and promotes good body composition [52]. However, the relative importance of each of these factors is not known. One concrete situation reported in some studies [53] is the increased susceptibility of women to falls as compared with men; however, the reasons for this difference are little known.

**The injury**

The most obvious consequence of falls is injury [54, 55]. In this work, an injury is considered to be an infirmity that involves the necessary interaction of three elements (Figure 2):

- an agent that causes the infirmity (uncontrolled energy released by an object depending on the velocity, shape, material and time of exposition);
- a host in which the agent may reside;
- an environment in which the agent and the host come together [24].

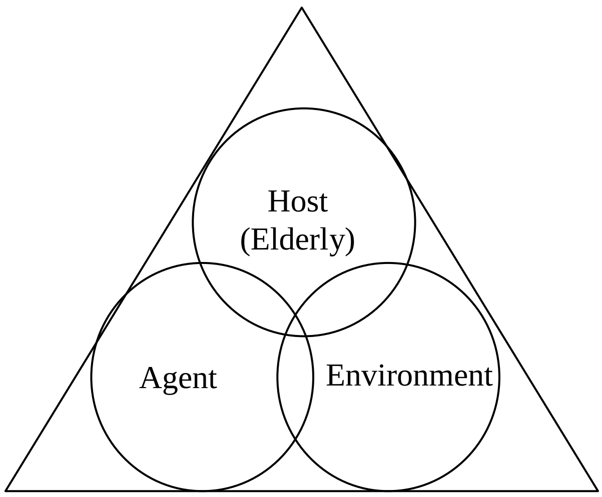


**Figure2.** Disease triangle (adapted from AEMT ACoS, 2003) [24].

The fall is a serious problem because it is the main determining factor of injury [55, 56]. Injury severity depends on:

- the environment that enables the interaction between the agent and the host;
- the injury agent, for example the surface type where the mechanical aggression occurs;
- host susceptibility (which is increased in the elderly), for example body tissue resistance and the ability of the individual to decrease the impact of the fall [24, 57, 58].

Injuries severity range from simple abrasions or contusions to bone fractures, and depend on the location in the body [55, 59, 60]. However, injury can be controlled by adapting the environment, destroying the agent, or by strengthening the host.

### *Injury prevention*

Preventive interventions should promote every action that decreases the occurrence and probability of falls [61]. As it is impossible to remove the possibility of falls because they may occurs in any place and any object may unexpectedly act as an injury agent (a chair, the bathtub, stairs, or the floor), the priority is on decreasing the risk of a fall. The identification of environmental hazards and the implementation of measures to control them (the use of a bath chair in the bathtub, for example) or possibly eliminate them (removing dangerous objects from the environment) may prevent injury or at least decrease the severity of injuries [29, 42].

The reduction of host susceptibility to the agent is also an option. However, this is to attempt to counteract the natural trend towards aging [38]. Elderly people gradually lose their reflexes and functional abilities, which may lead to an increase in the amount of uncontrolled energy released by the aggressive agent. They also have less tissue elasticity and are consequently more susceptible to tissue rupture [62, 63]. Moreover, age is associated with the osteoporosis phenomenon, the main reason for decline in bone resistance and the consequently increase in fracture susceptibility [64, 65], which is higher in women [66].

It is known that weight-bearing physical activity/exercise throughout life represents an efficient method for preventing osteoporosis-related fractures in the elderly [67, 68]. However, physical activity/exercise effect on other type of fall-related injuries has not been satisfactorily explained.

## Maintenance of autonomy in elderly people

Associated with falls, there is the problem of the maintenance of autonomy for the accomplishment of everyday tasks, thereby enabling elderly people to lead an independent life.

Fall-related fractures are responsible for further falls, loss of autonomy, and sometimes lead to institutionalization [7, 8, 69]. However, fear of falling may constitute the reason why the elderly do not carry out everyday tasks independently, even if there is no physical impairment [70, 71]. There are no in-depth studies on how physical function/fitness interacts with the fear of falling and the consequent refusal to accomplish everyday tasks. Even so, fear of falling has been point to as a risk factor for falls[50]. Age, health status, physical activity and fitness, including body composition, are considered the main predictors of falls, fall-related injuries and loss of autonomy [10, 14-21, 50, 72], but the role of each predictor and their interaction on the outcomes of these variables are not clear.

## OBJECTIVE

The main objective of this research was to analyze the factors involved in falls and injuries, fear of falling, and loss of autonomy, and determine which and how the elements described in theoretical approach (task, individual [elderly], environment; and injury agent) can be controlled in order to counteract the trend towards the rupture that will result in these undesirable events. In particularly, this work aimed to analyze the role of physical activity and fitness, including body composition, and also the role of health status and environmental hazards as predictors of falls and injuries, fear of falling and loss of autonomy. To this end, five studies were conducted with the following purposes:

- to analyze the variation of the different attributes that enable physical functioning in community-dwelling older adults using scores from young adults as reference (Chapter 3);
- to analyze the influence of gender on the occurrence of falls after accounting for health status, body composition and physical function differences (Chapter 4);
- to analyze the role of physical activity in the occurrence of falls and fall-related injuries (Chapter 5);
- to analyze the associations between falls, fall-related injuries, fear of falling and disability in activities of daily living (Chapter 6);

- to analyze the influence of health status, physical activity and fitness on autonomy over a 5-year period (Chapter 7).

In Chapter 2 there is a review of the literature focusing on falls and their consequences which potentially lead to loss of autonomy.

Chapter 8 includes a general discussion of the main findings of the studies conducted and provides recommendations based on the main findings of the investigation.

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# CHAPTER 2

## ROLE OF PHYSICAL ACTIVITY IN THE PREVENTION OF FALLS AND THEIR CONSEQUENCES IN THE ELDERLY [1]

[1] Pereira C. Vogelaere P. Baptista F. Role of physical activity in the prevention of falls and their consequences in the elderly. Eur Rev Aging Phys Act 2008; 5:51-58.

**ABSTRACT**

This work aims to provide an inventory of the risk factors and consequences of falling in the elderly, namely fractures, and to identify strategies to prevent falls and minimise their effects. Falls in elderly people are a major cause of injuries leading to a general fear of falling, poorer quality of life and even death. The increase in life expectancy brought by developments in the medical and health sciences has not always brought enhanced quality of life. More elderly people live with reduced functional capacities resulting in a higher prevalence of falls and associated problems, for themselves and for society. Risk factors for falling, commonly resulting from normal aging processes, have already been identified through multiple studies. Exercise may play an important role in fall prevention and their consequences. Although, effective strategies are usually multidisciplinary and focus simultaneously on several risk factors. However, only large scale prevention programmes can have significant effective social impact. To minimize occurrence and consequences of falls, policies to systematically implement prevention programmes should be established.

**Key words:** Falls; Risk factors for falling; Elderly Fractures; Physical activity.

**Problems of falls**

Falls are a major health problem among the elderly. Thirty percent of people aged 65 and older living in community fall at least once a year [1] and this rate increases with age [2].

As life expectancy increases, there are a higher number of less healthy and less fit elderly people living longer with their infirmities [3-5]. Consequently, the risk of falls and their consequences is now greater than before [6, 7], as is illustrated by statistics from Finland [8].

Falls are the major cause of death related to mechanical injuries in the elderly, and the mortality rate increases when the individual fall rate increases [9-11]. According to Rubenstein [12], about 4% of falls result in fractures and about 11% result in other serious injuries such as head trauma, soft-tissue injuries, and severe lacerations. Those who survive falling commonly restrict their activities due to soft tissue injuries and fractures [13, 14]. Besides injuries and more evident physical consequences, psychological consequences must also be considered: the fear of falling leads to a large percentage of the elderly restricting their activities [15-18]. Both these reasons for loss of functionality can result in the "post-fall anxiety syndrome". Less confidence in the ability to walk safely can lead to further functional decline, depression, feelings of helplessness, social isolation [12, 19, 20] and consequently a loss of quality of life [21]. Inevitably, also, falls and fear of falling are among the major reasons for the institutionalisation of elderly people [11, 22].

According to these factors, falls in the elderly and the resulting injuries have to be considered a social concern, not only because of health care costs, but also due to psychological problems associated with behavioural modifications, which restrict functional mobility, thus promoting physical dependence and potential changes in lifestyle [23].

## Risk factors for falling and fractures

Falls are defined as any incident in which a person "suddenly and involuntary come to rest upon the ground or a surface lower than the original station" [24, 25]. Fall consequences, such as fractures, depend fundamentally on three factors:

- Risk factors related to fall occurrences, such as health problems, activity and physical environment.
- Risk factors referring to bone strength, namely bone mineral density (BMD), bone structure or the spatial arrangement of the bone trabecular and bone quality or the mechanical properties of the bone tissue.
- Risk factors associated to the impact of the fall, i.e. fall severity, floor material, soft tissue surrounding the impacted bone, etc. [26-31].

Fractures may occur in any bone of the skeleton. Humeral, fist, pelvis and hip fractures are positively correlated with age and usually result from the combined effects of osteoporosis and the fall proper [14, 32-36]. Fractures of the vertebrae, also common, are generally associated with osteoporosis [37] and produce a high rate of morbidity and mortality [38]. However, falls may not be the determinant factor of this occurrence in spine.

Table 1 present the most cited risk factors for falling according to several authors [12, 20-22, 26, 28, 30, 31, 35, 36, 39-53]. In the elderly living in communities, the majority of falls occur during usual activities, such as walking or changing position [7, 16]. They happen mostly at home, so that a "safe home" is fundamental [7, 54]. Only 5% of the falls are the consequence of clearly hazardous activities, such as climbing on a chair or a ladder or participating in sport activities. About 10% of the falls occur on stairs. It has been shown that going down stairs is more hazardous than climbing [7, 16]. Environmental factors are responsible for most of the falls, although they are not the main cause for falling. However, few falls result from unpredictable events [7].

**Table 1.** Risk factors for falling

| **Intrinsic risk factors** | | **Extrinsic risk factors** | |
|---|---|---|---|
| **Chronic** | **Temporary** | **Activity** | **Environmental** |
| Age over 75 years | Loss of conscience | Usual activities | Indoor: |
| Incapacity and chronic diseases usually associated to the degenerative process of aging: | Medication/drugs/ alcohol | Hazardous activities | Bad lighting |
| Degenerations and disturbances of the nervous and muscular–skeletal system functions and consequent decrease of functional capacity: reaction speed, muscular strength, reflexes, balance, mobility, gait pattern and speed | Other hallucinogenic substances | | Slippery floors, loose rugs, telephone threads, other objects |
| Urinary incontinence | | | Ladders |
| Deficient vision | | | Stairways with steep steps, without walls and/or handrails |
| Vestibular function disturbance | | | Kitchen with difficult access to utensils and movable tables |
| Audition loss | | | Bathroom without handrails for tub, shower and toilet and non-skid mat in tub or shower |
| Cognitive function disturbance | | | Bed too high or too low |
| Insanity | | | Outdoor: |
| Depression | | | Uneven pavements, streets, paths |
| Memory loss | | | Repair works, obstacles |
| Neurological pathologies such as Parkinson's disease | | | Slippery floors |
| Secondary effects of medication | | | Rain, snow and ice |
| | | | Traffic |
| | | | Public transport |
| | | | Animals |
| | | | Footwear |

According to Bath and Morgan [55], falls in outdoor and indoor environments present different risk profiles. Risk factors associated with outdoor falls are both intrinsic and extrinsic. Intrinsic risk factors include decreased functional capacities such as reduced strength, and/or reduced gait velocity, while extrinsic factors are related to hazardous environments and performance outside habitual activities. Risk factors associated with indoor falls are mainly intrinsic and their occurrence increases when the elderly are housebound, due to poor health, frailty or to the use of high levels of prescribed medications. It is important to note that people falling at home present a higher mortality rate, although the relationship between causality and effect is still unclear.

Table 2 provides a review of the risk factors for fractures due to falling [29, 30, 33, 43, 46, 48, 56-60]. Bone strength is determined 65-80% by BMD (quantity of bone mineral per square or cubic centimetre) and 20-35% by bone structure (spatial arrangement of the bone trabecular), as well as by bone quality (the material properties of bone tissue) [30, 44]. BMD, in turn, is determined by genetic and hormonal factors, body composition, nutrition, physical activity, chronic diseases and the use of medication [30, 44, 51, 61-65].

Evaluation of BMD may be performed by dual-energy X-ray absorptiometry [66]. Osteoporosis is diagnosed in postmenopausal women and in men aged 50 and older if BMD expressed as T-score is -2.5 or less at the lumbar spine, total hip of femoral neck [67]. The T-score indicates how many standard deviations (SD), above or below the average value, the result in question actually lies. The reference standard from which the T-score is calculated is the BMD of the young adult age 20-29 years. A T-score between –1.0 and –2.5 SD indicates low bone density or mass, also usually referred as osteopenia. Contrary to osteoporosis, people with low bone mass are not necessarily at high fracture risk [46, 68].

The risk of falling and fracture is related to the number of existing risk factors and is potentiated by the interaction and cumulative effect of multiple risks [16, 29, 69, 70]. However many of those risk factors can be avoided [56, 70] or reduced when some contributing factors are modified by intervention programmes [16, 53, 60], particularly, when these programmes are multifactorial [54, 71, 72].

**Table 2.** Risk factors for fractures due to falling.

| **Risk factors** |
|---|
| Risk factors inherent to the individual: |
| Age (specially over 75 years) |
| Female (vs. male) |
| Family history of fractures due to osteoporosis (maternal hip fracture) |
| Recurrent falls in previous year |
| Previous fracture caused by a low energy impact |
| Osteopenia, osteoporosis and associated disorders |
| Low body weight (body mass index <19 kg/m$^2$) |
| Bone structure: geometry and length |
| Corticosteroids treatments |
| Hormonal factors |
| Behaviour risk factors: |
| Nutritional factors |
| Low consumption of calcium (<700 mg/d) |
| Vitamin D deficit (low exposition to sun light) |
| Physical inactivity |
| Tobacco |
| Alcohol |
| Factors that potentiate falls impact: |
| Height (the taller the person the greater the impact) |
| Decreased muscular and fat mass |
| Lateral falls |
| Point of impact on the bone (for instance the femoral neck) |
| Loss of defence reflexes |
| Floor surface |
| No use of artificial shock absorber (reduction of the occurrence of fractures by 40%) |

**Prevention strategies for falls and fractures**

Most elderly people are not aware of their predisposition to fall, or identify their inherent risk factors and thus they cannot express their limitations to physician or other healthcare personnel. Consequently, as prevention is often overlooked, the risk becomes evident only after a lesion or incapacity due to a fall [73, 74].

The correct diagnosis of this reality is fundamental. The use of proficient instruments to recognize the predisposed risk factors responsible for the occurrence of serious lesions, and the evaluation of behavioural risk factors, allow the identification of populations and individuals at risk [25, 72, 75-77]. This knowledge leads to the setting up and implementation of efficient intervention programmes – focussed on the existing risk factors and providing answers to the needs of the individual or specific population groups (age, gender, functional competence, clinical condition, type of performed activities, etc.) [1, 24, 25, 76].

***Physical exercise programmes***

Independently of individual differences, fragilities or pathologies, light to moderate intensity exercise programmes revealed to be effective in the prevention of falls and their consequences. Tai-chi, step, strength, agility, stretching, and multi modal training, or adhesion to specific programs of exercise directed to prevent falls have reduced fall events, falls injuries and also fear of falling [1, 41, 47, 50, 78-85]. Exercise may prevent falls and their consequences either in healthy old people or in elderly people with medical conditions like osteoporosis, Parkinson, diabetes, physical or visual impairment and even after a stroke [37, 82, 86-91].

Maintenance or recovery of the elderly physical functionality through such exercise programmes [57, 83, 85, 92-96], besides decreasing falls rate and its consequences [97-100], contribute to improving the quality of life [101]. To be effective, these programmes, performed on a daily basis, have to be focussed on functional capacities, such as coordination, agility, balance, mobility, muscular strength and flexibility [23, 52, 53, 72, 77, 102-105]. They should also include multi-sensorial training [50, 106], as well as exercises like walking, stepping up or downstairs carrying objects [41, 50, 95]. Training programmes aiming to improve weight-bearing bones and muscles, can also improve functionality, reduce fall severity and even lower the mortality rate [107-111].

Regarding the bone health, increase of bone strength during pre-puberty and adolescent years is fundamental for the prevention of osteoporosis and related fractures in older people [45, 112]. Mechanical loading such as high-impact and resistance exercise enhances peak bone mass during growing years and prevents bone loss during aging throughout bone formation stimulation [35, 40, 108, 109]. Recently, the use of high-frequency vibratory platforms has showed significant increase of bone mineral at hip level associated with an improvement of balance [113]. These exercise programmes need to be long-term projects as any interruption will induce a reversibility of the benefits in health and function, especially at muscle and skeleton level [98, 108, 114, 115]. Moreover, decreases in physical performance associated with the lack of activity in the elderly are associated with dependence and the incapacity to perform daily tasks [116].

As it has been exposed, studies suggest that moderate level of physical activity can reduce the risk of falls and prevent their consequences like fractures and other injuries [117, 118]. Even light or vigorous exercise can produce health benefits [95, 98]. However there are no guidelines for exercise prescription, namely the optimal intensity and amount of activity necessary to prevent falls. "Staying Active - Staying Safe" [119] does not mean the grater the amount of physical activity the better. In fact, several authors exposed that either inactivity or excessive physical activity may conduce to the occurrence of falls events, particularly when heavy tasks are involved [120, 121]. The higher rate of falls associated to inactivity seems to be due to the usual function decline of sedentary elderly people [40, 82, 122, 123]. The higher rate of falls associated to excessive physical activity may be due to the fact that people falls when they are moving, especially performing heavy tasks in a non-controlled environment, and then the probability of the occurrence of an accidental fall is amplified [124]

***Multi-disciplinary programmes***

In addition to the evidence that interventions centred on physical exercise are beneficial, literature also reveals the importance of multifaceted intervention in the prevention of falls and consequent fractures [1, 24, 54, 125]. Besides exercise, prevention programmes must include strategies to improve cognition, especially the capacity to perform dual task walking, to ensure appropriate nutrition, particularly ingestion of calcium and vitamin D, and when appropriate, to change prescription of drugs with possible negative secondary effects. Home assessment performed by specialized personnel and continuous counselling about safety conditions in the house and its accesses are also recommended. Such work has to be performed in close consultation with the subjects and in their local environment [39, 42, 125-130].

It is not yet clear, which is the most valuable component in a multifactorial intervention programme. However, prevention programmes have already been implemented and are providing effective results [48, 53, 85, 131-134]. Despite, a universally successful prevention strategy is not applicable because falling and consequent fractures depend on each faller [24], preventive measures need to be implemented systematically and performed on a large scale [135-137].

## CONCLUSION

For the elderly, falls and fear of falling induce loss of autonomy and reduce the quality of life. Aside from the financial costs, falls cause both physical and psychological suffering. Risk factors for falling are multiple and well documented, as are their consequences. Most risk factors are due to normal aging processes and can be attenuated or eliminated. Others are intractable which means that the elderly must simply learn to live with them.

Physical exercise should be part of a multidisciplinary strategy to prevent falls and their consequences to maximize intervention benefits. Although risk factors for falling have been accurately defined and some management strategies studied and, in some cases, implemented, most approaches lack continuity. What remains are the policies to raise awareness and promote the widespread, systematic implementation of comprehensive prevention programmes.

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# CHAPTER 3

## VARIATION OF THE DIFFERENT ATTRIBUTES THAT SUPPORT THE PHYSICAL FUNCTION IN COMMUNITY-DWELLING OLDER ADULTS [2]

[2] Pereira C. Baptista F. Variation of the different attributes that support the physical function in community-dwelling older adults. J Sports Med Phys Fitness; September 2011 *(in Press)*

## ABSTRACT

**Aim.** This study investigated the variation with age of different attributes that support the physical functioning in community-dwelling older adults having as reference scores from young adults.

**Methods.** The study was a cross-sectional study. Participants were 559 older adults and 79 young adults grouped according to gender and age (Y:20-29, A:60-64, B:65-69, C:70-74, D:75-79 and E:≥80 years). Strength, flexibility, agility, aerobic endurance, and balance were evaluated by Fullerton tests.

**Results.** ANOVA and Bonferroni post-hoc test showed that compared to young, the 60-64 years group showed decreased values in almost all attributes of physical function. In older adults, additional differences were observed in females mainly between the 60-64 years group and the 70-74 years, 75-79 years, and:≥80 years groups, and in males between the 60-64 years group and the ≥80 years group ($P<0.05$). Comparisons between standardized physical function attributes (T-scores) done by repeated measures and contrasts demonstrated that, across age groups, agility and dynamic balance showed the highest rate loss in both genders, and lower body flexibility showed the lowest ($P<0.01$).

**Conclusion.** Physical function reduction seems to occur earlier in women than in men and abilities involving multiple structures such as balance, agility, and aerobic endurance showed the most loss.


**Key Words***:* physical function; older adults; reference scores

**Running title**: Physical function in old adults

## INTRODUCTION

Like other western countries [1], Portugal faces an aging population. In 2008, 17% of the Portuguese population was over 65 and 4% over 80. Projections suggest that in 2060, the corresponding numbers will be 32% and 13%, respectively [2]. If this population does not age successfully, the country will face a rapidly increasing number of people who are less healthy and have reduced physical functioning [3, 4]. Successful aging means maintaining high physical and cognitive function, and low health risk thereby enabling subjects to live independently and participate actively in society [5, 6].

Normal aging (also called primary aging) is characterized, even in the absence of disease, by structural and functional change (deterioration) in most physiological systems. These processes are cumulative and inevitably have a direct impact on the daily activities of older adults. More generally, normal aging involves complex processes combining the primary factors just mentioned, as well as secondary and genetic factors. Secondary factors involve chronic disease and lifestyle [7]. Healthy lifestyles may limit the development and progression of chronic diseases and incapacitating conditions — whether physical, psychological or mental — and in so doing, increase life expectancy and improve quality of life [8-10]. While decline dominates the clinical picture of aging, the lifestyles adopted by different population groups determinate the variability of their aging processes. Recent European Union guidelines promoting increased physical activity for older adults are an attempt to respond to this problem [11].

Older adults undergoing physical function evaluation are typically told that they should increase their level of physical activity or do specific exercises on a regular basis. Evaluation enables health professionals to predict functional independence [12] and diagnose disabilities, particularly subclinical functional incapacities leading to loss of ability to perform daily tasks. Evaluation is, therefore, a critical step towards the definition of targets and strategies for reducing and delaying physical incapacity and associated problems [12-14].

Fullerton tests (Senior Fitness Test and Fullerton Advanced Balance Scale) can be conducted almost anywhere to quickly determinate a person’s ability to perform daily tasks safely and independently. Because these tests are easy to perform and inexpensive, they are among the most popular physical function evaluation tests [15-17]. The results of

Senior Fitness Test are usually compared with normative scores for US residents of the same age group and gender [17, 18]. On this basis, a reasonable result for a specific attribute — for example a lower-limb strength score for a 70-year-old woman that is in the 50th percentile — may nevertheless compromise her ability to perform daily tasks. Compared with values for young adults, this same result, probably, will be associated with a high loss of lower-limb strength. It may be more useful to standardize the results of tests performed by older adults using reference scores for young adults aged 20-29 years, i.e., the age range corresponding to peak physical function [19]. Using this approach, one can identify, quantify, and compare possible losses of different attributes to predict physical functioning. Evaluation of the risk of loss of physical functioning is determined by the distance in standard deviations between each attribute score and the corresponding mean value for young adults. This method of analysis has been used in clinical research and practice to diagnose osteoporosis in postmenopausal women and men over 50 on the basis of bone densitometry [20-22]. The aim of this study is to compare the variation of physical attributes used to determinate physical functioning in active community-residing older women and men as a function of age with scores for young adults as reference.

## MATERIALS AND METHODS

### Participants

The participants were 559 community-dwelling elderly, showing autonomy levels that allow them to live independently in their own home, and 79 young adults. The elderly group consisted of 422 women (69.2±5.8 years) and 137 men (70.2±6.0 years) aged 60 to 87 years who participated at least twice a week in a supervised exercise program (tai-chi, hydrogymnastics, step, weight resistance and aerobics) in the previous year. The young adult group consisted of 50 women and 29 men aged 20 to 28 years, 61% of whom exercised regularly. The elderly participants were recruited in community institutions that promote supervised exercise programs. The young participants were university students majoring in sport sciences, veterinary medicine, and literature college, or recent former students. All participation was voluntary and all provided informed consent. No one had suffered a recent episode of illness that would have caused a temporary decrease of physical function. Sixteen volunteers were excluded because they did not meet these criteria. Participants were separated into the following six age groups: 20 to 29 (Y), 60 to 64 (A), 65 to 69 (B), 70 to 74 (C), 74 to 79 (D) and ≥80 (E). This grouping followed similar age organization used to describe normative values of physical function in the elderly population in the United States [17]. The University's Ethics Committee approved this study.

**Measures and data collection**

***Physical function and body composition***

Lower and upper body strength, lower and upper body flexibility, agility and dynamic balance, and aerobic endurance were evaluated by the Fullerton Senior Fitness Tests. These six attributes were assessed, respectively, by the following item tests: 1) 30-s chair stand (rep); 2) arm curl (rep); 3) chair sit-and-reach (cm); 4) back scratch (cm); 5) 8 ft up-and-go (sec); and 6) 6-min walk (m). This battery of tests has been validated for the evaluation of community-dwelling older adults [14, 15].

Multidimensional balance was assessed by the Fullerton Advanced Balance Scale, which consists of 10 item tests designed to measure higher-functioning older adults. These 10 item tests include a combination of static and dynamic balance activities performed in different sensory environments. The tests are the following: 1) stand with feet together, eyes closed; 2) reach forward to object; 3) turn in a full circle; 4) step up and over; 5) tandem walk; 6) stand on one leg; 7) stand on foam, eyes closed; 8) two-footed jump; 9) walk with head turns; and 10) reactive postural control. The 10 tests were scored according to an ordinal scale going from 0 (worst) to 4 (best). The final score is the sum of the points obtained in each one of the item tests and goes from 0 to 40 [16].

The results of the lower and upper body strength and flexibility, agility and dynamic balance and aerobic endurance were expressed in absolute and standardized values. Standardized values, designated as T-scores, were calculated for each gender separately. The T-score indicates the number of SD above or below the young adult average value (male or female) for each elderly participant [20]. The agility T-score was multiplied by (-1) because, contrary to the other attributes, a higher result is associated with a poor performance. A multidimensional balance T-score was not calculated because there is a reference value (maximum:40).

Additionally, body fat mass (%) was evaluated by bioimpedance using a HBF-306C, waist circumference (cm) was measured at the navel level using a measuring tape, body weight was measured on an electronic scale (Secca Bella 840), and standing height was measured on a stadiometer (Secca 770). The body mass index (BMI) was calculated as body weight in kilograms divided by the square of the height in meters ($kg.m^{-2}$).

Physical function and body composition measurements were performed by a team of qualified technical personnel, who received common training in order to standardize procedures and assessment protocols.

***Health, physical impairments, education and physical activity***

Level of education, number of prescribed medications drug and physical impairments were evaluated by questionnaires administered by an interviewer. Physical impairments included the following: urinary incontinence, habitual dizziness, feet problems (e.g., sores, corns, skewed toes, amputation of toes or foot, insufficient muscle function), poor vision (not recognizing someone’s face at a distance of four meters with glasses or contact lenses), hearing problems (not able to follow a conversation in a group of four people with a hearing aid**),** and balance problems (occasional loss of balance) [23]. Physical activity was assessed by using the short form of the International Physical Activity Questionnaire (IPAQ) [24]. Physical activity was expressed as the sum of metabolic expenditure (MET-min/wk) spent on walking moderate and vigorous-intensity activity, for periods of at least 10 minutes.

**Statistical analysis**

Statistical analysis was performed with SPSS version 16.0. ANOVA and Bonferroni post hoc test were used to compare general characteristics (age, body composition, health, education, and physical activity) and physical function attributes among age groups (or Kruskal Wallis and Dunnett C post-hoc test in the case of no homoscedasticity). The comparisons of these variables between genders in all age groups were analyzed by independent sample t-tests. Comparisons between standardized physical function attributes (T-scores) in each gender and age group were done by repeated measures and contrasts. Data were expressed as mean ± standard deviations. Statistical significance was considered for a $P<0.05$.

## RESULTS

Characteristics of the sample are presented in Table 1. Compared with young adults, older adults had less education and higher body weight, BMI, body fat mass, and waist circumference. They also had more physical impairments and took more medication.

Regarding body composition, at 60-64 years old, an increase in BMI was observed in women (+6.4 $kg/m^2$, $P<0.001$) and in men (+5.8 $kg/m^2$, $P<0.001$), in waist circumference in women (+ 18.4 cm, $P<0.001$) and in men (+ 22.3 cm, $P<0.001$) and in body fat mass in women (+ 17.0%, $P<0.001$) and in men (+ 15.4%, $P<0.001$). After this age, no BMI or waist circumference difference was observed between older groups; body fat mass percentage was higher for women after 65 years old than from 60-64 years old. In the older age categories, only physical impairments and education reported differences between genders (women have +0.6 physical impairments than men in the 65-69 group and +0.8 in the 75-79 group, and were -2.8 years of education than men in the 60-64 group, $P<0.05$). Physical activity was similar among age and genders groups. The exception were young and older men, where the young group reported to be more active than the 75-79 group (+2287 MET-min/wk) and the ≥ 80 group (+2239 MET-min/wk), and, in age of 75-79 years, where women reported to be more active than men (+914 MET-min/wk), $P<0.05$. Furthermore, there were no differences between age groups in the number of prescribed medication drugs, physical impairments, and education level.

**Table 1.** Age, body composition, health, education, and physical activity of the sample. Data are mean ± standard deviation.

| | Y (20-29year) | A (60-64 year) | B (65-69 year) | C (70-74 year) | D (75-79 year) | E (≥ 80 year) | P-value | Post hoc test |
|---|---|---|---|---|---|---|---|---|
| Total (N=638) | | | | | | | | |
| Women (n=472) | (n=50) | (n=106) | (n=121) | (n=113) | (n=62) | (n=20) | - | - |
| Men (n=166) | (n=29) | (n=21) | (n=48) | (n=33) | (n=23) | (n=12) | - | - |
| Age (year) | | | | | | | | |
| Women | 22.8±2.1 | 62.2±1.4 | 67.0±1.5 | 71.8±1.3 | 76.8±1.5 | 82.6±2.0 | - | - |
| Men | 23.2±1.6 | 61.8±1.4 | 66.9±1.5 | 72.0±1.6 | 76.8±1.3 | 81.8±2.4 | - | - |
| Height (m) | | | | | | | | |
| Women | 1.61±0.06$^{b}$ | 1.56±0.06$^{b}$ | 1.55±0.06$^{b}$ | 1.54±0.06$^{b}$ | 1.53±0.05$^{b}$ | 1.51±0.07$^{b}$ | <0.001 | Y>A>C,D,E |
| Men | 1.77±0.05 | 1.67±0.07 | 1.67±0.06 | 1.69±0.05 | 1.70±0.06 | 1.66±0.07 | <0.001 | Y>A,B,C,D,E |
| Weight (kg) | | | | | | | | |
| Women | 55.2±6.1$^{b}$ | 67.5±10.8$^{b}$ | 67.9±12.0$^{b}$ | 66.8±11.5$^{b}$ | 63.2±10.2$^{b}$ | 60.3±10.7$^{b}$ | <0.001 | Y, E <A,B,C,D |
| Men | 73.2±8.3 | 81.6±13.3 | 76.3±13.1 | 77.0±11.3 | 77.9±11.7 | 75.5±11.1 | 0.240 | - |
| Body mass index (kg/m$^2$) | | | | | | | | |
| Women | 21.3±2.2$^{b}$ | 27.7±4.1 | 28.4±4.4 | 28.3±4.2 | 26.9±4.1 | 26.5±4.3 | <0.001 | Y<A,B,C,D,E |
| Men | 23.4±2.7 | 29.2±4.8 | 27.3±4.1 | 27.1±3.8 | 27.7±3.4 | 27.3±3.5 | <0.001 | Y<A,B,C,D,E |
| Body fat mass (%) | | | | | | | | |
| Women | 22.3±4.0$^{b}$ | 39.3±4.6$^{b}$ | 41.8±3.6$^{b}$ | 42.5±4.4$^{b}$ | 42.3±4.2$^{b}$ | 43.0±5.3$^{b}$ | <0.001 | Y<A<B,C,D,E |
| Men | 15.7±3.4 | 31.1±4.7 | 30.8±5.1 | 32.7±3.5 | 33.7±3.4 | 33.6±5.8 | <0.001 | Y<A,B,C,D,E |
| Waist circumference (cm) | | | | | | | | |
| Women | 68.5±4.5$^{b}$ | 86.9±10.4$^{b}$ | 90.0±10.2$^{b}$ | 89.9±11.7$^{b}$ | 87.1±10.8$^{b}$ | 87.9±9.8$^{b}$ | <0.001 | Y<A,B,C,D,E |
| Men | 80.2±3.2 | 102.5±12.5 | 97.3±11.3 | 98.4±11.0 | 99.0±10.5 | 99.8±9.0 | <0.001 | Y<A,B,C,D,E |
| Medication (n) | | | | | | | | |
| Women | 0.1±0.5 | 3.7±2.4 | 3.5±2.3 | 4.0±2.3 | 4.0±2.4 | 3.4±2.0 | <0.001 | Y<A,B,C,D,E |
| Men | 0.0±0.2 | 2.9±1.5 | 2.9±2.7 | 3.2±2.0 | 3.1±2.9 | 2.6±2.0 | <0.001 | Y<A,B,C,D,E |
| Physical impairments (n) | | | | | | | | |
| Women | 0.1±0.4 | 1.1±1.3 | 1.0±1.1$^{b}$ | 1.2±1.3 | 1.5±1.4$^{b}$ | 1.4±1.1 | <0.001 | Y<A,B,C,D,E |
| Men | 0.0±0.0 | 0.5±0.9 | 0.4±0.8 | 0.9±0.9 | 0.7±1.0 | 0.9±1.2 | 0.026 | Y<A,B,C,D,E |
| Education (year) | | | | | | | | |
| Women | 13.9±1.2 | 7.6±4.2$^{b}$ | 6.7±3.9 | 6.4±3.6 | 5.6±3.8 | 6.5±4.2 | <0.001 | Y>A,B,C,D,E |
| Men | 13.9±1.1 | 10.4±3.5 | 7.0±4.6 | 7.1±3.7 | 7.7±4.7 | 7.8±4.1 | <0.001 | Y>A,B,C,D,E |
| Physical Activity (MET-min/wk) | | | | | | | | |
| Women | 2833±2767 | 2739±1100 | 3129±1430 | 2973±1395 | 2822±1496$^{b}$ | 1985±1327 | 0.132 | - |
| Men | 4195±2908 | 2586±1396 | 2963±2197 | 2448±1165 | 1908±474 | 1956±687 | 0.017 | Y>D,E |

$^{b}$ Significant differences between women and men P<0.05.

Table 2 shows the comparison of the physical function attributes among age groups with descriptive data expressed in absolute scores. The same data expressed in standardized scores (having young adult as reference group) is presented in Figure 1. Considering absolute and standardized scores, it was verified that at the 60-64 age group, all physical attributes decreased, except aerobic endurance in men, which was only significantly reduced at 65-69 year old (-121 m, P<0.001, -2.0±1.3 SD). After that, an additional decrease was observed in women at the 70-74 year age group in lower body flexibility (-12.0 cm, -1.2±0.9 SD, P<0.001), agility and dynamic balance (2.1 sec, -7.1±5.8 SD, P<0.001), aerobic endurance (-151.4 m, -3.1±1.6 SD, P<0.001), and multidimensional balance (-8.2 points, p <0.001) and after the age of 79 in lower body strength (-11.3 rep, -2.7±0.9 SD, P<0.001) and upper body flexibility (-19.5 cm, -3.6±2.3 SD, P=0.002). In men, an additional reduction only occurred after 79 year old in lower body strength (-12.8 rep,-3.6 SD, P=0.025), agility and dynamic balance (2.8 sec, -9.2±3.8 SD, P=0.004), aerobic endurance (-226.8 m, -4.3±1.6 SD, P=0.005), and multidimensional balance (-8.0 points, P=0.005). There were no differences among groups of elderly women in upper body strength, and among groups of elderly men in upper body strength, and lower and upper body flexibility.

Comparison between women and men in the 20-29 age group showed differences in all physical attributes except in multidimensional balance, in which both genders obtained the maximum score (40). Women presented higher values in flexibility, while men presented higher values in all other physical attributes. Physical function differences between women and men progressively diminished with age. After the age of 79, only multidimensional balance was 5.2 points higher in men than in women (P=0.006).

**Table 2.** Comparison of physical function attributes (absolute scores) among age groups. Data are mean ± standard deviation.

| | Y (20-29 year) | A (60-64 year) | B (65-69 year) | C (70-74 year) | D (75-79 year) | E (≥ 80 year) | P- value | Post hoc test |
|---|---|---|---|---|---|---|---|---|
| Lower body strength (rep) | | | | | | | | |
| Women | 25.4±4.2 [b] | 17.9±4.7 | 17.9±4.5 | 16.5±4.2 | 16.3±3.6 [b] | 14.1±3.9 | <0.001 | Y>A,B,C,D,E<br>A, B>E |
| Men | 28.5±3.6 | 19.0±4.1 | 18.7±4.0 | 16.7±3.7 | 18.3±3.6 | 15.7±1.6 | <0.001 | Y>A,B,C,D,E<br>A, B>E |
| Upper body strength (rep) | | | | | | | | |
| Women | 27.1±3.4 [b] | 17.9±4.4 [b] | 17.5±4.8 | 16.5±4.3 [b] | 16.9±4.1 [b] | 16.7±3.9 | <0.001 | Y>A,B,C,D,E |
| Men | 29.8±4.0 | 20.5±4.8 | 18.2±5.1 | 18.6±5.0 | 19.6±4.3 | 17.8±3.2 | <0.001 | Y>A,B,C,D,E |
| Lower body flexibility (cm) | | | | | | | | |
| Women | 11.3±9.7 | 2.9±8.0 [b] | 0.8±8.0 [b] | -0.7±8.3 [b] | -1.2±7.4 | -4.7±11.7 | <0.001 | Y>A,B,C,D,E<br>A>C,D,E |
| Men | 6.7±12.6 | -9.3±9.2 | -8.2±11.5 | -8.5±11.3 | -1.8±8.3 | -5.0±8.9 | <0.001 | Y>A,B,C,D,E |
| Upper body flexibility (cm) | | | | | | | | |
| Women | 7.2±5.4 [b] | -3.9±9.0 [b] | -6.9±9.0 [b] | -7.6±9.5 [b] | -7.9±11.4 | -12.3±12.4 | <0.001 | Y>A,B,C,D,E<br>A>E |
| Men | 3.5±5.4 | -10.3±12.7 | -11.3±11.9 | -12.9±11.1 | -10.8±11.8 | -13.7±8.6 | <0.001 | Y>A,B,C,D,E |
| Agility and dynamic balance (sec) | | | | | | | | |
| Women | 3.8±0.3 [b] | 5.23±0.8 | 5.42±0.82 [b] | 5.93±1.73 | 6.19±1.04 [b] | 7.05±2.28 | <0.001 | Y<A,B,C,D,E<br>A,B<C,D,E<br>C<E |
| Men | 3.4±0.3 | 5.0±0.9 | 5.0±0.9 | 5.5±1.2 | 5.2±1.0 | 6.2±1.1 | <0.001 | Y<A,B,C,D,E<br>A,B<E |
| Aerobic endurance (m) | | | | | | | | |
| Women | 650.1±48.4 [b] | 542.7±69.4 [b] | 517.3±68.7 [b] | 498.7±75.7 [b] | 498.0±54.0 [b] | 443.5±76.0 | <0.001 | Y>A,B,C,D,E<br>A>C,D,E<br>B>E |
| Men | 701.9±60.7 | 637.8±110.4 | 580.9±76.2 | 583.4±96.9 | 590.0±74.2 | 475.1±100.1 | <0.001 | Y>B,C,D,E<br>A,C,D>E |
| Multidimensional balance score (point) | | | | | | | | |
| Women | 40.0±0.0 | 34.7±3.6 | 33.3±4.1 [b] | 31.8±4.8 [b] | 30.8±4.6 [b] | 26.8±4.7 [b] | <0.001 | Y>A,B,C,D,E<br>A>C,D,E<br>B>D,E<br>C,D>E |
| Men | 40.0±0.0 | 35.9±3.4 | 36.2±3.1 | 34.3±4.7 | 34.1±3.6 | 32.0±4.2 | <0.001 | Y>A,B,C,D,E<br>B>E |

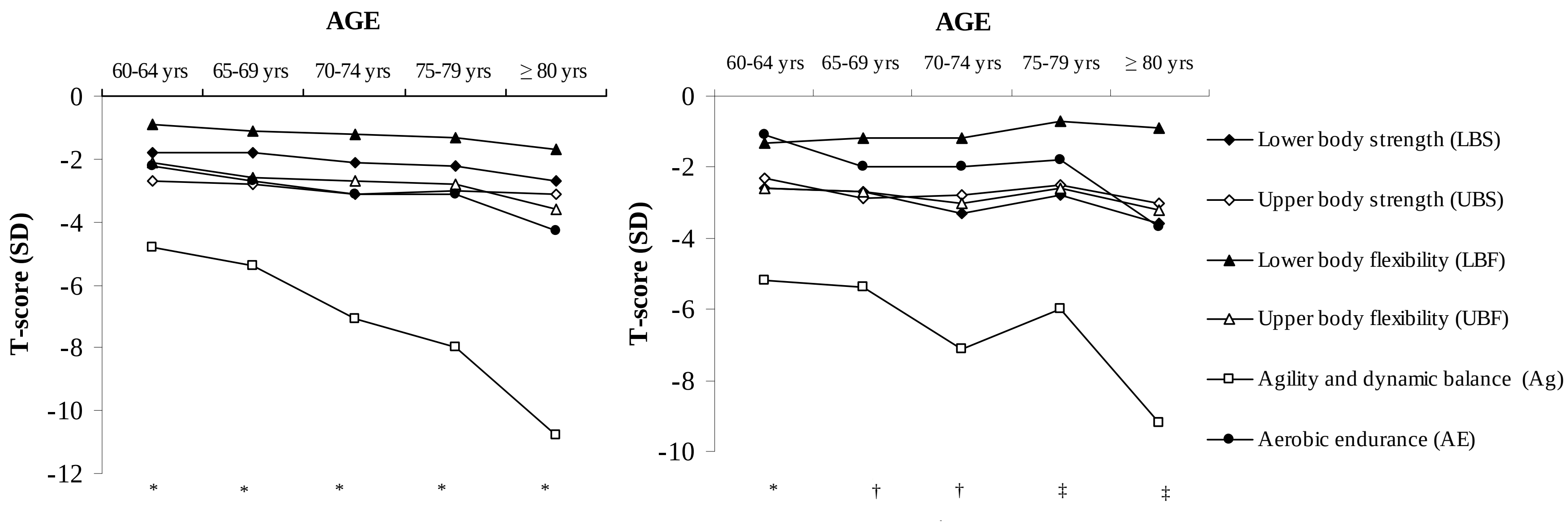
[b] Significant differences between women and men P<0.05.

Comparisons between physical attributes (T-score) according to age group in elderly women and men are presented in Figure 1. In women aged 60-64, lower body flexibility presented the highest T-score (-1.1±0.9 SD), followed by lower body strength (-2.0±1.0 SD), upper body flexibility (-2.6±1.8 SD), upper body strength (-2.9±1.3 SD), aerobic endurance (-2.9±1.5 SD), and finally agility and dynamic balance (-6.3±4.4 SD), which presented the lowest T-score and the highest rate loss ($P<0.001$). The same physical attributes sequence was observed for the other female age groups. In men aged 60-64, aerobic endurance (-1.1±1.8 SD) and lower body flexibility (-1.3±0.7 SD) presented the highest T-scores, followed by a similar decline in upper body strength (-2.3±1.2 SD), upper body flexibility (-2.6±2.4 SD), lower body strength (-2.6±1.1 SD), and finally agility and dynamic balance (-5.2±3.0 SD), which presented the lowest T-score ($P<0.001$). The same sequence was observed in the other male age groups, with the exception of aerobic endurance.

## DISCUSSION

The main purpose of this investigation was to analyze physical function variation in active, community-residing older people, using scores from young adults as reference. Multidimensional balance was the physical attribute that declined the most in old age, particularly in women. Participants over 60 years of age showed balance losses approaching 1.5 % in men and 3.3 % in women for every 5-year period; after 79 year of age, losses approximated 5.3 % in men and 10 % in women. Beyond multidimensional balance, agility and aerobic endurance also demonstrated pronounced losses across age. Between 60 and 79 years of age, there was an agility reduction near 1 SD for each 5-year period and near 3 SD after the age of 79 in both genders. In women, aerobic endurance was reduced almost 0.5 SD for each 5-year period before 80, and near 1 SD after this age. In men, the reduction only became serious after 80, with values near 2 SD.

Agility is closely associated with balance, and these abilities are usually trained and evaluated together [25, 26]. These complex functions require the central processing of inferences from the visual, vestibular and somatosensory systems and imply the organization of motor responses [27-29]. Loss of agility and balance are linked to the




* LBF > LBS > UBS, UBF, AE > Ag, P≤0.01

* LBF, AE > UBS, UBF, LBS > Ag, P<0.001;

† LBF > AE > UBS, UBF, LBS > Ag, P<0.001;

‡ LBF > UBS, UBF, LBS, AE > Ag, P<0.001

Women

Men

**Figure 1.** Comparison between physical attribute T-scores according to each age group in elderly women and men.

deterioration of these structures, as well to the normal loss of muscular and skeletal system function with age, [29, 30]. The faster decrease reported by this study in the capacity to perform tasks that require balance, agility, and aerobic capacity may be attributed to the multiple structures that begin to function more poorly. Aerobic endurance decline caused by ageing also reflects functional deterioration, ranging from the lungs to skeletal muscle to mitochondria [31, 32].

In general, at the 60-64 year age range, flexibility and strength of the lower limbs were the attributes that presented the lowest rate of loss. It was further observed that after this age, the rate of loss in the lower limbs was slightly faster to that of the upper limbs.

Several studies reported increasing disability, fall occurrences, and loss of autonomy when extremity impairment or strength losses are diagnosed, particularly in the lower limbs [33-35]. Maintaining the capacity to get out of a chair and walk is fundamental for the maintenance of aerobic endurance, which in turn correlates with self-reported functional ability [36], cardiovascular disease, mobility limitation, disability and mortality [37].

Despite the analogous pattern of physical function decline seen in the Rikli and Jones study [17], in the present investigation physical function declined earlier in women (aged 70-74) compared to men (after 79), possibly due to the combined effect of a poor body composition and health status [10, 21]. A lower education level (~7 years) in this study compared with others with a higher level of education (~15 years), may partially explain a less favorable score in some physical attributes of the study participants, particularly aerobic endurance and BMI [17, 38, 39].

As already reported by others in young adults [19], flexibility was higher in women and the remaining attributes were higher in men. Differences were also observed in all physical function attributes between women and men until 79 year of age. After that, there were no differences between genders, except in multidimensional balance, due to an age-related attenuation of physical function differences and possibly also to the sample size of the oldest groups and thus to limited statistical power. The small number of participants in the last age group may also reflect lack of access to supervised exercise for unhealthier and older people who are more prone to falls, more afraid of falling, more likely to restrict their activities, less autonomous, and more dependent on social support services [17, 38, 40].

By age 60, all physical attributes were reduced significantly, except aerobic endurance in men. During the interviews, older men reported that they walked extensively more frequently than younger men. These results agree with several studies [16-18] that also found a progressive loss of physical function across age. In the elderly, the most accentuated losses occurred after the age of 79. While all these losses have been interpreted as naturally attributable to ageing [17, 21, 31, 33], complementary linear regression analysis suggested a limited importance of age, since the variation of physical attributes explained by chronologic age ranged just from 3% (in upper body flexibility) to 13% (in multidimensional balance) ($P<0.05$). By its turn, medication explained 2-18% of physical function variation and physical activity explained 1-5% of this variation ($P<0.05$)

The main limitation of this study was its cross-sectional nature. In order to minimize this limitation, we tried to delineate homogeneous groups concerning variables that potentially might influence physical function, namely medication and physical impairments (as surrogates of health), body composition, school years, and physical activity. However, it was a study with a large sample and with a physical activity level that may be higher than general population from the same age, since participants were involved in exercise programs and reports a high house/yard and transportation-related physical activity[41]. Young reference group included participants with a varied physical activity level, in order to be representative of general young from this range age. In this context, it is estimated that losses of physical function in general population across aging may be slightly higher than those observed in the present work.

## CONCLUSIONS

By the age of 60, all physical attributes decreased significantly, except aerobic endurance in men. The most pronounced losses occurred after 79 years of age in both genders. Physical function decreased earlier in women than in men, with fewer differences between genders after the age of 79. Chronologic age was, however, a weak predictor of physical function variance, suggesting that other factors need to be considered. Abilities involving multiple structures, specifically agility, balance and aerobic endurance, presented more significant losses across age than strength and flexibility, which depend primarily on the muscle-skeletal structure. Furthermore, small losses affecting the lower limbs were greater than those of the upper limbs in older age.

Thus, intervention for similar groups should be designed, taking into account training priorities, namely: balance, agility, and aerobic endurance. Lower limb exercises should be emphasized.

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**Conflict of interest statement**

The authors declare that there is no conflict of interest.

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# CHAPTER 4

## OVER 50 YEARS OLD MEN ARE MORE LIKELY TO FALL THAN WOMEN UNDER SIMILAR CONDITIONS OF HEALTH, BODY COMPOSITION AND BALANCE [3]

[3] Pereira C, Baptista F, Infante P. Over 50 years old men are more likely to fall than women under similar conditions of health, body composition and balance. 2011 (*in review*)

## ABSTRACT

Women are more prone to fall than men. However, the reasons for this higher incidence of falls in old women are not well known. This study aimed to analyze cross-sectionally the contribution of gender in falls occurrence, after accounting for co-morbidities, body composition and physical function differences. Participants were 587 community-dwelling old adults of both genders. Falls occurrence, co-morbidities (number of diseases and physical impairments), body composition (body height, weight, lean mass, and fat mass), and physical function (lower and upper body strength and flexibility, agility, aerobic endurance, balance) were evaluated by questionnaires, bioimpedance and Fullerton batteries, respectively. Compared with men, women revealed a 10% higher fall prevalence, 1.7 more diseases/impairments, 10% more body fat, 26% less lean body mass, and a lower physical function ($p<0.05$). Multivariate logistic regression showed that male gender (OR:2.723, 95% CI:1.190-6.230) increased the likelihood of falling, after adjusted for co-morbidities (OR:1.213, 95% CI:1.109-1.328), lean mass (OR:0.958, 95% CI:0.927-0.989), fat mass (OR:1.053, 95% CI:1.021-1.086), and balance (OR:0.942, 95% CI:0.914-0.971), that were the most important predictors of falls. In conclusion, women were more susceptible to falling because they have, at least, poorer health, body composition and physical function than men. However, considering similar values for these risk factors in both genders, men demonstrated a higher fall probability. Age was not a significant risk factor for falls in a favorable condition of health, body composition and balance.

**Key words:** falls; gender; co-morbidities; physical function; body composition

**Short Title:** Falls and gender

## INTRODUCTION

Falls are the major cause of death related to mechanical injuries in the elderly [1], especially in women since they are more prone to fall and have a higher predisposition to osteoporotic fractures than men [2-4]. Although some authors cite gender differences in the mechanical properties of tendons to explain discrepancies in the risk of falling [5], the reasons for a higher incidence of falls in women are not well known.

Falls can be a problem before age 60 years [6]. However, their occurrence increases with age and is estimated that at least 30% of people aged 65 or older living in community fall at least once a year [7, 8]. Apart from health status, the progressive loss of physical function and mobility with age seems to contribute to a fall event [9]. Moreover, these losses showed contribute differentially to the occurrence of diverse types of falls (e.g. indoor and outdoor falls) [10]. Exercise, as a single or a multifactorial intervention to prevent falls is one of the most effective and frequent strategy with an overall 17% reduction in risk of falls [11], particularly if it includes skill-related (coordination, agility, balance, mobility), and/or health-related components of physical function as muscular strength, flexibility and aerobic capacity/endurance [12, 13]. However, for the success of a fall prevention intervention, it is important to weight the influence and associated risk of each factor in both men and women.

Recent research to predict falls and to distinguish fallers from non-fallers has been focused in the lifestyle, health status, and physical function, particularly, in balance and mobility [2, 3, 14-16]. Nevertheless, despite being seen as risk factors for falls [3, 9, 12, 13] the influence of parameters such, muscle strength, flexibility, agility, body composition or other personal characteristics as gender remains unclear. Study the effect of gender is pointed as fundamental in current research on aging [17]. Thus, the main purpose of this study was to investigate the influence of gender in the occurrence of falls in community-residing persons aged 50 and older after accounting for co-morbidities, body composition and physical function differences.

## MATERIALS AND METHODS

### Participants

Participants were recruited by invitation and via leaflets in community settings (health center, recreational, sporting, cultural and senior university). They lived independently and did not suffer recent infirmities that provoking a temporary decrease in physical function. All participants had no dementia according to Mini-Mental State Examination [18]. Twenty-six volunteers did not meet these criteria, and were excluded. The final sample consisted of 587 active community-dwelling persons aged 50 and older (463 women - 153 of whom were fallers, and 124 men - 29 of whom were fallers), with 77.8 % of the participants attending at least twice weekly in a supervised exercise program during the previous year. All subjects were volunteers, and provided informed consent. The University's Ethics Committee approved this study.

### Measures

#### *Physical function and body composition*

Physical function, namely lower and upper body strength, lower and upper body flexibility, agility and dynamic balance, aerobic endurance and body mass index (BMI) were evaluated by the Fullerton Functional Fitness Test Battery [19]. These seven parameters were assessed, respectively, by the following tests: 1) 30-s chair stand (rep); 2) arm curl (rep); 3) chair sit-and-reach (cm); 4) back scratch (cm); 5) 8 ft up-and-go (sec); 6) 6-min walk (m); and 7) body mass index (BMI) calculated as body weight divided by height squared (kg/m$^2$). Body weight (kg) was measured by an electronic scale (Secca Bella 840, Hamburg, Germany) and standing height (cm) with a stadiometer (Secca 770, Hamburg, Germany).

Evaluation of multidimensional balance was conducted by the Fullerton Advanced Balance (FAB) Scale [20]. This battery consists of 10 tests and includes a combination of static and dynamic balance activities performed in different sensory involvements. The tests were: 1) stand with feet together, eyes closed; 2) reaching forward to object; 3) turn in full circle; 4) step up and over; 5) tandem walk; 6) stand on one leg; 7) stand

on foam, eyes closed; 8) two-footed jump; 9) walk with head turns; and 10) reactive postural control. The 10 tests are scored according to an ordinal scale going from 0 (worst) to 4 (best) points. The final score is the sum, from 0 to 40, of the points obtained in each of the tests.
Fat body mass percentage was assessed by bioimpedance (HBF-306C, Schaumburg, USA) [21]. Lean body mass (kg) was calculated as: body weight (kg)–[(body weight (kg)× fat body mass (%))/100].

***Falls, co-morbidities, and socio-demographic characteristics.***

History of falls, health, and socio-demographic characteristics were assessed by a questionnaire. Participants were interviewed and a questionnaire filled in, indicating the number of falls in the last 12 months, diseases and physical impairments, time spent in supervised exercise (hr/wk), age, educational level, and other socio-demographic characteristics, besides describing the circumstances surrounding falls (e.g., habitual, exceptional or high difficulty tasks; indoor or outdoor). A fall was operationally defined as "a subject unintentionally coming to rest on the ground or another lower level, except those that result from a major intrinsic event (e.g. stroke or syncope) or overwhelming hazard" [8]. A faller was defined as a subject who fell at least once in the previous12 months. Diseases reported by all participants were listed in a total of 24 diseases. Physical impairments included involuntary loss of urine, regular dizziness, feet problems (e.g. sores, corns, skewed toes, amputation of toes or foot, insufficient muscle function), poor vision (not recognizing someone's face at a distance of 4 meters with glasses or contact lenses), hearing problems (not able to follow a conversation in a group of four people with a hearing aid), and occasional loss of balance [14]. The presence or absence of each disease and physical impairment were checked for each participant. The number of diseases and physical impairment defined co-morbidities.

**Statistical analysis**

Subject´s characteristics, namely potential predictors of falling (age, education, co-morbidities, and body composition and physical function parameters), were compared between fallers and non-fallers and between males and females by t-test for independent samples in case of normality and homoscedasticity of the variables, or by the Wilcoxon-Mann-Whitney test, when these conditions were not met. Complementary analyses were performed by chi-squared independent test and Mantel – Haenszel test.

The influence of gender, co-morbidities, physical function, body composition, exercise and age in the occurrence of falls (yes/no) were analyzed by binary logistic regression [22] using the traditional approach, seeking the most parsimonious model. The selection process started with the univariate analysis of each variable. Variables that presented a p-value $<0.20$ were candidates for the multivariable model. At first, a model was created containing all variables of reported importance and the significance of each variable was tested by the Wald statistic ($p<0.05$). Variables that did not meet these criteria were eliminated, and a new model was fitted. Each new model was compared with the previous one, using the likelihood ratio test. This process of deleting, refitting, and verifying continued until all significant variables examined were included in the model. For continuous variables, the assumption of linearity was checked by the logit. The main effects model was refined, and the possible interactions among the variables were tested until a final model was established. A Hosmer-Lemeshow test evaluated the overall fit measures. Discriminative ability of potential predictors was examined by the Receiver Operating Characteristic (ROC) analysis, which computed the area under the ROC curve (AUC). Established sensitivity and specificity relied on a cut-point that maximized both [23]. Finally an analysis of the individual components of the summary statistics was performed, looking for outliers and influential points. The final model-equation with the significant predictor variables for falling and its weight was determined.

Internal validation of the model was performed by a resampling or cross-validation procedure [24]. Participants were divided into 10 equal groups by sampling randomly without replacement. For each one of the randomized groups, it was generated the predicted probabilities for fall occurrence by using parameters that were estimated from a logistic regression model that used data from the other nine groups. These 10 logistic regressions had identical specification; each one used 90% of the data. Finally it was calculated the AUC for the probabilities generated by the cross-validation.

Statistical analyses were performed with SPSS version 17.0, considering statistical significance to be $p <0.05$.

## RESULTS

Of the 587 volunteers, 182 reported at least one fall in the previous 12 months (Table 1). Regarding falls occurrence, fallers had poorer body composition than non-fallers. Lean body mass was lower among fallers (-2.2 kg, p=0.004), and fat body mass percentage was higher among fallers (+2.5%, p<0.001). Regarding height, non-fallers were 2.3 cm shorter (p=0.001). Non-fallers showed better values in all parameters of physical function (from +2 points in multidimensional balance to +26 m in aerobic endurance, p<0.05), except in upper body strength and in lower body flexibility. Non-fallers also were younger (-1.36 yrs, p=0.014), healthier (-1.3 diseases or impairments, p<0.001) and more educated (+1.53 yrs, p<0.001).

**Table 1.** Characteristics of subjects (N=587). Data are mean ± Standard Deviation.

| | **Non-fallers (n =405)** | **Fallers (n =182)** | **p** | **Women (n =463)** | **Men (n =124)** | **p** |
|---|---|---|---|---|---|---|
| Age (yrs) | 67.8±6.9 | 69.1±6.7 | 0.012 | 67.8±6.9 | 69.6±6.5 | 0.011 |
| Co-morbidities (n) | 3.0±2.1 | 4.3±2.6 | <0.001 | 3.7±2.4 | 2.2±1.6 | <0.001 |
| Education (yrs) | 6.8±4.3 | 5.3±3.9 | <0.001 | 5.9±4.0 | 8.0±4.4 | <0.001 |
| Exercise (hr/wk) | 2.1±1.2 | 1.9±1.3 | 0.215 | 2.0±1.2 | 2.3±1.4 | 0.015 |
| Height (cm) | 157.1±8.4 | 154.8±7.8 | 0.001 | 153.5±6.3 | 167.1±5.9 | <0.001 |
| Weight (kg) | 69.5±12.5 | 69.4±12.7 | 0.979 | 67.1±11.6 | 78.1±12.3 | <0.001 |
| Body mass index ($kg/m^2$) | 28.1±4.3 | 29.0±4.8 | 0.115 | 28.5±4.6 | 28.0±4.1 | 0.216 |
| Lean body mass (kg) | 42.8±8.3 | 40.6±8.0 | 0.004 | 38.9 ±5.7 | 52.7±6.5 | <0.001 |
| Fat body mass (%) | 38.7±6.2 | 41.2±5.7 | <0.001 | 41.7±4.6 | 32.2±4.8 | <0.001 |
| Lower body strength (rep) | 16.9±4.6 | 15.6 ±4.4 | 0.002 | 16.3±4.7 | 17.4±4.2 | 0.005 |
| Upper body strength (rep) | 17.6±4.6 | 16.7±4.4 | 0.063 | 17.1±4.4 | 18.3±4.7 | 0.010 |
| Lower body flexibility (cm) | -1.4±9.7 | -1.3±8.6 | 0.987 | 0.3±8.1 | -7.5±11.0 | <0.001 |
| Upper body flexibility (cm) | -8.6±10.5 | -11.6±11.3 | 0.002 | -8.9±10.5 | -11.8±11.7 | 0.010 |
| Agility and dynamic balance (sec) | 5.7±2.0 | 6.0±1.7 | 0.001 | 6.0±2.0 | 5.3±1.1 | <0.001 |
| Aerobic endurance (m) | 519.4±96.3 | 493.7±94.2 | 0.004 | 495.3±90.1 | 579.1±92.6 | <0.001 |
| Multidimensional balance (points) | 33.2±5.5 | 31.1±5.9 | <0.001 | 31.9±5.8 | 34.9±4.5 | <0.001 |

Regarding gender, fall prevalence and annual rate was higher among women (women: 33.0 vs. men: 23.4%, p=0.039; women: 0.64 fall/year vs. men: 0.31 fall/year, p<0.001).

In both genders ~40% of the falls occurred indoor, and ~60 occurred outdoor. Body composition and physical function were also better in men than in women: from -9.5% in fat body mass to +13.8 kg (+9.4%) in lean body mass, $p<0.01$; and from +1.1 rep (6.5 %) in lower body strength to + 82.8m (16.9 %) in aerobic endurance $p<0.05$). Nonetheless, women demonstrated a better body flexibility (upper and lower) than men (+7.8 cm and +2.9 cm, respectively) ($p<0.01$). Although older (+1.7 yrs, p=0.011), men were healthier (with 1.74 less disease or impairments, $p<0.001$) and had more years of education (+2.11 yrs, $p<0.001$).

Complementary analysis done by chi-squared independent test showed that the percentage of women who fall was significantly higher than that in men (33.0 vs. 23.4%, p=0.039). It also showed that men reported a higher percentage of falls than women when performing exceptional or high difficulty tasks (17% vs. 4%, p=0.017) but a lower falls percentage when performing habitual tasks (83% vs. 96%, p=0.017). Mantel – Haenszel test showed that there were no significant differences between the percentage of men and women who fall, or did not fall, when controlled for each health, body composition or physical function variables (categorized by quartiles and used as layer).

Multivariate binary logistic regression analysis was performed in order to compute a model with an improved ability to predict falls occurrence, with the inclusion of the significant variables. This analysis (Table 2) showed that the predictor variables to falls occurrence were gender (male OR: 2.723 CI 95%: 1.190-6.230), co-morbidities (OR: 1.213 CI 95%: 1.109-1.328), lean body mass (OR: 0.958 CI 95%: 0.927-0.989), fat body mass percentage (OR: 1.053 CI 95%: 1.021-1.086), and multidimensional balance (OR: 0.942 CI 95%: 0.914-0.971). In the multivariate model, male gender increased the likelihood of falling. Chronologic age was not a significant predictor of falls

**Table 2.** Predictors of falling. Data are Multivariate Odds Ratios (OR), 95% Confidence Intervals (CI), Area Under the ROC Curve (AUC), 95% Confidence Intervals (CI), Specificity and Sensibility (Cut-off Point: 0.336).

| Predictor | OR (95%CI) | AUC (95%CI) | Specificity (%) | Sensibility (%) |
|---|---|---|---|---|
| Gender | 2.723 (1.190-6.230) | | | |
| Co-morbidities | 1.213 (1.109-1.328) | | | |
| Lean body mass | 0.958 (0.927-0.989) | 0.710 (0.661-0.758) | 72.0 | 60.2 |
| Fat body mass | 1.053 (1.021-1.086) | | | |
| Multidimensional balance | 0.942 (0.914-0.971) | | | |

The ROC analysis showed that the multivariate model discriminated fallers from non-fallers, with an AUC of 0.710 (CI 95%: 0.661-0.758). The optimal cut-off point was established at 0.336, corresponding to the maximum sum of sensitivity (60.0%) and specificity (72.0%). The multivariate logistic regression and was defined by the follow equation:

$$\pi(x) = \frac{\exp\{1.002 \times Gender + 0.193 \times C - 0.043 \times LBM + 0.052 \times FBM - 0.060 MB\}}{1 + \exp\{1.002 \times Gender + 0.193 \times C - 0.043 \times LBM + 0.052 \times FBM - 0.060 MB\}}$$

*Where $\pi(x)$ is falling probability; exp is exponential; Gender is 0 for female and 1 for male; LBM is lean body mass (kg); C is co-morbidities (number of diseases and impairments); FBM is fat body mass (%), and MB is multidimensional balance (point).*

In order to define cut-off values that distinguish fallers from non-fallers depending on co-morbidities, lean body mass, fat body mass percentage and multidimensional balance, the equation of the multivariate model of logistic regression was solved for each of these four predictors. To this end, it was considered in each calculation (in a total of four) a cut-off value of 0.336 for the probability of falling (π) and the value corresponding to the 50th percentile in the remaining variables (except in the variable on which the calculation was being processed). In men, the 50th percentile corresponded respectively to the following values: 2 diseases or incapacities in co-morbidities; 51.5 kg in lean body mass; 32.2% in fat body mass; and 36 points in multidimensional balance. In women, the 50th percentile corresponded to 3 diseases or incapacities in co-morbidities; 38.9 kg in lean body mass; 42.1% in fat body mass; and 33 points in multidimensional balance.

Figure 1 shows, separately for men and women, the change in the probability of falling due to the variation of each one of these variables, indicating the value at which the participant moves from the non-faller to the faller category.

Concerning the multivariate equation, men who fall will be the ones that show more than 5 diseases/incapacities, or a lean body mass below 36.7 kg, or a fat body mass above 44.4 %, or a multidimensional balance under 26 points. The fallers women will be the ones that show more than 4 disease/incapacities, or a lean body mass below 34.2 kg, or a fat body mass above 46.0 %, or a multidimensional balance under 30 points.

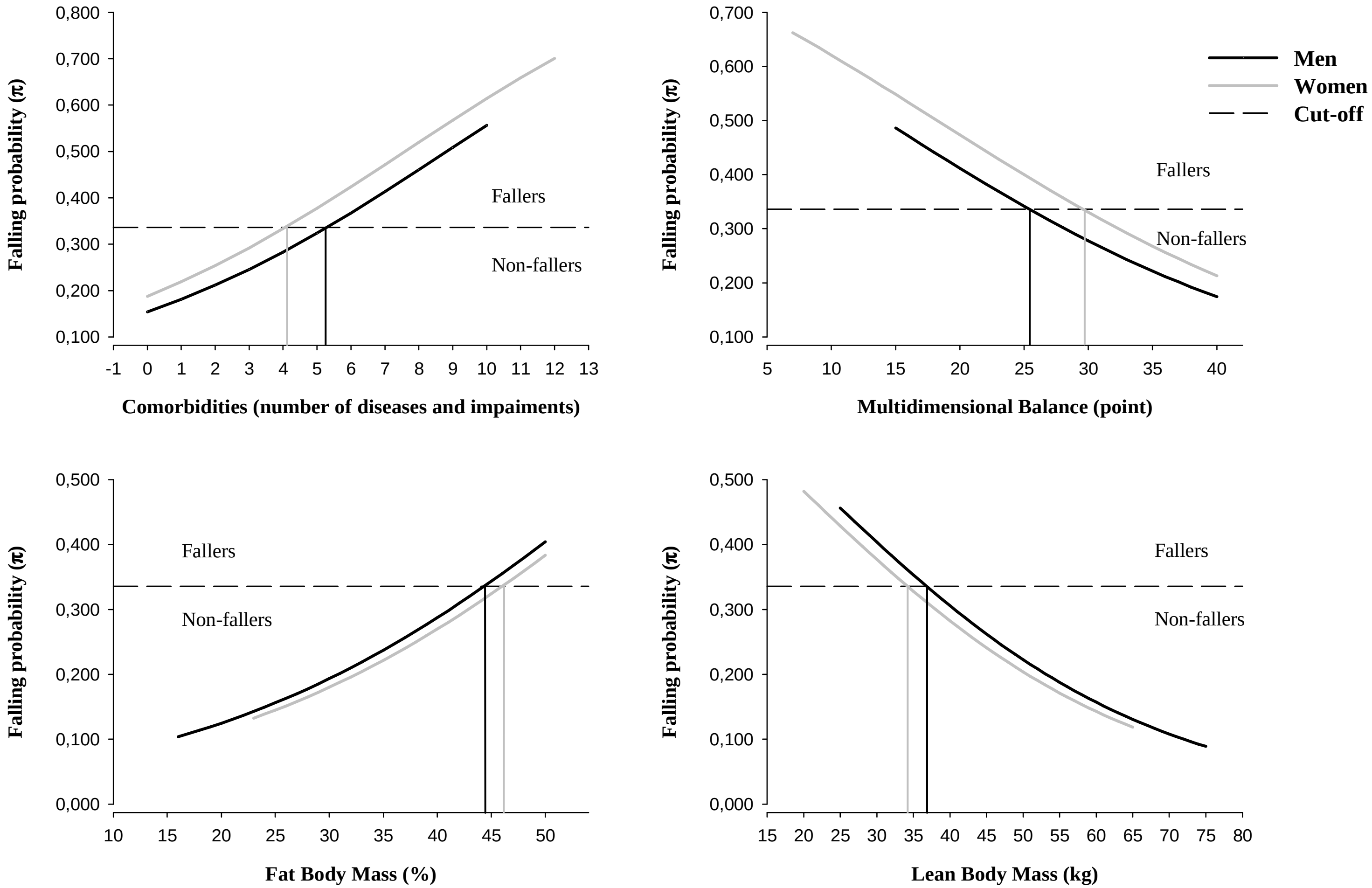


**Figure 1**. Falling probability variance according gender, co-morbidities, multidimensional balance, fat, and lean body mass. The values of each of these variables were calculated from logistic regression considering the 50$^{th}$ percentile of the remaining variables in the equation and a cut off-point of 0.336 to discriminate fallers from non-fallers.

## DISCUSSION

The main goal of this work was to study the influence of gender in falls occurrence in community-residing persons aged 50 and older.

This investigation reported that women were more susceptible to falling than men, a result that is consistent with other studies [2, 3, 25]. However, when similar conditions of health, body composition and physical function were considered for both men and women, men were more than twice prone to fall than women. As also mentioned by some researchers [26, 27], fallers demonstrated worst values in co-morbidities and in almost all physical function and body composition variables. Multivariate logistic regression results showed that the most important predictors of falls were co-morbidities, lean and fat body mass, and multidimensional balance, in both genders.

As noted earlier [3, 28], men had better values than women in almost all body composition and physical function parameters, and, apart from being older, men also presented improved values in health status and fell less than women. The poorer results for women, suggest the reasons for women to be more susceptible to falling than men. Thus, consistent with other authors [3, 29], the risk probability for falling in women was ~10% higher than in men, when a single analysis was conducted. However, when the risk of falling was adjusted for co-morbidities, lean and fat body mass, and multidimensional balance, men showed a higher predisposition to fall than women. For example, for similar conditions in both gender (e.g. 2 diseases or impairments, 40 kg of body lean mass, 40% of body fat mass, and 30 points on multidimensional balance), the probability of falling for the man will be 48.7%, and for the women will be 25.8%. This reversal occurred only when equating the cumulative effect of the variables, since the study of the effect of each single variable analyzed by the Mantel – Haenszel test revealed not to be significant.

Results from the complementary analysis were consistent with the hypothesis that men put themselves in more hazardous situations than women. In this study, men reported a higher percentage of falls than women when performing exceptional or high difficulty tasks, but a lower percentage of falls when performing habitual tasks. This is consistent with the observations reported by other researchers that male gender is a higher risk for falling than female gender in a hospital setting [30], and that a higher risk of falls is associated with the performance of high demanding activities [31].

As already observed, co-morbidities was the most important predictor of falls in both genders [6, 14, 32], with a 21% increase of falling likelihood for each additional disease/incapacity. This finding means for example, that a successful cataract surgery, a significant risk factor for falls and for related-injuries since visual impairments leads to inaccurate assessment of environmental obstacles [33], decreases the likelihood of falling by 21%, besides other evident benefits. This percentage is consistent with the results of Nitz and Choy [6] who revealed that for each additional co-morbidity, depending on age, the likelihood of falls increases from 8% to 35%.

Regarding body composition, this study estimated that for an additional 1% in fat body mass (~0.7 kg in men and ~0.8 kg in women), the likelihood of falling increases 5%, and for each additional kg in lean body mass, it decreases 4%. This finding reinforces the importance of lean mass, namely muscle mass, in falls prevention [9, 34].

Balance evaluated by FAB Scale battery, has revealed to be a strong predictor for recurrent falling. Hernadez and Rose study [15] found that for every point increased in the total balance score, there was ~10% decrease in the older adult's likelihood of falling. The present study reported that, among all physical function parameters, multidimensional balance was the most important predictor of falls occurrence, showing a decrease of 6% in the likelihood of falling for each additional point. This fact may be principally relevant for women because in this test they obtained ~ 3 points less than men. Moreover, balance evaluated by FAB battery was a stronger predictor of falling than balance evaluated by the up-and-go test, which has also been used to predict falls with contentious results [35-37]. As each item test of the FAB battery has the ability to detect failures and handicaps in the different sensory and locomotors systems and mechanisms [20], its use as an evaluation tool also allows outlining recommendations for preventive interventions.

Health, body composition and physical function variables were the ones that allowed estimation of falling risk. This study estimated the risk associated with the change of each one of these predictor variables, and estimate values (different for men and women) from which the individual modifies the condition of faller for non-faller and vice-versa. For example, if a woman increase the lean body mass of 33 kg to 35 kg, maintaining the other variables constant (i.e. median values), the likelihood of falling would decrease 8.4%, and change from a faller to a non-faller status. Within limits, a more favourable score in one variable seems to compensate a less favourable score in other variable.

Age per se loses its importance as risk factor for falling if health, body composition and physical function are maintained across aging. Age emerged as a risk factor for falling in pair wise comparisons [3, 8], but lost significance in multivariate regression analysis. Therefore, younger people in poorer health, body composition or physical function condition have a higher probability of falling than older people in better condition. Thus, the results of this study emphasize the importance of promoting a healthy body composition and physical function particularly multidimensional balance; avoiding perform risky tasks, especially in hazard environments. They underlines special attention to women because their conditions tend to be more fragile and to men because they tend to expose themselves to situations of greater risk.

A major difficulty in this investigation was the recruitment of male participants. Consequently, the sample was composed mainly by women (78.9%), with a participation percentage exceeding that reported in last Portuguese census [38] for the population aged 50 and older (~58% women). However, the sample reflects the higher number of women involved in community initiatives and physical exercise programs. In addition, most of the participants were physically and socially active, maintaining average levels of capacities and independence [28]. Even so, in accordance with other studies [7, 8], 31 % of them fell at least once in the previous year. However, the real dimension of the problem is likely to be underestimated, because, the most frail individuals are unlikely to volunteer for this type of studies.

Another possible limitation of this study may be the inclusion of one-time faller persons in the multivariate model, since Gill et al. [39] recommend to analyse the risk of falls using regression models for recurrent events. Nevertheless, the inclusion of one-time fallers, beyond to deliver similar results to those found when considering recurrent fallers in the model, showed to be more explanatory in data analysis. On the other hand, the final multivariate model presented a discriminate capacity (AUC: 0.710) with analogous values to those found in other studies focussing on recurrent fallers (AUC: 0.60-0.79) [29, 32, 36], and the predicted probabilities that were generated with the cross-validation procedure had a similar AUC (0.693, 95% CI: 0.643-742). Furthermore, the model included all discordant observations from the sample and the results were similar when Poison regression was used.

Finally, in a cross-sectional study, the relationship between variables can be interpreted bi-directionally. That is, health, body composition and physical functioning may influence the occurrence of falls, but the reverse can also occur. Nevertheless, mostly co-morbidities, particularly chronic diseases such as diabetes, or physical impairments such as poor vision are very unlike to result from falls, and all volunteer who suffered recent infirmities with temporary decrease in physical function were excluded from the study.

## CONCLUSIONS

This study found that women were more susceptible to falling than men because they have, at least, poorer health, body composition and physical function. However, in similar conditions, men were more than twice as prone to fall. Reduced co-morbidities and a good multidimensional balance decreased falling probability, as did a high lean body mass and a low body fat percentage, in both genders. The importance of chronologic age as a risk factor for falling appears to be minimal if these conditions are maintained across the ageing process.

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**Conflict of interest statement**

The authors declare that there is no conflict of interest.

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# CHAPTER 5

## ROLE OF PHYSICAL ACTIVITY IN THE OCCURENCE OF FALLS AND INJURIES IN COMMUNITY-DWELLING ADULTS OVER 50 YEARS OLD [4]

[4] Pereira C, Baptista F, Infante P. Role of physical activity in the occurrence of falls and injuries in community-dwelling adults over 50 years old. 2011 *(in review)*

**ABSTRACT**

**Objective** This study examined the effect of the amount and intensity of physical activity in falls and fall-related injuries in 505 adults aged over 50 years.

**Methods** Participants were 505 adults aged over 50 years (390 women: 67.7±6.8 years, and 116 men: 69.6±6.6 years). Falls, fall-related injuries, physical activity, and potential confounders, namely, co-morbidities, fear of falling, environmental hazards, physical function and body composition were evaluated by Composite Physical Function, Falls Efficacy Scale, and International Physical Activity questionnaires, and by Fullerton batteries and bioimpedance**.**

**Results** After adjustment for confounders, logistic analysis revealed that the likelihood of falling decreased 2% for each 100 MET-min/wk of total physical activity and increased 5% for each 100 MET-min/wk of vigorous intensity physical activity. Increased physical activity levels diminished the likelihood of severe fall-related injuries occurrence on 76% (moderate level) and 58%, (high level) ($p<.05$).

**Conclusion** Physical activity did not promote the occurrence of falls in old people and reduced the severity of injuries in case of fall when the total expenditure was at least 1,125 MET-min/wk if vigorous intensity did not exceed 500 MET-min/wk.

**Key words**: Falls; Injuries; Physical activity; Physical function; Environmental hazards; Elderly

**Running Title:** Role of physical activity in falls and injuries

## INTRODUCTION

A fall is an accident in which a person suddenly and involuntary comes to the ground or to a surface lower than the original position[1] that usually occurs when the demands of a given task exceed the person's ability. The demands of a task are determined by its difficulty and by the environmental conditions[2-4]. The ability to perform daily tasks without falling declines with age due to diminishing physical, sensorial, and mental functions regardless a weak health status that intensifies this process[5, 6]. These facts combined with increasing life expectancy [7] have led to an increase in the incidence of falls and their consequences in older populations [8]. However, falls may be a problem before the 60s years [9]. The main immediate consequence of a fall is the injury or injuries, which may sometimes be fatal. Another possible short-term consequence is an increased fear of falling that often leads to a loss of functional independence while performing daily tasks [10, 11].

Physical activity is a key factor for the maintenance of health-related quality of life, including functional competence [12]. However, the performance of any physical task, including daily tasks, is inevitably associated with a certain risk of falling and injury. For this reason, many community-dwelling older people and some carers might believe that inactivity is the best way to avoid or reduce the risk of falling.

Physical activity/exercise reduces the rate of falling in older people by 17% [13]. On the other hand, both low and high levels of physical activity have been associated with an increased fall risk [14, 15]. Besides, it is known that the risk of falling varies according to the types of activities [16], as do the risk of fall-related injuries [17]. It is not clear, however, what amount or intensity of physical activity/exercise is needed to reduce falls and related injuries or how physical activity interacts with other risk factors for falls. The successful completion of daily tasks (without falling) is dependent on intrinsic factors such as age, health, physical function, body composition and fear of falling but also on extrinsic factors such as the demands of each task and environmental hazards [4, 18, 19]**.** Thus, the main purpose of this study was to analyze the role of physical activity in falls and related injuries in community-dwelling adults aged over 50 years, with adjustment for these intrinsic and extrinsic risks factors.

## METHODS

### Subjects

Participants were 506 community-residing adults aged over 50 years (390 women: 67.7±6.8 years and 116 men: 69.6±6.6 years) from which 31.2% fell at least once in the previous 12 months. They were recruited by invitation and via leaflets and posters distributed in community settings (health center, recreational, sporting, cultural and senior university, etc.). All subjects lived independently and did not suffer from recent illnesses or disabilities resulting in a temporary loss of physical function. Inclusion in the study required the absence of dementia according to the criteria established by the Folstein Mini-Mental State Examination [20]. People who were not sure about the number of falls or with comprehension problems (i.e., did not understand the questions of the evaluation questionnaires) were excluded. A single interviewer filled out the questionnaires and verified whether people understood the questions or not. Forty-one volunteers did not meet these criteria and were excluded, including two subjects that experienced hip fractures due to a fall in the previous months. The University's Ethics Committee approved this study.

### Measures and data collection

#### *Physical activity*

Physical (in)activity was assessed using the short form of the International Physical Activity Questionnaire (IPAQ) [21]. This questionnaire covers metabolic expenditure (MET-min/wk) on walking (3.3 MET), moderate (4.0 MET) and vigorous-intensity activity (8.0 MET). Total metabolic expenditure was calculated by determining the time (minutes/day) and frequency (days/week) spent in each one of these activities/intensities. Individuals were also categorized as “low”, “moderate” or “high active” according to the IPAQ criteria [21]. In order to ensure a representative measure of habitual physical activity, the interviewer asked every participant to relate an ordinary week.

***Physical function and body composition***

Lower and upper body strength and flexibility, agility and dynamic balance, aerobic endurance and body mass index (BMI) were evaluated by the Fullerton functional fitness test battery[22] namely 30-s chair stand (repetitions or reps in 30 sec); arm curl (reps in 30sec); chair sit-and-reach (cm); back scratch (cm); 8-ft up-and-go (sec); 6-min walk (m). Standing height (cm) was measured with a stadiometer (Secca 770, Hamburg, Germany) and BMI ($kg/m^2$) using electronic scales (Secca Bella 840, Hamburg, Germany). The mean of the standardized scores of the physical fitness (fitness test battery without BMI), was calculated [23].

Balance was also evaluated by the Fullerton advanced balance (FAB) scale [24]. This includes the following tests: stand with feet together, eyes closed; reach forward to object; turn full circle; step up and over; tandem walk; stand on one leg; stand on foam, eyes closed; two-footed jump; walk with head turns; and reactive postural control. The final score was calculated as the sum of points obtained in each of the ten tests, from 0 (worst) to 4 (best) for a range from 0 to 40 points.

Fat body mass (%) was evaluated by bioimpedance [25] (HBF-306C, Schaumburg, USA), and lean body mass index ($kg/m^2$) was calculated as [total body mass (kg) - fat body mass (kg)] / [body height $^2$ ($m^2$)].

***Fear of falling***

Fear of falling was assessed using the modified version of the Falls Efficacy Scale (FES) [26, 27]. All persons reported how concerned they felt about falling while performing each of the ten daily activities listed in FES. Each item was rated on a points scale from 0 (not concerned) to 3 (very concerned). Total score was the sum of the points obtained in each one of the tests for a range from 0 to 30.

***Falls, fall-related injuries, environmental hazards, co-morbidities and education***

The number of falls in the previous 12 months, the circumstances surrounding each fall and their consequences, the quantification of environmental hazards, chronic diseases, chronic physical impairments and educational level were assessed by questionnaire administered by an interviewer.

A faller was defined as a subject who fell at least once in the previous 12 months. The number of falls was also categorized as no falls, one fall, two falls, three falls and four or more falls.

All diseases reported by participants were listed (totaling 24). Physical impairments included involuntary loss of urine, frequent dizziness, feet problems (e.g. sores, corns, skewed toes, amputation of toes or foot, insufficient muscle function), poor vision (not recognizing someone's face at a distance of four meters with glasses or contact lenses), hearing problems (not able to follow a conversation in a group of four people with a hearing aid**)** and balance problems (occasional loss of balance) [27]. The presence or absence of each chronic disease and physical impairment was checked for each participant. The number of diseases and physical impairments defined co-morbidities.

Environmental hazards include: indoor hazards (bad lighting, slippery floors, loose rugs, telephone cables, other objects, ladders, stairways with steep steps, without walls and/or handrails, kitchens with difficult access to utensils and movable tables, bathrooms without tub handrails, shower and toilet and non-skid mat in tub or shower, bed too high or too low); outdoor hazards (bad lighting, uneven pavements, streets, paths, repair works, obstacles, slippery floors) and the presence of animals and footwear (minimum: 0, maximum: 34) [28].

**Statistical analysis**

Subjects' characteristics, (age, co-morbidities, fear of falling, hazard environments, physical activity/inactivity, body composition, and physical function parameters) were compared between groups (fallers vs. non-fallers and fallers with vs. fallers without severe injuries) by t-tests. Comparisons of the prevalence of physical activity level and gender between these groups were done using Chi-Square Test or Fisher's Test. Injury severity was classified as light (no injury, light scratches and edema) and severe (serious abrasion, strained muscles, torn muscles, sprains, dislocations and fractures). For injuries statistical analysis, it was decided to consider each person's most severe fall (the fall that resulted in the most severe injury).

Binary logistic regressions[29] were used to identify predictor variables of falls and related severe injuries. In order to include all significant variables in the multivariate analysis, the most parsimonious model was determined. The Wald statistic was used to test the significance of each variable and the Likelihood Ratio to compare each new model with the previous one. The assumption of linearity in continuous variables was checked using the logit function and the overall fit evaluated using the Hosmer-Lemeshow Goodness-of-Fit Test. When correlations between variables were above 0.8, only the most explanatory variable remained in the model. Outliers and influential points were identified. Receiver operating characteristic (ROC) analysis was used to examine the discriminative ability of the models used to predict falls and injuries. A cut-off point for falls probability was established by maximizing both sensitivity and specificity [30]. Internal validation of the model was performed by resampling or cross-validation procedure [31]. For cross-validation participants were divided into 10 equal groups by sampling randomly without replacement.

In order to identify possible cut-off values, age and the number of falls were categorized in different forms. It was studied the significance of each of these new variables in the regression models. Physical activity values were presented as 100 MET-min/wk in order to interpret the data from regression analysis.

Complementary analysis was performed using either the Pearson test or the Spearman Correlation tests. Statistical analyses were performed with SPSS version 17.0, considering statistical significance to be $p < .05$.

## RESULTS

### Falls occurrence

One hundred and fifty-eight subjects (31.2%) fell in the previous 12 months, for 298 falls. Sixty-three of the falls had no consequences. The other falls resulted in 25 fractures, 10 dislocations, 14 sprains, 3 torn muscles, 5 strains, 15 serious abrasions, 93 edemas, and 128 light scratches. Of the 158 fallers, 108 were classified as light and 50 as severe fallers, considering each participant’s most severe fall-related injury.

Fallers had poorer values than non-fallers participants for almost all variables (Tables 1 and 2). The exceptions were some physical activity (moderate, vigorous and total), body composition (body mass, BMI, waist circumference), and flexibility (lower body) variables.

**Table 1.** Subjects characteristics: age, education, health, fear of falling, environment hazards, and physical activity according falls and severe injuries occurrence.

| | Participants | | | Fallers | | |
|---|---|---|---|---|---|---|
| | **Non-fallers (n = 348)** | **Fallers (n =158)** | **p-value** | **No/light injury (n =108)** | **Severe injury (n =50)** | **p-value** |
| Age (yrs) | 67.5±6.8 | 69.6±6.6 | .001 | 69.5±6.9 | 69.8±6.2 | .787 |
| Education (yrs) | 7.0 ±4.2 | 5.3±4.0 | <.001 | 5.2±3.7 | 5.5±4.7 | .764 |
| Co-morbidities (n) | 2.9±2.1 | 4.3±2.6 | <.001 | 4.2±2.6 | 4.5±2.6 | .553 |
| Fear of falling (point) | 1.6±2.4 | 4.0±4.5 | <.001 | 3.4±3.8 | 5.2±5.6 | .050 |
| Environmental hazards (n) | 5.3±2.6 | 6.3±2.8 | <.001 | 6.0±2.7 | 7.0±3.1 | .035 |
| Walking (MET-min/wk) | 778±573 | 669±508 | .039 | 635±438 | 741±633 | .225 |
| Moderate-PA ( MET-min/wk) | 2009±1308 | 1818±1131 | .114 | 1767±1107 | 1928±1187 | .407 |
| Vigorous PA ( MET-min/wk) | 192±637 | 225±931 | .636 | 226±1011 | 224±739 | .990 |
| Total PA (MET-min/wk) | 2979±1628 | 2712±1815 | .100 | 2628±1816 | 2893±1817 | .395 |
| PA level (% of participants) | | | | | | |
| Low | 52.0 | 48.0 | | 50.0 | 50.0 | |
| Moderate | 65.6 | 34.4 | .095 | 81.0 | 19.0 | .068 |
| High | 71.0 | 29.0 | | 65.4 | 34.6 | |
| Falls (n) | --- | 1.89 ±1.63 | --- | 1.7±1.5 | 2.3±1.9 | .074 |
| Gender (% of participants) | | | | | | |
| Females | 66.2 | 33.8 | .020 | 68.9 | 31.1 | .722 |
| Males | 77.6 | 22.4 | | 65.4 | 34.6 | |

Data are mean ± standard deviation or percentage of participants in each physical activity or gender categories. PA: Physical activity.

**Table 2.** Subjects characteristics: body composition and physical function according falls and fall-related severe injuries occurrence.

| N=506 | Participants | | | Fallers | | |
|---|---|---|---|---|---|---|
| | **Non-fallers (n =348)** | **Fallers (n =158)** | **p-value** | **No/light injury (n =108)** | **Severe injury (n =50)** | **p-value** |
| Height (cm) | 157.5±8.6 | 154.4±7.8 | <.001 | 154.2±.7.9 | 154.9±7.5 | .554 |
| Weight (kg) | 69.9±12.4 | 68.9±12.3 | .403 | 68.6±12.8 | 69.4±11.1 | .705 |
| BMI (kg/m$^2$) | 28.1±4.3 | 28.9±4.6 | .085 | 28.83±4.81 | 28.9±4.0 | .951 |
| Lean body mass index(kg/m$^2$) | 17.1±2.2 | 16.8±2.2 | .117 | 16.78±2.22 | 16.8±2.2 | .957 |
| Fat body mass (%) | 38.7±6.2 | 41.4±5.6 | <.001 | 41.3±5.3 | 41.6±6.3 | .733 |
| Waist circumference (cm) | 91.7±11.4 | 93.2±11.4 | .177 | 93.13±12.41 | 93.3±9.1 | .944 |
| Hand grip strength (bar) | 0.43±0.15 | 0.38±0.12 | .001 | 0.38±0.12 | 0.38±0.14 | .973 |
| Lower body strength (rep) | 17.1±4.6 | 15.6±4.5 | .001 | 15.6±4.5 | 15.8±4.3 | .728 |
| Upper body strength (rep) | 17.7±4.5 | 16.6±4.3 | .009 | 16.1±4.3 | 17.6±4.3 | .048 |
| Lower body flexibility (cm) | -1.4±9.67 | -1.6±8.7 | .863 | -2.2±9.0 | -0.3±7.8 | .183 |
| Upper body flexibility (cm) | -7.9±10.0 | -11.9±11.6 | <.001 | -12.9±11.6 | -10.0±11.3 | .146 |
| Agility (sec) | 5.5±1.2 | 6.0±1.8 | .001 | 6.1±1.9 | 6.0±1.6 | .810 |
| Aerobic endurance (m) | 529.6±87.7 | 495.0±90.1 | <.001 | 493.8±87.5 | 497.7±97.0 | .811 |
| Mean Fitness (SD) | 0,12±0,58 | -0,16±0,65 | <.001 | -0.21±0.66 | -0.05±0.61 | .187 |
| Balance (points) | 33.7±4.9 | 30.9±6.0 | <.001 | 30.8±5.6 | 30.9±6.8 | .917 |

Data expressed as mean ± standard deviation (SD).

Multivariate analysis showed that the main fall predictors were co-morbidities, fear of falling, hazard environments, body lean mass index, body fat mass, balance, vigorous physical activity, and total physical activity (Table 3). Falling likelihood increases 12-13% for each additional unit in co-morbidities (1 disease or physical impairment), in fear of falling (1point), or in environmental hazards (1 hazard). Falling likelihood increases 4-5% for each additional unit in body fat mass (1%), or vigorous intensity physical activity (100 MET-min/wk). Inversely, falling likelihood decreases 9% for each additional k/gm$^2$ of body lean mass index; 5% for each point less in balance, and 2% for each additional 100 MET-min/wk in total physical activity. Regarding these significant predictors, fallers demonstrated poorer health status (33% more diseases and physical impairments), body composition (2.7% more body fat), and physical function (8.3% lower balance), and reported living in environments with 16% more hazards (p<.001) than non-fallers (Tables 1-2).

**Table 3.** Predictors of falls and fall-related severe injuries

| | **OR 95%CI** | **AUC 95%CI** | **Sensitivity** | **Specificity** |
|---|---|---|---|---|
| **Falls** | | | **Cut-off point:0.275** | |
| Vigorous physical activity | 1.052 (1.016-1.087) | 0.746 (0.701-0.792) | 0.741 | 0.644 |
| Total physical activity | 0.982 (0.967-0.998) | | | |
| Co-morbidities | 1.119 (1.011-1.238) | | | |
| Fear of falling | 1.131 (1.054-1.213) | | | |
| Environmental hazards | 1.122 (1.036-1.216) | | | |
| Body lean mass index | 0.914 (0.846-0.987) | | | |
| Body fat mass | 1.037 (1.006-1.068) | | | |
| Balance | 0.950 (0.919-0.982) | | | |
| **Severe injury** | | | **Cut-off point:0.283** | |
| Physical activity level | | 0.696(0.605-0.787) | 0.767 | 0.592 |
| Low | -- | | | |
| Moderate | 0.238 (0.097-0.585) | | | |
| High | 0.425 (0.265-0.682) | | | |
| Mean Fitness | 1.967 (1.013-3.820) | | | |
| Falls (> 3) | 7.409 (1.638-33.509) | | | |

Data expressed as OR: multivariate odds ratios, 95% CI: confidence intervals, AUC: area under the roc curve, specificity and sensitivity. Physical activity OR calculated using as units 100 MET-min/wk.

These multivariate model revealed an area under the curve of 0.746 (CI 95%: 0.701-0.792) with an optimal cut-off point of 0.27469 (~27.5%) for the probability of falling, that corresponds to the maximum sum of sensitivity (74.1%) and specificity (64.4%) (Table 3). This cut-off point was used to determine the total physical activity and vigorous physical activity cut-off values that discriminate fallers from non-fallers, according to the following equation.

$$\pi(x) = \frac{\exp\{0.112C + 0.123FES + 0.115HE - 0.090BLMI + 0.036BFM - 0.051MB + 0.050VPA - 0.018TPA\}}{1 + \exp\{0.112C + 0.123FES + 0.115HE - 0.090BLMI + 0.036BFM - 0.051MB + 0.050VPA - 0.018TPA\}}$$

*Where $\pi(x)$ is the probability of falling, exp is exponential; C is co-morbidities (number of diseases and physical impairments); FES is fear of falling score (points); HE is the number of environmental hazards; BLMI is body lean mass index (kg/m$^2$); BFM is body fat mass (%); MB is balance (multidimensional) score (point); VPA is vigorous intensity physical activity performed during the week (100 MET-min/wk.); and TPA is total physical activity performed during the week (100 MET-min/wk).*

The equation was solved separately for each of the two physical activity variables (total and vigorous). To this end, it was specified the 50th percentile value to all variables in the equation except for total physical activity (in the first calculation) and vigorous physical activity (in the second calculation). The 50th percentile corresponded to 3 diseases or physical impairments in co-morbidities; 1 point in fear of falling; 5 environmental hazards; 16.9 kg/m$^2$ in body lean mass index; 40.3% in body fat mass; 34 points in balance; 0 MET-min/wk in vigorous-intensity activity; 2,514MET-min/wk in total activity. Figure 1 shows the probability of falling as a function of physical activity. Fallers were identified as those who performed more than 501 MET-min/wk of vigorous-intensity physical activity and less than 1,125 MET-min/wk of total physical activity (Figure 1).

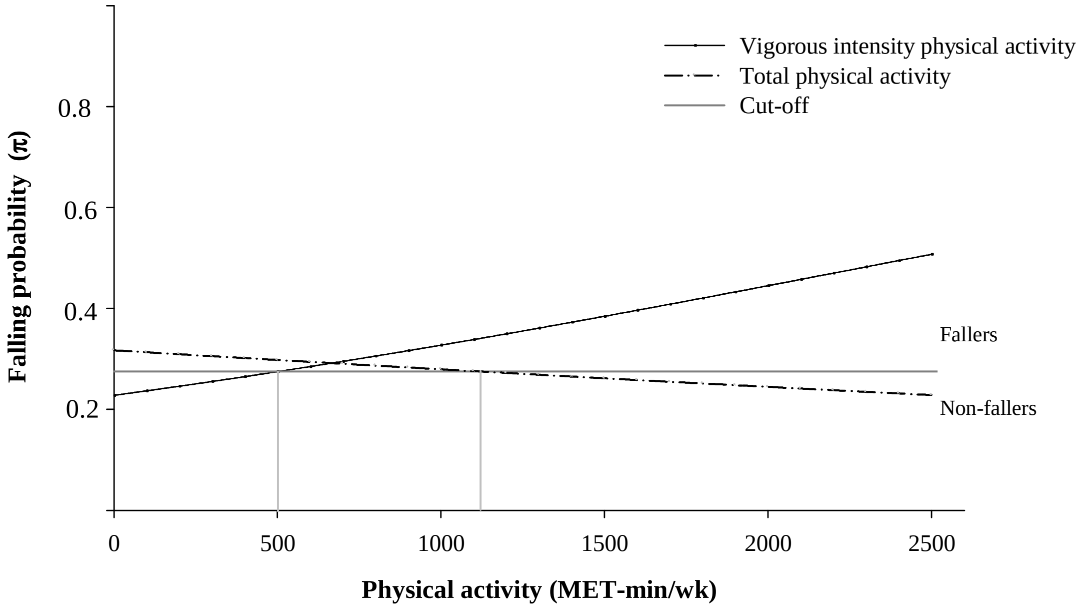


**Figure 1.** Fall probability as a function of habitual total, and vigorous-intensity physical activity performed during the week. This graph shows cut-off values for total and for vigorous-intensity physical activity (1,125 MET-min/wk and 501MET-min/wk, respectively) that discriminate fallers from non-fallers.

## Fall-related injuries

Fallers participants with severe injuries reported 26.9% more fear of falling, 14.3% more hazards in indoor and outdoor environment, and to be 8.5% stronger in upper body than fallers participants without severe injuries (Tables 1 and 2). Additionally, those who fell more than three times suffered severe injuries 46.9% more frequently than those who fell three or less times ($p<.05$).

Multivariate regression analyses showed that the significant predictor for fall-related severe injuries were fitness, falling more than three times, and physical activity level (Table 3). The likelihood of occurrence of severe fall-related injuries increased 96.8% for each additional standard deviation of mean fitness. For those who fell more than three times, the likelihood of severe injury was almost 7.5 times higher. Finally, multivariate regression analyses showed that the likelihood of the occurrence of severe fall-related injuries for moderate physical activity level decreases 76.2% relative to those classified as low level in physical activity level, and 57.5% for those classified as high in physical activity level relative to those classified as low level (Figure 2).

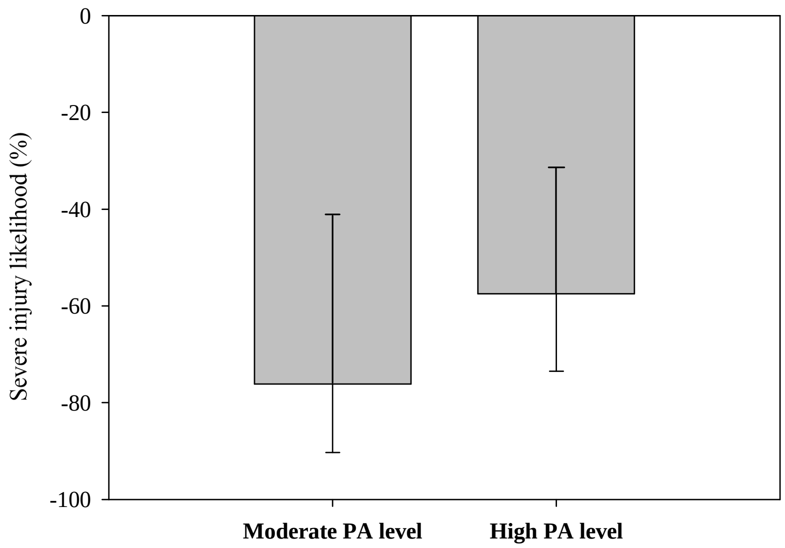


**Figure. 2.** Severe injury likelihood according to physical activity (PA) level. This graph quantifies the decrease in the likelihood of fall-related severe injuries in people with moderate (less 76%) and high (less 58%) physical activity levels relative to people with low physical activity level (considered as reference).

## DISCUSSION

The main purpose of this study was to analyze the role of physical activity (amount and intensity) in falls and related injuries, after adjustment for physical function, body composition, fear of falling, and environmental hazards. The results showed that the total amount of physical activity did not promote falls occurrence. However, the probability of fall increased with vigorous physical activity. Total physical activity of at least 1,125 MET-min/wk with no more than 501 MET-min/wk (i.e., less than ~1 hr/wk) of vigorous intensity significantly reduced falls. This total physical activity amount is more than double the lowest value recommended for older people for general health benefits (i.e., 150 min/wk $\times$ 3 MET: 450 MET-min/wk) of moderate intensity [12, 21, 32]. Furthermore, physical activity also seems to influence fall-related injuries. Being active, particularly moderately active, decreased severe fall-related injuries, possibly because fall occurred less often (i.e., the opportunity for injury is reduced), and/or, the resistance to fall impact might be improved when fall occurs [33]. In this study, falling more than three times a year increases exponentially the risk for severe injury. Old people that are highly active are less prone to fall-related injury than those who are most inactive. However, the moderately active participants had the lowest risk. Most of the studies about falls related injuries focus on fractures and points bone mineral density as a major risk factor, recommending regular exercise as preventive measure [34]. Only a few researches begun to focusing on other fall-related injuries and physical activity, such as the study of Gill et al. [17] that founded a positive association between injurious falls and lower subsequent household physical activity but a negative association between injurious falls and higher recreational physical activity.

Total physical activity reduces fall probability because it improves the individual's capacity to perform tasks [35], even in more frailty people - with low levels of health (high co-morbidities), body composition and balance, and with a high fear of falling score. Total physical activity implies the inclusion of different types of activity, namely walking, moderate and vigorous. In this study, an increase of 100 MET-min/wk on total physical activity, measured by IPAQ, led to 2% decrease in the risk of one or more falls. Peeters et al. [36] reported a 4% decrease in the risk of recurrent falling for each 100 MET-min/wk on total physical activity measured by LASA Physical Activity Questionnaire. Moreover, vigorous physical activity reduced the risk of falls only up to the threshold defined above, by increasing total activity. Nevertheless, vigorous physical activity increased the risk of falls (5% for each 100 MET-min/wk), most likely because at higher physical activity levels (e.g. farming), the tasks are more demanding [4]. This may help to understand why either inactivity or excessive physical activity promoted the increase of reported falls in other studies, [14, 15] particularly when heavy tasks were involved, like sports [16].

The main intrinsic fall risk factors affecting an individual's ability to perform physical tasks successfully (without falling) were the fear of falling (OR:13.1%), co-morbidities (OR:11.9%), body fat (OR:3.7%) and lean mass (OR:8.6%), and balance (OR:5.0%). Fear of falling has been considered a risk factor for falling and consequent injuries [27, 37]. However, in this study, it was observed that people with more fear of falling avoid more risk-prone daily tasks, like going up and down stairs or getting objects out of cupboards and wardrobes. Moreover, they also performed less total physical activity, had reduced physical function and had more diseases and physical impairments ($p<.001$), besides falling more and suffering more severe injuries as also noted by others [10, 11]. These results suggest that, mostly, fear of falling works as a self-perceived risk of falling due to frailty and previous experience of falling and injury (a protective device) and less as a real risk factor for falling and consequent injury.

As the number of hazard conditions increases, the possibility of falling usually augments [27, 28]. Data from multivariate regression analysis revealed, nevertheless, that fall probability is reduced when older people are healthier and fitter and they do not fall as often as younger unhealthier and unfitted persons, even when living in environments that are more hazardous. This reinforces recommendation of Nitz & Choy [9] for prevention interventions in middle-age as well in older ages. In fact, extrinsic risk factors (environment) appear to contribute to falls particularly in the presence of intrinsic risk factors (co-morbidities, decreased balance, and poor body composition). In general, good fitness appears to reduce the severity of fall-related injuries [38], probably because fit subjects react during the fall, thereby reducing the impact. On the other hand, for fallers, higher fitness may contribute to more severe fall-related injuries since it has been observed that high-fitness participants were more confident and put themselves in situations that are more dangerous. It was observed a positive correlation between fitness score and number of falls when performing high-difficulty tasks ($r=0.179$; $p=.033$, $n=158$).

Limitations of this study include the sample size regarding those who fell and suffered injuries (and therefore the sample's statistical power to predict the severity of fall-related injuries), and the relatively small number of men compared to women since some authors points gender as a moderator of falls and consequent injuries [39]. The use of the number of diseases and physical impairment to analyses health status influence may be questionable because a disease as epilepsy obviously predisposes to falls more than asthma. However, the significance of each disease and physical impairment in the regression analysis was tested and "co-morbidities" was the variable that best explained the occurrence of falls. This methodology has already been used in similar studies [9]. Additionally it was considered acceptable to use a retrospective recall to assess the falls and injuries in the last 12 months, given that it was required a normal cognitive function to all participants and the circumstances surrounding each fall and their consequences were described in detail. Still, it is possible an underestimation of the number of falls that occurred in this period. Unlike other works that focused exclusively in recurrent fallers [27] the present study integrates one-time fallers showing yet a similar discrimination capacity for falls (AUC: 0.746, CI 95%: 0.701-0.792). Further, the predicted probabilities that were generated with the cross-validation procedure had a similar AUC (0.723, 95% CI: 0.675 - 0.771). A major limitation of this investigation was the evaluation of physical activity by questionnaire because the use of this method tends to overestimate the amounts of physical activity [40]. Moreover, the relationship between current physical activity and the retrospective reports of fall and injuries was explored cross-sectional. However, the inherent error associated with this design has been minimized because participants reported maintaining their physical activity over the previous year, as well as their health status, weight and environmental hazards. Furthermore, subjects that suffer from recent illnesses or disabilities resulting in a temporary loss of physical function were excluded from the study.

## CONCLUSION

Increasing total physical activity do not promote falls whereas vigorous physical activity exceeding 500 MET-min/wk seems to increases the occurrence of falls. Physical activity appears to be especially important in reducing the consequences of falls. Being sufficiently active reduces falls and provides protection against severe injuries when falls occur. Reduced co-morbidities, a good body composition and physical function, principally balance, improve the ability to perform physical task without falling, even in environments that are more hazardous. Nevertheless, a good physical function may not provide protection against severe fall-related injuries. Thus, at least 1,125 MET-min/wk of total physical activity with no more than 500 MET-min/wk of vigorous-intensity activity appears to reduce falls and fall-related injuries.

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### Conflict of interest statement

The authors declare that there is no conflict of interest.

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# CHAPTER 6

## ASSOCIATIONS BETWEEN FALLS, FALL-RELATED INJURIES, FEAR OF FALLING AND DISABILITY IN ACTIVITIES OF DAILY LIVING IN ADULTS OVER 55 YEARS OLD [5]

[5] Pereira C, Baptista F. Associations between falls, fall-related injuries, fear of falling and disability in activities of daily living in adults over 55 years old.2011 *(in submission)*

## ABSTRACT

**Objective:** To analyze associations between falls, injuries, fear of falling (FF) and disability in activities of daily living (ADL).

**Design:** Cross-sectional

**Setting:** Community

**Participants:** Community-dwelling persons (N=506, aged 68.2±6.9).

**Main outcome measures:** Falls, injuries, FF, and ADLs disability evaluated by using questionnaires adjusted for potential confounders - co-morbidities, physical activity, fitness and body composition, evaluated by the International Physical Activity Questionnaire, the Senior Fitness Test, and bioimpedance, respectively.

**Results:** Multinomial regression showed that fall-related severe injuries and FF increased by 6 to 7 times, respectively, the likelihood of ADLs disability (P<.05). Binary logistic regression revealed that the likelihood of disability increased with FF, particularly in advanced and instrumental ADLs (OR: 2-3, P<.05), and with the occurrence of fall-related severe injuries in some instrumental ADLs (OR: 3-4, P<.05).

**Conclusions**: FF was shown to be a higher risk factor for disability than falls, even with serious injuries, restricting the performance of ADLs. Regarding these risk factors, disability seems to occur mainly in advanced and more demanding instrumental ADLs than basic ADLs. Consequently, the implementation of prevention programs should increase subjects' self-confidence through the successful accomplishment of functional exercises that mimic ADLs and are not just focused on fitness (aerobic, muscular or neuro-motor) exercises.


**Key words**: Activities of daily living; Falls; Injuries; Fear of falling; Elderly

## INTRODUCTION

Falls and fall-related injuries have been reported as a major restrictive factor for autonomy, and, where death does not occur, may become the main reason for the institutionalization of elderly people [1, 2]. Not only the physical but also the psychological consequences of falls, namely fear of falling, restrict activities of daily living (ADLs) which result in loss of autonomy and dependence [3, 4]. ADLs include basic activities (BADLs) of hygiene, personal care, and getting around inside; instrumental activities (IADLS) cover activities necessary for residing in the community such as using transportation, shopping, preparing meals, and paying bills; and advanced activities (AADLs) comprise more demanding and non-survival type activities that enrich life, namely social, religious or leisure activities [5, 6].

For old people that live independently in the community, besides the maintenance of BADLs that allow them to remain non-institutionalized, it is also important to maintain those activities that enable enjoyment of life independently with a degree of quality[7], especially if life expectancy is high [8]. Thus, performing IADLs and AADLs is a determining issue for successful aging [9].

Some factors affecting the ability to perform ADLs are similar to those that are considered to be risk factors for falls and fall-related injuries [10-12]. Most of them are associated with the subject's intrinsic factors, such as age, co-morbidities, physical fitness, body composition, fear of falling, and, among frailer and institutionalized individuals, cognition status [13, 14]. Habitual physical activity has also been pointed to as a key element in the ability to perform ADLs [15, 16], as well as in the occurrence of falls and fall-related injuries [17-19], probably mediated by body composition and physical fitness improvement. However, it is essential to determine the relative contribution of falls, fall-related injuries and fear of falling in overall physical functioning or disability [20] and, therefore, in the loss of autonomy and, particularly, in the disability of the ADLs category (AADLs vs. IADLs vs. BADLs). Mainly because the majority of the studies did not control for potential confounders, in particular to intrinsic and extrinsic risk factors. This approach will allow more appropriate measures either to prevent or to reverse loss of autonomy. Thus, the aim of this study is to analyze associations between falls and their consequences (injuries and fear of falling) and the disability of community-dwelling adults over 50 years old in the performance of ADLs, adjusted for potential physical activity/fitness confounders.

## METHODS

### Participants

The participants were 588 community-dwelling persons, aged 55 years and over (464 women: 67.8±6.8 years and 124 men: 69.6±6.5 years), of which 31% had fallen in the previous 12 months, 9% had suffered fall-related severe injuries, and 76% had exercised at least twice a week in the previous year. Participants were recruited by invitation and in response to leaflets and posters distributed in community settings (health centers, recreational, sports and cultural associations, universities for seniors, etc.). Participation in the study required the absence of dementia, in accordance with the Folstein Mini-Mental State Examination [21]. Subjects that had suffered recent illnesses resulting in a temporary loss of physical fitness or dependence were excluded. Forty-nine respondents were excluded because they did not meet these criteria. Since many participants could not read and write because have never attended school, an interviewer filled out the questionnaires for all participants. All subjects were volunteers and provided informed consent. The study was approved by the University's Ethics Committee.

### Outcome measures

#### *ADL disability*

Physical functioning level was determined by responses to the 12 items on the Composite Physical Function (CPF) scale [20]: Item 1. Take care of own personal needs - like dressing yourself; Item 2. Bathe yourself, using tub or shower; Item 3. Climb up and down a flight of stairs (like a second story in a house); Item 4. Walk outside (one or two blocks); Item 5. Do light household chores – like cooking, dusting, washing dishes, sweeping a walkway; Item 6. Shop for groceries or clothes; Item 7. Walk ½ mile (6-7 blocks); Item 8. Walk 1 mile (12-14 blocks); Item 9. Lift and carry 10 lb (full bag of groceries); Item 10. Lift and carry 25 lb (medium to large suitcase); Item 11. Do heavy household activities – like scrubbing floors, vacuuming, raking leaves; Item 12. Do strenuous activities – like hiking, digging in the garden, moving heavy objects, cycling, aerobic dance activities, strenuous calisthenics, etc. Participants were asked to indicate whether they could do the activity (score of 2), could do it with difficulty or with help (score of 1), or could not perform the activity at all (score of 0). The total score ranges from 0 to 24.

Respondents were categorized as having high functioning – with no disability (24 points); moderate functioning – moderate disability (18 to 23 points); or low functioning – severe disability (less than 18 points). Functioning with regard to each of the 12 itemized activities was also categorized dichotomously as follows: 'with no disability' (can do) versus 'with disability' (cannot do or can do with difficulty or help).

### *Physical fitness and body composition*

Lower and upper body strength (rep) and flexibility (cm), agility and dynamic balance (sec), aerobic endurance (m) and body mass index ($kg/m^2$) were evaluated by using the Fullerton functional fitness test battery [22]. Standing height (cm) was measured with a stadiometer (Secca 770, Hamburg, Germany) and weight (kg) using an electronic scale (Secca Bella 840, Hamburg, Germany). Multidimensional balance was evaluated by conducting the ten tests associated with the Fullerton advanced balance (FAB) scale [23]. The final score, ranging from 0 to 40 points, was the sum of points obtained in each of these ten tests, ranging from 0 (worst) to 4 (best). Fat body mass (%) was evaluated by bioimpedance [24] (HBF-306C, Schaumburg, USA), and lean body mass index ($kg/m^2$) was calculated as [total body mass (kg) – fat body mass (kg)] / [body height $^2$ ($m^2$)].

### *Physical activity*

Habitual physical activity was assessed using the short version of the International Physical Activity Questionnaire (IPAQ) [25]. This questionnaire covers metabolic expenditure (MET min/wk) on walking (3.3 MET), moderate (4.0 MET) and vigorous-intensity activity (8.0 MET). Total metabolic expenditure (MET min/wk) was calculated by determining the time (minutes/day) and frequency (days/week) spent on each of these activities. Physical exercise (hour/wk) was also assessed by means of a questionnaire.

### *Fear of falling*

Fear of falling was assessed by using the modified version of the Falls Efficacy Scale (FES) [26, 27]. Participants were asked how concerned they felt about falling while performing each of ten everyday activities listed in FES. Each Item was rated on a points scale from 0 (not concerned) to 3 (very concerned). The total score was the sum of the points obtained in each of the tests for a range from 0 to 30. Fear of falling was classified according to three categories (no fear of falling: FES score 0-1; vs. fear of falling ±: FES score 2-3; vs. fear of falling +: FES score ≥4).

### *Falls, fall-related injuries, co-morbidities and education*

Diseases, physical impairments, falls during the previous 12 months, fall-related injuries and age were assessed by using a questionnaire. Participants listed a total of 24 chronic diseases. Physical impairments included involuntary loss of urine, frequent dizziness, foot problems, poor vision, hearing problems, and occasional loss of balance [27]. The presence or absence of each disease or physical impairment was checked for each participant. The number of chronic diseases and physical impairments defined co-morbidities. Injury severity was classified as light (no injury, light scratches and edema) or severe (serious abrasion, strained muscles, torn muscles, sprains, dislocations and fractures). The occurrence of falls and injuries was expressed by a dichotomy variable (no fall/fall without injury or with light injury: injury – vs. fall with severe injury: injury +).

### **Statistical analysis**

Comparison of subjects' characteristics between groups according to functioning level in ADL (a – severe disability vs. b – moderate disability vs. c – no disability) was performed by ANOVA followed by Bonferroni post hoc test to identify pairwise differences. In the case of no homoscedasticity, comparisons between groups were carried out by conducting the Kruskal-Wallis test, followed by multiple simultaneous examinations using the Mann-Whitney test. Comparisons of percentages (male/female; low/moderate/high active; no fall/fall-related light injury/fall-related severe injury) among groups were carried out using the Chi-Square test or Fisher's test. Multinomial logistic regression was used to quantify the relative effect of fear of falling, falls, and fall-related injuries (light and severe) on physical functioning disability (able vs. moderately disabled vs. severely disabled). Analyses were adjusted for potential confounders. Binary logistic regressions using the forward stepwise conditional method were used to quantify the relative risk of fear of falling, falls, and fall-related injuries (light and severe injuries) for disability for each of the 12 activities reported in the CPF (able vs. disable). Adjustments were made for respective potential confounders. Statistical analyses were performed by using SPSS version 17.0, and statistical significance was set at $P \leq .05$ for all tests.

## RESULTS

The percentage of participants who could or could not do each of the 12 itemized activities of the CPF is illustrated in Figure 1. Over 95% of subjects had no difficulty in performing BADLs, and only ~1.5% reported difficulty in performing Item 1 and Item 2. With regard to IADLs, the percentage of disabled subjects ranged from 4% in relation to less demanding activities to 59% for more demanding activities. Disability in performing advanced activities of daily living was reported by 39% of participants for Item 11 and by 59% of participants for Item12.

The group of participants with severe disability was older and less healthy than the group with moderate disability or with no disability (Table 1). In general, these participants also had worse body composition and physical fitness, were more afraid of falling, more likely to fall and to suffer injury, and were also less active. The group of participants with no disability showed the best results for these variables ($P<.05$).

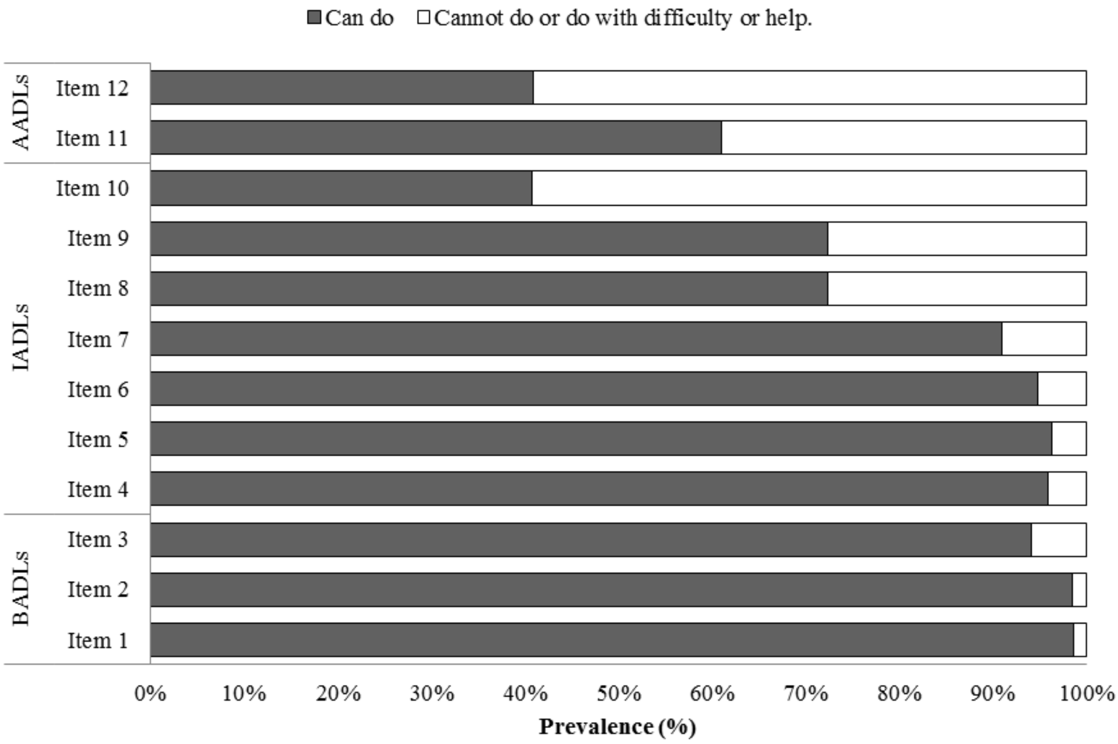


**Figure 1**.**Prevalence of disability in the 12 activities of daily living evaluated by the Composite Physical Function Scale.**

Item 1. Take care of own personal needs - like dressing yourself; Item 2. Bathe yourself, using tub or shower; Item 3.Climb up and down a flight of stairs (like a second story in a house); Item 4.Walk outside (one or two blocks); Item 5. Do light household chore – like cooking, dusting, washing dishes, sweeping a walkway; Item 6. Shop for groceries or clothes; Item 7. Walk ½ mile (6-7 blocks); Item 8. Walk 1 mile (12-14 blocks); Item 9. Lift and carry 10 lb. (full bag of groceries); Item 10. Lift and carry 25 lb. (medium to large suitcase); Item 11. Do heavy house activities – like scrubbing floors, vacuuming, raking leaves; Item 12. Do strenuous activities – like hiking, digging in garden, moving heavy objects, bicycling, aerobic dance activities, strenuous calisthenics, etc. BADLs: basic activities of daily living; IADLs: instrumental activities of daily living; AADLs: advanced activities of daily living.

**Table 1.** Characteristics of the sample by groups of ADLs functioning. Data are mean ±SD or percentage

| | **a (n =100) Severe disability** | **b (n = 331) Moderate disability** | **c (n =157) With no disability** | **P** | **Post hoc test** |
|---|---|---|---|---|---|
| Physical functioning (point) | 15.0±2.4 | 21.0±1.6 | 24±0 | <.001 | a<b<c |
| Age (yrs) | 71.0±7.6 | 68.0±6.6 | 66.6±6.4 | <.001 | a<b,c |
| Co-morbidities (n) | 5.2±2.5 | 3.4±2.1 | 2.2±1.9 | <.001 | a<b<c |
| Body mass index (kg/m$^2$) | 29.4±5.0 | 28.1±4.3 | 28.2±4.3 | .030 | a>b |
| Lean body mass index(kg/m$^2$) | 16.8±2.3 | 16.7±2.1 | 17.8±2.2 | <.001 | a,b<c |
| Fat body mass (%) | 42.9±4.5 | 40.2±5.5 | 36.2±6.6 | <.001 | a>b>c |
| Lower body strength (rep) | 14.6±4.3 | 16.4±4.5 | 18.0±4.3 | <.001 | a<b<c |
| Upper body strength (rep) | 15.2±3.6 | 17.2±4.2 | 19.2±5.0 | <.001 | a<b<c |
| Lower body flexibility (cm) | -2.5±9.1 | -1.0±9.5 | -1.4±9.3 | .384 | -- |
| Upper body flexibility (cm) | -14.0±10.5 | -8.9±10.8 | -7.9±10.3 | <.001 | a<b<c |
| Agility and dynamic balance (sec) | 7.1±3.3 | 5.7±1.2 | 5.1±0.8 | <.001 | a>b>c |
| Aerobic endurance (m) | 440±104 | 507±80 | 567±86 | <.001 | a<b<c |
| Multidimensional balance (point) | 28.3±7.5 | 32.7±5.1 | 35.0±3.6 | <.001 | a<b<c |
| Exercise (hour/wk) | 1.8±1.2 | 1.9±1.2 | 2.3±1.3 | .001 | a,b<c |
| Total PA (MET-min/wk) | 2436±1807 | 2729±1405 | 3298±1956 | <.001 | a,b<c |
| Walking (MET-min/wk) | 544±489 | 741±551 | 825±545 | <.001 | a<b,c |
| Number of falls | 0.9±1.6 | 0.6±1.3 | 0.33±0.7 | .002 | a<b,c |
| Fear of falling score (point) | 5.6±5.5 | 2.2±2.8 | 0.9±1.7 | <.001 | a<b<c |
| Fall-related injuries | | | | | |
| No/light injury (x) | 21.6% | 61.6% | 16.8% | .025 | x,y≠z |
| Severe injury (y) | 22.8% | 52.6% | 24.6% | | |
| Non- fallers( z) | 14.8% | 55.2% | 30.0% | | |
| Gender | | | | | |
| Female (x) | 20.5% | 60.3% | 19.2% | <.001 | x≠y |
| Male (y) | 4.0% | 41.1% | 54.8% | | |

PA: physical activity.

Considering the three categories of physical functioning score, multinomial logistic regression was used to quantify the risk of becoming disabled (moderately or severely) due to the occurrence of falls, with and without severe injuries, and due to fear of falling, assessed by using the FES (Figure 2). Values were adjusted for co-morbidities, aerobic endurance, balance, and lean body mass index, which were revealed to be significant predictors of physical functioning in the exploratory analyses. Subjects who had a fall-related severe injury were 2.5 times more likely to be moderately disabled (OR: 2.50, 95% CI: 1.05-5.95), and 5.6 times more likely to be severely disabled (OR: 5.55, 95% CI: 1.52-20.24) than subjects without severe injuries (who had not fallen, or had fallen but had suffered no injury, or had fallen and had suffered light injuries). As long as fear increased, the likelihood of a person becoming moderately disabled doubled or virtually tripled (OR: 2.08, 95% CI: 1.09-3.98 for FES ±; OR: 2.71, 95% CI: 1.22-6.05 for FES +) but the likelihood of a person becoming severely disabled could be almost seven times higher (OR: 3.11, 95% CI: 1.20-8.01 for FES ±; OR: 6.62, 95% CI: 2.44-17.91 for FES +) than a person with no fear of falling.

The risk of disability in each advanced, instrumental and basic ADL due to falls/injuries and due to fear of falling was quantified by means of binary logistic regression (Figure 3). Results were adjusted for potential confounders. For AADLs and more demanding IADLs, adjustments were made for co-morbidities, aerobic endurance, lean body mass index, and balance. For less demanding IADLs and BADLs adjustments were made for co-morbidities, balance, strength, flexibility, and body fat mass. Analyses were also adjusted for physical activity in three ADLs (Items 3, 8, 12). All these covariates were revealed to be significant predictors of ADLs in the exploratory analyses ($P<.05$).

The occurrence of falls with severe injuries increased by ~3 to 4 times the likelihood of disability in two ADLs (OR: 2.665, 95% CI: 1.091- 6.512; OR: 3.777, 95% CI: 1.678 - 8.501). Reporting a fear of falling score of 2-3 (FES ±), in contrast with no fear of falling category, increased the chance of disability in Item 9 (lift and carry 10 lb) by 2 times (OR: 2.195, 95% CI: 1.140 - 4.223), while reporting a fear of falling score ≥4 (FES +) increased by 2 to 3 times the likelihood of disability in six ADLS (from OR: 1.994, 95% CI: 1.069 - 3.720 in item 10 to OR: 3.296, 95% CI: 1.071 -10.140 in item 3).

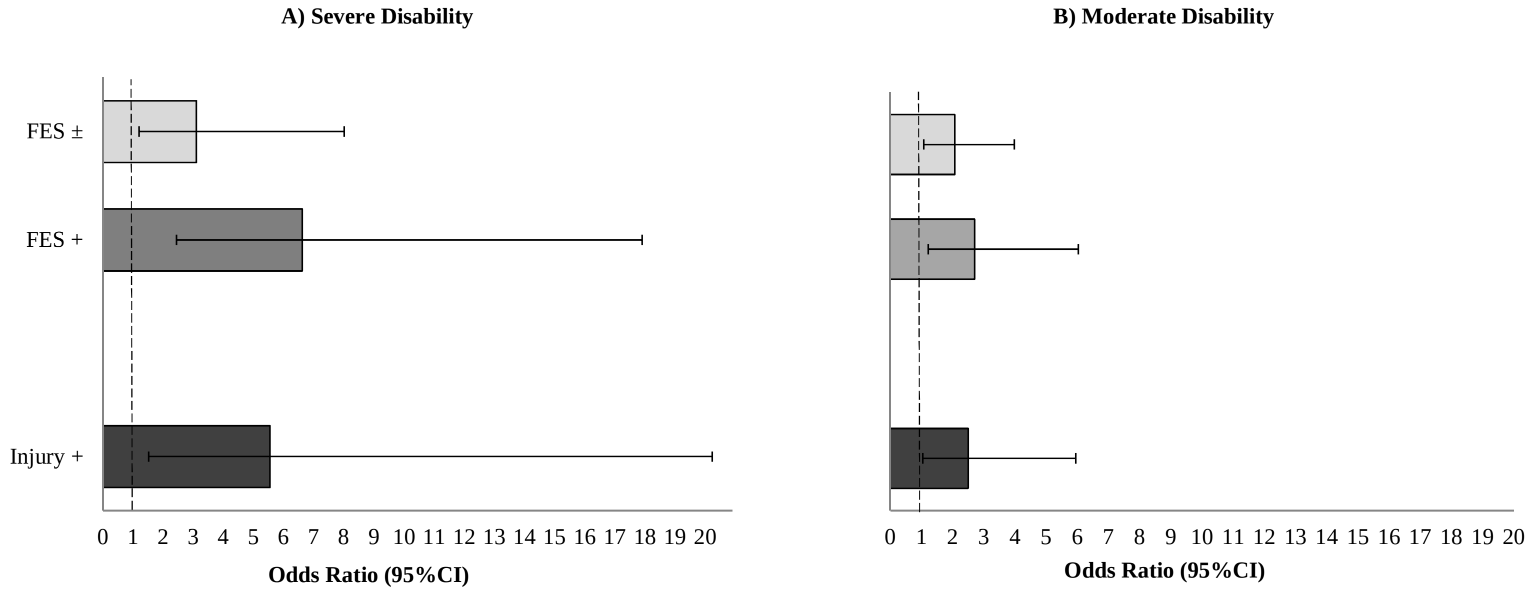


**Figure 2 –Disability odds ratio due to fall-related injuries and fear of falling.**

The figure illustrates the likelihood of a person with no disability becoming severely (A) or moderately (B) disabled due to the occurrence of fall-related severe injuries and fear of falling. The dashed line represents a reference (no fall or fall without injury or with light injury and with no fear of falling). FES±: fear of falling score from 2 to 3; FES+: fear of falling score ≥4; Injury +: occurrence of fall-related severe injury.

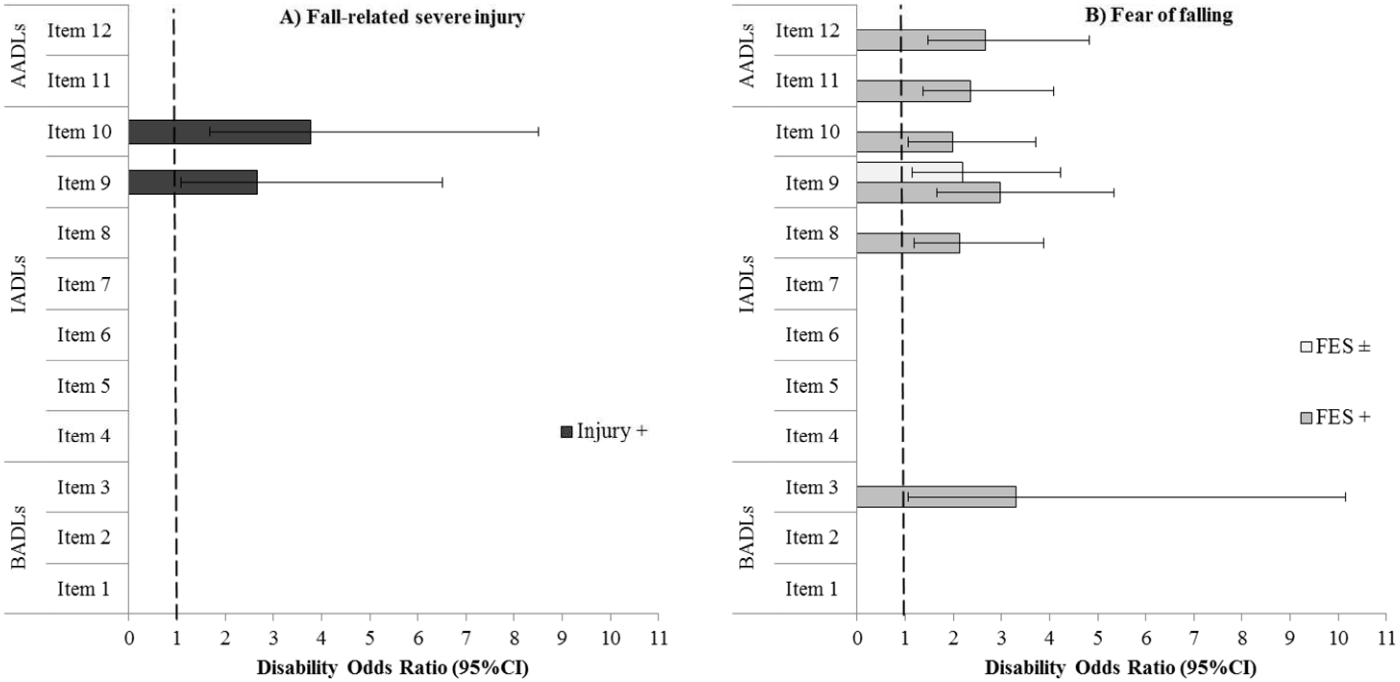


**Figure 3 –Disability in basic (BADLs), instrumental (IADLs) and advanced activities of daily living (AADLs) due to fall-related severe injuries and fear of falling.** The figure illustrates the significant increase in the likelihood of a person becoming disabled (cannot do or can do with difficulty or help), in the performance of each activity of daily living due to the occurrence of fall-related severe injuries (Injury +) and the increase in fear of falling (FES ±; FES +). The dashed line represents a reference (A): no fall or fall without injury or with light injury, and (B): with no fear of falling. FES ±: fear of falling score from 2 to 3, FES +: fear of falling score ≥ 4.

## DISCUSSION

The main objective of this study was to analyze associations between falls and their consequences (injuries and fear of falling) and disability in the performance of advanced, instrumental and basic ADLs. The results showed that fear of falling promotes disability and represents a constraint for the performance of general ADLs, while the occurrence of falls, even with serious injuries, seems to interfere to a lesser degree than fear of falling with the ability to carry out ADLs, regardless of chronologic age, comorbidities, body composition and physical fitness.

Increasing fear of falling increased the risk of a person changing from high to moderate and especially to low or disabled functioning. Moreover, as long as the fear score increased, the likelihood of disability in advanced, instrumental or basic ADLs could be 2 to 3 times higher than in cases of no fear. Nevertheless, fear of falling is usually associated with the occurrence of falls and injuries, and may also be caused by frailty [28]. Subjects with the poorest physical activity, fitness or health, even in the absence of falls, reported a high fear of falling ($P<.05$, data not shown). The self-perception of fragility inhibits the performance of ADLs. However, in present study results were adjusted for these potential confounders, thus concern about falling showed to leads able-bodied subjects to avoid activities that they can perform [26]. Moreover, the restriction of activity due to fear of falling leads to a further deterioration in ADL disability [29].

The occurrence of falls causing light injuries or no injuries was not shown to be a significant predictor of ADLs disability while fall-related severe injuries were revealed as increasing by 3 to 4 times the likelihood of disability in more demanding instrumental ADLs. Besides this, severe injuries also increased the likelihood of a person becoming moderately or, especially, severely disabled. Candel-Parra et al. [30] observed that 6 months after a fall-related hip fracture, only 33% of patients recover their independence in activities of daily living.

In accordance with the findings reported by other researchers, the present study revealed that risk factors for ADLs disability [31], in particular poor health, were common for falls and fall-related injuries [10, 12, 19, 27]. Thus, preventive strategies for these both negative outcomes may also be common. Co-morbidities explained 16% of physical functioning variance in this study and were the main predictor of fear of falling ($R^2$= 22%, $P<.001$).

This data suggests a more complex relationship between ADLs disability and the occurrence of falls than previously found [17, 32].

Our findings showed that fear of falling and severe injuries appear to limit to a greater degree more demanding ADLs than basic ADLs and, in accordance with Seidel et al. [33], recovery from disability is less frequent with regard to more demanding activities than for basic ADLs. In keeping with the findings of Sato et al. [34] for preventing disability with regard to less demanding ADLs may be important maintain or recover health status, muscle strength and flexibility, balance, and confidence (data not shown). Physical activity promotes quality of life (health status and independent functioning) in elderly people and is pointed to as an effective strategy for preventing falls and fall-related injuries [15, 35-37]. Also in our analyses, physical activity contributed significantly to low scores of fear of falling, regardless of physical fitness level, body composition, and the occurrence of severe injuries (P=.025, data not shown).

Limitations of this study include the reduced ability of cross-sectional studies for the establishment of cause-effect relationships. Additionally, only a few participants show disability in performing less demanding ADLs, diminishing the statistical power of analyses that comprised these activities. Another difficulty was the accuracy of the questionnaires used for measuring physical activity and ADL disability, since many participants could not read or write. This was minimized by the use of an interviewer who filled out a questionnaire for each participant and the inclusion of criteria for the absence of dementia.

## CONCLUSIONS

Fear of falling was shown to be a higher risk factor for disability than falls, even when subjects suffered serious injuries, restricting the performance of AADLs, IADLs and BADLs. Regarding these risk factors, disability seems to occur mainly in advanced and more demanding instrumental ADLs than basic ADLs. Consequently the implementation of prevention programs should increase the self-confidence of individuals through the successful accomplishment of functional exercises that mimic ADLs and not just fitness (aerobic, muscular or neuro-motor) exercises.

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**Conflict of interest**

The authors declare that there is no conflict of interest.

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# CHAPTER 7

# INFLUENCE OF HEALTH STATUS, PHYSICAL ACTIVITY AND FITNESS IN AUTONOMY OF COMMUNITY-DWELLING OLD ADULTS OVER A FIVE YEAR PERIOD [6]

[6] Pereira C, Baptista F. Influence of health status, physical activity and fitness in autonomy of community-dwelling old adults over a five year period**.** 2011 *(in submission)*

## ABSTRACT

**Objective:** To analyze the influence of health status, physical activity and fitness on the autonomy of community-dwelling old adults over a five year period.

**Design:** 5-year follow-up study.

**Setting:** Community.

**Participants:** Community-dwelling persons (N=85) aged 60 years and older at baseline.

**Main outcome measures:** autonomy/physical functioning, co-morbidities, physical activity, physical fitness including body composition, evaluated by using the Composite Physical Function scale, International Physical Activity Questionnaire, Fullerton batteries and bioimpedance, respectively.

**Results:** Linear regression revealed that the main predictors of change in autonomy over a 5-year period were initial autonomy ($\beta$=0.032, $R^2$=9.8%); health status (initial number of co-morbidities: $\beta$=-0.191, $R^2$=6.3%; and change in the number of co-morbidities: $\beta$=-0.244, $R^2$=10.8%); and changes in agility ($\beta$=-0.288, $R^2$=6.7%), aerobic endurance ($\beta$ =0.007, $R^2$=3.2%), and walking expenditure ($\beta$ =0.001, $R^2$=5.1%), $P<.05$).

**Conclusions**: Initial autonomy level and health status seems to moderate autonomy change in community-dwelling old adults over a 5-year period, however physical activity (walking) and fitness (agility and aerobic endurance) also account for autonomy loss variability, justifying the promotion of intervention programs for the maintenance or improvement of these factors.


**Key words**: Autonomy; Physical activity; Physical fitness; Elderly; Variability

## INTRODUCTION

Life expectancy among the elderly has increased [1]. Current projections indicate that the population of the European Union will continue to grow older, with the proportion of people aged 65 years and over rising from 17% in 2010 to 30% in 2060, and those aged 80 years and over rising from 5% to 12% over the same period [2]. As life expectancy increases, a significant number of people are likely to live longer while subject to infirmities [3-5] and disabilities, and thus loss of autonomy [6]. However increased life expectancy could be disability-free [6-8] particularly if diseases are diagnosed earlier and become less disabling over time [6], if levels of education rise [9], and if rehabilitation and physical activity/exercise programs are promoted to prevent physiological and functional deterioration, and, thus, to decrease loss of autonomy in activities of daily living (ADLs) [10, 11].

Most factors affecting the level of ability to perform ADLs involve disease and impairments, physical activity and fitness and, in frail, institutionalized populations, cognition status [11-16]. However, studies focusing on disability and autonomy have been mainly based on cross-sectional results and few studies have analyzed longitudinally predictors of health and physical functioning variables [17-20]. Therefore, this study is aimed to analyze the influence of health status, physical activity and fitness on the autonomy of community-dwelling old adults over a five year period.

## METHODS

### Design

This study involves a follow-up over a 5-year period (2006-2011). Participants were evaluated twice. The first evaluation was carried out in 2006 and the second one in 2011. The sample was split according to autonomy (physical functioning): Group A was characterized by maintained or improved autonomy over the 5-year period and Group B by decreased autonomy over the same period.

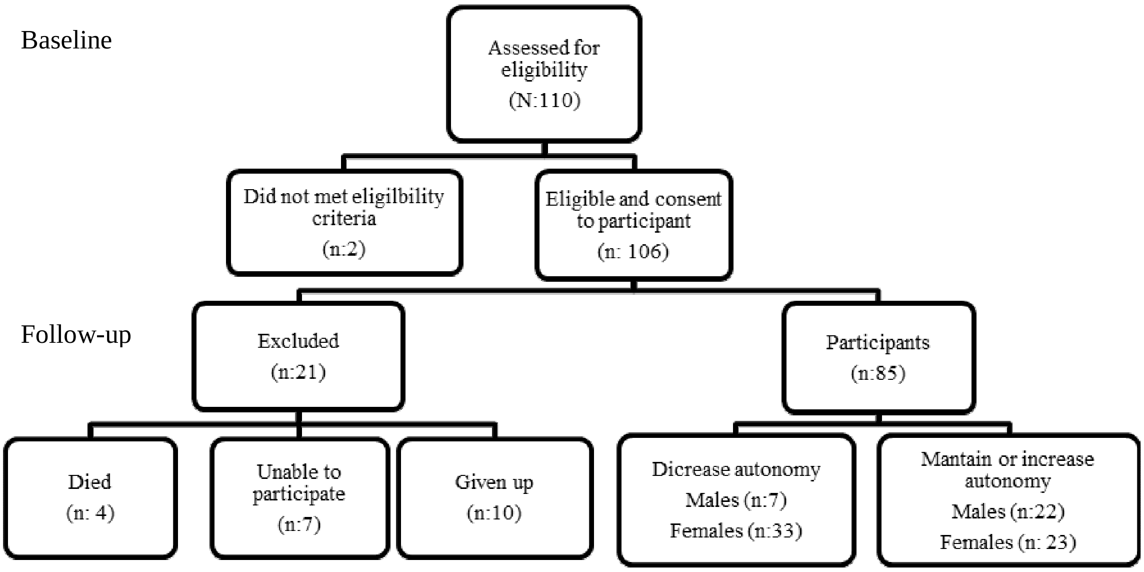


**Figure 1.** Flow of participants through study.

## Participants

One hundred and ten community-dwelling persons (42 men and 68 women) were assessed for eligibility (Figure 1). Participants were recruited by invitation and in response to leaflets and posters distributed in pharmacies and community settings (e.g. health centers, recreational and cultural centers, and universities for seniors). Inclusion in the study required the absence of dementia in accordance with the Folstein Mini-Mental State Examination [21]. Two subjects who had suffered recent illnesses resulting in a temporary loss of physical fitness were excluded at the first evaluation stage. Four persons (men) died during the 5-year follow-up. At the second evaluation stage, 7 persons reported being too ill or frail to continue participating in the study and 10 dropped out due to difficulties in traveling to the evaluation center or inability for performing the evaluation tests. As a result, there remained 85 participants. Since many participants could not read or write, an interviewer filled out the questionnaires for all participants. All subjects were volunteers and provided informed consent. The study was approved by the University's Ethics Committee.

**Outcome measures**

***Autonomy***

Autonomy as regards physical functioning was determined by responses to the 12-item Composite Physical Function (CPF) scale [22]: Item 1. Take care of own personal needs – like dressing yourself. Item 2. Bathe yourself, using tub or shower. Item 3. Climb up and down a flight of stairs (like a second story in a house). Item 4. Walk outside (one or two blocks). Item 5. Do light household chores – like cooking, dusting, washing dishes, sweeping a walkway. Item 6. Shop for groceries or clothes. Item 7. Walk ½ mile (6-7 blocks). Item 8. Walk 1 mile (12-14 blocks). Item 9. Lift and carry 10 lb. (full bag of groceries). Item 10. Lift and carry 25 lb. (medium to large suitcase). Item 11. Do heavy household activities – like scrubbing floors, vacuuming, raking leaves. Item 12. Do strenuous activities – like hiking, digging in the garden, moving heavy objects, cycling, aerobic dance activities, strenuous calisthenics, etc. Participants were asked to indicate whether they could do the activity (score of 2), could do it with difficulty or with help (score of 1), or could not perform the activity at all (score of 0). Total scores range from 0 to 24.

***Physical activity***

Habitual physical activity was assessed using the short version of the International Physical Activity Questionnaire (IPAQ) [23]. This covers metabolic expenditure (METmin/wk) when walking (3.3 MET) or when performing moderate-to-vigorous activities (4.0 to 8.0 MET). Total metabolic expenditure was calculated by determining the time (minutes/day) spent doing each activity and the frequency of activity (days/week).

***Fitness and body composition***

Lower and upper body strength, agility, aerobic endurance and body mass index [BMI (kg/m$^2$)] were evaluated using the Fullerton functional fitness test battery [24], namely by 30-s chair stand (repetitions or reps in 30 sec); arm curls (reps in 30 sec); 8-ft up-and-go (sec); and 6-min walk (m). Standing height (cm) was measured with a stadiometer (Secca 770, Hamburg, Germany) and weight (kg) using electronic scales (Secca Bella 840, Hamburg, Germany). Balance was evaluated using a reduced version of the Fullerton advanced balance (FAB) scale [25, 26] comprising the following four tests: stepping up and over a bench; walking along a line with feet in tandem position; standing on one leg; and standing on foam with the eyes closed. The final balance score was calculated by summing the partial scores of each of the four tests. Each test was scored from 0 (worst) to 4 (best). Fat body mass (%) was evaluated by bioimpedance [27] (HBF-306C, Schaumburg, USA). Lean mass index ($kg/m^2$) was calculated as [total body mass (kg) - fat body mass (kg)] / [body height $^2$ (m)].

### *Health status*

Chronic disease and physical impairments were assessed by using a questionnaire. Participants listed a total of 24 diseases. Physical impairments included involuntary loss of urine, frequent dizziness, foot problems, poor vision, hearing problems, and occasional loss of balance [28]. The presence or absence of each disease or physical impairment was checked for each participant. Co-morbidities referred to the number of diseases and physical impairments.

All variables were evaluated in 2006 and again in 2011.

### Statistical analysis

The main effect of time (year 1 vs. year 5) on autonomy groups (Group A and Group B) regarding health status, physical activity and fitness including body composition were analyzed by repeated measures and the Bonferroni post hoc test. Group A included participants who maintained or increased autonomy and Group B comprised participants who decreased autonomy over time. In the case of no homoscedasticity, comparisons between the two moments in time and between groups were carried out using t-tests. Gender prevalence comparisons between groups (e.g. male vs. female) were performed using the Chi-Square or Fisher’s test and between moments using McNamar’s test. Analyses performed with multiple simultaneous tests were carried out using the Bonferroni correction for P-value.

Multiple linear regression using the backward elimination was employed to identify significant predictors for change in autonomy and to determine the variance accounted for by each predictor. Since in this analysis gender and age were not significant predictors of the change in autonomy, all statistical analysis included both genders and were not adjusted for age.

Assumptions underlying statistical techniques, such as homoscedasticity, linearity and the independence of error terms, were duly tested. Normality was assumed, based on the central limit theorem. Statistical analyses were performed using SPSS version 17.0, considering statistical significance to be $P<.05$.

## RESULTS

At the end of the 5-year follow-up, only 80.8% of the eligible participants remained in the study. The majority of them presented the best results in health status, physical activity and fitness at the start of the study. The other 19.2 %, were who dropped out (9.4%), were too ill (6.6%), or died (3.8%). Of the remaining 85 participants, 29 were male and 56 female. More females than males lost autonomy over the follow-up period (59% of females vs. 24% of males decreased autonomy $P=.003$).

Tables 1 and 2 present the characteristics of the participants at baseline and after 5 years by group. Over the follow-up period, most of the characteristics changed unfavorably. Compared to Group A, Group B increased one more disease or physical impairment in co-morbidities, 1 more second in agility, decreased more 356 METs-min/wk in walking expenditure and more 748 METs-min/wk in total physical activity expenditure, and performed 27 fewer meters in the distance covered in the aerobic 6-min walk test. No difference was observed in fat body mass, balance, or upper body strength between year 1 and year 5.

**Table 1**. Initial and final chronological age, autonomy, health status and physical activity of the participants.

| | | **Year 1**<br>**Mean± SD** | **Year 5**<br>**Mean± SD** | **Change**<br>**Mean (95%CI)** | **P-value**<br>**Moment*Group** |
|---|---|---|---|---|---|
| Age (year) | Group A | 66.9±5.2 | 71.8±5.0 | 5 | |
| | Group B | 67.9±5.6 | 73.2±5.8 | 5 | - |
| | Total | 67.4±5.4 | 72.5±5.4 | 5 | |
| Autonomy | Group A | 22.0±2.2 | 22.7±1.7 | 0.7 (0.4 - 1.0)* | |
| (point) | Group B | 21.8±2.8 | 19.7±3.4 | -2.1 (- 2.6 - -1.6)* | - |
| | Total | 21.9±2.5 | 21.3±3.0 | -0.6 (-1.0 - -0.2)* | |
| Co-morbidities | Group A | 2.5±2.0 | 2.9± 1.8 | 0.4 (-0.1-0.9) | |
| (n) | Group B | 3.2±2.0 | 4.7±2.2 | 1.5 (0.9-2.0)* | .005 |
| | Total | 2.9±2.0 | 3.7±2.2 | 0.9 (0.5-1.3)* | |
| Vigorous PA | Group A | 236±569 | 53±255 | -182 (-307- -58)* | |
| (MET-min/wk) | Group B | 255±579 | 54± 240 | -201 (-381 - -20.9)* | .860 |
| | Total | 245±570 | 54±247 | -191 (-296 - -86)* | |
| Moderate PA | Group A | 1663±1038 | 914±583 | -748 (-1075- -422)* | |
| (MET-min/wk) | Group B | 2008±1247 | 850±833 | -1291 (-1500- -817)* | .084 |
| | Total | 1825±1147 | 884±708 | -1004 (-1177- -706)* | |
| Walking | Group A | 789±441 | 593±492 | -196 (-334- -58)* | |
| (MET-min/wk) | Group B | 980±866 | 466±326 | -552 (-779- -249)* | - |
| | Total | 879±678 | 533±425 | -363 (-491- -200)* | |
| Total PA | Group A | 2687±1231 | 1561±725 | -1126 (-1487- -766)* | |
| (MET-min/wk) | Group B | 3243±1469 | 1369±1032 | -1874 (-2284- -1464)* | .007 |
| | Total | 2949±1369 | 1470±883 | -1478 (-1756- -1200)* | |

*Significant pre-post difference, P<.05; PA: physical activity; Group A: maintained or increased autonomy over 5-years; Group B: decreased autonomy over 5-years; SD: standard deviation; CI: confidence interval.

**Table 2** Initial and final body composition and physical fitness of the participants.

| | | year 1 Mean± SD | year 5 Mean± SD | Change Mean (95%CI) | P-value Moment*Group |
|---|---|---|---|---|---|
| Fat mass (%) | Group A | 36.3±6.1 | 36.7±5.9 | 0.4 (-0.6-1.3) | |
| | Group B | 39.8±6.0 | 40.2±5.8 | 0.3 (-1.0-1.6) | .963 |
| | Total | 38.0±6.3 | 38.3±6.0 | 0.3 (-0.4-1.1) | |
| Lean mass index | Group A | 17.5±2.2 | 17.3±2.1 | -0.2 (-0.6-1.3) | |
| ($kg/m^2$) | Group B | 16.7±2.0 | 16.4±2.2 | -0.3 (-0.65-0.01)* | .636 |
| | Total | 17.1±2.1 | 16.8±2.2 | -0.3 (-0.5--0.1)* | |
| Balance (points) | Group A | 14.1±1.8 | 13.9±2.8 | -0.2 (-1.0-0.5) | |
| | Group B | 13.6±2.6 | 12.9±2.9 | -0.7 (-1.4-0.0) | - |
| | Total | 13.9±2.2 | 13.4±2.9 | -0.4 (-1.0-0.1) | |
| Agility (sec) | Group A | 5.2±1.1 | 5.7±1.2 | 0.5 (0.1-0.9) | |
| | Group B | 5.4±0.8 | 6.7±1.9 | 1.3 (0.8-1.8)* | .011 |
| | Total | 5.3±1.0 | 6.2±1.7 | 0.9 (0.6-1.2) | |
| Aerobic endurance | Group A | 559±89 | 546±76 | -13 (-31.9-5.5) | |
| (m) | Group B | 536±64 | 496±80 | -40 (-59- -21)* | .042 |
| | Total | 548±79 | 522±81 | -26 (-39.3- -12.6)* | |
| Upper body | Group A | 18.3±4.6 | 18.3±4.2 | 0.0 (-1.6-1.6) | |
| strength (rep) | Group B | 16.3±3.8 | 17.4±3.3 | 1.1 (-0.4-2.6) | .303 |
| | Total | 17.4±4.4 | 17.9±3.8 | 0.5 (-0.6-1.6) | |
| Lower body | Group A | 17.6±5.5 | 15.9±4.6 | -1.7 (-3.3-0.0) | |
| strength (rep) | Group B | 16.9±3.7 | 13.9±4.2 | -3.0 (-4.5- -1.4)* | - |
| | Total | 17.2±4.8 | 15.0±4.5 | -2.3 (-3.4- -1.2)* | |

*Significant pre-post difference, P<.05; Group A: maintained or increased autonomy over 5-years; Group B: decreased autonomy over 5-years; SD: standard deviation; CI: confidence interval.

Table 3 shows the results for linear regression. The main predictors of change in autonomy were the variables with the greatest change over time. However, the initial values of some variables also predicted changes in autonomy, specifically co-morbidities and autonomy itself. A high initial autonomy or number of co-morbidities promoted autonomy loss. Furthermore, increase the number of co-morbidities over time also induced autonomy loss. Increasing walking expenditure, aerobic endurance and agility over the 5-years resulted in improved autonomy while reductions in these predictors favored autonomy loss. The explanation for the autonomy change variation by the predictors ranged from 3.2% (change in aerobic endurance) to 10.8% (change in co-morbidities).

**Table 3** – Predictors of change in autonomy over 5 years.

| | **β (95%CI)** | **P-value** | **$R^2$ (%)** |
|---|---|---|---|
| Initial autonomy | 0.032 (0.003 - 0.062) | .033 | 9.9 |
| Initial co-morbidities | -0.191 (-0.379 - -0.003) | .047 | 6.3 |
| Change in co-morbidities | -0.244 (-0.450 - -0.038) | .021 | 10.8 |
| Change in walking | 0.001 (0.000 - 0.001) | .027 | 5.1 |
| Change in agility | -0.288 (-0.562 - -0.014) | .040 | 6.7 |
| Change in aerobic endurance | 0.007 (0.000 - 0.013) | .041 | 3.2 |

Data are multivariate coefficient (β), 95% confidence interval (CI), and adjusted coefficient of determination ($R^2$).

Several scenarios were constructed to examine the effect of predictors in autonomy change over the 5-year period (Figure 2) using the following multivariate linear regression equation:

$$cA = 0.032\times iA - 0.191\times iC - 0.244\times cC + 0.001\times cW - 0.288\times cAg - 0.007\times cAE$$

*Where cA is change in autonomy, iA is initial autonomy, iC is initial co-morbidities, cC is change in co-morbidities, cW is change in walking expenditure, cAg is change in agility and cAE is change in aerobic endurance.*

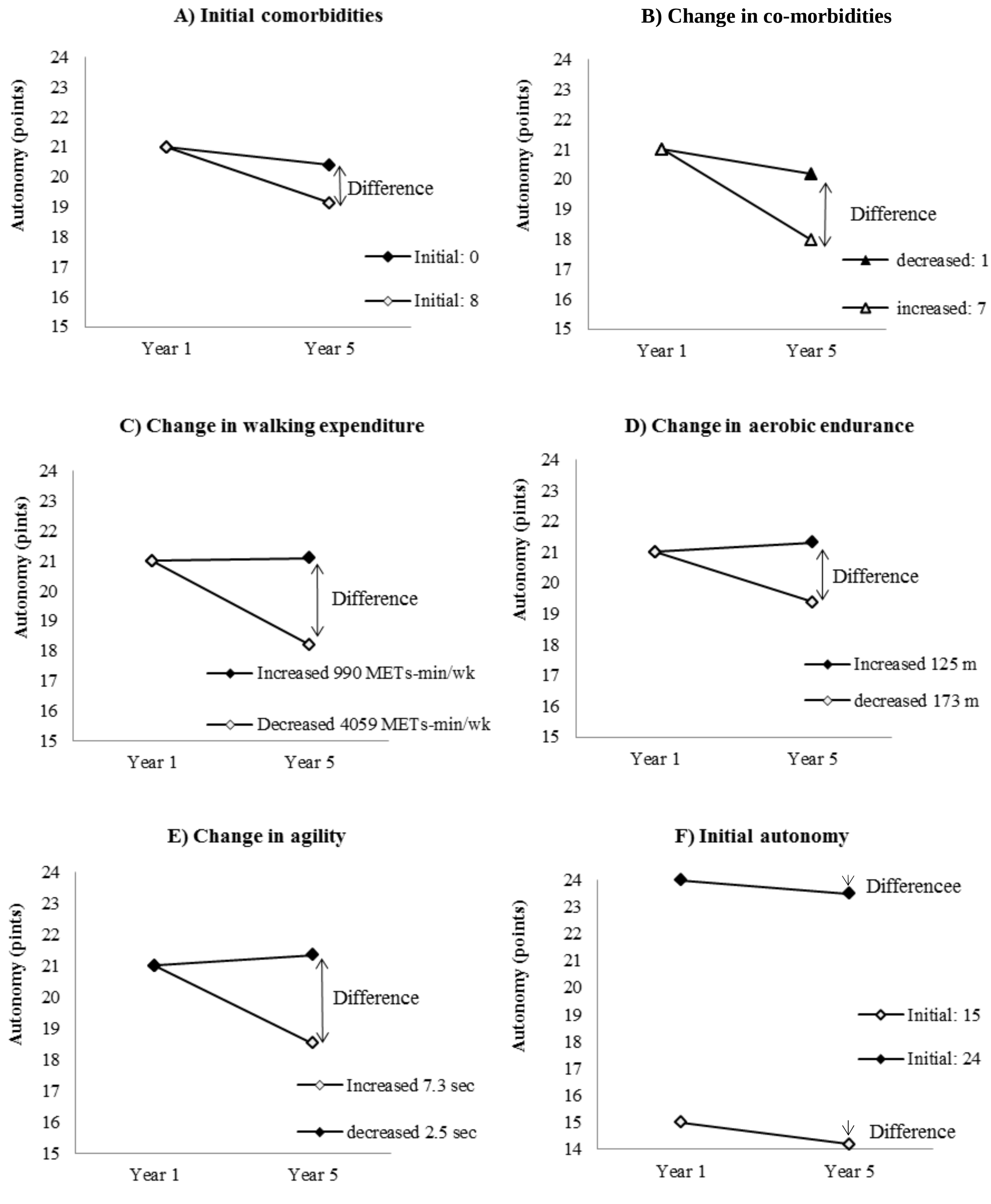


**Figure 2. Change in autonomy over 5-year follow-up in accordance with minimum and maximum variation observed in predictors.** Lines and marks show limits of change in autonomy; arrows illustrate potential differences at the end of the follow up period.

The medians of each predictor were used to solve the equation, except for the predictor that illustrates the scenario where the minimum and maximum values were used. An autonomy figure of 21 was considered in year 1 as the reference for variations observed over the 5-year period. The median values of predictors of change in autonomy were: 3 diseases or physical impairments in initial co-morbidities; 1 disease or physical impairment in change in co-morbidities; - 247.5 METs-min/wk in change in walking expenditure; 0.75 sec in change in agility; and -17 m change in change in aerobic endurance. The different scenarios showed that, over the 5-year period, each predictor potentially induced different changes in autonomy. Variability in agility change had the greatest impact on the variability of autonomy over time (a range from -2.48 to 0.34).

## DISCUSSION

This study analyzed the influence of health status, physical activity and fitness on the autonomy of community-dwelling old adults over a five year period. Among predictor variables, five factors emerged as significant for change in autonomy over this period, namely: co-morbidities, agility, aerobic endurance, walking expenditure, and autonomy itself. The study revealed that poor autonomy is itself a risk for loss of autonomy and that the larger the number of co-morbidities, the greater the loss of autonomy over time. The principal effect of agility, aerobic endurance and walking expenditure on changes in autonomy derives from the change in these factors over the 5-year period. Variability in agility change had the greatest impact on the variability of autonomy over time.

In agreement with the findings of other studies[29, 30], it was observed that older people, and women in particular, suffer from higher levels of ADL performance loss than younger (old) people and men, respectively. However, after statistical adjustment for the main factors affecting autonomy, gender lost its significance and thus its ability to predict ADL disability. The same applies to age.

The observation that higher initial autonomy or lower co-morbidities protect against autonomy losses over time is a strong indicator of how useful it is to build up a reserve of health and functionality. This reserve protects against dependence because poor autonomy and health have been associated with faster decline and even premature death [12, 30].

As expected [12-14], complementary analysis identified correlations between almost all the variables studied and autonomy. The only exception was vigorous physical activity. Low values for any physical fitness or body composition variable were associated with low autonomy as well as a high number of co-morbidities. Furthermore, decreased total and moderate physical activity and decreased walking expenditure were associated with low autonomy. Curiously, there was a general increase in the correlations strength between autonomy and the other variables in year 5 (r: 0.242-0.706, P<.05) compared with year 1 (r: 0.333-0.477, P<.05). This may be due to a general decline in results over the 5-year period. Indeed, some findings of previous studies suggest that the longer people live and the frailer they become, the greater the influence these variables have on ADL disability [31].

Fortunately, participants were able to maintain their balance, upper body strength and fat body mass over the follow-up period (and the number of falls also remained constant – data not shown). This was unexpected, since data from previous studies suggests that these variables normally decline over time [32]. These results may be interpreted in two ways. First, if there is no significant change in an independent variable, there will be no resulting change in the dependent variable. Second, the good news is that these people – probably because they have kept active in order to remain autonomous [33] – did not feel that their autonomy was negatively impacted by losses in these variables. However, people who suffered significant health problems or loss of independence did not remain as participants in the study. Besides this, in present study, the percentage of those who fell (23%) was lower than that found in other studies (30% and over) [28]. This fact, allied to the high activity reported by participants, indicates that they were above-average condition compared with typical populations of the same age [34]. Other variables that decreased from year 1 to year 5, including lower body strength and lean body mass index, did not predict changes in autonomy.

Thus, among all potential predictors, only the changes in four independent variables predicted variations in autonomy, namely changes in co-morbidities, agility, aerobic endurance and walking expenditure. These were the variables in which there was the greatest change over the five years. There were, however, individuals who contradicted this central tendency. In keeping with studies that have found increased disability-free life expectancy [6-8], the scores of independent variables studied improved in some people and, consequently, autonomy increased.

According to literature [18, 19] the results of this study emphasize the need for interventions programs to promote agility and aerobic endurance. We also recommend that subjects be encouraged to walk regularly as this healthy habit safeguards against disease and impairments [35], and has shown to directly affect autonomy. Given the importance of population variability, we recommend that each intervention be tailored to the needs of each subject, since population variability must always be fully taken into account. Physical frailty indicators must be monitored to identify old people who may benefit from specific preventive disability initiatives [31]. This recommendation applies specifically to persons presenting values that deviate significantly from the median values or change markedly over time.

The main limitation of this study was sample size and consequently the statistical power. The high percentage of persons who dropped out of the study aggravated this problem. To minimize errors in the scenarios used to predict changes in autonomy, missing data were not replaced. Any attempt to replace data for frail and dependent people would obviously introduce errors. Another limitation may be the reliability of the questionnaires used to measure physical activity and autonomy, since many participants could not read or write. To minimize negative impact, the absence-of-dementia criterion was included and an interviewer undertook to fill out questionnaires for all participants. Even so, IPAQ may overestimate amounts of physical activity [36]. Finally, it should also be noted that the observed decreases in the number of co-morbidities were due mainly to surgery, in many cases for cataracts.

## CONCLUSIONS

The initial level of autonomy and health status seem to moderate the autonomy change of community-dwelling old adults over a 5-year period; however physical activity (walking) and fitness (agility and aerobic endurance) also account for autonomy loss variability, justifying the promotion of intervention programs for the maintenance or improvement of these factors.

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**Conflict of interest statement**

The authors declare that there is no conflict of interest.

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# CHAPTER 8

# GENERAL DISCUSSION AND RECOMENDATIONS

## DISCUSSION

The main objective of this investigation was to analyze the role of physical activity, physical fitness, health status and environmental hazards in the occurrence of falls and injuries, fear of falling and loss of autonomy in community-dwelling adults over 50 years of age. The results indicate that the key element causing a rupture of the system (the occurrence of falls and injuries, fear of falling and loss of autonomy) in old age, considering normal circumstances of daily living, is conditions of frailty associated with the individual. It was also found that, as the individual becomes more fragile, that is, as increase the risk of intrinsic factors, their susceptibility to extrinsic risk factors rises, especially with regard to environmental hazards, and the greater their difficulty in successfully meeting the demands of tasks (without falls, injuries, fear of falling or disability). Furthermore, performance of activities of daily living is restricted due to lack of confidence. However, a good level of physical fitness can also increase the risk of falls and injuries because, as has also been observed by others [1,2], the fittest people were those who demonstrated most confidence in performing more demanding tasks, and in more hazardous environments, thereby exposing themselves to more dangerous situations. According to Braun [3], elderly people are not usually aware of their predisposition to falls and injuries, and consequently are not able to identify inherent risk factors with regard to falls; the risk becomes obvious only after the occurrence of injury or disability.

Similar to other studies [4-6] analyzing risk factors for falls, health status expressed by the number of diseases and physical impairments reported by the subject was the most important predictor for the occurrence of falls, and, consequently, for fall-related injuries, leading to an increase from 12% to 21% in the likelihood of falls for each additional disease/impairments (dependent on other predictors). Health status was also the most reliable indicator for explain loss of autonomy in physical functioning. Moreover, poor health status was shown to drastically limit the ability to perform either advanced, instrumental or basic activities of daily living. Fujiwara et al.[7] also observed that good or excellent self-assessed health was associated with a decrease in the likelihood of disability in instrumental and basic activities of daily living from 40.2% to 61%. The study carried out as part of this thesis quantified the increase in the likelihood of disability associated with each additional co-morbidity from 12% to 33%, depending on ADL. Moreover, the alteration of the number of co-morbidities over time (5 years) also proved to be a significant predictor of changes in physical functioning, accounting for ~11% of the variance of this issue. Additionally, co-morbidities also seem to contribute to individual fragility by inducing a fear of falling, since the number of co-morbidities accounted for 22% the fear of falling variance.

Fear of falling was the second most significant variable in explaining loss of autonomy (12%), and thus a more important factor than falls and severe injuries. Moreover, in contrast with previous studies that point to fear of falling as a serious risk factor for falls and consequent injuries [5, 8], our findings suggest that fear of falling acts mainly as a self-perception of risk of falling and/or injury resulting from frailty and/or previous experience of falling or injury. People with greatest fear of falling performed less physical activity, especially vigorous physical activity and avoided some riskier everyday tasks like going up and down stairs or getting objects from closets, which may lead to fewer falls and injuries. However, fear of falling was also the cause for the individual to avoid not only the riskier activities of daily living but also activities which could be performed safely [9]. Thus, our findings emphasized the importance of confidence in the maintenance of autonomy in activities of daily living.

As reported in this and other studies [10 11], there is an inverse relationship between the number of fall-related injuries and autonomy, which is determined by factors that affect both injuries and autonomy. Still, these common factors seem to demonstrate a higher propensity for predicting loss of autonomy (a larger area under the ROC curve) than the occurrence of falls (a smaller area under the ROC curve), as was observed in the present study and also by other investigators [5, 12-14].

Age is found to be one of the main risk factors for falls, injuries, and loss of autonomy [15, 16]. Nonetheless, it was found that there are old people who do not fall and have a high level of physical functioning. In contrast, some younger people are frail, experience fall-related injuries and demonstrate a low level of physical functioning in activities of daily living. However, age was not found to be a significant predictor of falls, injuries and loss of autonomy when health status and physical fitness, including body composition, were also considered in the analysis. Moreover, chronological age only accounted for 3% to 13% of the variation in physical fitness.

Balance was the physical attribute that most varied with age and contributed to fall occurrence, while aerobic endurance estimated by means of the 6-min walk test was the parameter that most contributed to disability in activities of daily living. However, in order for the prevention of disability in frail and less fit individuals to carry out basic activities of daily living, it seems that maintaining body strength and flexibility is important. Balance and aerobic endurance were found to be the physical attributes accounting for the greatest differences between adults over 50 years of age and young adults.

Regarding body composition, increased lean body mass and decreased fat body mass was found to provide protection against falls, injuries, and disability, besides being associated with a low level of fear of falling. This work estimate that the likelihood of falling decreases on 4% and 5% for each additional kg in lean body mass, and for each 1% decrease in fat body mass (~0.7 kg in men and ~0.8 kg in women), respectively. Furthermore, physical activity was found to prevent falls and consequent injuries. Probably because physical activity is positively associated with the ability for successfully performing tasks and also the capacity for avoiding collision in the case of a fall [17-19]. Several previous studies have showed that physical activity decreases the negative effects of illness and induces a good body composition [20], increasing self-resistance to injuries by reinforcing locomotion structures, namely bone and muscle [21-23]. In the present study, it was also found that physical activity was positively associated with a favorable body composition and physical fitness. The accumulation of at least 1,150 MET-min.wk$^{-1}$ of total physical activity, maintaining vigorous-intensity activity expenditure below 500 MET-min.wk$^{-1}$, seems to prevent falls and fall-related injuries. On the other hand, physical activity helps in the recovery of and/or the delay in the reduction of some physical functional abilities [24]. In this study, the likelihood of disability in the performance of activities of daily living decreased 3% to 8% (depending on the activity), for each additional 100 MET-min/wk. Therefore, increasing walking expenditure over time (5 years), for example, leaded to reduced loss of physical autonomy or even to an increase, besides decreasing fear of falling.

The practice of vigorous physical activity, especially in less controlled and more hazardous environments may increase falls and fall-related injuries and contribute to a loss of autonomy, since fall-related severe injury (e.g. fracture) is a main reason for disability and dependence. Therefore, a balance must be found between the potential positive and negative effects of physical activity. The findings of this research may provide an understanding of why on the one hand some studies have concluded that the occurrence of falls is associated with inactivity while on the other hand other studies have shown that it is a high level of activity which accounts for the occurrence of falls, particularly when extremely demanding tasks and or hazardous environments are involved [2, 25, 26].

In agreement with the findings of Tinetti et al. [27], in the present work, an analysis of fall circumstances demonstrates that most falls occur in the performance of usual or everyday tasks (96.5%), few falls occur in the performance of unusual and hazardous tasks (3.3%), and only 0.3% of fall occur during exercise programs. Additionally, it was found that subjects who fell during the performance of hazardous tasks were mostly fitter and typically male. In contrast with the findings of other studies showing a higher number of falls occurring at home[28, 29], in this study only 41.4% of falls were found to occur indoors; while the remaining percentage occurred outdoors (50.6% occurred in the street, 4.4% on public transport, and 3.6% in other places). However, participants demonstrated a good level of physical functioning, in accordance with the Composite Physical Function scale (with a maximum of 24, the mean value was 20.8 ± 3.3 points) [30]. Even participants classified as demonstrating a low level of functioning in this study recorded a mean score of 15±2.4 points and may be considered as showing a moderate level of functioning [31]. Nevertheless, similar to the findings of other studies [27], 30% of subjects fell at least once during the course of one year.

Frail people were not included in this study and consequently old people over 80 years were poorly represented in the analysis as a whole. At the same time, subjects demonstrating a lower level of physical functioning were those showing a tendency to drop out of the follow-up study. As with other studies [32, 33], women were also found to demonstrate an increased susceptibility to falls and disability in activities of daily living [12, 34]. Females were found to be 38% more likely to fall than males, and gender (analyzed single) accounted for 10% of the variation in physical functioning. A higher susceptibility to falls and disability in women as compared with men seems to be caused by poorer health, body composition and physical fitness. Nevertheless, under similar conditions of health status (expressed by the number of co-morbidities), body composition and physical fitness (mainly balance), the probability of falling in men increases to a level which is approximately twice that of women (due to the fact that men classically expose themselves to more hazardous situations).

The findings of the 5-year follow-up study seem to support the most relevant results of cross-sectional studies. Similar predictors for autonomy loss over the 5-year period were identified and it was found that the major losses of physical attributes over time occurred in agility/dynamic balance and also aerobic endurance. Moreover, a tendency was found for decreased physical activity and fitness, including body composition, and thus to reduce autonomy over the time; however, there was marked variability across individuals. The requirement for differentiating intervention programs in accordance with differences in physical functioning has recently been reported [35-37]. Vermeulen et al. [38] pointed to the importance of monitoring physical frailty indicators in the community-dwelling elderly in order to allow them to benefit from disability prevention programs. In the present research it was verified that there are people who deviate significantly from the average, or whose profile changes markedly over time. In order to achieve optimal results from prevention programs, these differences should be taken into account.

The limitations of the present research include the reliability of mathematical models used to predict falls, fall-related injuries and disability in activities of daily living. Across participants, there were people showing a high probability of falling but who did not fall; and the opposite also occurred, with people showing a low probability of falling who nevertheless had fallen. Consequently, the capacity for discriminating fallers (AUC) ranged just between 0.71 and 0.75, a range that was no different from the AUCs reported in other fall studies [5, 6, 13, 32, 33, 39]. Furthermore, significant predictors identified in this study accounted for only ~40% of the variation in physical functioning, revealing that other factors are involved.

## RECOMMENDATIONS

The findings of this research suggest:

- A healthy lifestyle, in order to avoid co-morbidities or, at least, to minimize their effects.
- The reduction of environmental hazards, principally when fitness decreases and frailty increases (regardless of the difficulty of tasks), and the restraint of difficult tasks in hazardous environments.
- The practice at least 1,150 MET-min.wk$^{-1}$ of total physical activity, with no more than 500 MET-min.wk$^{-1}$ of vigorous physical activity.
- The implementation of exercise programs to prevent loss of balance and aerobic endurance. Further, muscle strength and flexibility exercises may be particularly relevant for less fit and frail people in order to preserve the ability to perform basic activities of daily living.

- The performance of functional exercises that mimic everyday life tasks and promote confidence.
- Special attention for women, who tend to be more fragile, and for men, who tend to expose themselves to more hazardous situations.
- Differentiated interventions in accordance with individual needs, especially in the case of those presenting profiles which deviate significantly from the average or change markedly over time.

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