Effects of a Multimodal Exercise Program in Motor Fitness, Functional Motor Asymmetry and Intermmanual Transfer of Learning: Study with Portuguese Older Adults of Different Contexts

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The present thesis was developed in order to achieve the PhD degree included in the doctoral course in Sport Sciences, designed by the Centre of Research, Education, Innovation and Intervention in Sport (CIFI²D), Faculty of Sport, University of Porto, according to the Decree-law n.º 74/2006 from March 24th.


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In memory of

Look at that nice old man! ...
Because in life he was already what he is now
He felt the rising sun in his heart,
And smiled delighted at the light of dawn.

Perhaps he suffered throughout existence,
Plowing and clearing the land.
Today the longing only brings times of yore,
Those times that aren’t anymore.

Don’t deny him the shelter of your arms,
Put your eyes in his dull eyes
And listen to the voice of warning and advice.

If you treat him well and with love,
So you will be treated one day,
The moment you arrive - God wants him old.

Portuguese priest and poet (Moreira das Neves)
To my parents,
because I owe them
all I am today.

And to my niece Maria João
and my nephew Diogo.
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Abstract

The aim of this thesis was to implement instruments that could provide information about the effects of a multimodal exercise program in the motor fitness, functional motor asymmetry and intermanual transfer (IMT) of learning in older adults from different contexts: a psychiatric hospital center (HC), residential care home (RCH) and daily living center (DLC). The research analyzed the variables manual dexterity (MD), pedal dexterity (PD), manual proprioceptive sensibility (MPS), coincidence-anticipation (CA), balance (B), simple reaction time (SRT), visuomotor memory (VMM) and hand grip strength (HGS) in function of the effect of a multimodal exercise program (pre- vs. post-training). Gender and interaction between time (pre- vs. post-training) and gender were also analyzed. This thesis includes two pre-experimental and four experimental studies whose results are the following: in the VMM, practitioners presented a better performance in time and in the number of errors when compared to non-practitioners of physical exercise (Study One). The Modified Baecke Questionnaire is an instrument with good validity coefficients that represents a great alternative to the accelerometer (Study Two). The exercise program improved the older adults’ performance in the MD, PD (but, in the HC, only the females increased their performance with both feet), MPS and HGS (only in the RCH). On the contrary, the control group decreased its performance in the MD, PD (non-preferred foot), MPS, RST, and HGS only in the RCH (older adults with mental health disorders) and in the RCH (Studies Three and Four). Analyzing the functional motor asymmetry, the older adults’ response varied according to the type of task as well as its complexity (Study Three). Regarding balance, the experimental group improved its performance in the HC, RCH (males better than females) and DLC (Study Four). In the task used to assess CA, the process of IMT of learning occurs regardless of the practice of exercise and the condition of transfer. This fact confirms that, in older adults, the ability of motor learning is preserved and it can be transferred from one upper limb to the other (Study Five). Finally, in the VMM, the experimental group (RCH and DLC) improved its performance both in the time of execution and in the number of errors; however, the HC did not show any significant alterations (Study Six).

KEYWORDS: AGING, MULTIMODAL EXERCISE PROGRAM, MOTOR FITNESS, FUNCTIONAL MOTOR ASYMMETRY, INTERMANUAL TRANSFER OF LEARNING
Resumo

O objetivo da nossa tese foi implementar instrumentos que fornecessem informações sobre os efeitos de um programa de exercício multimodal na aptidão motora, na assimetria motora funcional e na transferência intermanual (TIM) da aprendizagem em idosos de diferentes contextos: centro hospitalar (CH), lar (L) e centro de dia (CD). Ao longo destes estudos, foram analisadas as variáveis destreza manual (DM), destreza podal (DP), sensibilidade propriocetiva manual (SPM), antecipação-coincidência (AC), equilíbrio (E), velocidade de reação simples (VRsimples), memória visuomotora (MVM) e força de preensão manual (FPM) em função do efeito de um programa de exercício multimodal. As diferenças entre sexos e a interação entre momento de avaliação e sexo foram também analisadas. A dissertação inclui dois estudos pré-experimentais e quatro estudos experimentais cujos resultados são os seguintes: na MVM, os praticantes apresentaram um melhor desempenho no tempo e no número de erros quando comparados com os não praticantes de exercício físico (Estudo 1). O questionário de Baecke modificado é um instrumento com bons coeficientes de validade, representando assim uma ótima alternativa ao acelerómetro (Estudo 2). O programa de exercício melhorou a performance dos idosos na DM, na DP (mas, no CH apenas as mulheres melhoraram o seu desempenho com ambos os pés), na SPM e na FPM (apenas no Lar); por outro lado, o grupo controlo diminuiu a sua performance na DM, na DP (preferência podal esquerda), na SPM, na VRsimples e na FPM apenas no Lar (idosos com patologias mentais) e no Lar (Estudos 3 e 4). Em relação à assimetria motora funcional, a resposta dos idosos variou de acordo com o tipo de tarefa bem como da sua complexidade (Estudo 3). No equilíbrio, o grupo experimental melhorou o seu desempenho no CH, no L (os homens melhores do que as mulheres) e no CD (Estudo 4). Na tarefa usada para avaliar a AC, o processo de TIM de aprendizagem ocorre independentemente da prática de exercício e da condição da transferência. Este facto confirma que, nos idosos, a aprendizagem motora é preservada e pode ser transferida de um membro superior para o outro (Estudo 5). Finalmente, os idosos do grupo experimental (L e CD) melhoraram a sua performance na MVM, tanto no tempo de execução como no número de erros; contudo, o CH não apresentou alterações significativas (Estudo 6).

PALAVRAS-CHAVE: ENVELHECIMENTO, PROGRAMA DE EXERCÍCIO MULTIModal, APTIDÃO MOTORA, ASSIMETRIA MOTORA FUNCIONAL, TRANSFERÊNCIA INTERMANUAL DA APRENDIZAGEM
List of abbreviations

ACSM – American College of Sports Medicine
BH – Both Hands
CG – Control Group
CA – Coincidence-anticipation
DAS – Domestic Activity Score
DB – Dynamic Balance
DWT – Discrimination Weights Test
DLC – Daily Living Center
EG – Experimental Group
FTS – Leisure-Time Activity Score
HGD – Handgrip Dynamometer
HC – Psychiatric Hospital Center
IMT – Intermanual Transfer of Learning
LI – Laterality Index
LQ – Laterality Quotient
LEDs – Light Emitting Diodes
MMDT – Minnesota Manual Dexterity Test
M-CRTA – Multi-Choice Reaction Time Apparatus
MMSE – Mini-Mental State Examination
NPH – Non-Preferred Hand
NPH-PH – Practicing with the Non-Preferred Hand and being tested on the Preferred Hand
NPF – Non-Preferred Foot
PE – Physical Exercise
PH – Preferred Hand
PPT – Purdue Pegboard Test
PRT – Pursuit Rotor Test
POMA – Performance-Oriented Mobility Assessment
PH-NPH – Practicing with the Preferred Hand and being tested on the Non-Preferred Hand
PF – Preferred Foot
RCH – Residential Care Home
SAS – Sport Activity Score
SB – Static Balance
TPT – Tapping Pedal Test
TT – Tinetti Test
TB – Total Balance
VMM – Visuomotor Memory
WHO – World Health Organization
CHAPTER I

GENERAL INTRODUCTION AND ORGANIZATION OF THE THESIS
General introduction and organization of the thesis

Aging is a world growing phenomenon that is particular marked in Europe and in developed countries (Giannakouris, 2008). The ratio of adults with 65 years old or more in the European Union (27 countries) is estimated to grow from 17.1% to 30.0% and the number will rise from 84.6 millions in 2008 to 151.5 millions in 2060. In Portugal, the aged with 65 years old or more will almost double from 17.4% in 2008 to 32.3% in 2060 (Instituto Nacional de Estatística, 2009). The decrease of the young population and the simultaneous increase of older adults will cause the rise of the population aging index: it is estimated that, in 2060, there will be in Portugal 271 older adults for each group of 100 young adults, more than the double of the number in 2009: 116 older adults for each group of 100 young adults (Instituto Nacional de Estatística, 2009).

The ensuing demographic change will have an obvious impact on society and on health care systems in relation to a decreased level of functioning and associated loss of autonomy. The consequence of this increased longevity represents a longer period of time in which the older adults suffer from chronic diseases that will increase their dependence (Sousa et al., 2010).

From a public health standpoint it is, therefore, important to identify and develop interventions that can attenuate the gradual degeneration associated with the ageing process.

Among others, dementia has taken on greater importance as a public health problem due to the increasing older adults population, because neurological disorders are the leading cause of disability and dependence in aging. Being a general irreversible process and to which there is no perspective of medication, the existence of adults with dementia will be an increasingly common reality in our society (Caldas, 2002).

In the human being, aging is marked by a biopsychosocial process of changes that occur throughout existence bringing a progressive reduction of the bodily functions. Aging is also characterized by the creation of a new social role of the older adult that can be positive or negative according to the social and
cultural values of the group to which the older adult belongs (Barreiros, 1999, 2006; Masoro & Austad, 2006).

In addition, aging is a complex process that is accompanied by a series of degenerative changes in the different body systems, namely at the anthropometric, muscular, articular, cardiovascular, pulmonary and neural levels. Also, a decline in mental, cognitive and psychological functioning is evident (Barreiros, 1999, 2006; Faro, Lourenço, & Barros, 1996; Matsudo, 2006; Matsudo & Matsudo, 1992; Mazo, Lopes, & Benedetti, 2001; Mota & Carvalho, 2002; Mota & Carvalho, 2006; Spirduso, 1995; Spirduso, Francis, & MacRae, 2005; Yazbeck & Batistella, 1994).

Improving the older adults’ quality of life is, therefore, one of the main challenges of the 21st century. Among others, physical activity performed by older adults aims not only at preventing and delaying the possible changes and common pathologies of these age groups (thus maintaining the abilities that allow them to have a good quality of life), but also at improving and rehabilitating some of these shortcomings and pathologies, provided that the activity is done in a continuous and adapted way (Ferraro & Booth, 1999). However, most of the aged are considered nowadays sedentary (Sousa et al., 2010). It should be noted that the older adults’ sedentary lifestyle is more the result of social and cultural impositions than a disability from their own (Carvalho, 1999, 2006; Spirduso, Francis, & MacRae, 2005). In fact, according to the same authors, the senescence associated to the decline of the various organ functions should not only be assigned to aging per se, but essentially to physical inactivity and disuse.

Although with some differences across the countries, the older adults population present actually high levels of physical inactivity which are more pronounced in institutionalized subjects (Henry, Webster-Gandy, & Varakamin, 2001). In this case, research indicates that institutionalization brings a decline of functions according to the physical mobility and the mental state and welfare and the loss of social contacts and social relations (Schols, Crebolder, & Van Weel, 2004). All these occurrences lead to feelings of disability which echoes on the older adults’ quality of life (Mitchell & Koch, 1997).
Following this, Coimbra and Brito (1999) argue that, for the older adults, the quality of life is an overall positive perception of their personal life to which contribute various domains and components including education, health, the physical and social well-being, personal relationships, civic and recreational activities, among others.

Going back to the issue of dementia, the World’s Alzheimer’s Report from 2009 states something new: it is estimated that 36 million adults live all over the world with dementia and these numbers duplicate every twenty years reaching 66 million in 2030 and 115 million in 2050 (Prince, Bryce, & Ferri, 2011).

It is important to highlight that adults with schizophrenia often experiment motivation and energy problems which reduce their ability to have a healthy nutrition and a regular access to the practice of physical exercise (Allison et al., 1999; Aubin, Stip, Gélinas, Rainville, & Chapparo, 2009; Spruit et al., 2010; Vancampfort et al., 2010). Some studies carried out in the last years suggest that regular physical exercise has a protective effect against the risk of developing dementia (Fratiglioni, Paillard-Borg, & Winblad, 2004; Larson et al., 2006; Middleton et al., 2011; Rovio et al., 2005; Vercambre, Grodstein, Manson, Stampfer, & Kang, 2011).

From a physiological perspective, the frequent stimulation of the nervous system through the systematic training of dexterity, coordination, strength and sensorimotor perception, reinforces the idea that training the neuromotor abilities seem to prevent significant losses at any age.

The older adults take more time performing simple tasks like bleaching, reaching and grabbing with precision. Even when the differences related with speed are minimum, the older adults use different patterns of movement compared with adults and young adults. In the tasks that require speed and precision, they tend to choose precision over speed (Spirduso, Francis, & MacRae, 2005).

However, besides the importance of the neuromotor variables, most of the studies concerning the effects of training involving older adults are based on aerobic and/or strength training protocols. More studies about the efficiency of
the nervous system are needed (Barreiros, 1999, 2006; Mota & Carvalho, 2002; Mota & Carvalho, 2006; Okuma, Teixeira, Marchetti, & Rinaldi, 1994; Spirduso, 1995; Spirduso, Francis, & MacRae, 2005), because it plays a primordial role in the activities of daily life, namely at the level of the upper and lower limbs.

The hand plays a central role in the before mentioned neuromotor abilities, because it is the most active and important part of the upper end of the human body. Accordingly, the hands must be able to perform extremely delicate and sensitive movements and also to perform tasks that require a considerable strength. The anatomy and functional biomechanics of the hand are extremely complex. The hands go through many physiological and anatomic changes associated with aging, but the effects of normal aging in the function and dysfunction of the adult hand are still poorly understood. The doctors, therapists and researchers need to understand the normal and abnormal functioning of the hand, including the degeneration related with age (Carmeli, Patish, & Coleman, 2003). Many functional types of movements like buttoning, handling pins, cutting with a knife, combing, tighten the shoelaces and dialing a telephone number are changed in older adults and these deficits are of particular importance, because they affect the ability to live autonomously (Spirduso, Francis, & MacRae, 2005).

The systematic use of the hands may contribute to the maintenance of some types of motor function for many years, but the efficiency and speed of the manual performance eventually decrease in the last decades of life. With the passage of time, the efficiency and speed of processing decrease; as a consequence, the older adults develop inevitably strategies to deal with these losses. Thus, for many years, the loss of function in a healthy individual is small, so small that it is hardly noticeable. Those compensatory strategies include coincidence anticipation, simplification and balance in speed-precision of the movement (Spirduso, Francis, & MacRae, 2005).

Concerning the coincidence anticipation (ability requested in various tasks), the older adults develop ways to anticipate movements in order to perform tasks in a rapid and efficient way. They learn throughout life that certain movements must be accomplished in a determined time and, knowing this, they
can start planning the movement earlier. As to simplification: when the older adults become aware of the reduction of their manual dexterity they start looking for simpler, slower or less extensive movements that achieve the same objectives as the previous ones performed by more complex movements. And finally, to what concerns balance in speed-precision, the older adults often choose precision over speed, because in general they prefer to be more precise than fast (Spirduso, Francis, & MacRae, 2005).

To what concerns the motor ability strength, losses of approximately 1% per year start in the middle of the 40s, with greater annual losses found in older adults over 70 years old. Longitudinal studies showed that, with advancing age, there are less losses of strength (in the upper part of the body) in women than in men (Spirduso, Francis, & MacRae, 2005).

The notion that our senses and sensory integrity decrease with aging is widely accepted. In many cases, the changes in the sensory perception are studied in specific areas of the body, whereas sensory changes in other important areas, like the hand, are neglected (Carmeli, Patish, & Coleman, 2003).

Carvalho and Mota (2002) refer that the older adults privilege precision over speed when confronted with tasks in which precision and speed are concerned. These authors still mention that being slower can be caused by inactivity, loss of sensory discrimination and difficulty in focusing on relevant information and taking decisions. For Glass et al. (2000) and Llano, Manz and Oliveira (2002), all this aspects causes the slower transmission of the nerve impulses which affect the coordination ability.

Carmeli and Liebermann (2007) and Carmeli, Patish and Coleman (2003) refer that the tactile sensibility of the hands is essential for the precise control in the manipulation of small objects and in the needs of many everyday activities.

The physical inactivity is the cause that mostly contributes for the loss of muscle in the older adults. So the training of force is of extreme importance in this age group since it has a central role, not only in the maintenance and promotion of health, but also in the autonomy of the older adults (performing
their daily tasks) and consequently in the improvement of their life’s quality (Spirduso, Francis, & MacRae, 2005).

Thus, what is the role of physical exercise in improving the quality of life of older adults with or without mental health disorders?

From the need for a more comprehensive and deeper knowledge about the behavior of motor abilities in older adults and its changes across a multimodal exercise program, we decided to investigate the effects of such program in the older adults’ motor ability, functional motor asymmetry and intermanual transfer of learning in an integrating way and applying the adequate instruments and methodologies. This path will guide the present research in view of a combined knowledge of certain characteristics of aging and its consequences in order to improve the older adults’ quality of life.

One of the strengths of our investigation is that, to our knowledge, there is few information and research on this subject. So, we believe that our results may contribute for a better understanding of the effect of exercise on different perceptual and motor abilities of senior males and females from different environmental contexts. Although the contexts of our study were not compared, we collected data, analyzed and discussed results coming from three different human realities in the same research. The majority of the studies conducted in this domain only deal with one context.

Thus, considering that aging is an increasingly investigated phenomenon, we intend to study the effects of a multimodal exercise program in motor ability in eight motor tasks, comprising the manual and pedal dexterity, the visuomotor coordination, the manual proprioceptive sensibility, the simple reaction time, the balance, the visuomotor memory, the coincidence anticipation and the hand grip strength.

We will use the following tests to assess the variables previously referred: the Minnesota Manual Dexterity Test, the Purdue Pegboard Test, the Pursuit Rotor Test, the Discrimination Weights Test, the Multi-Choice Reaction Time Apparatus, the Takei TKK Digital Handgrip Dynamometer, the Tapping Pedal Test, the Bassin Anticipation Timer, the Visuomotor Memory Test, the Tinetti Test, the Modified Baecke Questionnaire, the Dutch Handedness
Questionnaire, the Lateral Preference Questionnaire and the Mini-Mental State Examination Questionnaire.

It is our intention to build a set of objectives (through a program of systematic physical exercise) in order to find results that contribute to the progress of the knowledge in the intersection of the conceptual and experimental fields of motor behavior and aging in the major domain of the Sport Sciences.

Main objective:

The main objective of the studies included in this thesis was to investigate the effects of a multimodal exercise program on motor fitness, functional motor asymmetry, intermanual transfer of learning and visuomotor memory in older adults from different contexts.

Specific objectives:

The specific objectives are outlined in the aims of the articles related to the pre-experimental and experimental studies that are included in this thesis and they are the following:

(i) To investigate the visuomotor memory in older adults: comparison of practitioners and non-practitioners of physical exercise (pre-experimental Study One) (This study was based on the thesis by Fechine (2007) to which we had access permission, namely to the database and the results; we were also allowed to test the instrument used in the experimental study six);

(ii) To verify the interrelations between the Modified Baecke Questionnaire and accelerometry in assessing the physical activity of Portuguese older adults (pre-experimental Study Two) (This study was based on the thesis by Azevedo (2009) to which we had access permission, namely to
the database and the results; we were also allowed to test the instrument used in the experimental studies);

(iii) To examine the effects of a multimodal exercise program in motor fitness and functional motor asymmetry: study with Portuguese older adults of different contexts (experimental Study Three);

(iv) To verify the effects of a multimodal exercise program in pedal dexterity and balance: study with Portuguese older adults of different contexts (experimental Study Four);

(v) To examine the effects of a multimodal exercise program in the intermanual transfer of learning (experimental Study Five);

(vi) To investigate the effects of a multimodal exercise program on the visuomotor memory: study with Portuguese older adults of different contexts (experimental Study Six).

All the scientific articles were submitted to peer-reviewed national and international journals.

**General organization of the thesis:**

The structure of the thesis is close to the Scandinavian model. The elaboration of the studies and the following submission to publication not only raises the scientific level, but it also allows a wider and faster dissemination of the results.

Five chapters are included in the present thesis:

**Chapter I** where the general introduction is presented contains a short theoretical contextualization, the relevance of the study and its objectives.
Chapter II that provides a theoretical background to our experimental work, namely some considerations about the older adults in the 21st century, the implementation of physical exercise programs in older adults (a critical review) and some concerns about the motor, psychological and social aspects of the older adults.

Chapter III presents the pre-experimental and experimental studies. Study one (pre-experimental), aims to investigate the visuomotor memory in older adults of both genders, practitioners and non-practitioners of regular physical exercise. The purpose of the second study (pre-experimental) is to contribute to validate the Modified Baecke Questionnaire by accelerometry in the assessment of physical activity patterns in Portuguese older adults of both genders. The third and the sixth studies (both experimental) examine the effects of a multimodal exercise program in the motor fitness, functional motor asymmetry and visuomotor memory in older adults from different contexts, namely, in a psychiatric hospital center, residential care homes and daily living centers. The fourth study (experimental) verifies the effects of a multimodal exercise program in the pedal dexterity and balance in older adults from different contexts previously described in study three. Last, study five (experimental) examines the effects of a multimodal exercise program in the intermanual transfer of learning in older adults.

Chapter IV presents a summary of the main conclusions from the different studies and makes a perspective of some development lines for future investigations.

Chapter V closes the thesis with the appendix used in all the pre-experimental and experimental studies.

All articles included in this thesis are presented according to the norms of the scientific journals to which they were submitted. Table 1 presents a synopsis of the structure adopted in this document, the studies carried out and the details of its publication or submission.
**Table 1.** Synopsis of the structure and contents of the present thesis.

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CHAPTER II

THEORETICAL BACKGROUND
Theoretical background

The older adults in the 21st century

Ageing is a growing phenomenon in the world’s population, particularly in Europe and in developed countries (Giannakouris, 2008). The same author also provides that in the European Union (27 countries) the proportion of adults aged 65 or more years will increase from 17.1% to 30.0%, being reportedly that this number will go up from 84.6 million in 2008 to 151.5 million in 2060. In Portugal, like in the other EU countries, the older adults population with 65 years of age or older, in the central scenario, will almost double, increasing from 17.4% in 2008 to 32.3% in 2060 (National Institute of Statistics, 2009).

According to the same entity (NIS, 2009), the decrease in the young population and the simultaneous increase in the older adults population will climb up the index of an ageing population: there will be 271 older adults for every 100 young ones in Portugal in 2060 in the central scenario: twice as much of the designed number for 2009: 116 older adults for every 100 young adults.

In Portugal, the inequality in life expectancy among men and women has been accentuated by the end of the 20th century, following the trend to the overall increase in average duration of life. As recently as 2007, women had a life expectancy of around 82.2 years and men of around 75.9 years (National Institute of Statistics, 2009).

One of the main challenges of the 21st century will be the improvement of the quality of life in old age. In this sense, it is rather understandable that one is prolonging the lives of these adults, if that does not mean living with quality and joy. Medicine cannot do everything alone. It is only possible to achieve the purposes with the help and commitment of the older adults population. However, this population presents behaviors as passivity and immobility as well as a reduced practice of physical exercises which create a certain type of patterns and stereotypes (which are more the result of social and cultural constraints than a functional disability of the older adults) that constantly
determine their shape of acting (Carvalho, 1999, 2006; Spirduso, Francis, & MacRae, 2005).

The aging process in particular in the subjects from 65 years, involves a series of changes at the level of various bodily structures and systems. Thus, it is verified a narrowing and hardening of the arteries in the cardiovascular system, (e.g., aorta), the heart is not able to achieve levels of maximum heart rate that were possible during youth, which consequently leads to a lesser cardiovascular effectiveness (Spirduso, Francis, & MacRae, 2005); in the respiratory system, there is a loss of lung elasticity and a reduction of alveolar surface, which leads to a decrease of the level of maximum consumption of oxygen and vital capacity (Shephard, 2003); in the locomotor system, the planning of responses registers significant delays in sequences of movements that are highly dependent on perceptive information, specially on the external information. The neural and motor delays are also visible in sequences of complex movements with important temporal constraints, such as crossing the security strip. On the other hand, one can observe a reasonable level of performance in the older adults in performing slow actions that were extensively practiced throughout life (Barreiros, 2006; Spirduso, Francis, & MacRae, 2005). Finally, there is some slowness in the neuromotor system which is functionally significant due to the biological deterioration (Rosano et al., 2012).

The errors in the performance of manual skills are accompanied by a progressive decline of perceptual-motor skills as we grow old. Long periods of reaction time, sensory capacity deterioration and a decrease in the muscle strength contribute to the functional deterioration of manual dexterity. The result is an overall change in the coordination of the hand, which cannot be seen in an isolated way from the parallel changes of sensory-motor capabilities, specially the deterioration of vision (Carmeli & Liebermann, 2007).

Thus, based on what was stated above, we will then deepen the topic of physical exercise programs which arise in order to slow down the aging process.
The implementation of physical exercise programs (PEP) in the older adults. A critical review

An active lifestyle, complementing with PEP can empower the older adults for day-to-day tasks, providing significant improvements: on the physical level (American College of Sports Medicine, 2009; Aoyagi & Shephard, 2010; Bean et al., 2009; Benjamin, Edwards, & Bharti, 2005; Mota & Carvalho, 1999; Osório, 2004; Rubenstein et al., 2000; Sorace, 2010; Yang et al., 2011); on the psychic level (Aoyagi & Shephard, 2010; Benjamin, Edwards, & Bharti, 2005; Osório, 2004; Sorace, 2010; Spirduso, Francis, & MacRae, 2005; Yang et al., 2011); on the cognitive level (Netz, Argov, & Inbar, 2009; Netz, Tomer, Axelrad, Argov, & Inbar, 2007; Paúl, 2005; Spirduso, Poon, & Chodzo-Zajko, 2008; Spirduso, 2009); and still on the social level (Osório, 2004; Sardinha & Batista, 1999; Spirduso, Francis, & MacRae, 2005).

In order to provide healthy and pleasurable lifestyles for the older adults population, several and diverse PEP have been developed aiming at a positive intervention on a level of improvement or, at least, of the maintenance of motor fitness skills which enable good functional performance in the activities of daily life and on the physical and psycho-affective well-being.

The following paragraphs report a critical review of those programs, highlighting their benefits and their limitations. We begin, however, by making some general remarks on the implementation of the PEP.

Before starting any type of PEP in the older adults population, it is essential that they undergo a medical examination in order to assess their physical condition and their state of health. The regular PEP can and should be made by this age group, but should be progressive, controlled and adapted to each older adults (Carvalho, 1999; Faria Júnior, 1999; Mota & Carvalho, 1999).

In order to have positive effects on the older adults’ health, well-being and quality of life, PEP should be done based on a regular practice and some principles (American College of Sports Medicine, 1998; Evans, 1999; Sorace, 2010; Young & Dinan, 1994) such as: (i) include all components of physical fitness in order to work, on a regular basis, the various motor skills that are fundamental to everyday life; (ii) include a minimum of three to five sessions
per week, with approximately 45 to 60 minutes each; (iii) establish attractive and motivating programs with exercises that are easy to understand and perform; (iv) include progressive exercises, both in intensity and complexity; (v) include group exercises, due to their nature of socialization, in order to provide communication and social integration; (vi) perform, ideally, those programs with cultural and recreational activities and, whenever it is possible, outdoors; and (vii) diversify the range of activities (walking, swimming, gymnastics, dance, games, among others).

We have conducted a review which aimed at investigating the effects of regular physical exercises in improving conditional motor skills in older adults based on five selected studies. The first study has generally focused on assessing the strength, balance, flexibility and aerobic resistance (Taguchi, Higaki, Inoue, Kimura, & Tanaka, 2010). The second study has assessed the balance and the ability of aerobic resistance (Hatch & Lusardi, 2010). The third (Madureira et al., 2007) and the fourth ones (Carvalho, Pinto, & Mota, 2007) have intended to assess the balance. Finally, the fifth study has assessed the strength and balance to prevent falls (Waters, Hale, Robertson, Hale, & Herbison, 2011). In order to understand how the relationship between motor ability and the PEP is over time, four studies (1, 2, 3 and 5) have presented a longitudinal design (PEP with a duration of twelve months) while the fourth study has had a design of a transversal nature (PEF in recent twelve months). In general, the studies corroborated that, after twelve months, the effects of regular physical exercises have significantly improved the studied capacities.

Thus, the benefits of regular PEP are immense. We will start by describing some physical and physiological benefits: the main physical and physiological changes relate to the improvement of aerobic capacity (VO2máx.) (Francisco, Ricci, Rebelatto, & Rebelatto, 2010; Muster, Kim, Kane, & McPherson, 2009), flexibility (Sato et al., 2011; Silva Neto, 2011), strength (Hayao, Motohiko, Toshiaki, & Takashi, 2011; Mayer et al., 2011; Taguchi, Higaki, Inoue, Kimura, & Tanaka, 2010; Villareal, Smith, Sinacore, Shah, & Mittendorfer, 2011), muscular endurance (Mayer et al., 2011), neuromotor coordination (Arampatzis, Peper, & Bierbaum, 2011), balance (Madureira et al.,
2007; Sato et al., 2011; Siegrist, 2008), and postural control, leading to a decrease in the risk of falls (Siegrist, 2008; Silva Neto, 2011), as well as the decrease in body fat percentage (Baeza, García-Molina, & Fernández, 2009; Riedl et al., 2010), blood pressure (Westhoff et al., 2007), postural problems (Bogaerts et al., 2011), cholesterol (Van Roie et al., 2010), risk of cancer (Astrand, 2000), osteoarthritis (Schlenk, Lias, Sereika, Dunbar-Jacob, & Kwoh, 2011) and osteoporosis (Cousins et al., 2010; Silva Neto, 2011).

We have also highlighted the risks of PEP with advancing age, being more pronounced in individuals with a history of cardiovascular and pulmonary diseases as well as osteoporosis and arthritis (Shephard, 2003). The same author states that the limitations during the practice of PEP include physical lesions (which might be attributed to an inadequate supervision and the use of inappropriate equipment or hazardous installations), cardiac problems and environmental risks arising from heat, cold and immersion in water.

Simon and Harvey (2005) advise the practice in the PEP with security, namely: (i) learn to listen to your body, recognizing the warning signs of heart disease, including chest pain or pressure, disproportionate shortness of breath (e.g., panting), fatigue or sweating, irregular pulse, dizziness or even indigestion; (ii) do not ignore any pain that might mean risk of injury (early intervention may prevent more serious problems); (iii) do not practice physical exercise if you are sick or have fever; and (iv) return to PEP gradually after a period of illness or injury.

Thus, summarizing what was described earlier, the PEP need to be progressive, regular, supervised by adults with specialized training and tailored to each person in this age group. In addition, those programs should be directed primarily to conditional motor skills, but also to the coordinative motor skills, including at least three to five sessions per week, with approximately 45 to 60 minutes each. The PEP improve motor function, seem to increase the sensations of well-being and reduce the risk of falls and injuries in the older adults. Finally, one should always bear in mind the limitations that the PEP may incorporate.
Considerations about the various parameters to motor, psychological and social level in a regular PEP for older adults

It would be appropriate to focus our attention on developing capacities in PEP to older adults population, taking into consideration their applicability and appropriate supervision. As previously stated, it is crucial to develop conditional capacities as well as the coordinative capacities on the motor domain level. Sorace (2010) states that the older adults should be encouraged to perform moderate aerobic exercises at least three to five or more days per week and between 20 to 60 minutes per day. The improvements of VO2max - the key indicator of aerobic capacity – seem to occur when the exercise involves the use of large muscle groups for prolonged periods (e.g., walking, swimming and cycling).

The progressive deterioration of muscular strength may contribute to the functional impairment of the older adults (Visser et al., 2005). Physical exercise promotes muscle strength and mass which also effectively increases bone mass (bone mineral density and content) and bone strength of the specific stressed bones (Maïmoun & Sultan, 2011; Suominen, 2006).

American College of Sports Medicine (1998b) refers to the inclusion of strength training as part of PEP to the older adults. Such programs can produce a substantial increase of muscle mass even in individuals extremely older adults, with a corresponding increase in the ability to perform activities of everyday life (Shephard, 2003). Sorace (2010) recommends two to three days per week (nonconsecutive days); use modes (e.g., free weight, machines, elastic bands) that are suitable for the individual; 8 to 10 exercises for the major muscle groups; 1 to 3 sets per exercise; 10 to 15 repetitions. Finally, Carvalho and Soares (2004) emphasize that during the sessions of strength training, and with the purpose to minimize fatigue without overloading the muscular and cardiovascular system, the upper and bottom body should be worked alternately, as well as the intervals between sets should allow full recovery.

Regarding flexibility, Carvalho and Mota (2002) state that it develops to adulthood (20-25 years) and, from there, suffers a decline, which, in turn, is most evident from the 55-60 years. Shephard (2003) and Spirduso, Francis and
MacRae (2005) emphasize that the deterioration of the articular mobility can increase the risk of falls. Sorace (2010) recommends flexibility training 3 to 7 days per week; static stretching to the point of mild tension using all major muscle groups with 15 to 60 seconds in duration.

Regarding the balance, it should be stressed that the control of body sway during a still position is called static balance; in turn, the use of appropriate internal and external information to react to disturbances of stability and activate the muscles to cause them to work in coordination, in order to prevent changes in balance, is called dynamic balance (Spirduso, Francis, & MacRae, 2005). The loss of balance is of utmost importance for the locomotor actions and other activities in the standing position. In fact, the oscillation of the body in bipedal position is significantly affected by age, with important increments after 30 years (Barreiros, 1999, 2006).

American College of Sports Medicine (2009a) refer that, because of a lack of adequate research evidence, there are currently no specific recommendations regarding specific frequency, intensity, or type of balance exercises for older adults. However, the ACSM (2009a), namely the Exercise Prescription Guidelines recommend using activities that include the following: (i) progressively difficult postures that gradually reduce the base of support (e.g., two-legged stand, semi tandem stand, tandem stand, one-legged stand); (ii) dynamic movements that perturb the center of gravity (e.g., tandem walk, circle turns); (iii) stress-postural muscle groups (e.g., heel stands, toe stands); or (iv) reducing sensory input (e.g., standing with eyes closed).

Regarding the reaction time, this can be defined as the time interval that begins with the presentation of a stimulus until the beginning of a voluntary response (American College of Sports Medicine, 2009; Gallahue & Ozmun, 2005; Magill, 2001). When the situation involves only a stimulus and a response, the latter is called simple reaction time; if, on the other hand, there are two or more stimuli involved, the individual should identify them, and finally, select the most appropriate response from among the various possible, it is called choice reaction time (Magill, 2001). It should also be mentioned that the reaction time is reduced progressively from childhood until around 20 years of
age to later be increased slowly and steadily up to 50 years and, more quickly, after that age (Grouios, 1991). However, the possible influence of PEP was analyzed in researches aimed at studying its effects on various skills associated with driving. It was done through longitudinal comparisons which demonstrated a better reaction time in the older adults subjected to PEP, if compared to sedentary individuals of the same age (Marmeleira, Godinho, & Orlando, 2009; Marmeleira, Melo, Tlemcani, & Godinho, 2011).

It is important that we also focus our attention on proprioceptive sensitivity: it is an ability that, through the neuromuscular receptors (neuromuscular spindles and Golgi bodies), and cutaneous and articular receptors, allows to provide information of orientation on the movement and the position of joints, muscle contraction speed and strength, weight and effort associated with muscle contractions (Lephart, Riemann, & Fu, 2000; Magill, 2001). According to many authors (Costa, 1985; Haywood & Getchell, 2004; Magill, 2001; Schmidt & Lee, 1999) it is important to note that the fingers are one of the areas of the body where there are high concentrations of skin receptors which provide information through tact about surfaces of objects. Likewise, a recent study by Goble et al. (2011), refer that, proprioceptive information from the foot/ankle provides important information regarding body sway for balance control, especially in situations in which visual information is degraded or absent. Thus, one may conclude that besides essential peripheral reflex mechanisms, the central processing of proprioceptive signals from the foot is critical for balance control.

The older adults are less able to discriminate movements of the limbs, either active or passive. This inability to adequately recognize the position of the segments associated with the reduction of sensitivity and pressure, can cause postural control problems (Goble, Coxon, Wenderoth, Van Impe, & Swinnen, 2009), especially under conditions of reduced sight (Christoforidis et al., 2011).

Regarding the ability of anticipation-coincidence, it develops from childhood and reaches its peak around 14 to 15 years of age according to Dorfman (1977). However, with increasing age, some signs of degradation of motor performance are detected regarding accuracy and variability in tasks of
anticipation-coincidence (Meeuwsen, Goode, & Goggin, 1997) and a significant increase in all measures of performance in individuals from 70 years of age (Santos, Corrêa, & Freudenheim, 2003): loss of accuracy, consistency and delay in motor responses (increase of the magnitude of errors).

As regards the motor coordination, this capacity can be improved up to 20 to 25 years of age, remaining stable around 40 to 50 years of age, and from these ages there is an effective reduction which is based on the changes highlighted in the neuromuscular system (Appell & Mota, 1991). In general, when adults describe the others as "coordinates", this comment relates to the ability of that person to coordinate the vision, the upper and lower limbs so that a specific movement can be performed to achieve a goal (Spirduso, Francis, & MacRae, 2005). Regarding manual dexterity, this ability involves two important categories: the fine dexterity and the global dexterity. Fine dexterity refers to the ability to manipulate objects using the distal parts of the fingers and involves fast, precise movements when they manipulate small objects; in the context of global dexterity, which is generally referred to as manual dexterity, the objects to be handled are usually larger and their handling requires global movements, to the detriment of interdigital movements (Desrosiers, Rochette, Hébert, & Bravo, 1997). Several studies have described that it is possible to avoid the decline of manual dexterity with the practice of regular exercise (Desrosiers, Rochette, Hébert, & Bravo, 1997; Dias & Duarte, 2002; Mesquita, 2002; Ranganathan, Siemionow, Sahgal, Lui, & Yue, 2001; Silva & Vasconcelos, 2003).

On the other hand, it is crucial to understand the pedal dexterity: the foot offers the only direct contact with the surface of the ground and it is, therefore, reasonable to expect that problems at this level will cause losses at the level of the mobility of the older adults. The characteristics of the foot and ankle are fundamental determinants in the evaluation issue of the older adults functional capacity (Spink et al., 2011). Thus, the musculoskeletal structure of the lower limbs has an even greater relationship with the mobility and functionality of the older adults, resulting in the capability of transferring, walking, balancing, stooping down and getting up (Carmeli, Reznick, Coleman, & Carmeli, 2000).
Kauranen and Vanharanta (1996) claim that the manual dexterity and pedal dexterity decrease significantly with age, especially after the age of 50. Regarding the PEP, the pedal dexterity can be improved through a practice of regular exercise as the evidence of several studies in the age group of the older adults (e.g., Hartmann, Murer, De Bie, & De Bruin, 2009; Jacobson, Thompson, Wallace, Brown, & Rial, 2011; Nagai et al., 2011; Spink et al., 2011).

Finally, we point out that, according to Garber et al. (2011), neuromotor exercise training, sometimes called functional fitness training, incorporates motor skills such as balance, coordination, gait, and agility, and proprioceptive training.

Garber et al. (2011), namely the ACSM, recommends 2 to 3 neuromotor exercise training days per week; exercise sessions of 20 to 30 minutes in duration may be needed; for a total of ≥ 60 minutes of exercise per week; neuromotor exercises involving motor skills (e.g., balance, agility, coordination, and gait), exercise training, proprioceptive and multifaceted activities (e.g., tai chi and yoga) are recommended for older adults to improve and maintain physical function and reduce falls in those at risk for falling; an intensity of neuromotor exercise have not been determined and more research is needed before any definitive recommendations can be made. There is no available evidence concerning the number of repetitions of exercises needed, the intensity of the exercise or optimal methods for progression.

The psychological and social spheres are of paramount importance in the complexity of aging. Then we provide the description of the psychological domain. Studies on the psychological effects of PEP show a positive impact on different psychological variables, such as self-concept, and self-esteem (e.g., Klusmann, Evers, Schwarzer, & Heuser, 2011; Shahbazzadeghan, Farmanbar, Ghanbari, & Roshan, 2010): the older adults were able to directly perceive an improvement in their cognitive faculties after undergoing a course of computing along with PEP; moreover, they had positive experiences on their bodies (Klusmann, Evers, Schwarzer, & Heuser, 2011). Penttinen et al. (2010) also report that physical exercise can improve depressive symptoms.
Nowadays our society gives priority to the consumption and productivity, but it does not prepare the individual for retirement. As a result, signs and depressive symptoms, isolation, lack of confidence and self-esteem may emerge from this situation (Spirduso, Francis, & MacRae, 2005).

Finally, we should also highlight the sociological benefits, in the social field: according to Prevc and Doupona (2009), the PEP has a fundamental role in the process of development and socialization of human being. In addition, they can provide the older adults with the opportunity to broaden their social relationships, constituting themselves as a suitable approximation strategy which fosters intergenerational relations in a different stage of the people’s lives (Carvalho, 2006).

On the other hand, as the gerontologists claim: to live the last few twenty years of life in good physical condition but without useful activities is, for the older adults, psychological and sociologically impossible. The society needs to create opportunities for them to live. The "hostile survival" is worse than death (Beauvoir, 1990). In short, it is increasingly necessary to establish another paradigm: it becomes important to find activities that may take the older adults out of their isolation and require their contact with the outside world; a society that integrates the ageing and also considers those individuals as active contributors and beneficiaries of development.

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CHAPTER III

PRE-EXPERIMENTAL AND EXPERIMENTAL STUDIES
Visuomotor Memory in Older Adults: Comparison of Practitioners and Non-Practitioners of Physical Exercise

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(Submitted)

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Abstract

Memory, namely visuomotor memory (VMM), is one of the most essential cognitive functions in older adults' life. Among others, regular exercise seems to be an important factor in counteracting age-related-cognitive skills changes and thus prevent memory loss. However, in spite of the importance of VMM, the results of the scarce studies concerning the influence of exercise on this ability are contradictory.

The aim of this study was to compare the practitioners and non-practitioners of physical exercise (PE) in VMM of older adults in function of gender and age. VMM (time spent in performing the test and errors during the execution) of 74 subjects aged 60-90 years, 36 being practitioners of PE (P - mean age of 70.22 ± 0.90 years) and 38 being non-practitioners (NP - mean age of 68.26 ± 1.12 years) was assessed by a VMM Test (Thinus-Blanc, Gaunet, & Péruch, 1996). The results showed that (i) P presented better results than NP in terms of time taken to perform the test and in the number of errors, and (ii) gender and age did not influence the VMM performance. Data suggests that PE seems to have positive effect on VMM, independent of gender and age.

Keywords: aging, visuomotor memory, physical exercise
Introduction

Aging is a complex dynamic, progressive and irreversible process which is linked to biological, psychological, cognitive, and social factors (Spirduso, Francis, & MacRae, 2005).

Cognitive aging is associated with decreases in memory, attention, and visuomotor performance and skills. Forgetfulness is a common complaint among older adults. Visual memory is a form of memory, which preserves some characteristics of our senses pertaining to visual experience, and is linked to the relationship between perceptual processing and the encoding, storage and retrieval of the resulting neural representations. The development of the visuospatial perception is a consequence of experience and it produces certain patterns of representation that are kept in one’s memory, with a progressive automation of the activation of some of them, as in mental rotation. Aging, as well as disease, will interfere with visuospatial representations (Sternberg, 2000).

A recent study with rats examining age-related changes in the detection of spatial novelty (e.g., Maasberg, Shelley, & Gilbert, 2012) by investigating if older rats showed significant deficits compared to younger rats in detecting spatial displacement of objects. The results showed that aged rats do not detect changes in object–place associations when exploring an environment.

In this regard, some studies, using both older adults and younger adults, investigated the neural correlates of aging-related changes during encoding and retrieval of spatial contextual memory (e.g., Kukolja, Thiel, Wilms, Mirzazade, & Fink, 2009) and aspects of episodic memory (e.g., Plancher, Gyselinck, Nicolas, & Piolino, 2010). These studies concluded that aging-related changes in neural activity were associated with impaired spatial memory, including episodic memory.

Fortunately, since the brain is capable of producing new brain cells at any age, significant memory loss is not an inevitable result of aging (Shors, 2009; Smith, Robinson, & Segal, 2012). Lifestyle, health habits, and daily activities seem to have a huge impact on brain health (Patoine et al., 2009). Among others, regular exercise seems to be an important factor in
counteracting age-related-cognitive skill changes, and thus helps to prevent memory loss. According to some authors, physical exercise (PE) is responsible for subjects experiencing a higher cognitive well-being (Barella, Etnier, & Chang, 2006; Berger, 1996; Brandão & Matsudo, 1990; Di Lorenzo et al., 1999; Gill, 1994; Grego et al., 2005; Kramer, 2000; Lachman, Neupert, Bertrand, & Jette, 2006; Spalding, Jeffers, Porges, & Hatfield, 2000). In fact, some studies found significant improvements on cognitive functions after older adults practiced a single session of aerobic exercise. The control group experienced no improvements (Netz, Argov, & Inbar, 2009; Netz, Tomer, Axelrad, Argov, & Inbar, 2007).

Moreover, regular exercise seems to boosts brain growth factors and encourages the development of new brain cells (Smith, Robinson, & Segal, 2012). Additionally, exercise also reduces the risk for disorders that lead to memory loss, such as diabetes and cardiovascular disease (American College of Sports Medicine, 1998; Siddiqui, Nessa, & Hossain, 2010; Smith, Robinson, & Segal, 2012).

According to the American College of Sports Medicine (1998), memory, as well as attention and reaction time, are some of the cognitive sphere points that are positively influenced by regular physical exercise.

However, there are some inconsistent results in studies that investigate the improvement of cognitive functions caused by PE (American College of Sports Medicine, 1998). Therefore, it is important to achieve a better understanding of the effects of exercise on the visuospatial memory in older adults.

Thus, the aim of this study was to compare the practitioners and non-practitioners of PE in visuomotor memory of older adults considering gender and age.

**Methods**

**Participants**

The study involves a sample of 74 older adults (54 women and 20 men) aged between 60 and 91 years old, divided into two main groups: 36
practitioners of PE (P - mean age of 70.22 ± 0.90 years) and 38 non-practitioners (NP - mean age of 68.26 ± 1.12 years).

All subjects were required to be in perfect physical and mental condition to perform the visuomotor memory test. Members of the NP group had not participated in any systematized PE program in the last twelve months. Members of the P group were involved in some kind of regular and systematic PE program for at least the last twelve months and participated in that program at least two times a week.

Four women of the NP group were excluded because they had musculoskeletal disorders that contra-indicated participation in the testing.

Both samples were also split in function of gender and age (younger old adults - from 60 to 70 years old, and older adults - more than 71 years old). The summary of the sample characteristics, according to gender and age, is illustrated in Table 1.

Table 1. Summary of the sample characteristics. Number and percentage of subjects.

<table>
<thead>
<tr>
<th>Characteristics of practitioners and non-practitioners of PE</th>
<th>Practitioners of PE</th>
<th>Non-practitioners of PE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N (%)</td>
<td>N (%)</td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>12 (17.2%)</td>
<td>08 (11.4%)</td>
</tr>
<tr>
<td>Females</td>
<td>24 (34.2%)</td>
<td>26 (37.2%)</td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>60 to 70 years old</td>
<td>21 (30%)</td>
<td>24 (34.3%)</td>
</tr>
<tr>
<td>71 or more</td>
<td>15 (21.4%)</td>
<td>10 (14.3%)</td>
</tr>
</tbody>
</table>

Participants in this study were tested individually and all of them gave informed consent. All the scientific procedures of this investigation followed the “Ethical Principles for Medical Research Involving Human Subjects” from the World Medical Association Declaration of Helsinki modified in Edinburgh (Archer & Osswald, 2000).
Instruments

Visuomotor memory test (Thinus-Blanc, Gaunet, & Péruch, 1996). A square was used with dimensions of 78.74\times 78.74 inches, perfectly delimited for an off-the-ground panel measuring 74.80 inches high. For the performance of the route, three points (A, B and C) were marked in this space, with A (in the middle of the sides of the square) being the starting point, B (placed in the diagonal of the sides of the square) 7.87 inches off the left corner, and C (also placed in the diagonal of the square), 9.84 inches off the right corner.

The visuomotor memory test implies that subjects go from A to point B and thereafter to point C, and from here return to the starting point A. Figure 1 shows the route followed in this study by the older adults to assess their visuomotor memory, and Figure 2 shows the apparatus of the visuomotor memory test.

Legend:
- Support with Stick: △
- Panel: □
- Performer: ♂
- Direction of the Route: → →

Figure 1. Map of the way of the visuomotor memory test.

Figure 2. VMM Apparatus.
The older adults performed the route twice in order to get familiar with the visuospatial information (spatial codification) and to retain it in the memory. Both courses were performed with eyes open and later on, at the test, the route was performed with the eyes closed. The time spent in performing the route as well as the number of errors were counted and registered by the researchers. It was considered an error when the participant gets away from the target, touches the panel or uses the feet or the hands to progress along the panel. The maximum time of performance was set at five minutes, above which the test was considered null (Thinus-Blanc, Gaunet, & Péruch, 1996).

**Statistical analysis**

The independent variables were represented by practice of PE, gender, and age. The dependent variables were the ones provided by the visuomotor memory test, according to the time to perform the route and the number of errors committed. All data was analyzed with Statistical Package for the Social Sciences (SPSS: version 19.0). Data was checked for distribution and all means ± SD, percentage, and coefficient of variation were calculated. Potential differences among groups were evaluated using a univariate analysis of variance (ANOVA). Significance level was set at $p \leq 0.05$.

**Results**

**Visuomotor memory in older practitioners and non-practitioners of PE in relation to gender and age.**

Table 2 presents the descriptive statistics (mean and standard deviation) and Figure 3 demonstrates graphically the means of the data obtained from the visuomotor memory test (time of performance and number of errors).

<table>
<thead>
<tr>
<th>Gender</th>
<th>Time of Performance</th>
<th>Number of Errors</th>
<th>Age</th>
<th>Time of Performance</th>
<th>Number of Errors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Practitioners of PE</td>
<td></td>
<td>Practitioners of PE</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Non- Practitioners of PE</td>
<td></td>
<td>Non- Practitioners of PE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>17.75±7.79</td>
<td>02.42±1.98</td>
<td>60 to 70 years old</td>
<td>30.55±37.02</td>
<td>07.95±4.97</td>
</tr>
<tr>
<td></td>
<td>14.98±133.70</td>
<td>47.78±49.89</td>
<td></td>
<td>80.6±109.61</td>
<td>25.87±29.37</td>
</tr>
<tr>
<td></td>
<td>30.01±34.88</td>
<td>06.00±14.40</td>
<td>71 or more</td>
<td>19.44±10.52</td>
<td>03.60±5.44</td>
</tr>
<tr>
<td></td>
<td>79.70±106.82</td>
<td>24.77±89.03</td>
<td></td>
<td>132.14±125.95</td>
<td>45.80±46.72</td>
</tr>
</tbody>
</table>
Figure 3. Means of performance time and number of errors in the visuomotor memory test in the practitioners and non-practitioners of physical exercise (PE), in relation to (A) each gender and (B) each age. * Statistical significance $p \leq 0.05$. 
The analysis of variance indicated a significant main effect of group, $[F_{1,69} = 16.892; p < 0.001]$ but not gender $[F_{1,69} = 1.638; p = 0.200]$ for time of performance. The ANOVA for errors also presented a significant main effect of group $[F_{1,69} = 14.621; p < 0.001]$ but not gender $[F_{1,69} = 1.145; p = 0.280]$.

Likewise, with respect to the time of performance, the analysis of variance showed a significant main effect for group $[F_{1,69} = 15.242; p < 0.001]$ but not for age $[F_{1,69} = 0.941; p = 0.336]$. The ANOVA for errors also presented a significant main effect for group $[F_{1,69} = 14.371; p < 0.001]$ but not for age $[F_{1,69} = 1.354; p = 0.240]$.

Discussion

The present study aimed to compare the visuomotor memory (VMM) of active older adults and inactive older adults, taking into consideration gender and age.

The results showed that active adults presented a better performance both in terms of time and number of errors committed than did non-practitioners of PE.

Studies about VMM in old age are scarce and they all relate to visuospatial memory terminology and emphasize the existence of a decline with age. Some of the papers about spatial memory, like the ones written by Kukolja, Thiel, Wilms, Mirzazade and Fink (2009), Boutet and Faubert (2006), and Holtzer, Stern and Rakitin (2004) point to a decline with age related to complex scenes or images. In spite of aging, our results demonstrated that PE has a positive effect in VMM, independent of gender and age.

In addition, researchers such as Boutet and Faubert (2006), Lamont, Williams and Podd (2005), and Crook and Larrabee (1992) state the existence of a decline with age related to memory for faces. Lipman and Caplan (1992) report that memories related to urban routes present a gradual decline with aging. Also, Salthouse (1992) and Salthouse and Miles (2002) mention a strong decline in older adults’ abilities of thinking, memory, and spatial tasks related to the memory of faces, urban routes, maps of museums, and places of buildings in cities. As expected, the authors reported that losses emerge at the level of
VMM with aging. However, our study found that older adults who participated in PE experience better VMM compared to non-practitioners; hence, exercise seems to counteract the effects of aging in cognitive processes.

Although the majority of the studies have suggested a decline of memory with aging (Birren & Shaie, 1996; Elias, Elias, D’Agostino, & Wolf, 1997; Gerven, Paas, Merriënboer, & Schmidt, 2000; Kramer, 2000; Kramer & Larish, 1996; Salthouse, 1996), our study verified that practitioners of PE experience a greater amount of visual, manual, and pedal information provided by the exercises; consequently, this helped improve their expected VMM. In summary, we can extrapolate that physical exercise contributes to improving VMM because the tasks in the practice sessions require constant demands to cognition.

This is in accordance with many authors who suggest that the cognitive processes can be improved with systematic exercise (Barry, Steinmetz, Page, & Rodahl, 1966; Baylor & Spirduso, 1988; Clarkson-Smith & Hartley, 1989; Colcombe et al., 2003; Colcombe et al., 2006; Emery & Getz, 1990; Stones & Kozma, 1989). In spite of the contradictory data where some studies (Angevaren, Aufdemkampe, Verhaar, Aleman, & Vanhees, 2008a, 2008b; Blumenthal et al., 1989; Blumenthal & Madden, 1988) did not find any significant improvement after training in older subjects’ memories, the majority of the studies are in accordance with our results and indicate that exercise, namely aerobic training, enhances cognitive function (Erickson & Kramer, 2009; Erickson et al., 2011; Netz, Argov, & Inbar, 2009; Netz, Tomer, Axelrad, Argov, & Inbar, 2007; O’Dwyer, Burton, Pachana, & Brown, 2007). However, further studies will be necessary to confirm if regular exercise improves the cognitive processes in a consistent manner (Dustman, Emmerson, & Shearer, 1994; Spirduso, Francis, & MacRae, 2005). Furthermore, given the proportion of older adults reporting memory problems, it is necessary to determine whether improvements in motor fitness brought about by a physical exercise program can result in subsequent attenuation of VMM problems, or potentially in improvements in VMM.
In a test of spatial orientation where adult subjects were to follow a route on a map, Kimura (1992) concluded that males and females present differences in the ways they orient themselves. The author found that, in the test, males learned the route in fewer attempts and with fewer errors than the females. The males used strategies of coordinates – north-south, left-right, distance-speed. On the contrary, females used an orientation involving memory of the location of shops, markets, and places with some special characteristics.

The results of our study found that gender and age did not influence VMM performance, and for this reason, are contrary to previous studies. Furthermore, the practitioners of regular physical exercise presented better VMM in both genders suggesting that the memory visuomotor tests required psychomotor ability, vigilance (attention and concentration), perceptual acuity, information processing, short term memory, and motor planning. These abilities are a consequence of physical exercise (American College of Sports Medicine, 1998; Baddeley, 1992a; Baddeley, 1992b; Grieve, 2005; Magill, 2011).

A study by Botelho (2006), involving 46 Portuguese older adults of both sexes between 65 to 93 years old, found that those who had participated in exercise for the last five years had better results in visuomotor memory than the non-exercise practitioners. Our results are consistent with this Portuguese author in suggesting that regular PE is very important to maintain, or even improve, visuomotor memory in older adults.

The major limitation of this study was finding a sufficient number of older adults with a high level of education. Because it was our intention to include the assessment of the effects of educational status on VMM in the initial objectives; this variable should be included in future investigations. Likewise, our study was transversal; however, it is important to mention the need for longitudinal studies. It is essential to analyze the variations in the characteristics of the same sample elements.

A key strength of this study is that, to our knowledge, there is not much information or systematic research on this subject. Therefore, our results contribute to a better understanding of the relationship between a cognitive variable (memory) and physical exercise in older adults of both genders.
In summary, our study reveals that PE induces significant effects in visuomotor memory. The same effects did not occur with gender and age level factors. However, taking into account the our cross-sectional study design, more studies are necessary to investigate if practice of systematic PE, can decrease, in a gradual way, the effects of aging on older persons’ cognition, namely on visuomotor memory.

**Ethics approval**

The study was approved by institutional review board.

**Acknowledgements**

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Interrelations between the Modified Baecke Questionnaire and Accelerometry in Assessing the Physical Activity of Portuguese Older Adults

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(Resubmitted after reviewers’ comments)

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Abstract

The present study intended to contribute to the interrelations between the Modified Baecke Questionnaire and accelerometry, so that it becomes a credible tool in future studies to assess the levels of physical activity in older adults. The sample included 59 subjects aged between 65 and 84 years old (mean age of 72.81 ± 5.40), 39 institutionalized (mean age of 73.62 ± 5.47) and 20 non-institutionalized (mean age of 71.25 ± 5.02) of both sexes, 14 males (mean age of 73.07 ± 5.90) and 45 females (mean age of 72.73 ± 5.30).

The instruments used in the data collection were the ActiGraph GT1M accelerometer, which was applied to all subjects of the sample during seven days and the Modified Baecke Questionnaire, completed by means of an interview.

Comparing the measurements obtained from these two instruments, we verified that the correlation is high ($r = 0.665$) and statistically significant ($p < 0.05$), leading us to infer that there is a good association between the values of both assessment methods. These data show that the Modified Baecke Questionnaire is an instrument with good validity coefficients, with the advantage of being practical, fast, easily understandable and enabling the assessment of a great number of subjects, thus representing a great alternative to the accelerometer.

**Keywords:** aging, Modified Baecke Questionnaire, accelerometer, physical activity, measurement
Introduction

Physical activity (PA) has been defined as any movement performed by the muscles that results in energy expenditure (Caspersen, Powell, & Cristenson, 1985). This energy expenditure varies with the duration and intensity of exercise (Montoye, Kemper, Saris, & Washburn, 1996). We can say that PA is characterized by any energy expenditure when a movement is carried out, regardless the type of PA or the context in which it occurs (leisure, work, sports, etc.).

PA is known to have a positive effect on functionality and health and contribute to developing and maintaining a high quality of life (Warburton, Charlesworth, Ivey, Nettlefold, & Bredin, 2010; Warburton, Katzmarzyk, Rhodes, & Shephard, 2007). However, the relationship between PA and health has raised some questions such as the type and quantity of PA indicated for different age groups, considering the differences of each subject (Rabacow, Gomes, Marques, & Benedetti, 2006).

Therefore, the accurate measurement of habitual PA is fundamental to both the epidemiological study of relationship between PA and health and the recommendation of an appropriate pattern of PA to maintain good health (Bouchard, 2001; Macera & Powell, 2001).

Several techniques have been used to assess PA such as questionnaires, diaries, seven-day recall, movement sensors and doubly labeled water. Most of these methods calculate the energy expenditure associated with the activity. Questionnaires are the most widely used method to obtain information on PA, owing to their low cost, simplicity, briefness and ease for study participants (Shephard & Aoyagi, 2011).

However, most questionnaires are considered subjective methods, where participants can easily overestimate or underestimate their time spent on activities. With questionnaires, older adults may be prone to recall problems, since they may suffer from impaired memory. According Jorstad-Stein et al. (2005), the use of questionnaires is not recommended with older subjects.

The Modified Baecke Questionnaire, (Vorrips, Ravelli, Dongelmans, Durenberg, & Van Staveren, 1991) which has been used frequently over the
past year to measure habitual PA in older adults, was originally designed by Baecke, Burema and Frijters Baecke in Netherlands in 1982. Likewise, Bonnefoy et al. (2001) conducted a study that compared several questionnaires with doubly labeled water. The results of that study showed relatively low correlation coefficients between doubly labeled water and the Modified Baecke Questionnaire ($r = 0.28$).

The Modified Baecke Questionnaire has been shown to generate valid and reliable classification scores for activity in a group of older adults (Vorrips, Ravelli, Dongelmans, Durenberg, & Van Staveren, 1991), but to our best knowledge, no Portuguese versions of this instrument have been validated so far.

Measurements of energy expenditure using doubly labeled water are commonly accepted as the optimum for PA questionnaire validation (Shephard, 2003). However, the necessary analyses are costly and the data provides a two-week average of energy expenditure at best. Alternatively, some form of motion sensor such as the accelerometer has provided a second, cheaper construct.

The purpose of this study is to contribute to the validation of the Modified Baecke Questionnaire in the Portuguese-speaking population, so that it becomes a credible tool in future studies about PA performed with Portuguese older adults.

**Methods**

**Participants and protocol**

The sample includes 59 subjects aged between 65 and 84 years old (mean age of 72.81 ± 5.40), 39 institutionalized (mean age of 73.62 ± 5.47) and 20 non-institutionalized (mean age of 71.25 ± 5.02), and 14 males (mean age of 73.07 ± 5.90) and 45 females (mean age of 72.73 ± 5.30). Institutionalized older adult users were recruited from two daily living centers and one residential care home, and non-institutionalized older adults were recruited from the district of Porto and they were invited by the Faculty of Sport, University of Porto, Portugal.
None of the subjects demonstrated any serious illness or abnormality that would influence the study results or had preexisting contraindications that would prevent them from following the rules of the accelerometer. As for the selection criteria for the sample, we selected older adults who could move by themselves and follow the rules of the accelerometer. The investigation was conducted according to the principles outlined in the Declaration of Helsinki. The study was approved by the institutional review board.

The older adults were recruited to put on an accelerometer for seven consecutive days and then answer a Baecke, Burema and Frijters questionnaire (1982) that had been modified and validated for older adults by Vorrips, Ravelli, Dongelmans, Durenberg and Van Staveren (1991).

**Accelerometer ActiGraph GT1M**

The participants met to learn how to use the accelerometer (GT1M model by ActiGraph) over the next seven days (recording five weekdays, Saturday and Sunday), as an objective measure of daily PA. The GT1M model of the accelerometer (Manufacturing Technology, Fort Walton Beach, FL) is a small monitor (dimensions 3.8 x 3.7 x 1.8 cm, weight 27 g). This biaxial accelerometer is designed to detect vertical and horizontal accelerations ranging from approximately 0.05 to 2.0 G with a frequency range of 0.25 to 2.50 Hz. To get the results of the PA levels, the interval of the data record (epoch) was 15 seconds to allow a more detailed estimation of the PA intensity.

The accelerometer was placed on participants' waists just above their hip, always on the right side, with an elastic belt, according to the recommendations of Freedson, Melanson and Sirard (1998). Subjects were provided with written instructions regarding care and placement of the accelerometers. A daily record sheet of paper was given to each individual to record the time of placement of the accelerometer, providing instructions for removing the accelerometers each time they go sleep or performed any water-related activities such as showering and swimming.

Data from each monitor were downloaded by the investigators, and the periods of consecutive minutes of zeros (inactivity) were excluded. The ActiLife
Lifestyle Monitoring System software version 4.4.1 and firmware version 6.0 was used to examine the data.

The levels of activity were expressed in counts per minute \((\text{counts.min}^{-1})\) (number of records during one minute), steps and \text{counts.time} (expresses the minutes in sustained activity for periods of 10 minutes).

The counts of activity were processed to determine the time spent in the different intensities of PA (moderate to vigorous, light and sedentary activity). To classify the PA intensity we used cut-off points related to adults (Davis & Fox, 2006; Freedson, Melanson, & Sirard, 1998; Matthews, 2005).

Table 1 presents the cut-off points from which the classification of the PA was done.

<table>
<thead>
<tr>
<th>Intensity</th>
<th>Counts.min-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sedentary</td>
<td>0-99</td>
</tr>
<tr>
<td>Light</td>
<td>100-1951</td>
</tr>
<tr>
<td>Moderate</td>
<td>1952-5724</td>
</tr>
<tr>
<td>Vigorous</td>
<td>5725-9498</td>
</tr>
<tr>
<td>Very Vigorous</td>
<td>&gt;9498</td>
</tr>
</tbody>
</table>

**Modified Baecke Questionnaire**

The level of daily PA for each subject was also assessed using the Modified Baecke Physical Activity Questionnaire (appendices 1 and 2), which was completed by the same researcher during a personal interview (Vorrips, Ravelli, Dongelmans, Durenberg, & Van Staveren, 1991), after the collection of the accelerometers. This questionnaire (1982) includes three major parts and it refers to the participant’s usual activities over the previous year. The first part asks the subjects about their usual house chores. The second part addresses issues related to the practice of sports activities, and the third part refers to leisure time activities. Each part has a score, and the sum of the three parts...
results in a total PA score, where the higher values indicate greater subject activity.

Thus, there are a domestic activity score (DAS), a sport activity score (SAS) and finally a leisure-time activity score (LTS). The DAS is the result of the sum of the number of each question in this domain, divided by the number of questions.

The sport and leisure time activity scores are calculated as the sum of intensity multiplied by time, multiplied by the proportion of time in a year spent doing that activity. An intensity code, originally based on net energetic costs of activities is used to classify each activity. It has a high test-retest reliability ($r = 0.89$), and when compared with objective measures such as pedometers and doubly labeled water, it shows a Spearman’s correlation of 0.73 and 0.69; $p < 0.001$ (Philippaerts, Westerterp, & Lefevre, 1999; Vorrips, Ravelli, Dongelmans, Durenberg, & Van Staveren, 1991).

**Statistical analysis**

We used the Statistical Package for the Social Sciences (SPSS: version 19.0) for the statistical analysis of the study variables.

The descriptive statistics ($M \pm SD; range$) were computed. After an exploratory analysis with the Kolmogorov-Smirnov test, non-parametric statistics were used.

The Spearman’s correlation coefficient ($\rho$) was used to assess the relationship between the accelerometer and the Modified Baecke Questionnaire, and Cohen’s Kappa was used to assess the level of concordance between the two instruments. The level of significance in all the statistical tests was fixed in $p \leq 0.05$.

Participants were categorized according to the measurements from the self-administered questionnaire and the accelerometer.
Results

Assessment of PA: ActiGraph’s GT1M accelerometer and the Modified Backe’s Questionnaire

The sample was divided into three groups in relation to the levels of PA shown by accelerometry (time in minutes of moderate to vigorous activity, light activity and sedentary activity) (Table 2).

Taking into account the reduced values of vigorous and very vigorous PA (during the seven days of monitorization), these categories were combined according to the recommendations from the Physical Activity Guidelines for Americans (2008) into moderate to vigorous activity (MVA).

Table 2. Weekly total volume (minutes) of moderate to vigorous, light, and sedentary activity. All values as median, inter-quartile range, minimum, and maximum. Mean and standard deviation, and range values.

<table>
<thead>
<tr>
<th>Intensity</th>
<th>M ± SD</th>
<th>range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moderate to vigorous</td>
<td>68.22 ± 95.03</td>
<td>0 – 400</td>
</tr>
<tr>
<td>Light</td>
<td>1229.31 ± 672.77</td>
<td>166 – 2673</td>
</tr>
<tr>
<td>Sedentary</td>
<td>4280.37 ± 1810.72</td>
<td>949 – 8134</td>
</tr>
</tbody>
</table>

Table 3 presents the values of count.min⁻¹, count.time, and steps obtained with the ActiGraph GT1M accelerometers.

Table 3. Values of the total sample of PA recorded in count.min⁻¹, count.time, and steps. All values as median, inter-quartile range, minimum, and maximum. Mean and standard deviation, and range values.

<table>
<thead>
<tr>
<th>Intensity *</th>
<th>M ± SD</th>
<th>range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Count.min⁻¹</td>
<td>978.43 ± 726.01</td>
<td>68 – 2727</td>
</tr>
<tr>
<td>Count.time</td>
<td>14.81 ± 36.91</td>
<td>0 – 173</td>
</tr>
<tr>
<td>Step</td>
<td>3795.52 ± 3289.34</td>
<td>247.57 – 13476.67</td>
</tr>
</tbody>
</table>

* Metabolic equivalents (METs) in each activity were obtained from the compendium of American College of Sports and Medicine (ACSM) (Ainsworth et al., 2000). The activity cut-off points in MET values and “Counts” per minute for the accelerometer were adapted on the study of Freedson, Melanson and Sirard (1998); sedentary
activity (<3 METs = 0-1951 count.min⁻¹); light activity (3-6 METs = 1952-5724 count.min⁻¹); and MVA (7-8 METs = 5725-9497 count.min⁻¹ / ≥9 METs = ≥9498 count.min⁻¹).

Table 4 shows the estimations of PA obtained through the Modified Baecke Questionnaire.

Table 4. Values (total sample) of the domestic activity score (DAS), sport activity score (SAS), leisure-time activities score (L-TAS), and the total score of the Questionnaire. All values as median, inter-quartile range, minimum, and maximum. Mean and standard deviation, and range values.

<table>
<thead>
<tr>
<th>Activities</th>
<th>M ± SD</th>
<th>range</th>
</tr>
</thead>
<tbody>
<tr>
<td>DAS</td>
<td>1.29 ± 0.74</td>
<td>0.2 – 2.8</td>
</tr>
<tr>
<td>SAS</td>
<td>0.77 ± 0.73</td>
<td>0.00 – 4.29</td>
</tr>
<tr>
<td>L-TAS</td>
<td>0.09 ± 0.37</td>
<td>0.00 – 1.89</td>
</tr>
<tr>
<td>Total Score</td>
<td>2.14 ± 1.35</td>
<td>0.20 – 6.68</td>
</tr>
</tbody>
</table>

In summary, the most relevant results are presented in the tables above, showing that: (i) the mean of the time values in which the older adults were sedentary was 4280.37 ± 1810.72 minutes, presenting a minimum of 949 minutes and a maximum time of 8134 minutes (Table 2); (ii) the older adults were in movement or activity during 978.43 ± 726.01 minutes for a week. From the time they were active, 14.81 ± 36.91 minutes were spent in sustained activity in periods of 10 minutes. During the time of monitorization, the older adults took 3795.52 ± 3289.34 steps (Table 3); and (iii) the total PA score measured with the Modified Baecke Questionnaire was 2.14 ± 1.35 points, with domestic activity (1.29 ± 0.74 points) being the most influential result in the total score (Table 4).

Correlation between the accelerometer and the Modified Baecke Questionnaire

Table 5 shows the correlation between the assessment methods of PA: ActiGraph GT1M accelerometer and Modified Baecke Questionnaire.
Table 5. Correlation matrix between the GT1M accelerometer and the Modified Baecke Questionnaire - domestic activity score (DAS), sport activity score (SAS), and leisure-time activities score (L-TAS). Values of \( r \) of Spearman and significant values \( p \).

<table>
<thead>
<tr>
<th></th>
<th>Count.min(^{-1})</th>
<th>Count.time</th>
<th>Steps</th>
<th>DAS</th>
<th>SAS</th>
<th>L-TAS</th>
<th>ScoreTotal</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Count.min(^{-1})</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( r )</td>
<td>1</td>
<td>0.609*</td>
<td>0.915*</td>
<td>0.728*</td>
<td>0.341*</td>
<td>0.270*</td>
<td>0.665*</td>
</tr>
<tr>
<td>( p )</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.008</td>
<td>0.039</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td><strong>Count.time</strong></td>
<td><strong>ró</strong></td>
<td>0.609*</td>
<td>1</td>
<td>0.680*</td>
<td>0.458*</td>
<td>0.443*</td>
<td>0.296*</td>
</tr>
<tr>
<td>( p )</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.023</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td><strong>Steps</strong></td>
<td><strong>ró</strong></td>
<td>0.915*</td>
<td>0.680*</td>
<td>1</td>
<td>0.688*</td>
<td>0.377*</td>
<td>0.239</td>
</tr>
<tr>
<td>( p )</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.023</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td><strong>DAS</strong></td>
<td><strong>ró</strong></td>
<td>0.728*</td>
<td>0.458*</td>
<td>0.688*</td>
<td>1</td>
<td>0.364*</td>
<td>0.178</td>
</tr>
<tr>
<td>( p )</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.005</td>
<td>0.178</td>
<td>0.000</td>
</tr>
<tr>
<td><strong>SAS</strong></td>
<td><strong>ró</strong></td>
<td>0.341*</td>
<td>0.443*</td>
<td>0.377*</td>
<td>0.364*</td>
<td>1</td>
<td>0.371*</td>
</tr>
<tr>
<td>( p )</td>
<td>0.008</td>
<td>0.000</td>
<td>0.003</td>
<td>0.005</td>
<td>0.004</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td><strong>L-TAS</strong></td>
<td><strong>ró</strong></td>
<td>0.270*</td>
<td>0.296*</td>
<td>0.239</td>
<td>0.178</td>
<td>0.371*</td>
<td>1</td>
</tr>
<tr>
<td>( p )</td>
<td>0.039</td>
<td>0.023</td>
<td>0.068</td>
<td>0.178</td>
<td>0.004</td>
<td>0.002</td>
<td>0.000</td>
</tr>
<tr>
<td><strong>ScoreTotal</strong></td>
<td><strong>ró</strong></td>
<td>0.665*</td>
<td>0.521*</td>
<td>0.653*</td>
<td>0.868*</td>
<td>0.750*</td>
<td>0.398*</td>
</tr>
<tr>
<td>( p )</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.002</td>
</tr>
</tbody>
</table>

* Significant correlation \( p \leq 0.05 \).
The total questionnaire score was significantly \((p < 0.001)\) and highly \((r = 0.665)\) associated with the accelerometer’s count.min\(^{-1}\). There was also a high and statistically significant correlation between the count.min\(^{-1}\) and the DAS \((r = 0.728; p < 0.001)\), a moderate significant \((r = 0.341; p = 0.008)\) correlation between the count.min\(^{-1}\) and the SAS, and a significant \((p = 0.039)\) but low \((r = 0.270)\) correlation between the count.min\(^{-1}\) and the score of leisure-time activity.

For the count.time, there was a moderate and significant correlation with the score of sports activities \((r = 0.443, p < 0.001)\) and the questionnaire total score \((r = 0.521; p < 0.001)\). Also, there was a moderate and significant correlation between accelerometer’s steps and the total score of the questionnaire \((r = 0.653; p < 0.001)\).

**Concordance between the values of the accelerometer and the Modified Baecke Questionnaire**

Table 6 presents the concordance between the recorded count.min\(^{-1}\) and moderate to vigorous activity (MVA) by the accelerometer, and the total score of the Modified Baecke Questionnaire.

**Table 6.** Concordance between the total score and the count.min\(^{-1}\) / moderate to vigorous activity (MVA). Number of less active and more active subjects.

<table>
<thead>
<tr>
<th>Count.min(^{-1}) / MVA</th>
<th>Less active (n)</th>
<th>More active (n)</th>
<th>(x^2)</th>
<th>(p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Score</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less active</td>
<td>23</td>
<td>7</td>
<td>16.28</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>More active</td>
<td>7</td>
<td>22</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kappa of Cohen</td>
<td>0.525</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The kappa coefficient for the concordance between the information obtained with the questionnaire and the reference method in terms of counts.min\(^{-1}\) and MVA was 0.525 \((p < .001)\).
Discussion

This study aimed to contribute to validate Portuguese version of the Modified Baecke Questionnaire using accelerometry to assess PA in Portuguese older adults. According to Lamonte and Ainsworth (2001), the accelerometry that uses movement sensors (e.g., accelerometers) is considered a direct method of daily PA assessment, while the questionnaire is considered indirect.

In our study, the correlations between the estimates obtained by the Modified Baecke Questionnaire and the objective measurement (biaxial accelerometer) for PA were sufficient to good ($r_ó = 0.665; p < .001$). These results were also found by Santos, Hirayama and Gobbi (2005), who investigated the validity of the Modified Baecke Questionnaire through the number of moments recorded by the pedometer. The results showed that the correlation coefficient was 0.72, which is also considered high and an indicator of a good association between the two methods.

Likewise, other studies also used different types of monitors/accelerometers to examine the validity of the Baecke Questionnaire in adults and older adults. Philippaerts, Westerterp and Lefevre (2001) reported a validation of a total 0.47 with the Tracmor (tri-axial accelerometer) in adult males. Voorrips, Ravelli, Dongelmans, Deurenberg and Van Staveren (1991) adapted this questionnaire, reporting a validation of 0.73 with the pedometer in healthy older adults aged 63-80 years. Finally, Pols et al. (1995) found that, with the accelerometer and questionnaire, the repeatability after 5 and 11 months was good with test-retest correlation coefficients between 0.65 and 0.89 for the main sections of the questionnaire in adults of both sexes, aged 20–70 years. Moreover, at a younger age, De Cocker, De Bourdeaudhuij and Cardon (2009) found a validation of 0.44 with the pedometer and the Baecke questionnaire in adults of both sexes, with a mean age of 38.7 years.

Our results (a sufficient to good correlation – $r_ó = 0.665; p < .001$) are also sustained by other studies that yielded moderate to good correlations, namely, comparative tools used against the Baecke Questionnaire include aerobic capacity/maximal oxygen consumption. Jacobs, Ainsworth, Hartman
and Leon (1993) found a validation of total 0.54 with the VO2 max and the Baecke in American male and female adults, aged 20–59 years. This suggests that the Baecke Questionnaire was the most accurate method of compiling information on high-intensity activities.

In addition, our results from the Modified Baecke Questionnaire have a reasonable validity about PA, that is, other studies used comparative tools against the Baecke Questionnaire, which includes PA diaries and doubly labeled water. For example, Pols et al. (1995) reported a validation of 0.56 for males and 0.44 for females with the PA diaries and the Baecke in subjects aged 20–70 years. Philippaerts, Westerterp and Lefevre (1999) found a validation total of 0.68 with the doubly labeled water and the Baecke, with subjects mean aged 40 years. Furthermore, this suggests that published correlation coefficients varied widely between the different comparative tools. Also studies investigating the validity of the same questionnaire in different populations resulted in dissimilar correlation coefficients, indicating that one should be cautious when generalizing results to populations with different characteristics, namely, adults and older adults or females and males.

In summary, the Baecke Questionnaire can provide valid data about PA. According to some studies (e.g., Guirao-Goris, Cabrero-Garcia, Moreno Pina, & Muñoz-Mendoza, 2009; Vilaró et al., 2007), the results demonstrated the validity and reliability of the Modified Baecke Questionnaire. Therefore, its use is recommended. Likewise, accelerometry data are considered a reliable and valid standard to examine one’s individual PA level (Butte, Ekelund, & Westerterp, 2012; Chen & Bassett, 2005; Dongwoo & Kim, 2007).

Our results showed a good association between the values obtained by accelerometry and the Modified Baecke Questionnaire.

Through the values obtained with the Modified Baecke Questionnaire, it was observed that the value with the most influence in the total score was the value of domestic activities. In our opinion, this evidence is justified by the fact that the majority of the subjects in the sample were females (76.27 per cent).

These results may be related to the fact that in the Portuguese population census of 2002 (National Statistics Institute), domestic activities such
as cooking and cleaning were performed mainly by women, while gardening, shopping and administrative work were shared by both sexes. The older adults said talking to neighbors was their most important social activity (68 per cent daily). Ninety-six per cent mentioned watching TV as their most frequent leisure activity. The level of activity and community participation was very low. On average, less than 5 per cent of the individuals reported that they participated in community activities and organizations and the majority said they stayed at home all day (Paúl, Fonseca, Martín, & Amado, 2005).

In our study, the values of leisure-time activities emerge as the lowest, which allows us to understand that, in this age group, the older adults spend little free time performing activities that are not sedentary. We emphasize that our results are in agreement with the study by Varo et al. (2003), who found that the prevalence of sedentary lifestyle in the European Union is high.

The results of this study are similar to those of Carvalho, Feijó, Teixeira and Mota (2002), who also investigated the standards of PA in Portuguese older adults with accelerometry. They concluded that, during the time of monitorization, subjects occupied a great percentage of their time in light activities and a much lower percentage performed moderate to vigorous activities.

In conclusion, the results of this analysis demonstrate that it is an instrument with a good level of validity in Portuguese-speaking institutionalized and non-institutionalized older adults. The questionnaire’s advantages such as being practical, fast, easy to understand and inexpensive support the use of this questionnaire in epidemiological studies that include Portuguese-speaking subjects, representing a great alternative to the accelerometer.

Dale, Welk, and Matthews (2002) refer to some limitations that should be present at the time of using the accelerometers, including the time spent processing and analyzing the data, the financial cost of monitors, and problems with monitor placement when data are collected over a number of days.

The major limitation of our study was the size of the sample, including more females than males and the use of the biaxial accelerometer instead of the triaxial model (triaxial accelerometers obtain better estimations than other
accelerometers, since under normal conditions, individuals make multi-
directional movements) (Bouten, Westerterp, Verduin, & Janssen, 1994).

The key strengths of our study are that, first, we included institutionalized
and non-institutionalized older adults; second, we contribute to validate an
instrument that has been widely used with success in older adult PA
epidemiology for use in the Portuguese-speaking population.

Conclusion

Taking these findings together, despite the limitations above, our data
demonstrate the validity of the Modified Baecke Questionnaire about PA in
Portuguese-speaking older adults. This is of great importance since this report
supports the use of this inexpensive, practical, fast and easy to understand
questionnaire in epidemiological studies that include Portuguese-speaking older
subjects.

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Appendix 1: Modified Baecke Questionnaire.

**Domestic Activities**
(What are your domestic activities? How do you consider them?)

1. Do you perform any light domestic activities (making beds, washing the dishes, etc.) ( )
   - 0. Never (less than 1 time a month)
   - 1. Sometimes (only when I don't have someone to help)
   - 2. Often (sometimes with the help of someone else)
   - 3. Always (alone or with help)

2. Do you perform heavy domestic activities (wash the floor or windows, wash the car, etc.)? ( )
   - 0. Never (less than 1 time a month)
   - 1. Sometimes (only when I don't have someone to help)
   - 2. Often (sometimes with the help of someone else)
   - 3. Always (alone or with help)

3. For how many people do you perform household chores (including yourself, "0" if you answered never in questions 1 and 2)? ( )

4. How many rooms do you usually clean in your house, including the kitchen, bedroom, garage, attic, bathroom, etc. ("0" if you answered never in questions 1 and 2)? ( )
   - 0. None
   - 1. 1 to 6 rooms
   - 2. 7 to 9 rooms
   - 3. 10 or more rooms

5. If you clean some, how many floors are there in your house? ("0" is never answered in questions 1 and 2)? ( )

6. Do you cook or help someone in this kind of task? ( )
   - 0. Never
   - 1. Sometimes (1 to 2 times a week)
   - 2. Often (3 to 5 times a week)
   - 3. Always (more than 5 times a week)

7. How many flights of stairs do you usually climb a day? (one includes 10 stairs) ( )
   - 0. I never climb stairs
   - 1. 1 to 5
   - 2. 6 to 10
   - 3. Over 10
8. Which means of transport do you use to travel in your city?  
   0. I never leave home  
   1. The car  
   2. Public Transport  
   3. The Bicycle  
   4. I walk  

9. How often do you leave home or go shopping?  
   0. Never or less than 1 time a week  
   1. 1 time a week  
   2. 2 to 4 times a week  
   3. Every day  

10. When you leave to go shopping which means of transport do you use?  
    0. I never go shopping  
    1. The car  
    2. Public Transport  
    3. The Bicycle  
    4. I walk  

---

**Domestic Activity Score (DAS) = (Q1+Q2+……………Q10/10)**

**Sport Activities**

Do you practice any sports?

<table>
<thead>
<tr>
<th>Name</th>
<th>Intensity</th>
<th>Number of Hours/Week</th>
<th>Period of the Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sport 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sport 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sport 3</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Sport Activity Score (SAS) = \( \sum (i_a \times i_b \times i_c) \)**
### Leisure-Time Activities

Do you perform any other type of physical activity?

<table>
<thead>
<tr>
<th>Name</th>
<th>Intensity</th>
<th>Number of Hours/Week</th>
<th>Period of the Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activity 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Activity 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Activity 3</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Leisure-Time Activity Score** = \( \sum (ia*ib*ic) \)

**Questionnaire Score** = DAS + SAS + L-TAS

### Table of Codes for the Modified Baecke Questionnaire

**Intensity:**
- 0. Laying without load ................................................................. Code 0.028
- 1. Sitting without load ............................................................... Code 0.146
- 2. Sitting with movements of upper limbs ....................................... Code 0.297
- 3. Sitting with body movements .................................................... Code 0.703
- 4. Standing position without load ................................................ Code 0.174
- 5. Standing position with upper limb movements ................................ Code 0.307
- 6. Standing position with body movements, walking ........................ Code 0.890
- 7. Walking, with upper limb movements .......................................... Code 1.368
- 8. Walking, with body movements, cycling, swimming ........................ Code 1.890

**Number of Hours a Week:**
- 0. Less than 1 hour a week ............................................................. Code 0.5
- 1. 1 to 2 hours a week .................................................................... Code 1.5
- 2. 2 to 3 hours a week .................................................................... Code 2.5
- 3. 3 to 4 hours a week .................................................................... Code 3.5
- 4. 4 to 5 hours a week .................................................................... Code 4.5
- 5. 5 to 6 hours a week .................................................................... Code 5.5
- 6. 6 to 7 hours a week .................................................................... Code 6.5
- 7. 7 to 8 hours a week .................................................................... Code 7.5
- 8. More than 8 hours a week ............................................................. Code 8.5

**Months a Year:**
- 0. Less than a month a year ............................................................. Code 0.04
- 1. 1 to 3 months a year .................................................................... Code 0.17
- 2. 4 to 6 months a year .................................................................... Code 0.42
- 3. 7 to 9 months a year .................................................................... Code 0.67
- 4. More than 9 months a year ............................................................ Code 0.92
Appendix 2: Questionário de Baecke Modificado.

**Atividades Domésticas**

(Quais as suas atividades domésticas? Como as considera?)

1. Realiza tarefas domésticas ligeiras (fazer a cama, lavar a louça, etc.) ( )
   1. Nunca (menos de 1 vez por mês)
   2. Por vezes (apenas quando não tem ajuda)
   3. Frequentemente (algumas vezes com ajuda)
   4. Sempre (sozinho ou com ajuda)

2. Realiza tarefas domésticas pesadas (lavar o chão e/ou janelas, lavar o carro, etc.)? ( )
   1. Nunca (menos de 1 vez por mês)
   2. Por vezes (apenas quando não tem ajuda)
   3. Frequentemente (algumas vezes com ajuda)
   4. Sempre (sozinho ou com ajuda)

3. Para quantas pessoas faz a manutenção da casa (incluindo você mesmo; “0” se respondeu Nunca nas questões 1 e 2)? ( )

4. Quantos compartimentos da casa costuma limpar, incluindo cozinha, quarto, garagem, sótão, casa de banho, etc. (“0” se respondeu Nunca nas questões 1 e 2)? ( )
   1. Nenhum
   2. 1 a 6 compartimentos
   3. 7 a 9 compartimentos
   4. 10 ou mais compartimentos

5. Se limpa alguns, por quantos pisos é que eles se dividem? (“0” se respondeu Nunca nas questões 1 e 2)? ( )

6. Cozinha ou ajuda alguém neste tipo de tarefa? ( )
   1. Nunca
   2. Por vezes (1 a 2 vezes por semana)
   3. Frequentemente (3 a 5 vezes por semana)
   4. Sempre (mais de 5 vezes por semana)
7. Quantos lanços de escada sobe habitualmente por dia? (um lanço inclui 10 escadas) 
   1. Nunca subo escadas 
   2. 1 a 5 
   3. 6 a 10 
   4. Mais de 10

8. Que tipo de transporte utiliza para se deslocar na sua cidade? 
   1. Nunca saio 
   2. Carro 
   3. Transporte público 
   4. Bicicleta 
   5. A pé

9. Com que frequência costuma sair de casa ou ir às compras? 
   1. Nunca ou menos de 1 vez por semana 
   2. 1 vez por semana 
   3. 2 a 4 vezes por semana 
   4. Todos os dias

10. Quando sai para ir às compras que tipo de transporte utiliza? 
    1. Nunca vou às compras 
    2. Carro 
    3. Transporte público 
    4. Bicicleta 
    5. A pé

Score da Atividade Doméstica (SAD) = (Q1+Q2+……………Q10/10)

Atividades Desportivas

Pratica Desporto?

<table>
<thead>
<tr>
<th>Nome</th>
<th>Intensidade</th>
<th>N.º de Horas/Semana</th>
<th>Período do Ano</th>
</tr>
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<tbody>
<tr>
<td>Desporto 1</td>
<td></td>
<td></td>
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<tr>
<td>Desporto 2</td>
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<tr>
<td>Desporto 3</td>
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</tbody>
</table>

Score da Atividade Desportiva (SD) = Σ (ia*ib*ic)
**Atividades de Tempos Livres**

Realiza outro tipo de atividade física?

<table>
<thead>
<tr>
<th>Nome</th>
<th>Intensidade</th>
<th>N.º de Horas/Semana</th>
<th>Período do Ano</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atividade 1</td>
<td></td>
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<tr>
<td>Atividade 2</td>
<td></td>
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<tr>
<td>Atividade 3</td>
<td></td>
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</tbody>
</table>

Score da Atividade dos Tempos Livres (STL) = \( \sum (ia \times ib \times ic) \)

Score do Questionário = SAD + SD + STL

### Tabela de Códigos para o Questionário de Baekke Modificado

#### Intensidade:

- 0. Deitado, sem carga ................................................................. Código 0.028
- 1. Sentado, sem carga ................................................................. Código 0.146
- 2. Sentado, com movimentos dos membros superiores ................ Código 0.297
- 3. Sentado, com movimentos do corpo ......................................... Código 0.703
- 4. De pé, sem carga ................................................................. Código 0.174
- 5. De pé, com movimentos dos membros superiores ................ Código 0.307
- 6. De pé, com movimentos do corpo, andar ................................ Código 0.890
- 7. Andar, com movimentos dos membros superiores ........................ Código 1.368
- 8. Andar, com movimentos do corpo, andar de bicicleta, nadar ... Código 1.890

#### N.º de Horas por Semana:

- 0. Menos de 1 hora por semana ........................................................ Código 0.5
- 1. 1 a 2 horas por semana ............................................................ Código 1.5
- 2. 2 a 3 horas por semana ............................................................ Código 2.5
- 3. 3 a 4 horas por semana ............................................................ Código 3.5
- 4. 4 a 5 horas por semana ............................................................ Código 4.5
- 5. 5 a 6 horas por semana ............................................................ Código 5.5
- 6. 6 a 7 horas por semana ............................................................ Código 6.5
- 7. 7 a 8 horas por semana ............................................................ Código 7.5
- 8. Mais de 8 horas por semana .................................................... Código 8.5

#### Meses por Ano:

- 0. Menos de 1 mês por ano ............................................................. Código 0.04
- 1. 1 a 3 meses por ano ............................................................... Código 0.17
- 2. 4 a 6 meses por ano ............................................................... Código 0.42
- 3. 7 a 9 meses por ano ............................................................... Código 0.67
- 4. Mais de 9 meses por ano ....................................................... Código 0.92
References


Effects of a Multimodal Exercise Program in Motor Fitness and Functional Motor Asymmetry: Study with Portuguese Older Adults of Different Contexts

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(Resubmitted after reviewers’ comments)

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Abstract

This study investigated the effects of a multimodal exercise program in motor fitness and functional motor asymmetry (FMA) in two groups of older adults (N = 112): an experimental group (EG) and a control group (CG). The EG was comprised of older adult participants from a hospital center (HC), a residential care home (RCH), and a daily living center (DLC). The CG included older adults from an RCH with mental health disorders, an RCH, and a DLC. Each participant’s hand was assessed in the following abilities: dexterity (fine and global), visuomotor coordination, proprioceptive sensitivity, reaction time, and grip strength. Pedal dexterity was also evaluated.

Results suggest that the factor time in the EG had a main positive effect for all contexts and abilities evaluated. Gender had a significant effect in all contexts, with males generally presenting a better performance. FMA decreased significantly after the exercise program. An interaction between time and gender was observed.

Keywords: aging, older adults, exercise program, motor fitness, functional motor asymmetry

Introduction

Aging along with its accompanying degeneration is a growing phenomenon in current societies. In fact, the number of older adults (normal or with dementia) accessing rehabilitation and intermediate care services, either in hospital or at home, is rising and will continue to increase (Comas-Herrera, Wittenberg, Martin Knapp, & MRC-CFAS, 2003).

The aging process leads to a decline in various abilities, namely strength, sensorimotor functioning, proprioception, tactile sensitivity, manual and pedal dexterity, and reaction time. This degeneration affects many daily life activities and, as a consequence, falls or accidents may occur that could be avoidable if older adults were to maintain good levels of motor fitness (Boatright, Kiebzak,
Besides overall functional fitness, the age-related changes in motor behavior are of great importance. Despite this, there is not much information or enough systematic investigation about manual dexterity, visuomotor coordination, proprioceptive sensitivity, and pedal dexterity. Therefore, this subject needs to be further studied to better understand the effects of exercise on these abilities in aged males and females.

With this research, it was our intention to investigate older adults from a wide range of the population as a whole, that is, we sought to include older adults with mental health disorders (from a psychiatric hospital center [HC] and a residential care home [RCH]) and without mental health disorders (namely, from an RCH and a daily living center [DLC]).

Thus, an investigation about this subject is pertinent, specifically at the level of some traits of motor fitness in its expression in older adults of both gender and from different contexts. The aim of the present study was to verify if a regular multimodal exercise program leads to the development of motor fitness in older adults from different contexts.

The following hypotheses were formulated a priori: (i) a multimodal exercise program improves the motor fitness and functional motor asymmetry in older adults from different contexts, and (ii) interventions targeted by a multimodal exercise program (over twelve months in older adults from different contexts) are effective in males and females.

**Methods**

**Subjects**

A convenience sample of one hundred and thirty-six older adult participants from an HC, an RCH and a DLC participated in this study. The eligible subject pool was restricted to older adults from both genders with the following characteristics: aged ≥ 65 years; not engaged in any regular exercise training in the last year; older adults from an RCH and a DLC, lack of use of any medication known to affect the balance, postural stability and lack of any
diagnosed or self-reported neurologic disorders, or orthopedic medical conditions that contraindicate the participation in exercise and testing. We point out that the older adults from the HC and the RCH (older adults with mental health disorders) were previously diagnosed with neurological deficits by neurologists, and give authorization to participate in the study.

We try to compose the sample with an identical number of older adult participants in each context according to the gender and age. However, in some circumstances this proceeding was not possible, as was the case of HC and RCH (older adults with mental health disorders), contexts where the number of subjects in each group was different.

The sample, in each context, was divided into two groups: an experimental group (EG) with practice of the multimodal exercise program and a control group (CG).

Before conducting the study, all participants received a complete explanation of the purpose, risks, and procedures of the investigation, and provided their written informed consent. However, some older adults were excluded due to medical reasons, namely: in the EG, 4 males and 2 females from the HC, 2 males and 2 females from the RCH and 4 males and 2 females from the DLC. In the CG, 1 male and 1 female from the RCH (mental health disorders), 2 males and 3 females from the RCH, and 1 female from the DLC. The characteristics of the participants of the study are shown in Table 1.

<table>
<thead>
<tr>
<th>Table 1. Subject characteristics of experimental and control groups. Contexts, age, and gender.</th>
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<tbody>
<tr>
<td><strong>Experimental Group</strong></td>
</tr>
<tr>
<td>Subject</td>
</tr>
<tr>
<td>HC (n=8)</td>
</tr>
<tr>
<td>HC (n=11)</td>
</tr>
<tr>
<td>RCH (n=9)</td>
</tr>
<tr>
<td>RCH (n=17)</td>
</tr>
<tr>
<td>DLC (n=11)</td>
</tr>
<tr>
<td>DLC (n=16)</td>
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</tbody>
</table>

Hospital center (HC), residential care home (RCH), daily living center (DLC), residential care home (RCH): older adults with mental health disorders, males (M), and females (F).
Older adults from the EG were submitted to a multimodal exercise program, for a period of twelve months while those in the CG maintained their normal physical activity routine. All measurements and the multimodal exercise program were performed by the same evaluator together with teachers graduated from the Faculty of Sport, University of Porto, Portugal. We emphasize that they were the evaluators prior and after training in both groups (EG and CG).

The investigation was in full compliance with the Helsinki declaration of 1975, as revised in 2004, and all methods and procedures were approved by the Institutional Review Board.

**Training Protocol**

The twelve-month multimodal training protocol was held three times per week and each session lasted about 60 min. All sessions were accompanied by appropriate music considered relevant to the required activity and participants’ age. A physical education instructor with specialization in older adults training conducted the sessions. The exercise training was designed to promote the development of abilities, such as visuomotor coordination skills, flexibility, balance, strength, reaction time, speed of movements of the hands and feet, proprioceptive sensitivity, coincidence-anticipation, and visuomotor memory, as well as emotional and social aspects and awareness of the benefits of regular physical exercise.

Each training session included three main components: initial, a 10-min light warm-up and stretching exercises; fundamental, 45 min of light- to moderate-intensity exercises for the development of the abilities previously mentioned, such as marching in place, stepping exercise at a speed of 40–60 beats per minute using a 15-cm-high bench, heel-drops performed on a hard surface (a heel-drop consists of raising the body weight onto the toes and then letting it drop to the floor, keeping the knees locked and hips extended), muscular endurance exercises performed concentrically and eccentrically involving the upper and lower limbs; strength training performed with elastic bands and dumbbells; balance training with static and dynamic exercises...
(e.g., walking in a straight line, walking heel to toe, using additional resources, such as, balls, balloons, gymnastics parachutes and ribbons, hoops, ropes and sticks), flexibility training involved the major muscle groups (quadriceps, back and chest) and agility training (visuomotor coordination) aimed at challenging hand-eye coordination, foot-eye coordination, dynamic balance, standing and leaning balance, and psychomotor performance (coincidence-anticipation, proprioceptive sensitivity, visuomotor memory and reaction time) including ball games, relay races, dance movements, and obstacle courses; and finally, 5 min of stretching. For the exercises in the second part of the session, for all the abilities mentioned above, the repetitions were increased from eight to fifteen and the number of sets increased to three.

Handedness assessment

Older adults’ handedness was determined using the Dutch Handedness Questionnaire (Van Strien, 2002). Subjects were classified as right-handers or left-handers based on their score, which identified one hundred and ten strong right-handers (mean score of $29.62 \pm 1.25$, where 30 is maximal right-handedness) and two strong left-handers (mean score of $3.5 \pm 2.12$, where 0 is maximal left-handedness). Both right-handers’ and left-handers’ data were included in the analysis, and, according to their handedness, subjects used the preferred hand (PH) and the non-preferred hand (NPH) in the tests.

Footedness assessment

The footedness assessment was evaluated by applying the Lateral Preference Questionnaire (Coren, 1993). The older adults were classified as right-footed (value greater than zero) or left-footed (value lower than zero) based on their score on this questionnaire, which identified 110 strong right-footers (mean score of $92.84 \pm 11.39$, where 100 is maximal right-footedness) and 2 strong left-footers (mean score of $-80.0 \pm 0.0$, where 100 is maximal left-footedness). Both right-footers’ and left-footers’ data were included in our analysis, and according to their footedness, the subjects used their preferred foot (PF) and their non-preferred foot (NPF) in the test.
It is important to assess the non-preferred foot in order to appreciate – along with the preferred foot – its evolution from pre- to post-training and to observe if this evolution is similar when compared to the preferred foot.

In regards to the Lateral Preference Questionnaire, additional items were added to the Lateral Preference Inventory (Coren, Porac, & Ducan, 1979) that provided a measure of handedness, footedness, vision, and hearing. Coren (1993) and Coren, Porac, and Ducan (1979) reported that, measure of lateral preference has demonstrated a 92% concordance between self-reports and direct behavioural performance.

**Functional motor asymmetry assessment**

A Laterality Index (LI) was estimated in terms of manual and pedal performance using the following formula: \[ LI = \frac{\text{preferred limb} - \text{non preferred limb}}{\text{preferred limb} + \text{non preferred limb}} \times 100. \] The absolute values of the LI indicate the asymmetry between the hands or between the feet for each ability tested. Scores near zero indicate a low asymmetry between the limbs.

**Cognitive function assessment**

To assess the subjects’ global cognitive function, the Mini-Mental State Examination (MMSE) (Folstein, Robins, & Helzer, 1983) was applied. MMSE total score ranges from 0 to 30. According to this questionnaire, none of the participants had any cognitive impairment (RCH: mean score of 28.23 ± 2.11; DLC: mean score of 27.53 ± 2.43), except the older adults with mental health disorders of the experimental group and the control group, where the doctors confirmed pathologies like schizophrenia, dementia, and depression.

**Daily physical activity assessment**

In order to quantify and verify if there was any change in the daily activities of the sample during the research period, the Modified Baecke Questionnaire (1982) was completed before and after training. This questionnaire has been shown to generate valid and reliable classification
scores for activity in older subjects providing a domestic, a sport, and a leisure-time activity score. The sum of the different scores gives the total activity of the subject. The questionnaires were completed by the same researcher during a personal interview. For ethical reasons, this questionnaire was not applied to all the older adults with mental health disorders of the experimental group and the control group.

**Instruments**

According to the instruments applied, we describe the designs and procedures adopted. The **Minnesota Manual Dexterity Test (MMDT)** (Lafayette instrument, nº. 32023) was used as an indicator of the manual global dexterity. The Placing Test includes one trial with each hand. The Turning Test assesses both hands (BH) with one trial, with a rest interval between tests of 1 minute. Finally, the time to accomplish the test is recorded. The **Purdue Pegboard Test (PPT)** (Lafayette instrument, nº. 32020) was used as an indicator of the manual fine dexterity. Tests were conducted with the PH for 30 s, with the NPH for 30 s, and with BH for 30 s. The rest interval between the trials was 30 s and between the tests was 1 minute. The subjects performed three trials for each test and the best result was recorded (number of pegs introduced in the holes). The **Pursuit Rotor Test (PRT)** (Lafayette Instrument, nº. 30010A) was used as an indicator of the visuomotor coordination. With the PH and the NPH, two sets of four trials of 20 s duration each were done. The rotational speed is 15 rotations per minute. The rest interval between the trials was 20 s and between sets was 1 minute. The time in contact with the metallic round plate was recorded. The **Discrimination Weights Test (DWT)** (Lafayette Instrument, nº. 16015) was used as an indicator of the proprioceptive sensitivity. This test included three sets. The subject compared the standard weight with one weight at a time (belonging to each set of weights) and verbally stated whether the weight was heavier, lighter, or equal than the standard weight. Each of the eleven comparison weights was presented once in a method of constant stimuli to determine the proprioceptive sensitivity. The percentages of correct answers were recorded. The **Multi-Choice Reaction Time Apparatus**
Simple Reaction Time Test (SRTT) (Lafayette Instrument, nº. 63014 A) was used as an indicator of the simple reaction time. This test was comprised of five trials with the PH and the NPH and a rest interval of 30 s. The best result for each hand was recorded. The Takei TKK Digital – Handgrip Dynamometer (HGD) (model: A5401) was used as an indicator of the hand grip strength. This test consisted of six intercalary trials between the PH and the NPH and a rest interval of 1 minute. The best result for each hand was recorded. The Tapping Pedal Test (TPT) (Kondraske, 1991) was used as an indicator of pedal dexterity. This test included two trials of 10 s duration with each foot and a rest interval of 2 minutes between trials. The best result for each foot was recorded.

The sample was counterbalanced according to the hand or foot that initiates each test; that is, half of the group started each test with the PH or the PF, and the other half started the test with the NPH or the NPF. Following this procedure, the performance with the contralateral hand or foot was evaluated. This method is used in order to avoid the effect of transfer of learning.

Different evaluators measured all subjects two times (pre- and post-training) and conducted all the physical exercise program sessions. Standardized instructions and explanations of testing procedures were supplied to the subjects in a simple and easy way with respect to the participants from the HC. All procedures were followed as described in the specific batteries and manuals for older adults (e.g., Discrimination Weights Test, 2004; Echard, 2006; Kondraske, 1991; Minnesota Manual Dexterity Test, 1998; Purdue Pegboard Test, 2002; Richards, Olson, & Palmier-Thomas, 1996). The tests were demonstrated and each subject was allowed to perform one training trial on each test before the measured trials.

Statistical analysis

All data were analysed with Statistical Package for the Social Sciences (SPSS: version 19.0). They were checked for distribution and the means and standard deviation were calculated. Descriptive statistics and tests for normality (Shapiro-Wilks test) were performed for all outcome variables. To analyse the multimodal exercise program effect and the LI, a two-way ANOVA 2x2 (time:
from pre to post-training; gender: males and females) was used for each test according to the performance of the hand (PH, NPH, BH) and the feet (PF and NPF). This analysis was made separately for both groups (EG and the CG) and contexts (HC, RCH, DLC). When ANOVA revealed significant interaction (time x gender), Bonferroni post hoc tests were performed to determine the differences between the initial and the final values in each group. Statistical significance was set at $p \leq 0.05$.

**Results**

Concerning the Modified Baecke Questionnaire data, and regardless of the exercise program, significant increases from pre- to post-training in the experimental group were found in the residential care home and the daily living center ($p < .001$). The control group maintained the level of daily physical activities from pre- to post-training: residential care home ($p = 0.148$) and daily living center ($p = 0.248$).

**The Minnesota Manual Dexterity Test (MMDT): global manual dexterity**

Figure 1 presents the mean and standard deviation values of the MMDT for the experimental group (males and females) of the hospital center, the residential care home, and the daily living center, according to the time of assessment (pre- and post-training) and the hand (PH, NPH, and BH).
Experimental Group

Figure 1. Means of seconds with the preferred hand (PH), the non-preferred hand (NPH), and both hands (BH) from pre- to post-training in each gender and context: hospital center (HC), residential care home (RCH), and daily living center (DLC).

* Statistical significance \( p \leq 0.05 \).

In the experimental group of the hospital center, a significant main effect was found for time with the PH \( \left[ F_{1,11} = 12.296; p = .005 \right] \), the NPH \( \left[ F_{1,11} = 5.057; p = .046 \right] \), and BH \( \left[ F_{1,11} = 6.777; p = .025 \right] \). More specifically, there was a significant improvement in performance from pre- to post-training (PH: from 133.14 ± 19.68 s to 111.05 ± 19.50 s; NPH: from 146.66 ± 33.10 s to 126.89 ± 27.40 s; and BH: from 178.47 ± 65.38 s to 140.07 ± 56.48 s). No other main significant effect or interactions were found.

In the residential care home, a significant main effect was found for time with the PH \( \left[ F_{1,20} = 31.660; p < .001 \right] \), the NPH \( \left[ F_{1,20} = 28.593; p < .001 \right] \), and BH \( \left[ F_{1,20} = 26.849; p < .001 \right] \). There was a significant improvement in performance with the PH (from 94.36 ± 13.53 s to 83.17 ± 11.84 s), the NPH (from 97.94 ± 10.16 s to 90.08 ± 11.73 s), and BH (from 96.08 ± 20.48 s to 81.93 ± 14.83 s) from pre- to post-training. No other significant main effect or interactions were found.

In the daily living center, a significant main effect was found for time with the PH \( \left[ F_{1,19} = 35.640; p < .001 \right] \), the NPH \( \left[ F_{1,19} = 47.594; p < .001 \right] \), and BH \( \left[ F_{1,19} = 44.00; p < .001 \right] \). More specifically, there was a significant improvement
in performance from pre- to post-training of the PH (from $82.55 \pm 9.93$ s to $72.80 \pm 8.35$ s), the NPH (from $92.02 \pm 16.50$ s to $80.37 \pm 12.09$ s), and BH (from $84.00 \pm 17.59$ s to $69.33 \pm 13.75$ s). No other significant main effect or interactions were found.

Concerning the control group of the residential care home (older adults with mental health disorders), a significant main effect was found for time with the PH $[F_{1,4} = 14.298; \ p = .019]$ and the NPH $[F_{1,3} = 10.041; \ p = .051]$. There was a significant decrease in performance from pre-training (PH: $140.11 \pm 31.72$ s; NPH: $150.33 \pm 24.62$ s) to post-training (PH: $162.41 \pm 39.37$ s; NPH: $175.32 \pm 31.11$ s). No other significant main effect or interactions were found.

In the residential care home, a significant main effect was found for time with the PH $[F_{1,9} = 22.711; \ p = .001]$, the NPH $[F_{1,9} = 11.118; \ p = .009]$, and BH $[F_{1,9} = 10.893; \ p = .009]$. More specifically, there was a significant decrease in performance from pre-training (PH: $92.33 \pm 12.84$ s; NPH: $103.37 \pm 16.01$ s; BH: $88.67 \pm 18.58$ s) to post-training (PH: $100.41 \pm 14.16$ s; NPH: $112.57 \pm 14.96$ s; BH: $95.15 \pm 18.29$ s). No other significant main effect or interactions were found.

In the daily living center, a significant main effect was found for time with the NPH $[F_{1,13} = 12.105; \ p = .004]$ and BH $[F_{1,13} = 7.950; \ p = .014]$. Specifically, there was a significant decrease in performance from pre-training (NPH: $99.71 \pm 14.05$ s; BH: $89.51 \pm 12.97$ s) to post-training (NPH: $107.88 \pm 13.08$ s; BH: $94.96 \pm 14.55$ s). No other significant main effect or interactions were found.

The Purdue Pegboard Test (PPT): fine manual dexterity

Figure 2 presents the mean and standard deviation values of the PPT for the experimental group (males and females) of the hospital center, the residential care home, and the daily living center, regarding the time of assessment (pre- and post-training) and the hand (PH, NPH and BH).
In the experimental group of the hospital center, a significant main effect was found for time with the PH \(F_{1,11} = 29.594; p < .001\), the NPH \(F_{1,11} = 8.535; p = .014\), and BH \(F_{1,11} = 8.303; p = .015\). For the PH, there was a significant improvement in performance from 5.76 ± 2.00 pegs to 8.53 ± 1.76 pegs; for the NPH, an improvement from 5.38 ± 2.39 pegs to 7.61 ± 2.56 pegs; and for the BH, an improvement from 3.15 ± 1.77 pegs to 4.92 ± 1.84 pegs. No other significant main effects or interactions were found.

In the residential care home, a significant main effect was found for time with the PH \(F_{1,20} = 21.467; p < .001\), the NPH \(F_{1,20} = 18.416; p < .001\), and BH \(F_{1,20} = 11.997; p = .002\). There was a significant improvement in performance from pre- to post-training of the PH (from 9.36 ± 2.27 pegs to 10.86 ± 2.31 pegs), the NPH (from 9.13 ± 2.27 pegs to 10.59 ± 2.61 pegs), and BH (from 6.54 ± 1.76 pegs to 7.54 ± 2.17 pegs). No other significant main effect or interactions were found.

In the daily living center, a significant main effect was found for time with the PH \(F_{1,19} = 88.772; p < .001\), the NPH \(F_{1,19} = 82.465; p < .001\), and BH \(F_{1,19} = 40.646; p < .001\). More specifically, there was a significant improvement
in performance of the PH (from 10.95 ± 2.08 pegs to 13.19 ± 2.18 pegs), the NPH (from 10.23 ± 1.81 pegs to 12.09 ± 2.14 pegs), and BH (from 7.52 ± 1.91 pegs to 8.90 ± 1.92 pegs). A significant main effect was found for gender with the PH \( F_{1,19} = 4.829; \ p = .041 \) and the NPH \( F_{1,19} = 6.899; \ p = .017 \). Females presented a better performance (PH: 12.71 ± 1.63 pegs; NPH: 11.85 ± 1.65 pegs) than males (PH: 10.78 ± 2.50 pegs; NPH: 9.78 ± 1.94 pegs). Finally, a significant main effect was found for interaction between time and gender with the PH \( F_{1,19} = 5.172; \ p = .035 \). More precisely, in both genders there was an improvement in performance from pre-training (males: 10.00 ± 2.64 pegs; females: 11.42 ± 1.65 pegs) to post-training (males: 11.57 ± 2.37 pegs; females: 14.00 ± 1.61 pegs) and females presented a better performance (12.71 ± 1.63 pegs) than males (10.78 ± 2.50 pegs).

In the control group of the residential care home (older adults with mental health disorders), a significant main effect was found for time with the PH \( F_{1,4} = 32.000; \ p = .005 \) and the NPH \( F_{1,4} = 9.800; \ p = .035 \). More specifically, there was a significant decrease in performance from pre-training (PH: 6.33 ± 1.36 pegs; NPH: 4.83 ± 1.60 pegs) to post-training (PH: 5.00 ± 1.67 pegs; NPH: 3.66 ± 1.50 pegs). No other significant main effect or interactions were found.

In the daily living center, a significant main effect was found for time with the PH \( F_{1,13} = 5.095; \ p = .042 \), with a decrease in performance occurring from pre-training (9.73 ± 2.12 pegs) to post-training (9.20 ± 1.69 pegs). A significant main effect was found for interaction between time and gender with BH \( F_{1,13} = 5.095; \ p = .042 \). In both genders, there was a decrease in performance from pre-training (males: 9.75 ± 2.49 pegs; females: 9.71 ± 1.79 pegs) to post-training (males: 9.37 ± 2.06 pegs; females: 9.00 ± 1.29 pegs). No other significant main effects or interactions were found.

**The Pursuit Rotor Test (PRT): visuomotor coordination**

Figure 3 presents the mean and standard deviation values of the PRT for the experimental group (males and females) of the hospital center, the residential care home, and the daily living center, regarding the time of assessment (pre- and post-training) and the hand (PH and NPH).
Experimental Group

Figure 3. Means of seconds with the preferred hand (PH) and the non-preferred hand (NPH) from pre- to post-training in each gender and context: hospital center (HC), residential care home (RCH), and daily living center (DLC). * Statistical significance $p \leq 0.05$.

Describing the experimental group of the hospital center, a significant main effect was found for time with the PH $[F_{1,11} = 6.857; p = .024]$ and the NPH $[F_{1,11} = 13.838; p = .003]$. We observed a significant improvement in performance from pre- to post-training with respect to the PH (from $13.46 \pm 4.60$ s to $15.86 \pm 2.24$ s) and to the NPH (from $11.28 \pm 4.82$ s to $13.64 \pm 4.30$ s). A significant main effect was found for interaction between time and gender with the PH $[F_{1,11} = 8.234; p = .015]$ and to the NPH $[F_{1,11} = 7.778; p = .018]$. More precisely, with the PH, males slightly decreased their performance from pre- to post-training (PH: from $17.16 \pm 1.22$ s to $17.00 \pm 1.36$ s), while the females improved their performance (PH: from $11.82 \pm 4.63$ s to $15.36 \pm 2.44$ s). In both genders, there was an improvement in performance with the NPH from pre-training (males: $14.33 \pm 4.85$ s; females: $9.76 \pm 4.30$ s) to post-training (males: $14.87 \pm 4.96$ s; females: $13.03 \pm 4.15$ s). With the PH and the NPH, the factor gender showed no significant main effects.

In the residential care home, a significant main effect was found for time with the PH $[F_{1,20} = 15.513; p = .001]$ and with the NPH $[F_{1,20} = 29.942; p < .001]$. We verified a significant improvement in performance with the PH (from $15.35 \pm 3.16$ s to $16.76 \pm 2.45$ s) and the NPH (from $15.01 \pm 2.35$ s to
16.63 ± 1.71 s) from pre- to post-training. No other significant main effects or interactions were found.

In the daily living center, a significant main effect was found for time with the PH \([F_{1,19} = 14.104; p = .001]\) and the NPH \([F_{1,19} = 27.244; p < .001]\). There was a significant improvement in performance with the PH (from 16.65 ± 1.45 s to 17.66 ± 0.83 s) and the NPH (from 15.70 ± 1.94 s to 16.72 ± 1.44 s), from pre- to post-training. No other significant main effect or interactions were found.

In the control group of the residential care home (older adults with mental health disorders), a significant main effect was found for time \([F_{1,9} = 33.407; p < .001]\) with the PH. More specifically, there was a significant decrease in performance from pre-training (16.09 ± 2.05 s) to post-training (15.41 ± 2.12 s). No other significant main effect or interactions were found.

In the daily living center, a significant main effect was found for time with the PH \([F_{1,13} = 16.845; p = .001]\) and the NPH \([F_{1,13} = 8.107; p = .014]\). We observed a significant decrease in performance from pre-training (PH: 16.35 ± 1.88 s; NPH: 14.98 ± 2.19 s) to post-training (PH: 15.29 ± 1.74 s; NPH: 14.46 ± 2.05 s). No other significant main effect or interactions were found.

The Discrimination Weights Test (DWT): proprioceptive sensitivity

Figure 4 presents the mean and standard deviation values of the DWT for the experimental group (males and females) of the hospital center, the residential care home, and the daily living center, according to the time of assessment (pre- and post-training) and the hand (PH and NPH).
In the experimental group of the hospital center, a significant main effect was found for time with the PH \( F_{1,11} = 19.003; \ p = .001 \) and the NPH \( F_{1,11} = 7.277; \ p = .021 \). Regarding the PH, there was a significant improvement in performance (from 68.29 ± 4.72 % to 74.81 ± 5.72 % of correct answers) from pre- to post-training. The same occurred with the NPH (from 70.15 ± 8.09 % to 77.84 ± 6.35 % of correct answers). No other significant main effect or interactions were found.

In the residential care home, a significant main effect was found for time with the PH \( F_{1,20} = 13.349; \ p = .002 \) and the NPH \( F_{1,20} = 16.936; \ p = .001 \). There was a significant improvement in performance from pre- to post-training of the PH (from 73.68 ± 10.55 % to 82.36 ± 5.88 % of correct answers) and the NPH (from 71.61 ± 9.74 % to 81.67 ± 6.51 % of correct answers). No other significant main effect or interactions were found.

In the daily living center, a significant main effect was also found for time with the PH \( F_{1,19} = 23.434; \ p < .001 \) and the NPH \( F_{1,19} = 58.478; \ p < .001 \). There was a significant improvement in performance with the PH (from 72.28 ± 10.72 % to 82.09 ± 4.38 % of correct answers) and the NPH (from 72.43 ± 9.65 % to 81.67 ± 6.51 % of correct answers). No other significant main effect or interactions were found.
11.37 % to 82.96 ± 5.28 % of correct answers) from pre- to post- training. With
the NPH a significant main effect was found for gender \([F_{1,19} = 19.728; p < .001]\)
and for interaction between time and gender \([F_{1,19} = 16.144; p = .001]\). More
particularly, females had a better performance (81.37 ± 6.55 %) than males
(70.33 ± 5.74 %) and in both genders there was an improvement in
performance from pre-training (males: 60.60 ± 7.62 %; females: 78.34 ± 7.68 %
of correct answers) to post-training (males: 80.07 ± 3.85 %; females: 84.40 ±
5.42 % of correct answers).

Concerning the control group of the residential care home (older adults
with mental health disorders), a significant main effect was found for time
\([F_{1,4} = 12.000; p = .026]\) with the PH. More specifically, there was a significant
decrease in performance from pre-training (79.28 ± 2.97 % of correct answers)
to post-training (73.22 ± 7.01 % of correct answers). No other significant main
effect or interactions were found.

In the residential care home, a significant main effect was found for time
with the PH \([F_{1,9} = 8.523; p = .017]\) and the NPH \([F_{1,9} = 13.877; p = .005]\). There
was a significant decrease in performance from pre-training (PH: 73.82 ± 6.39
% and NPH: 75.19 ± 5.87 % of correct answers) to post-training (PH: 67.48 ±
9.59 % and NPH: 67.48 ± 8.14 % of correct answers). No other significant main
effect or interactions were found.

In the daily living center, a significant main effect was found for time with
the PH \([F_{1,13} = 11.898; p = .004]\) and the NPH \([F_{1,13} = 8.701; p = .011]\). There
was a significant decrease in performance from pre-training (PH: 75.75 ± 6.67
%; NPH: 74.13 ± 5.59 % of correct answers) to post-training (PH: 71.50 ± 5.58
%; NPH: 71.71 ± 4.94 % of correct answers). No other significant main effect or
interactions were found.

**The Multi-Choice Reaction Time Apparatus: simple reaction time**

In the experimental group of the three contexts (hospital center,
residential care home, and daily living center) no significant main effects or
interactions were observed with the PH and the NPH from pre- to post-training.
Regarding the control group of the residential care home (older adults with mental health disorders), a significant main effect was found for time with the PH \(F_{1,3} = 29.035; p = .013\) and the NPH \(F_{1,3} = 17.852; p = .024\). There was a significant decrease in performance from pre-training (PH: 0.380 ± .06 ms; NPH: 0.353 ± .04 ms) to post-training (PH: 0.479 ± .76 ms; NPH: 0.430 ± .07 ms). No other significant main effect or interactions were found.

In the residential care home, a significant main effect was found for time with the PH \(F_{1,9} = 12.326; p = .007\) and the NPH \(F_{1,9} = 6.010; p = .037\). There was a significant decrease in performance from pre-training (PH: 0.289 ± .03 ms; NPH: 0.295 ± .02 ms) to post-training (PH: 0.305 ± .04 ms; NPH: 0.315 ± .04 ms). No other significant main effect or interactions were found.

In the daily living center, a significant main effect was found for time with the NPH \(F_{1,13} = 11.751; p = .004\). More specifically, there was a significant decrease in performance from pre-training (0.296 ± 0.03 ms) to post-training (0.322 ± .04 ms). And with the PH, a significant main effect was found for gender \(F_{1,13} = 5.449; p = .036\). More precisely, males had better manual performance (0.300 ± .03 ms) than females (0.337 ± .03 ms). No other significant main effect or interactions were found.

**The Handgrip Dynamometer (HGD): grip strength**

Figure 5 presents the mean and standard deviation values of the HGD for the experimental group (males and females) of the hospital center, the residential care home, and the daily living center, regarding the time of assessment (pre- and post-training) and the hand (PH and NPH).
In the experimental group of the hospital center, a significant main effect was found for gender with the PH \( [F_{1,11} = 50.676; \ p < .001] \) and the NPH \( [F_{1,11} = 42.288; \ p < .001] \). More specifically, males had better manual performance (PH: 34.11 ± 3.15 Kgf; NPH: 29.60 ± 1.61 Kgf) than females (PH: 19.21 ± 4.03 Kgf; NPH: 17.69 ± 3.69 Kgf). No other significant main effect or interactions were found.

In the residential care home, a significant main effect was found for time with the PH \( [F_{1,20} = 19.351; \ p < .001] \) and the NPH \( [F_{1,20} = 10.287; \ p = .004] \). The performance with the PH improved significantly (from 21.50 ± 6.16 Kgf to 23.67 ± 6.59 Kgf) and the same occurred with the NPH (from 20.19 ± 6.14 Kgf to 22.44 ± 6.55 Kgf) from pre- to post-training. Gender also presented a significant main effect with the PH \( [F_{1,20} = 51,571; \ p < .001] \) and the NPH \( [F_{1,20} = 23.136; \ p < .001] \). Males had a better performance (PH: 30.20 ± 4.82 Kgf; NPH: 27.78 ± 6.62 Kgf) than females (PH: 19.03 ± 2.89 Kgf; NPH: 18.30 ± 3.28 Kgf). No other significant interactions were found.

In the daily living center, a significant main effect was found for gender with the PH \( [F_{1,17} = 20.331; \ p < .001] \) and the NPH \( [F_{1,17} = 29.964; \ p < .001] \).
More specifically, males had a better performance (PH: 35.32 ± 5.99 Kgf; NPH: 34.65 ± 4.30 Kgf) than females (PH: 22.71 ± 5.94 Kgf; NPH: 20.89 ± 6.00 Kgf). No other significant main effect or interactions were found.

Concerning the control group of the residential care home (older adults with mental health disorders), a significant main effect was found for time \([F_{1,4} = 10.771; p = .030]\) with the PH. There was a significant decrease in performance from pre-training (20.20 ± 7.49 Kgf) to post-training (16.21 ± 5.17 Kgf). The factor gender presented a significant main effect with the PH \([F_{1,4} = 13.413; p = .022]\) and the NPH \([F_{1,4} = 20.889; p = .010]\). More precisely, males had a better performance (PH: 23.16 ± 2.19 Kgf; NPH: 23.09 ± 3.61 Kgf) than females (PH: 13.25 ± 4.39 Kgf; NPH: 12.03 ± 4.32 Kgf). No other significant main effect or interactions were found.

In the control group of the daily living center, a significant main effect was found for time with the PH \([F_{1,8} = 5.553; p = .046]\) and the NPH \([F_{1,8} = 6.606; p = .033]\). There was a significant decrease in performance from pre-training (PH: 23.18 ± 6.21 Kgf; NPH: 22.02 ± 5.82 Kgf) to post-training (PH: 22.36 ± 5.63 Kgf; NPH: 21.59 ± 5.57 Kgf). The factor gender presented a significant main effect with the PH \([F_{1,8} = 16.722; p = .003]\) and the NPH \([F_{1,8} = 12.956; p = .007]\). More precisely, males had a better performance (PH: 26.53 ± 4.17 Kgf; NPH: 25.27 ± 4.65 Kgf) than females (PH: 17.12 ± 2.32 Kgf; NPH: 16.60 ± 1.06 Kgf). No other significant interactions were found.

In the daily living center, a significant main effect was found for gender with the PH \([F_{1,13} = 21.618; p < .001]\) and the NPH \([F_{1,13} = 14.206; p = .002]\). We verified that males had a better performance (PH: 27.49 ± 5.34 Kgf; NPH: 25.63 ± 5.09 Kgf) than females (PH: 17.82 ± 3.08 Kgf; NPH: 18.02 ± 3.58 Kgf). No other significant main effect or interactions were found.

The Tapping Pedal Test (TPT): pedal dexterity

Figure 6 presents the mean and standard deviation values of the TPT for the experimental group (males and females) of the hospital center, the residential care home, and the daily living center, regarding the time of assessment (pre- and post-training) and the foot (PF and NPF).
In the experimental group of the hospital center, a significant main effect was found for the interaction between time and gender with the PF $[F_{1,11} = 8.787; p = .013]$ and the NPF $[F_{1,11} = 7.007; p = .023]$. More particularly, males had slightly decreased performance with both feet from pre- to post-training (PF: from $18.25 \pm 2.36$ taps to $17.50 \pm 3.31$ taps and NPF: from $18.00 \pm 2.16$ taps to $17.50 \pm 2.64$ taps), while females improved their performance with both feet from pre- to post-training (PF: from $16.11 \pm 4.56$ taps to $19.11 \pm 3.98$ taps and NPF: from $15.00 \pm 4.58$ taps to $16.77 \pm 5.14$ taps). No other significant main effect was found.

In the residential care home, a significant main effect was found for time with the PF $[F_{1,19} = 31.637; p < .001]$ and the NPF $[F_{1,19} = 34.027; p < .001]$. Namely, there was a significant improvement in performance from pre- to post-training (PF: from $20.09 \pm 2.02$ taps to $23.95 \pm 3.58$ taps and NPF: from $18.85 \pm 2.08$ taps to $23.80 \pm 4.11$ taps). No other significant main effect or interactions were found.

In the daily living center, a significant main effect was found for time with the PF $[F_{1,17} = 53.901; p < .001]$ and the NPF $[F_{1,18} = 55.357; p < .001]$. More precisely, there was a significant improvement in performance from pre- to
post-training (PF: from 20.57 ± 3.53 taps to 26.52 ± 3.97 taps and NPF: from 19.25 ± 3.99 taps to 25.00 ± 3.97 taps). No other significant main effect or interactions were found.

In the control group of the residential care home (older adults with mental health disorders), a significant main effect was found for time \( [F_{1,4} = 9.308; \ p = .038] \), only for the NPF. More specifically, there was a significant decrease in performance from pre- (11.66 ± 1.63 taps) to post-training (9.83 ± 2.78 taps). No other significant main effect or interactions were found.

In the residential care home, a significant main effect was found for time \( [F_{1,6} = 11.605; \ p = .014] \), only for the NPF. In particular, there was a significant decrease in performance from pre- (18.00 ± 3.42 taps) to post-training (16.37 ± 3.37 taps). No other significant main effect or interactions were found.

In the daily living center, a significant main effect was found for time with the NPF \( [F_{1,13} = 12.430; \ p = .004] \). More specifically, there was a significant decrease in performance from pre- (17.93 ± 2.01 taps) to post-training (17.33 ± 1.67 taps). No other significant main effect or interactions were found.

The Laterality Index: functional motor asymmetry

Figure 7 presents the mean and standard deviation of the laterality index (LI) values for the experimental group of the hospital center, the residential care home, and the daily living center as regards the performance tests.
In the experimental group of the hospital center, in regards to the factor time, there was a main effect in the Pursuit Rotor Test [$F_{1,11} = 8.489; p = .014$] and a significant decrease of the LI from pre-training (15.45 ± 14.77 %) to post-training (9.09 ± 11.13 %).

In the experimental group of the residential care home, in regards to the factor time, there was a main effect in the Pursuit Rotor Test [$F_{1,20} = 21.851; p < .001$] and a significant decrease of the LI from pre-training (7.19 ± 4.40 %) to post-training (4.24 ± 5.19 %). In the Discrimination Weights Test [$F_{1,20} = 9.652; p = .006$] there was a significant decrease of the LI from pre-training (4.48 ± 3.25 %) to post-training (2.33 ± 2.13 %).

In the experimental group of the daily living center, in regards to the factor time, there was a main effect in the Discrimination Weights Test [$F_{1,19} = 20.533; p < .001$] and a significant decrease of the LI from pre-training (6.58 ± 5.12 %) to post-training (2.97 ± 1.68 %). In the Multi-Choice Reaction Time [$F_{1,10} = 8.670; p = .015$] there was a significant decrease of the LI from pre-training (9.76 ± 5.69 %) to post-training (3.97 ± 3.10 %). In the Handgrip Dynamometer [$F_{1,17} = 5.656; p = .029$] there was a significant decrease of the LI
from pre-training (6.80 ± 5.42 %) to post-training (4.28 ± 3.90 %). For the interaction between time and gender, there was a main effect in the Discrimination Weights Test \( F_{1,19} = 7.044; p = .016 \) and in both genders there was a significant decrease of the LI from pre-training (males: 10.06 ± 5.63 %; females: 4.84 ± 4.00 %) to post-training (males: 2.95 ± 1.50 %; females: 2.98 ± 1.82 %).

Concerning the control group of the residential care home (older adults with mental health disorders), in regards to the interaction between time and gender, there was a main effect in the Discrimination Weights Test \( F_{1,9} = 6.713; p = .029 \); that is, the males increased the LI from pre-training (2.06 ± 1.38 %) to post-training (4.26 ± 2.35 %), while the females decreased the LI from pre-training (5.18 ± 4.57 %) to post-training (2.18 ± 2.50 %).

In the control group of the daily living center, in regards to the factor time, there was a main effect in the Handgrip Dynamometer \( F_{1,13} = 8.650; p = .011 \) and a significant increase of the LI from pre-training (4.34 ± 3.53 %) to post-training (6.57 ± 5.15 %).

Besides the factors described in this section which presented a significant main effect, no other significant main effects and interactions were found.

**Discussion**

The present study aimed to investigate the effects of a multimodal exercise program in the expression of motor fitness and functional motor asymmetry in older adults of both genders from different contexts.

Synthesizing our results, the factor time had a significant effect in the performance of the limbs in the experimental group. The preferred and non-preferred hands and feet significantly increased their performance from pre- to post-training. The only exception was the Simple Reaction Time Test. In general, time also had a significant effect in the control group, but in a reverse way: participants significantly decreased their limb performance from pre- to post-training.
In our study and according to the subjects' manual dexterity (fine and
global) and visuomotor coordination, the experimental group of all contexts
(both genders included) presented a significant improvement from the beginning
to the end of the multimodal exercise program. These results are in accordance
with the investigations of Ranganathan, Siemionow, Sahgal, Lui, and Yue
(2001a) and Botelho and Azevedo (2009), since these authors concluded that
older adults who submitted to an exercise program improved their manual
dexterity and visuomotor coordination when compared to their sedentary
counterparts.

A key strength of our study was the inclusion of older adults from
different contexts. In other words, our sample included more independent and
active older adults living in their homes (and attending a daily living center), as
well as older adults with less autonomy living in a residential care home and a
hospital center both with and without mental health disorders. It is important to
point out that adults diagnosed with schizophrenia, included in our study, often
presented problems in the domain of motivation and energy control, symptoms
that reduce their capacity for healthy nutrition and regular physical exercise
(Allison et al., 1999; Aubin, Stip, Gélinas, Rainville, & Chapparo, 2009; Spruit et
al., 2010; Vancampfort et al., 2010). Nevertheless, in our study, the older adults
belonging to the hospital center showed an improvement in their performance in
the final measurement, with regard to the range of abilities developed and
assessed.

Our findings are supported by other studies (Carmeli & Liebermann,
2007; Carmeli, Patish, & Coleman, 2003; Desrosiers, Rochette, Hébert, &
Bravo, 1997; Francis & Spidurso, 2000), suggesting that through exercise, older
adults can gain better motor control, which is of great importance for an
independent life, namely for the execution of many of their daily activities
requiring manual skills (Carmeli & Liebermann, 2007; Carmeli, Patish, &
Coleman, 2003; Desrosiers, Rochette, Hébert, & Bravo, 1997; Francis &
Spidurso, 2000). This hints that motor strategies and motor control of
movements can be preserved using a multimodal exercise program where the
abilities that sustain these movements and actions are systematically trained.
Governments should be aware of the importance of developing multimodal exercise programs to assist sedentary older adults and to promote strategies allowing subjects to achieve old age with better health and function. In our opinion, finding ways to prevent or ameliorate age-related cognitive decline is a public health imperative, with potential benefits not just in terms of lessening aged care costs, but also in the enhancement of the well-being of a growing segment of society.

Through the data of the daily living center (e.g., Purdue Pegboard Test) our research supports some studies that suggest the superiority of females in manual dexterity (e.g., Amirjani, Ashworth, Gordon, Edwards, & Chan, 2007; Desrosiers, Rochette, Hébert, & Bravo, 1997; Sarafraz & Vahedi, 2008). However, this is still a topic of controversy where other studies using other evaluation methods (e.g., Pursuit Rotor Test) confirm the superiority of males in the same ability (e.g., Câmina, Arce, Real, Cancela, & Romo, 2001; Rudisill & Toole, 1993).

It is known that, with aging, there is a decrease in manual dexterity (Carmeli & Liebermann, 2007; Carmeli, Patish, & Coleman, 2003; Mathiowetz, Volland, Kashman, & Weber, 1985), as observed in our control group whose older adults diminished their performance from pre- to post-training. Emphasis is placed on several studies like ours, suggesting that the decline of manual dexterity can be fought with the practice of regular exercise (e.g., Botelho & Azevedo, 2009; Desrosiers, Rochette, Hébert, & Bravo, 1997).

Beyond that, the older adults from all contexts improved their proprioceptive sensitivity from pre- to post-training. Probably, the reasons for these improvements are related to a more accurate muscle response to the movements and tasks required for the performance of everyday life activities. A better proprioceptive sensitivity also provides a higher conscientiousness of the body in the tridimensional space, allowing better information processing with respect to time and space parameters that provide a more independent life (Carmeli & Liebermann, 2007). In general, these studies refer to the belief that the functioning of the manual proprioceptive sensibility and manual dexterity are essential for the accurate control in the manipulation of small objects and for the
completion of many daily activities. With aging, the muscle strength, the sensibility, the touch-pressure threshold, the neuromuscular coordination, the vision, the hearing, the nerve conduction velocity, the skin receptors, the sensory perception, and the central processing change (Carmeli, Patish, & Coleman, 2003). These changes affect the hand function (Carmeli & Liebermann, 2007; Carmeli, Patish, & Coleman, 2003; Franzoi & Koehler, 1998), but according to our results and others previously mentioned, exercise can delay the decline of these parameters or even promote their development.

In our study, concerning the variable gender and the interaction between time and gender in the experimental group, we verified an improvement in the older adults’ proprioceptive sensitivity from the daily living center, with females having obtained a better performance than males with the NPH from pre- to post-training. In this context, Ranganathan, Siemionow, Sahgal, Lui, and Yue (2001a) state that a training program which gives adequate stimuli to the sensory-motor system will possibly diminish the weakness related to age in the manual function. In this way, the exercise programs should explore exercises that emphasize the kinesthetic discrimination in order to improve the sensorial perception and the manual dexterity (Elfant, 1977). Considering this, the exercises of our one-year multimodal program aimed primarily at promoting the development of hand–eye and foot–eye coordination and proprioceptive sensitivity.

To what concerns the proprioceptive sensitivity, the advantage of females over males (NPH) observed in our study, can be a consequence of the type of activities traditionally performed by women, such as cooking, washing, and ironing. These activities, due to their nature, can afford a more proprioceptive sensitivity and dexterity proficiency in the use of the females’ hands (Amirjani, Ashworth, Gordon, Edwards, & Chan, 2007; Carol, Derek, & Chow, 1999; Van Heuvelen, Kempen, Brouwer, & De Greef, 2000). Particularly, considering the NPH, females usually incorporate this hand into their routine in activities that recruit the use of the NPH in movement of support and fixation or in the performance of manual arts. These activities are performed less frequently among men who are better in the normal use of the PH to perform
other activities related to manual skills, such as manual strength (Rand & Eng, 2010). As the proprioceptive sensitivity is a motor skill largely related to the implementation of tasks that require spatial orientation of the limb, perception, and precision, the specific activities of daily living could also favor females in somatosensory processing.

On the other hand, in the Discrimination Weights Test, in all contexts the older adults of the control group showed a significant decline of their proprioceptive sensitivity. As it was concluded in the study of Takeshima, William, Ueya, and Tanaka (2000), the digital sensibility declines with the advance of age.

Considering the simple reaction time ability, we found no influence from regular exercise in the experimental group from all contexts, in opposition to the majority of literature (e.g., Baylor & Spirduso, 1988; Behrman, Cauraugh, & Light, 2000; Botelho & Azevedo, 2009; Uemura et al., 2012). Otherwise, the levels of this ability did not decrease over time, confirming the results from another study by Olson, Chen, and Wang (2011). These authors speculate that the absence of exercises requiring quick and rapid responses, as occurred in our study, could be a reason for the no-training effect. However, when we observe the data from the control group in all contexts, the older adults’ performance in the Simple Reaction Time Test decreased from pre- to post-training, which is in accordance with the literature that refers to the reaction time slowing gradually with aging (Kauranen & Vanharanta, 1996).

Through the application of our multimodal exercise program, we confirm that the older adults with mental health disorders improved all the measured abilities from pre- to post-training, with the exception of the simple reaction time and the grip strength. Likewise, it was also observed in previous research that adults diagnosed with schizophrenia and depression are associated with cognitive slowing and poorer neuropsychological test performance (Ferrarelli et al., 2012; Ravnkilde et al., 2002).

Our data reinforces the importance of this type of activity in subjects with mental health disorders. According to Callaghan (2004) and Littbrand et al. (2011), exercise is associated with improvements in the quality of life of those
living with schizophrenia or dementia disorder. Several studies conducted in the last decade suggest that regular exercise has a protective effect against the risk of developing dementia (Fratiglioni, Paillard-Borg, & Winblad, 2004; Larson et al., 2006; Middleton et al., 2011; Rovio et al., 2005; Vercambre, Grodstein, Manson, Stampfer, & Kang, 2011). Our results confirm those involving older adults without mental health disorders, in which it was proved that exercise training found motor functional improvement after twelve months (e.g., Hatch & Lusardi, 2010; Madureira et al., 2007; Taguchi, Higaki, Inoue, Kimura, & Tanaka, 2010).

Our data showed that only in the residential care home (experimental group) the older adults improved their grip strength with the PH and the NPH. Research studies have found that strength loss, which is especially common in older adults, can be improved with accurate and specific exercise (ACSM’S & Sorace, 2010; American College of Sports Medicine, 2009; Christmas & Andersen, 2000; Haskell et al., 2007; Nelson et al., 2007; Singh, 2004). Probably, the no-effects observed in the hospital and the daily living centers were related to the low intensity or frequency of training. Another possible reason, according to Kraemer and Häkkinen (2002), is that the potential to change a physical variable is greater when training begins. This phenomenon can be called the “window of adaptation.” Thus, when the individual is less trained, the greater is his potential to change and the greater is his “window of adaptation.” Rather, this should be lower when the individual is more trained, or if he has already achieved a high level of physical conditioning.

Within the grip strength ability, and according to the factor gender as a main effect in all contexts, males had a better manual performance than females with the PH and the NPH. These results are consistent with some studies that show a better performance by males on tasks of manual grip strength (Massy-Westropp, Gill, Taylor, Bohannon, & Hill, 2011; Nicolay & Walker, 2005; Ranganathan, Siemionow, Sahgal, & Yue, 2001b). This may represent the reflection of the difference in muscle mass between genders, and consequently the greater muscle strength of men over women (Nicolay & Walker, 2005).
Reinforcing the effects of the exercise program, when we analyzed the older adults of the control group from all contexts, there were a decrease in performance from pre- to post-training; this decline is of great importance since some investigators have shown that hand strength and dexterity limitations are known to have negative impact on activities of daily living (e.g., Flunn, Trombly-Latham, & Podolski, 2007).

Taking into consideration the pedal dexterity ability, all the older adults from different contexts of the experimental group improved their proficiency with both feet from pre- to post-training (but the interaction between time and gender revealed that, from the hospital center, males slightly decreased their performance with both feet while females improved theirs).

Our results are in agreement with others studies in older adult men and women that reported that exercise programs improved the walking ability (Freiberger, Häberle, Spirduso, & Rixt Zijlstra, 2012; Leszczak, Olson, Stafford, & Brezzo, 2012; McCartney, Hicks, Martin, & Webber, 1995, 1996; Rooks, Kiel, Parsons, & Hayes, 1997).

It is important to remember that with advanced age, the muscles of the inferior members are particularly affected in comparison to the superior ones (Cavani, Mier, Musto, & Tummers, 2002; Hughes et al., 2001; Izquierdo et al., 2001; Marzilli, Schuler, Willhoit, & Stepp, 2004), thus causing large difficulties with locomotion, balance, and coordination (Lord, Menz, & Tiedemann, 2003; Mazzeo & Tanaka, 2001; Nikolic, Bajek, Bobinac, Vranic, & Jerkovic, 2005; Westhoff, Stemmerik, & Boshuizen, 2000).

Concerning the pedal dexterity, males slightly decreased their performance with both feet while females improved among the older adults belonging to the hospital center of the experimental group. Additional studies are necessary to elucidate the effects of exercise involving men with mental health disorders with respect to this ability.

With respect to the functional motor asymmetry, it was observed that, in the experimental group, the factor time had a main effect in all contexts. There was a significant decrease of the laterality index (LI) in the visuomotor coordination (hospital center and residential care home), the proprioceptive
sensitivity (residential care home and daily living center), and the simple reaction time and the grip strength (daily living center). For the functional motor asymmetry, the interaction between time and gender had a main effect in the daily living center; namely, in both genders there was a significant decrease of the LI in regards to the proprioceptive sensitivity. These results are in agreement with previous studies (Francis & Spirduso, 2000; Texeira, 2008) that mention that functional asymmetry depends on the type of tasks used as well as their complexity; that is, the nature of the task seems to have a determining role in the grade of manual asymmetry. In our study, depending on the task, the laterality index increased or decreased in both experimental group and control group from pre- to post-training, confirming the statements of the previous authors and the investigation of Bangert, Reuter-Lorenz, Walsh, Schachter, and Seidler (2010). These last authors suggest that age-related changes in bimanual coordination are specific to task conditions that establish complex timing demands on left- and right-hand movements. Nevertheless, we observed in our study that, in general, the LI decreased significantly from pre- to post-training in most tests. This is probably due to the frequent involvement of the NPH in the various exercises of the 12-month exercise program occurring in this hand and a higher performance evolution when compared to the PH (which, due to its condition of preferred hand, makes it more difficult to have a greater improvement). Consequently, the result is a reduction of the LI; there is enough evidence in literature that the differentiated practice of both hands has specific implications on the motor dimension of manual dexterity (Pascual-Leone & Torres, 1993; Provins, 1997).

Exercise seems to improve mental health and well-being, reduces depression and anxiety, and enhances cognitive functioning (Callaghan, 2004; De Moor, Beem, Stubbe, Boomsma, & De Geus, 2006; Spirduso, 2009). The mental health disorder which characterizes a part of our sample is adults diagnosed with schizophrenia, whose symptoms include not only the positive psychotic, disorganized thought and speech, delusions, hallucinations and other changes in perception, but also the negative symptoms, such as lack of motivation and social withdrawal (Sewell, Skosnik, Garcia-Sosa, Ranganathan,
The subjects of the experimental group benefited from the program which helps outline strategies for action, either to improve their motor condition, or to improve their quality of life, including their socio-affective relations. However, we emphasize that it is possible for these older adults to participate in these exercise programs.

Researchers found that midlife exercise may reduce the risk of dementia decades later (e.g., Andel et al., 2008), suggesting that exercise interventions should be explored as a potential strategy for delaying disease onset. They also found that light exercise, such as gardening or walking, and regular exercise involving sports were associated with reduced odds of dementia. It was verified in our study that the older adults of the control group decreased their performance in all the studied abilities. This suggests that inactivity affects functionality, mobility, and health, depriving older adults from of an autonomous and healthy life and harming their quality of life (Carmeli & Liebermann, 2007; Carmeli, Patish, & Coleman, 2003; Darcy & Lazaro, 2007; Spirduso, Francis, & MacRae, 2005).

The major limitation of our study was finding a sufficient number of older adults with mental health disorders who could perform a one-year program of regular exercise.

A key strength of our study is that, to our knowledge, there is not much information and systematic research on this subject. So, we believe that our results can contribute to a better understanding of the effect of exercise on different abilities of older males and females from different contexts. Although the contexts of our study were not compared, we collected data and analyzed and discussed results coming from three different human realities in the same investigation. The majority of studies conducted in this domain only deal with one context.

In summary, we partly confirmed our previous hypothesis, that our program of multimodal exercise had significant effects in older adults with and without mental health disorders from different contexts. We emphasize that we should give special attention to multicomponent exercise programs and apply them to older adults with or without mental health disorders, since they improve
motor fitness which is important for an independent lifestyle and thus for an older adult's quality of life. In the domain of this investigation, we suggest a follow-up study to investigate the effect of inactivity after six months or one year.

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References


Effects of a Multimodal Exercise Program in Pedal Dexterity and Balance: Study with Portuguese Older Adults of Different Contexts

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Abstract

This study investigated the effects of a multimodal exercise program (MEP) on pedal dexterity and balance in two groups of older adult participants (65-92 years of age) from a psychiatric hospital center (HC), a residential care home (RCH) and a daily living center (DLC). The experimental group (EG) trained three times per week for 12 months, and the control group (CG) maintained their normal activities.

The Mini-Mental State Examination and the Modified Baecke Questionnaire, as well as the Pedal Dexterity and the Tinetti tests, were applied to all subjects before and after the experimental protocol. Furthermore, the foot preference was controlled using the Lateral Preference Questionnaire proposed by Coren (1993).

In the EG, the results from the Pedal Dexterity test showed that both males and females from the RCH and DLC improved their performances after the MEP. In the HC, the males slightly decreased their performance with both feet, contrarily to females. Both males and females from the CG decreased their pedal dexterity performance, namely, with the non-preferred foot. Concerning the Tinetti test, the EG of both males and females from the HC, the RCH (males were better than females regarding the gender factor) and the DLC improved their balance after the MEP. In the CG, no significant effects or interactions were found for any of the context groups.

Keywords: aging, multimodal exercise program, pedal dexterity, balance, functional motor asymmetry
Introduction

Aging is characterized by a series of degenerative changes in the different systems of the organism at the anthropometric, muscular, articular, cardiovascular, pulmonary and neural levels, with consequences including the decline of the functional abilities and changes in physiological functioning (Akgün, Crothers, & Pisani, 2012; Mobasheri, 2011; Vaillancourt & Newell, 2002; Woolf & Pfleger, 2003).

Mobility problems in older adults are generally associated with deficits in balance, musculoskeletal pain, gait disorders and a decline in muscular strength of the lower limbs, which are also a factor of fall risk and loss of autonomy for the execution of daily life activities (Guralnik, Ferrucci, Simonsick, Salive, & Wallace, 1995; Lihavainen et al., 2010; Tinetti, 2003).

Compared to the upper limbs, the age-related reduction of muscle strength and mass of lower limbs is more evident (American College of Sports Medicine, 2010; Carmeli, Reznick, Coleman, & Carmeli, 2000; Hunter, McCarthy, & Bamman, 2004). This fact is important since these muscle changes of the lower limbs have higher correlations with mobility, functionality and everyday activities of the older adults (Carmeli, Reznick, Coleman, & Carmeli, 2000). Among other characteristics, pedal dexterity is especially important to facing unexpected situations in order to prevent a fall and subsequent fracture or immobilization. Besides a good dynamic balance, it is important that older adults are able to behave quickly and efficiently when faced with these conditions (Kauranen, 1999).

Dexterity is the ability to solve (precisely, quickly, rationally and deftly) a motor task in an adequate way using, in general, the limbs and the body. In this context, flexibility, in relation to the changing environment, is an important characteristic (Turvey & Carello, 1996).

Likewise, balance is the basis of all voluntary motor abilities in this population (Huxham, Goldie, & Patla, 2001; Nitz & Choy, 2004). Problems with balance control as a result of compromised balance conditions will inevitably affect motor strategies because one cannot activate muscle-response synergies with appropriate timing, force and muscle-response organization (Shumway-
Cook & Woollacott, 2007a). So, the concept of balance is the ability to maintain the body in equilibrium (Shumway-Cook & Woollacott, 2007b). If an older adult has reduced levels of balance, he or she will become more dependent on others and exposed to a higher risk of fall and fractures (Shephard, 1990).

The distinct movement patterns of postural recovery, also referred to as “postural strategies,” function to preserve equilibrium following external disruptions by restraining the center of mass within the base of support (Shumway-Cook & Woollacott, 2007b).

Several studies have shown the efficiency of physical exercise programs, not only in the reduction of the risk of fall (Becker et al., 2003; Day et al., 2002; DeVito, Morgan, Duque, Abdel-Moty, & Virnig, 2003; Schleicher, Wedam, & Wu, 2012), but also in the reduction of the fear of falling (Carvalho, Pinto, & Mota, 2007; Schleicher, Wedam, & Wu, 2012; Verfaillie, Nichols, Turkel, & Hovell, 1997).

We point out that a consequence of the aging process leads to a decline in the interference of pedal dexterity with balance. These aspects affect many of the older adults’ daily life activities; falls or accidents that often occur could be avoidable if the individuals maintained high levels of motor fitness (Kim & Lockhart, 2012; Liu-Ambrose et al., 2004; Lord & George, 2003).

Aging is a growing phenomenon in modern-day societies. In fact, the number of older adults (normal or with mental health disorders) accessing rehabilitation and intermediate care services, either in hospitals or at home, is rising and will continue to increase (Comas-Herrera, Wittenberg, Martin Knapp, & MRC-CFAS, 2003).

However, there is not much information or enough systematic investigation about pedal dexterity ability in the Portuguese population, so this subject needs to be further studied in order to better understand the effect of exercise on both abilities (dexterity and balance) in old males and females in different living situations.

With this research, it was our intention to investigate older adults from a wide range of the population as a whole, that is, we sought to include older adults with mental health disorders (from a psychiatric hospital center [HC] and
a residential care home [RCH]) and without mental health disorders (namely, from an RCH and a daily living center [DLC]).

The aim of this investigation was to analyse the effects of a multimodal exercise program on the pedal dexterity and balance of older adults from different contexts.

The following hypotheses were formulated a priori: (i) a multimodal exercise program improves pedal dexterity and balance and reduces the likelihood for falls in older adults from different contexts, and (ii) interventions targeted by a multimodal exercise program (during twelve-months in the older adults from different contexts) are effective in males and females.

**Methods**

**Subjects**

A convenience sample of one hundred and thirty-six older adult participants from an HC, an RCH and a DLC participated in this study. The eligible subject pool was restricted to older adults from both genders with the following characteristics: aged \( \geq 65 \) years; not engaged in any regular exercise training in the last year; older adults from an RCH and a DLC, lack of use of any medication known to affect the balance, postural stability and lack of any diagnosed or self-reported neurologic disorders, or orthopedic medical conditions that contraindicate the participation in exercise and testing. We point out that the older adults from the HC and the RCH (older adults with mental health disorders) were previously diagnosed with neurological deficits by neurologists, and give authorization to participate in the study.

We try to compose the sample with an identical number of older adult participants in each context according to the gender and age. However, in some circumstances this proceeding was not possible, as was the case of HC and RCH (older adults with mental health disorders), contexts where the number of subjects in each group was different.
The sample, in each context, was divided into two groups: an experimental group (EG) with practice of the multimodal exercise program and a control group (CG).

Before conducting the study, all participants received a complete explanation of the purpose, risks, and procedures of the investigation, and provided their written informed consent. However, some older adults were excluded due to medical reasons, namely: in the EG, 4 males and 2 females from the HC, 2 males and 2 females from the RCH and 4 males and 2 females from the DLC. In the CG, 1 male and 1 female from the RCH (mental health disorders), 2 males and 3 females from the RCH, and 1 female from the DLC. The characteristics of the participants of the study are shown in Table 1.

Table 1. Subject characteristics of experimental and control groups. Contexts, age, and gender.

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Mean age (years)</th>
<th>Gender</th>
<th>Subjects</th>
<th>Mean age (years)</th>
<th>Gender</th>
</tr>
</thead>
<tbody>
<tr>
<td>HC (n=8)</td>
<td>70.13±4.85</td>
<td>M</td>
<td>RCH (mental health disorders) (n=4)</td>
<td>79.25±8.01</td>
<td>M</td>
</tr>
<tr>
<td>HC (n=11)</td>
<td>69.91±4.27</td>
<td>F</td>
<td>RCH (mental health disorders) (n=4)</td>
<td>85.5±4.93</td>
<td>F</td>
</tr>
<tr>
<td>RCH (n=9)</td>
<td>80.00±8.27</td>
<td>M</td>
<td>RCH (n=8)</td>
<td>81.88±3.64</td>
<td>M</td>
</tr>
<tr>
<td>RCH (n=17)</td>
<td>83.88±5.30</td>
<td>F</td>
<td>RCH (n=8)</td>
<td>81.00±3.16</td>
<td>F</td>
</tr>
<tr>
<td>DLC (n=11)</td>
<td>71.73±5.51</td>
<td>M</td>
<td>DLC (n=8)</td>
<td>79.38±7.15</td>
<td>M</td>
</tr>
<tr>
<td>DLC (n=16)</td>
<td>72.19±6.45</td>
<td>F</td>
<td>DLC (n=8)</td>
<td>74.25±8.27</td>
<td>F</td>
</tr>
</tbody>
</table>

Hospital center (HC), residential care home (RCH), daily living center (DLC), residential care home (RCH): older adults with mental health disorders, males (M), and females (F).

Older adults from the EG were submitted to a multimodal exercise program, for a period of twelve months while those in the CG maintained their normal physical activity routine. All measurements and the multimodal exercise program were performed by the same evaluator together with teachers graduated from the University of Porto, Portugal. We emphasize that they were the evaluators prior and after training in both groups (EG and CG).

The investigation was in full compliance with the Helsinki declaration of 1975, as revised in 2004, and all methods and procedures were approved by the Institutional Review Board.
Training Protocol

The twelve-month multimodal training protocol was held three times per week and each session lasted about 60 min. All sessions were accompanied by appropriate music considered relevant to the required activity and participants’ age. A physical education instructor with specialization in older adults training conducted the sessions. The exercise training was designed to promote the development of abilities, such as visuomotor coordination skills, flexibility, balance, strength, reaction time, speed of movements of the hands and feet, proprioceptive sensitivity, coincidence-anticipation, and visuomotor memory, as well as emotional and social aspects and awareness of the benefits of regular physical exercise.

Each training session included three main components: initial, a 10-min light warm-up and stretching exercises; fundamental, 45 min of light- to moderate-intensity exercises for the development of the abilities previously mentioned, such as marching in place, stepping exercise at a speed of 40–60 beats per minute using a 15-cm-high bench, heel-drops performed on a hard surface (a heel-drop consists of raising the body weight onto the toes and then letting it drop to the floor, keeping the knees locked and hips extended), muscular endurance exercises performed concentrically and eccentrically involving the upper and lower limbs; strength training performed with elastic bands and dumbbells; balance training with static and dynamic exercises (e.g., walking in a straight line, walking heel to toe, using additional resources, such as, balls, balloons, gymnastics parachutes and ribbons, hoops, ropes and sticks), flexibility training involved the major muscle groups (quadriceps, back and chest) and agility training (visuomotor coordination) aimed at challenging hand-eye coordination, foot-eye coordination, dynamic balance, standing and leaning balance, and psychomotor performance (coincidence-anticipation, proprioceptive sensitivity, visuomotor memory and reaction time) including ball games, relay races, dance movements, and obstacle courses; and finally, 5 min of stretching. For the exercises in the second part of the session, for all the abilities mentioned above, the repetitions were increased from eight to fifteen and the number of sets increased to three.
Footedness assessment

The footedness assessment was evaluated by applying the Lateral Preference Questionnaire (Coren, 1993). The older adults were asked to perform five motor tasks, which were associated with the five questions in the questionnaire. After registering the foot with which the subjects performed the activities, a ratio called the Laterality Quotient (LQ), using the following formula, was calculated:

\[
LQ = \frac{\text{number of tasks with the right foot} - \text{number of tasks with the left foot}}{\text{total number of tasks}} \times 100
\]

The older adults were classified as right-footed (value greater than zero) or left-footed (value lower than zero) based on their score on this questionnaire, which identified 110 strong right-footers (mean score of 92.84 ± 11.39, where 100 is maximal right-footedness) and 2 strong left-footers (mean score of -80.0 ± 0.0, where 100 is maximal left-footedness). Both right-footers’ and left-footers’ data were included in our analysis, and according to their footedness, the subjects used their preferred foot (PF) and their non-preferred foot (NPF) in the test.

It is important to assess the non-preferred foot in order to appreciate – along with the preferred foot – its evolution from pre- to post-training and to observe if this evolution is similar when compared to the preferred foot.

In regards to the Lateral Preference Questionnaire, additional items were added to the Lateral Preference Inventory (Coren, Porac, & Ducan, 1979) that provided a measure of handedness, footedness, vision, and hearing. Coren (1993) and Coren, Porac, and Ducan (1979) reported that, measure of lateral preference has demonstrated a 92% concordance between self-reports and direct behavioural performance.

Cognitive function assessment

To assess the subjects’ global cognitive function, the Mini-Mental State Examination (MMSE) (Folstein, Robins, & Helzer, 1983) was applied. MMSE
total score ranges from 0 to 30. According to this questionnaire, none of the participants had any cognitive impairment (RCH: mean score of 28.23 ± 2.11; DLC: mean score of 27.53 ± 2.43), except the older adults with mental health disorders of the experimental group and the control group, where the doctors confirmed pathologies like schizophrenia, dementia, and depression.

**Daily physical activity assessment**

In order to quantify and verify if there was any change in the daily activities of the sample during the research period, the Modified Baecke Questionnaire (1982) was completed before and after training. This questionnaire has been shown to generate valid and reliable classification scores for activity in older subjects providing a domestic, a sport, and a leisure-time activity score. The sum of the different scores gives the total activity of the subject. The questionnaires were completed by the same researcher during a personal interview. For ethical reasons, this questionnaire was not applied to all the older adults with mental health disorders of the experimental group and the control group.

**Instruments**

**Tapping pedal test (TPT)**

The TPT, as an indicator of pedal dexterity, was adapted from the Human Performance Measurement/Basic Elements of Performance apparatus (Kondraske, 1991). A chair, a wooden ruler (1 m length, 1 cm width and 2 mm height) fixed to the floor at the midpoint between the subject's two feet in the longitudinal direction with two signalizing stickers (10 cm x 10 cm) and one chronometer were necessary. The participant sat on a chair, with the lower limbs at a right angle and slightly distant, so that each heel was near each anterior leg of the chair (see Figure 1).
Figure 1. Tapping pedal test.

The evaluator set the chronometer to 10 seconds and had it count down. At the command of “ready…start” by the evaluator, each participant was instructed to tap alternately as quickly as possible in the lateral direction (did a sort of tap-dance) using one foot at a time. In a period of 10 seconds, they tapped on the signalizing stickers (the width of the signalizing stickers was 10 cm, and the distance between them was 45 cm) to avoid accuracy errors.

The subjects performed two trials for each foot. The results included the greatest number of taps done by each foot; therefore this study only considered the better trial by each subject. Finally, the samples were counterbalanced; that is to say, half of the group began the tests with the preferred foot (PF), and the other half started with the non-preferred foot (NPF). Then, the contralateral foot was assessed. Following this procedure, we avoided the possibility of transfer of learning between feet. The same occurred with respect to the tests; subjects were counterbalanced according to the first test performed, with a time break between both tests.

The functional characteristics of footedness (e.g., the relationship between the preferred limb to execute a manipulative or mobilizing action, such as kicking a ball, and the other foot [non-preferred] that provides stabilizing support) have been studied in children (Teixeira & Teixeira, 2008) but not in older adults.
**Tinetti test**

Balance was evaluated using the Performance-Oriented Assessment of Balance and Mobility, also known as the Tinetti test. This instrument was developed by Tinetti (1986), and it assesses the predisposition for falls in older adults through the quantitative evaluation of a set of tasks related to balance and mobility that are performed by the subject after being explained by the investigator.

The Tinetti test consists of 9 balance items and 10 gait items to be scored on a 0- to 2-point scale. The balance items include: (i) sitting balance, (ii) rising from a chair, (iii) immediate standing balance (first 3-5 seconds), (iv) standing balance, (v) with feet as close together as possible, the examiner pushes lightly with his palm on the subject’s sternum 3 times (nudge), (vi) eyes closed in the same position, (vii) turning 360 degrees, and (viii) sitting down. Static balance is determined by adding up to a maximum score of 16 points.

The gait items include: (i) initiation of gait, (ii) step length and height, (iii) step symmetry and continuity, (iv) path direction, (v) trunk sway, and (vi) walking stance. This item adds up to a maximum score of 12 points. The total score ranges from 0 to 28 points. Lower scores indicate poorer performance.

Subjects that reach less than 19 points show high risk of fall, and those with scores between 19 and 24 points show moderate risk (Lin et al., 2004; Shumway-Cook & Woolacott, 2007; Tinetti, 1986; Tinetti, Speechley, & Ginter, 1988).

**Statistical analysis**

All data were analysed with Statistical Package for the Social Sciences (SPSS: version 19.0). They were checked for distribution and the means and standard deviation were calculated. Descriptive statistics and tests for normality (Shapiro-Wilks test) were performed for all outcome variables. To analyse the multimodal exercise program effect a two-way ANOVA 2x2 (time: from pre- to post-training; gender: males and females) was used. This analysis was performed for the two groups (experimental group and the control group) and contexts (HC, RCH, DLC) separately and for each foot (PF and NPF). When
ANOVA revealed significant interaction (time x gender), Bonferroni post hoc tests were performed to determine differences between the initial and the final values in each group. Statistical significance was set at $p \leq 0.05$.

**Results**

Concerning the Modified Baecke Questionnaire data, and regardless of the exercise program, significant increases from pre- to post-training in the experimental group were found in the residential care home and the daily living center ($p < .001$). The control group maintained the level of daily physical activities from pre- to post-training: residential care home ($p = 0.148$) and daily living center ($p = 0.248$).

**Tapping pedal test: pedal dexterity**

Table 2 presents mean and standard deviation values of the tapping pedal test for the experimental group (males and females) of the hospital center, residential care home, and daily living center as a function of times of assessment and foot.
Table 2. The experimental group's results of the tapping pedal test are shown with mean and standard deviation values of taps from pre- to post-training for each gender and context.

<table>
<thead>
<tr>
<th>Tests</th>
<th>Hospital Center</th>
<th></th>
<th></th>
<th>Factor</th>
<th>F</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Males</td>
<td>Females</td>
<td>Total</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PF (pre-training)</td>
<td>18.25±2.36</td>
<td>16.11±4.56</td>
<td>16.76±4.04</td>
<td>Time x Gender</td>
<td>8.787</td>
<td>.013</td>
</tr>
<tr>
<td>PF (post-training)</td>
<td>17.50±3.31</td>
<td>19.11±3.98</td>
<td>18.61±3.73</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NPF (pre-training)</td>
<td>18.00±2.16</td>
<td>15.00±4.58</td>
<td>15.92±4.15</td>
<td>Time x Gender</td>
<td>7.007</td>
<td>.023</td>
</tr>
<tr>
<td>NPF (post-training)</td>
<td>17.50±2.64</td>
<td>16.77±5.14</td>
<td>17.00±4.41</td>
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<th>p-value</th>
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<tr>
<td></td>
<td>Males</td>
<td>Females</td>
<td>Total</td>
<td></td>
<td></td>
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<tr>
<td>PF (pre-training)</td>
<td>20.00 ±1.89</td>
<td>20.13±2.13</td>
<td>20.09±2.02</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PF (post-training)</td>
<td>24.66±4.76</td>
<td>23.66±3.15</td>
<td>23.95±3.58</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NPF (pre-training)</td>
<td>18.50±1.87</td>
<td>19.00±2.20</td>
<td>18.85±2.08</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>NPF (post-training)</td>
<td>23.83±5.77</td>
<td>23.80±3.50</td>
<td>23.80±4.11</td>
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<th>Tests</th>
<th>Daily Living Center</th>
<th></th>
<th></th>
<th>Factor</th>
<th>F</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Males</td>
<td>Females</td>
<td>Total</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PF (pre-training)</td>
<td>22.33±2.80</td>
<td>19.76±3.63</td>
<td>20.57±3.53</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PF (post-training)</td>
<td>27.00±2.19</td>
<td>26.30±4.64</td>
<td>26.52±3.97</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NPF (pre-training)</td>
<td>20.50±4.13</td>
<td>18.71±3.96</td>
<td>19.25±3.99</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NPF (post-training)</td>
<td>25.16±3.76</td>
<td>24.92±4.19</td>
<td>25.00±3.97</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Preferred foot (PF), non-preferred foot (NPF), and Time x Gender (interaction between time and gender). Statistical significance \( p \leq 0.05 \).

In the experimental group of the hospital center, a significant main effect was found for the interaction between time and gender with the PF \( [F_{1,11} = 8.787; \ p = .013] \) and the NPF \( [F_{1,11} = 7.007; \ p = .023] \). More particularly, males had slightly decreased performance with both feet from pre- to post-training (PF: from 18.25 ± 2.36 taps to 17.50 ± 3.31 taps and NPF: from 18.00 ± 2.16 taps to 17.50 ± 2.64 taps), while females improved their performance with both feet from pre- to post-training (PF: from 16.11 ± 4.56 taps to 19.11 ± 3.98 taps and NPF: from 15.00 ± 4.58 taps to 16.77 ± 5.14 taps). No other significant main effect was found.
In the residential care home, a significant main effect was found for time with the PF \(F_{1,19} = 31.637; \ p < .001\) and the NPF \(F_{1,19} = 34.027; \ p < .001\). Namely, there was a significant improvement in performance from pre- to post-training (PF: from 20.09 ± 2.02 taps to 23.95 ± 3.58 taps and NPF: from 18.85 ± 2.08 taps to 23.80 ± 4.11 taps). No other significant main effect or interactions were found.

In the daily living center, a significant main effect was found for time with the PF \(F_{1,17} = 53.901; \ p < .001\) and the NPF \(F_{1,18} = 55.357; \ p < .001\). More precisely, there was a significant improvement in performance from pre- to post-training (PF: from 20.57 ± 3.53 taps to 26.52 ± 3.97 taps and NPF: from 19.25 ± 3.99 taps to 25.00 ± 3.97 taps). No other significant main effect or interactions were found. Table 3 presents mean and standard deviation values for the control group’s tapping pedal test (males and females) of the residential care home (older adults with mental health disorders), the residential care home, and the daily living center as a function of times of assessment and foot.
Table 3. Control group’s tapping pedal test is shown with mean and standard deviation values of taps from pre- to post-training in each gender and context.

<table>
<thead>
<tr>
<th>Residential Care Home (older adults with mental health disorders)</th>
<th>Residential Care Home</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tests</strong></td>
<td><strong>Males</strong></td>
</tr>
<tr>
<td>PF (pre-training)</td>
<td>11.66±2.08</td>
</tr>
<tr>
<td>PF (post-training)</td>
<td>10.00±3.46</td>
</tr>
<tr>
<td>NPF (pre-training)</td>
<td>11.00±1.73</td>
</tr>
<tr>
<td>NPF (post-training)</td>
<td>9.00±3.60</td>
</tr>
</tbody>
</table>

Preferred foot (PF) and non-preferred foot (NPF). Statistical significance \( p \leq 0.05 \).

In the control group of the residential care home (older adults with mental health disorders), a significant main effect was found for time \( [F_{1,4} = 9.308; p = .038] \), only for the NPF. More specifically, there was a significant decrease in performance from pre- \((11.66 \pm 1.63 \text{ taps})\) to post-training \((9.83 \pm 2.78 \text{ taps})\). No other significant main effect or interactions were found.

In the residential care home, a significant main effect was found for time \( [F_{1,6} = 11.605; p = .014] \), only for the NPF. In particular, there was a significant decrease in performance from pre- \((18.00 \pm 3.42 \text{ taps})\) to post-training \((16.37 \pm 3.37 \text{ taps})\). No other significant main effect or interactions were found.
In the daily living center, a significant main effect was found for time with the NPF \(F_{1,13} = 12.430; \ p = .004\). More specifically, there was a significant decrease in performance from pre- (17.93 ± 2.01 taps) to post-training (17.33 ± 1.67 taps). No other significant main effect or interactions were found.

**Tinetti test: balance**

Table 4 presents mean and standard deviation values of the Tinetti test for the experimental group (males and females) of the hospital center, the residential care home, and the daily living center as a function of times of assessment.
Table 4. Experimental group’s Tinetti test is shown with mean and standard deviation values of points from pre- to post-training in each gender and context.

<table>
<thead>
<tr>
<th>Test</th>
<th>Hospital Center</th>
<th>Residential Care Home</th>
<th>Daily Living Center</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tests</td>
<td>Males</td>
<td>Females</td>
</tr>
<tr>
<td>SB (pre-training)</td>
<td>12.25±2.06</td>
<td>10.33±1.87</td>
<td>10.92±2.06</td>
</tr>
<tr>
<td>SB (post-training)</td>
<td>15.50±0.57</td>
<td>14.33±2.29</td>
<td>14.69±1.97</td>
</tr>
<tr>
<td>DB (pre-training)</td>
<td>10.00±1.82</td>
<td>8.22±2.38</td>
<td>8.76±2.31</td>
</tr>
<tr>
<td>DB (post-training)</td>
<td>11.75±0.50</td>
<td>9.77±2.27</td>
<td>10.38±2.10</td>
</tr>
<tr>
<td>TB (pre-training)</td>
<td>22.25±3.86</td>
<td>18.55±3.71</td>
<td>19.69±4.00</td>
</tr>
<tr>
<td>TB (post-training)</td>
<td>27.25±0.50</td>
<td>24.11±4.45</td>
<td>25.07±3.94</td>
</tr>
</tbody>
</table>

Static balance (SB), dynamic balance (DB), and total balance (TB). TB (SB + DB): maximum 28 points. Interpretation: < 19 high risk of fall, 19-24 moderate risk of fall, and 25-28 low risk of fall. Statistical significance $p \leq 0.05$. 

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In the experimental group of the hospital center, the time factor was significant for the static balance (SB) \([F_{1,11} = 31.549; \ p < .001]\), the dynamic balance (DB) \([F_{1,11} = 14.489; \ p = .003]\) and the total balance (TB) \([F_{1,11} = 29.203; \ p < .001]\). From pre- to post-training, all of the older adults in the sample had a significant improvement of performance in the SB (from 10.92 ± 2.06 to 14.69 ± 1.97 points), DB (from 8.76 ± 2.31 to 10.38 ± 2.10 points) and TB (from 19.69 ± 4.00 to 25.07 ± 3.94 points). No other significant main effect or interactions were found. In the hospital center, after the physical exercise program, the older adults presented a low risk of fall (25.07 ± 3.94 points), but at the beginning they showed a moderate risk of fall (19.69 ± 4.00 points) as measured by the Tinetti test (1986).

In the residential care home, the time factor was significant for the SB \([F_{1,19} = 24.091; \ p < .001]\), the DB \([F_{1,19} = 6.126; \ p = .023]\) and the TB \([F_{1,19} = 20.487; \ p < .001]\). We found that from pre- to post-training, all the older adults in the sample experienced a significant improvement of performance in SB (from 10.57 ± 3.39 to 13.09 ± 2.98 points), DB (from 9.71 ± 2.32 to 10.85 ± 2.12 points) and TB (from 20.28 ± 5.53 to 23.95 ± 4.83 points). The gender factor was also significant for the SB \([F_{1,19} = 6.823; \ p = .017]\), the DB \([F_{1,19} = 5.691; \ p = .028]\) and the TB \([F_{1,19} = 6.930; \ p = .016]\). Males obtained a better performance in all of the three tests: SB (14.25 ± 1.18 points), DB (11.83 ± 0.25 points) and TB (26.08 ± 1.18 points). In comparison, females performed the tests as follows: SB (10.86 ± 3.23 points), DB (9.66 ± 4.69 points) and TB (20.53 ± 5.29 points). We verified that after the exercise program, females were at a threshold that indicated a moderate risk of fall (22.73 ± 5.24 points), but at the beginning they showed a high risk of fall (18.33 ± 5.35 points). On the other hand, males showed a low risk of fall in the pre- (25.16 ± 1.47 points) and post-training (27.00 ± .89 points), as measured by the Tinetti test (1986).

In the daily living center, the time factor was significant for SB \([F_{1,19} = 53.874; \ p < .001]\), DB \([F_{1,19} = 8.423; \ p = .009]\) and TB \([F_{1,19} = 27.262; \ p < .001]\). More specifically, from pre- to post-training, all the older adults in the sample showed a significant improvement of performance in SB (from 12.28 ± 2.68 to 15.04 ± 1.59 points), DB (from 9.90 ± 2.94 to 11.57 ± 0.81 points) and
In the tapping pedal test, the results showed that for the time factor, both genders of the experimental group from the residential care home and the daily living center improved their performance significantly with both feet (preferred foot and non-preferred foot). In the hospital center, a significant main effect was found for the interaction between time and gender; namely males slightly decreased their performance while females improved theirs with both feet (preferred foot and non-preferred foot). In the control group, a significant main effect was found for time in all contexts; that is, both genders decreased their performance with the non-preferred foot.

It should be noted that in our study, all the older adults without mental pathologies of the experimental group (from the residential care home and the daily living center) improved their pedal dexterity with both feet through regular physical exercise. In other words, our results are in accordance with previous studies, which claim that the pedal dexterity of older adults can be improved through the practice of regular physical exercise (Hartmann, Murer, De Bie, & De Bruin, 2009; Jacobson, Thompson, Wallace, Brown, & Rial, 2011; Nagai et al., 2011; Spink et al., 2011). On the other hand, low levels of physical activity and weakness of the lower limbs have been identified as risk factors for functional status decline and falls (Guralnik, Ferrucci, Simonsick, Salive, & Wallace, 1995; Guralnik et al., 1993; Hirvensalo, Rantanen, & Heikkinen, 2000).
Literature emphasizes that an active lifestyle, complemented by regular physical exercise programs, can make an old person capable for the performance of daily tasks, providing meaningful improvement at the physical level (American College of Sports Medicine, 2009; Aoyagi & Shephard, 2010; Bean et al., 2009; Sorace, 2010; Yang et al., 2011).

Furthermore, the muscular structure of the lower limbs presents a strong relation with the mobility and functionality of the older adults (Carmeli, Reznick, Coleman, & Carmeli, 2000). It is evident that the training of balance and muscular strength (especially directed to the lower limbs) can improve the physical function and the functional mobility (e.g., walking speed, transferences, climbing stairs and standing up from the position of sitting down) and reduce the risk of fall (Liu-Ambrose et al., 2004; Shumway-Cook, Gruber, Baldwin, & Liao, 1997).

As mentioned above, the males of the experimental group from the hospital center slightly decreased their performance with both feet from pre- to post-training. This means that the effect of the multimodal exercise program was not enough to improve this ability. Additional studies are necessary to elucidate the effects (with respect to this ability) of exercise on men with mental health disorders. In this way, the risk of injury – namely falls and fractures – is even greater among adults with impaired cognitive functioning (Buchner & Larson, 1987; Myers, Baker, Van Natta, Abbey, & Robinson, 1991).

Additionally, it is important to recall that due to their impaired motor and mental function, adults with dementia have an increased risk of falling, and those who do fall run the risk of further injuries (Muir, Gopaul, & Montero Odasso, 2012).

On the other hand, the females of the experimental group from the hospital center improved their performance with both feet from pre- to post-training. These results are in agreement with other studies that have shown that structured exercise training leads to an increase in physical fitness and function in daily life in adults diagnosed with dementia (Hauer et al., 2012; Heyn, Abreu, & Ottenbacher, 2004). Likewise, exercise in old age is increasingly recognized as an important tool to postpone disability and improve
function (Christmas & Andersen, 2000; Schnelle et al., 2002). Carmeli, Zinger-Vaknina, Morad and Merrick (2005) reported identical results to ours, with females improving their pedal dexterity; that is, an improvement in balance and muscle strength as the result of the applied exercise program.

Furthermore, findings have shown that adults who are generally active have a smaller risk of developing dementia than those who take part in fewer activities. Whether the activity is energy-intensive or not plays a minimal role in this context (Podewils et al., 2005). Even in the oldest subjects (over 85 years), there are indications that regular physical activity protects against the development of dementia (Sumic, Michael, Carlson, Howieson, & Kaye, 2007).

Exercise for adults diagnosed with dementia can yield physiological, psychological and emotional effects. There is no basis for assuming that the volume and intensity of exercise components, such as muscle strength, flexibility and balance, act differently in comparison to adults without dementia. When considering the impact of exercise on cognition and emotion, there is little knowledge regarding the amount and type of activity conducive to better results. Studies in the field of motor learning (Schmidt & Lee, 2011) indicate that the most important factors for learning are an adequate volume of practice together with a perceived meaningful and motivating task. However, considering our results, we think that additional studies are necessary to elucidate the effects of exercise on adults diagnosed with mental health disorders.

In our study, a pedal dexterity decrease was verified for the non-preferred foot in the control group (from the residential care home [older adults with mental health disorders], the residential care home and the daily living center) for both genders, from pre- to post-training. In this sense, our results may suggest that the effect of aging is most visible in subjects who prefer the left foot. Nevertheless, further studies are necessary to confirm this hypothesis.

Concerning the Tinetti test, the older adults of the experimental group from the hospital center, residential care home (gender factor: males better than females) and the daily living center improved their balance from pre- to post-training. The older adults from the hospital center, who had shown a
moderate risk of fall before the start of the exercise program, presented a low risk of fall after the program. In the residential care home, the males obtained a better performance than females (gender factor). However, after the training, the females were at a threshold that indicates a moderate risk of fall when, at the beginning, they exhibited a high risk. Otherwise, males showed a low risk. For the daily living center, the older adults displayed a low risk of fall after the training, when at the beginning it was moderate.

In summary, in the experimental group, all participants in this study improved their performance from pre- to post-training. Our results showed that the benefits of the multimodal exercise program are numerous, namely in balance, leading to a decrease of the fall risk (Madureira et al., 2007; Sato et al., 2011; Siegrist, 2008). As some studies also confer (e.g., Huxham, Goldie, & Patla, 2001; Nitz & Choy, 2004), it is expected that the older adults from our sample will be more autonomous when performing activities like sitting down, taking a bath, crossing a street or cleaning a window.

Studies have shown that improvements in the proprioception and standing balance control of older adults may be specific to the type of physical training undertaken (Tsang & Hui-Chan, 2003, 2004; Xu, Hong, Li, & Chan, 2004). It is important to mention that in our 12-month exercise program, we applied some Tai Chi exercises. One activity that has shown a strong relationship with the proprioceptive ability is the traditional Chinese exercise of Tai Chi, which involves slow movements and continuous monitoring of the body position. Tai Chi has been associated with increased joint position sense (Tsang & Hui-Chan, 2003, 2004) and a way to enable older adults to feel their joint motion (Xu, Hong, Li, & Chan, 2004).

In the control group, no significant main effect or interactions were found in any of the context groups. This data is not in agreement with the study developed by Demura et al. (2003), who find that with aging, balance declines especially after 80 years of age. Supported by these results, the authors suggest that the induced alterations through aging have influences on balance (Gauchard, Jeandel, & Perrin, 2001; Perrin, Gauchard, Perrot, & Jeandel, 1999). The loss of motor function is a common consequence of old age, and it
is associated with adverse health consequences (Buchman, Wilson, Bienias, & Bennett, 2009; Delmonico et al., 2007; Louis, Schupf, Marder, & Tang, 2006).

The major limitation of our study was the difficulty of finding a sufficient number of older adults with mental health disorders who could perform a one-year program of regular exercise.

A key strength of our study is that, to our knowledge, there is not much information or systematic research on this subject (in the Portuguese population). So we believe that our results can contribute to a better understanding of the effect of exercise in the pedal dexterity and balance in old males and females from different contexts.

As a conclusion, we partly confirmed our previous hypothesis, noting that from pre- to post-training: (i) in the hospital center, males slightly decreased their performance with both feet while females improved theirs; (ii) in the residential care home and the daily living center, the older adults improved their performance significantly with both feet. Furthermore, in the Tinetti test, the older adults from the hospital center, the residential care home (gender factor: males better than females) and the daily living center improved their balance. Finally, we believe that Portuguese society should pay special attention to multimodal exercise programs for older adults because they seem to improve some important motor and functional abilities, such as pedal dexterity and balance, contributing in this way to an increase of the autonomy and a better quality of life for the older population.

Acknowledgements

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Effects of a Multimodal Exercise Program in the Intermanual Transfer of Learning

European Journal of Sport Science

(Resubmitted after reviewers’ comments)

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Abstract

The current study investigated the effects of a twelve-month exercise program in the intermanual transfer (IMT) of learning in a group of older adults from a residential care home and a daily living center. The sample was divided into two groups of older adults (N = 79): an experimental group (EG) and a control group (CG).

A complex coincidence-anticipation task was used to measure the IMT. The subjects in the EG and the CG were assigned to two groups: one practicing with the preferred hand and being tested on the non-preferred hand (PH-NPH) and another receiving the reverse treatment (NPH-PH), both in pre- and post-training. In the EG, results showed that significant time differences were found in the NPH-PH condition; that is, there was a significant decrease in the IMT percentages from pre- (66.13 ± 13.92) to post-training (45.88 ± 42.83). In the PH-NPH condition, no significant differences were found for any of the variables analysed.

In the CG, no significant main factors or interactions were found. However, it should be noted that the subjects of the EG obtained considerable rates of positive IMT after the exercise program in both conditions, suggesting that older adults can learn and transfer some specific perceptual motor tasks. Data indicated that there were no statistically significant differences between the two conditions of IMT in any group, time or gender. We concluded that in older adults, the ability of motor learning is preserved, and it can be transferred from one upper limb to the other.

Keywords: aging, older adults, intermanual transfer of learning, multimodal exercise program, coincidence-anticipation
Introduction

The intermanual transfer (IMT) of learning has often been used as a paradigm to study functional specialization and hemispheric interactions in relation to handedness, and only more recently has there been in research an increase of the task’s complexity in order to simulate the tasks from the real world (Williams & Jasiewicz, 2001). In this regard, several authors reported that the ability of anticipating a motor answer is essential for a highly successful performance of any motor skill (e.g., Haywood, 1989; Santos & Tani, 1995). According to the premises of Schmidt and Lee (2011), the development of precision can be increased through physical exercise in coincidence-anticipation (CA) tasks.

However, as previous investigations suggest (Haywood, 1980; Meeuwsen, Goode, & Goggin, 1997; Santos, Corrêa, & Freudenheim, 2003), the ability of the participant to perform CA tasks undergoes a significant deterioration along the aging process. Several studies (e.g., Haywood, 1989; Santos, Corrêa, & Freudenheim, 2003) interpret this decline as a result of impairments concerning the initial perception of the stimulus speed (Haywood, 1989), the decline of the cognitive functions caused by aging (Santos, Corrêa, & Freudenheim, 2003), the necessity of more movement time by older adults to answer to certain stimuli (Jevas & Yan, 2001) and also the fact that the perceptual-motor system of older adults may be disturbed, not only by the aging process, but also by the stimulus characteristics (Meeuwsen, Goode, & Goggin, 1997).

Manual abilities have been considered essential for the accomplishment of daily life activities (Carmeli & Lieberman, 2007; Francis & Spidurso, 2000). However, a general age-related decline in hand performance and function has been extensively described (Kalisch, Wilimzig, Kleibel, Tegenthoff, & Dinse, 2006; Poston, Van Gemmert, Barduson, & Stelmach, 2009).

Despite the importance of the implications of aging, one of the most intriguing questions about the IMT is how it occurs, such as, how information is exchanged from one hemisphere of the brain to the other, namely, to the direction of the transfer.
Thus, the question is whether the amount of IMT is bigger from one hand to the other (asymmetric transfer) or if it is similar between hands (Vasconcelos, 2006). Several studies with right-handers suggest a larger amount IMT from the preferred to the non-preferred hand (Inui, 2005; Wang & Sainburg, 2004), others vice-versa (Kumar & Mandal, 2005; Lavrysen et al., 2003; Puretz, 1983; Taylor & Heilman, 1980) and others support an identical IMT of learning between hands (e.g., Teixeira, 2006).

The older adults’ daily physical activities often involve perceptual-motor actions that require skills based on the CA’s ability (crossing the road, driving a car, walking on escalators, reaching for and grabbing an object in movement or simply catching an object that falls) that call for time and space interaction processing.

Consequently, the older adults have a higher difficulty in making use of their sensorial information, in finding and correcting errors and in controlling motor actions when facing the environmental demands in which they live (Cinelli, Patla, & Stuart, 2008). In spite of this, in a study carried out by Seidler (Seidler, 2007b), there was a savings in performance time when participants were presented with a task with similar attributes to a previously practiced task.

Therefore, the present study aimed at investigating if older adults can learn specific skill processes by analysing the effects of a regular multimodal exercise program. There is little information or systematic research on this subject, so the present research can contribute to an understanding of the effects of a twelve-month exercise program in the IMT of learning in a group of older adults.

The following hypotheses were formulated a priori: (i) a multimodal exercise program improves the IMT of learning in older adults, and (ii) interventions targeted by a multimodal exercise program (over twelve months in older adults) are effective in males and females.
Methods

Subjects

A convenience sample of seventy-nine older adults participants from a residential care home (RCH) and a daily living center (DLC) participated in this study. The eligible subject pool was restricted to older adults from both genders with the following characteristics: aged ≥65 years; not engaged in any regular exercise training in the last year; older adults from an RCH and a DLC, lack of use of any medication known to affect the balance, postural stability and lack of any diagnosed or self-reported neurologic disorders, or orthopedic medical conditions that contraindicate the participation in exercise and testing.

The sample was divided into two groups: an experimental group (EG) with practice of the multimodal exercise program and a control group (CG).

Before conducting the study, all participants received a complete explanation of the purpose, risks and procedures of the investigation, and provided written informed consent. However, some older adults were excluded due to medical reasons, namely: in the EG, 2 males from the RCH and 4 males and 2 females from the DLC. In the CG, 2 males and 3 females from the RCH and 1 female from the DLC. And were excluded due to left-handers subjects in the EG, 2 females from the RCH.

Taking into account the previous practice of exercise, the characteristics of the participants of the study were: the EG was composed of 14 males and 27 females (mean age of 77.68 ± 7.94 years) and the CG included 10 males and 12 females (mean age of 78.36 ± 6.61 years).

Older adults from the EG were submitted to a multimodal exercise program, for a period of twelve months while those in the CG maintained their normal physical activity routine. All measurements and the multimodal exercise program were performed by the same evaluator together with teachers graduated from the Faculty of Sport, University of Porto, Portugal. We emphasize that they were the evaluators prior and after training in both groups (EG and CG).
The investigation was in full compliance with the Helsinki declaration of 1975, as revised in 2004, and all methods and procedures were approved by the Institutional Review Board.

Training Protocol

The twelve-month multimodal training protocol was held three times per week and each session lasted about 60 min. All sessions were accompanied by appropriate music considered relevant to the required activity and participants’ age. A physical education instructor with specialization in older adults training conducted the sessions. The exercise training was designed to promote the development of abilities, such as visuomotor coordination skills, flexibility, balance, strength, reaction time, speed of movements of the hands and feet, proprioceptive sensitivity, coincidence-anticipation, and visuomotor memory, as well as emotional and social aspects and awareness of the benefits of regular physical exercise.

Each training session included three main components: initial, a 10-min light warm-up and stretching exercises; fundamental, 45 min of light- to moderate-intensity exercises for the development of the abilities previously mentioned, such as marching in place, stepping exercise at a speed of 40–60 beats per minute using a 15-cm-high bench, heel-drops performed on a hard surface (a heel-drop consists of raising the body weight onto the toes and then letting it drop to the floor, keeping the knees locked and hips extended), muscular endurance exercises performed concentrically and eccentrically involving the upper and lower limbs; strength training performed with elastic bands and dumbbells; balance training with static and dynamic exercises (e.g., walking in a straight line, walking heel to toe, using additional resources, such as, balls, balloons, gymnastics parachutes and ribbons, hoops, ropes and sticks), flexibility training involved the major muscle groups (quadriceps, back and chest) and agility training (visuomotor coordination) aimed at challenging hand-eye coordination, foot-eye coordination, dynamic balance, standing and leaning balance, and psychomotor performance (coincidence-anticipation, proprioceptive sensitivity, visuomotor memory and reaction time) including ball
games, relay races, dance movements, and obstacle courses; and finally, 5 min
of stretching. For the exercises in the second part of the session, for all the
abilities mentioned above, the repetitions were increased from eight to fifteen
and the number of sets increased to three.

**Handedness assessment**

The older adults’ handedness was determined using the Dutch
Handedness Questionnaire (Van Strien, 2002). This questionnaire consisted of
sixteen hand-preference activities. For each activity, the participants indicated
whether the left or right hand was used or if they did not have a preference for
one hand over the other. Each item was coded from 0 to 2, with "left" receiving
a score of 0 and "right" receiving a score of 2 and "both" receiving a score of 1.
Therefore, the total score could range from 0 (i.e., extremely left-handed) to 32
(i.e., extremely right-handed).

**Cognitive function assessment**

To assess the subjects’ global cognitive function, the Mini-Mental State
Examination (MMSE) (Folstein, Robins, & Helzer, 1983) was applied. The
MMSE total score ranges from 0 to 30. This questionnaire assesses the
existence of cognitive impairment via six items: orientation (spatial and
temporal), retention (record), attention and calculation, recall (recent memory),
language and constructive ability.

**Daily physical activity assessment**

In order to quantify and verify if there was any change in the daily
activities of the sample during the research period, the Modified Baecke
Questionnaire (1982) was completed before and after training. This
questionnaire has been shown to generate valid and reliable classification
scores for activity in older subjects providing a domestic, a sport and a leisure-
time activity score. The sum of the different scores gives the total activity of the
subject. The questionnaires were completed by the same researcher during a personal interview.

**Intermanual transfer assessment**

The coincidence-anticipation apparatus used for the IMT evaluation was the Bassin Anticipation Timer (Lafayette Instruments, n°. 50575). This apparatus simulates a moving stimulus with a runway sequentially lit of LED lamps set 4.5 cm apart. Two 16-lamp runways attached end to end (152 cm long) were mounted on two standard tables. The angle of the stimulus runway approach was 30° (Payne, 1987). The runways were connected to a 60 cm x 72 cm plywood platform with six buttons (4 cm in diameter and 1.3 cm in height), in conjunction with a visual stimulus provided by a coincidence-anticipation device (see Figure 1). The platform was placed on a third table and was interfaced with a computer. Participants sat at the end of the third table and viewed the target as it moved toward them (see Figure 1).
Participants were instructed to press the start button in order to initiate the stimulus travelling and then to push the remaining five buttons sequentially (1-2-3-4-5) so that the last button-push (near the ending of the runway) would coincide with the arrival of the moving stimulus at the last LED.

After pressing the start button, participants had to cross their body midline and push the first button. The sequence used in the left hand
performance was a mirror condition of the sequence that was used in the right hand performance.

A constant fore-period of 1.0 s was used for all trials, at a constant velocity of 1 mph (44.8 cm/s), with an inter-trial interval of 10 s. Following a first, non-evaluated trial, five trials were recorded for each hand. The difference in time between the arrival of the target light (the last runway LED) and the response (on the last button – fifth) was measured to the nearest millisecond, early or late. Knowledge of results was provided after each trial, indicating the magnitude (milliseconds) and direction (early or late) of the response. The software AcqKnowledge 3.8.1 (Biopac MP Systems, Inc., Goleta, coincidence-anticipation) was used for data acquisition.

All the subjects were verbally informed of the aims of the study and of the tasks to be done, so there was no demonstration. One by one, participants were evaluated alone with the instructor in the room. A complex coincidence-anticipation task was used to measure the IMT, and the subjects in the EG were assigned into two groups: one practicing with the preferred hand and being tested on the non-preferred hand (PH-NPH) and the other receiving the reverse treatment (NPH-PH).

The assessment was composed of three execution phases studied in two times, pre- and post-training. As mentioned above, we applied a first, non-evaluated trial, meaning that there was only one trial followed by three execution phases: i) initial evaluation, five trials with the PH or with the NPH, according to the condition; ii) acquisition, 30 trials with the PH or the NPH, according to the condition; iii) final evaluation, with the same proceedings of the initial evaluation. An index of the IMT index was estimated using the following formula: mean value of the first five trials (time/error) - mean value of the last five trials (time/error) / mean value of the first five trials (time/error) x 100 (Woodworth & Schlosberg, 1971).

Statistical analysis

All data were analysed with Statistical Package for the Social Sciences (SPSS: version 19.0). They were checked for distribution, and the means and
standard deviation were calculated. Descriptive statistics and tests for normality (Shapiro-Wilks test) were performed for all outcome variables.

To analyse the differences between conditions (PH-NPH and NPH-PH) two times (pre- and post-training), an independent sample $t$ test was used in each group (EG and CG).

To examine the performance differences within and between both hands and groups over time, a two-way ANOVA 2X2 (time: from pre- to post-training; gender: males and females) with repeated measures on the first factor was conducted. This analysis was made separately for the two groups (the EG and the CG) and conditions (PH-NPH and NPH-PH). When ANOVA revealed significant interaction (time x gender), Bonferroni post hoc tests were performed to determine the differences between the initial and the final values in each group. Statistical significance was set at $p \leq 0.05$.

Results

In regards to the handedness assessment, subjects were classified as right-handers or left-handers based on their score. This identified sixty-three right-handers and two left-handers. Only the right-handers’ data were included in the analyses, and they were all strongly right-handed (mean score of 29.69 ± 0.94, where 32 is maximal right-handedness).

According to the Mini-Mental State Examination, none of the participants had any cognitive impairment (mean score: 27.80 ± 2.44). All subjects were in good health condition with normal or corrected-to-normal vision, and they had no history of motor or neurological disorders.

Concerning the Modified Baecke Questionnaire data, our results showed that there was a significant increase in daily physical activities from the pre- to the post-training, both in the residential care home and the daily living center ($p < .001$) of the experimental group, regardless of the exercise program used during the research. This was in opposition to the control group, which maintained the level of daily physical activities from the pre- to the post-training.

Concerning the differences between conditions (PH-NPH and NPH-PH) in the two times (pre- and post-training), the independent sample $t$ test showed
that, regarding the percentage of IMT, no significant differences were found in the experimental group between conditions in the pre-training \([t_{39} = -1.241; p = .222]\) as well as in the post-training \([t_{39} = .291; p = .772]\). Likewise, no significant differences were found in the control group between conditions in the pre-training \([t_{20} = -.135; p = .894]\) as well as in the post-training \([t_{20} = -.603; p = .553]\). Figure 2 presents the mean and standard deviation of percentage of IMT for the experimental group and the control group in the PH-NPH condition, and from the first (pre-training) to the second (post-training) time of assessment.

**Condition from PH to NPH**

![Figure 2](image)

**Figure 2.** Mean and standard deviation of intermanual transfer (IMT) percentage for the experimental group (EG) and control group (CG) in the PH-NPH condition, and from the first (pre-training) to the second (post-training) time of assessment.

Considering the entire sample, no significant main factors or interactions were found in the experimental group for the following: time \([F_{1,16} = 1.026; p = .326]\), gender \([F_{1,16} = .143; p = .710]\), and interaction between time and gender \([F_{1,16} = 2.671; p = .122]\). Neither were significant main factors or interactions found in the control group for the following: time \([F_{1,8} = 3.826; p = .086]\), gender \([F_{1,8} = .001; p = .981]\), and interaction between time and gender \([F_{1,8} = .486; p = .506]\). Figure 3 presents the mean and standard deviation of percentage of IMT for the experimental group and the control group in the NPH-PH condition, and from the first (pre-training) to the second (post-training) time of assessment.
Condition from NPH to PH

![Chart](chart.png)

**Figure 3.** Mean and standard deviation of intermanual transfer (IMT) percentage for the experimental group (EG) and control group (CG) in the NPH-PH condition, and from the first (pre-training) to the second (post-training) time of assessment. * Statistical significance \( p \leq 0.05 \).

The analysis of the all subjects of the experimental group revealed a significant main effect for time \([F_{1,21} = 4.882; \ p = .038]\). More specifically, there was a significant decrease of IMT percentages from pre- \((66.13 \pm 13.92)\) to post-training \((45.88 \pm 42.83)\). No other significant main effects were observed (gender \([F_{1,21} = .038; \ p = .846]\) or interaction between time and gender \([F_{1,21} = .013; \ p = .911]\)).

The analysis of the entire sample of the control group showed no significant main effects or interactions for the following: time \([F_{1,10} = 3.953; \ p = .075]\), gender \([F_{1,10} = 1.509; \ p = .247]\), and interaction between time and gender \([F_{1,10} = 2.117; \ p = .176]\).

**Discussion**

The present research aimed to investigate the effects of a multimodal exercise program in the IMT of learning (using a complex coincidence-anticipation task) in older adults of both genders.
The results indicate that in all subjects of the experimental group (total males and females) in the NPH-PH condition, significant differences were found for time; that is, there was a significant decrease of IMT percentages from pre-training (66.13 ± 13.92) to post-training (45.88 ± 42.83). However, it should be noted that the experimental group obtained considerable rates of positive IMT after the exercise program in both conditions, suggesting that older adults can learn and transfer some specific perceptual motor tasks. In fact, the results of our research corroborate those of Seidler (2007a, 2007b), who proposes that new motor skills can also be learned by older adults. In spite of being slower in performance, possibly due to deficits in the selection of information and difficulties in ignoring irrelevant information and in making decisions, older adults showed the ability to adapt both to environment demands and to motor skills (Larish & Stelmach, 1982; Santos & Tani, 1995; Schmidt & Lee, 2011). It is therefore a well-established principle in motor learning that in spite of having some ability to transfer learning, the acquisition of a motor skill is specific to the practiced task (Teixeira, 2004).

On the other hand, older adults exhibit reduced rates and magnitudes of skill acquisition in comparison to their young counterparts; several authors report that they show normal motor generalization (e.g., Bo, Borza, & Seidler, 2009; Lustig, Shah, Seidler, & Reuter-Lorenz, 2009; Seidler, 2007a, 2007b; Seidler, 2010).

Furthermore, it is known that the practice of physical exercise affords improvements in the information processing of older adults (Shubert, McCulloch, Hartman, & Giuliani, 2010) with evident developments in their cognitive performance (Netz, Argov, & Inbar, 2009; Netz, Tomer, Axelrad, Argov, & Inbar, 2007; Spirduso, Poon, & Chodzo-Zajko, 2008; Spirduso, 2009). Our results are in agreement with Lobjois, Benguigui and Berths (2005) who concluded that the maintenance of active lifestyles can be associated with better performances, attenuating the decrease of the ability to learn motor skills.

Therefore, learning with one hand is supposed to be carried over to the other hand (Mandal, Singh, Asthana, & Srivastava, 1992). Our results showed that no significant differences were found in the experimental group in the
condition from the PH-NPH for time, gender and interaction between time and gender. Likewise, in the same group, we found considerable percentages of IMT (around 50%) in pre- and post-training, and according to Vasconcelos (2006), it is likely that the transfer arises from the constant interaction of both cognitive and neuromuscular factors. Our results, namely considerable percentages of IMT, are consistent with a previous study by Langan and Seidler (2011). Although using a different task and different age groups, these authors found that older adults demonstrated a larger benefit from prior training (compared to their young counterparts in terms of reducing direction error at motor transfer to the 45° rotation), and remarkably, they did not demonstrate any deficits in motor transfer.

In the control group, no significant differences were found for time, gender and interaction between time and gender in any of the two conditions. However, considerable percentages of IMT were observed. In the pre- and post-training test (complex coincidence-anticipation task) acquisition phase, the older adults performed 30 trials (with the PH or the NPH, according to the condition) which supposedly were determinant regardless of having participated in a twelve-month exercise program. Hence, we expect that new motor skills can also be learned by older adults as corroborated by Seidler (2007a, 2007b).

According to the general model of hemispheric lateralization and task control, the two brain hemispheres are responsible for the specialized processing of different movement components (Birbaumer, 2007; Gazzaniga, Ivry, & Mangun, 1998; Serrien, Ivry, & Swinnen, 2006). Indeed, it has been suggested that performance differences are due to differences in the information-processing abilities of the left and right hemispheres of the brain, with a right hemisphere specialization for spatiotemporal and attention processes and a left hemisphere specialization for movement execution (Eikenberry et al., 2008; Grouios, 2006; Haaland, Prestopnik, Knight, & Lee, 2004; Lavrysen, Elliott, Buekers, Feys, & Helsen, 2007).

In addition, our data indicated that there were no statistically significant differences between the two conditions of IMT in any group, time or gender; in the coincidence-anticipation task, the IMT was symmetric, corroborating the
results of Teixeira (2006) with young populations. This observation suggests that there is no dominant cerebral hemisphere for synchronizing manual movements with environmental events with the equivalent potential of IMT in both preferred to non-preferred and non-preferred to preferred directions (Teixeira, 2006).

Furthermore, as shown in our research, there are also studies that report equal transfer in both directions (Imamizu & Shimojo, 1995; Palmer & Meyer, 2000; Teixeira, 2006). Others have presented a similar overall transfer for the right and left hand in visuomotor rotations, although different features of movement were transferred in different directions (Sainburg & Wang, 2002). Perhaps one of the most relevant aspects is that, according to Potter and Graves (1988), the two hemispheres work mainly in an integrated and not an independent way.

Final observations take into account the limitations and strengths of this study, along with recommendations for future studies. The major limitation of this research was that the sample size may have been too small to detect significant changes in the studied variable. In future investigations it would be interesting to study the differences between older adults with and without mental health disorders with respect to the IMT of learning using an easier task. A key strength of our study is that, to our knowledge, there is not much information or systematic research on this subject, so we believe that our results can contribute to a better understanding of the effect of exercise in the IMT in aged males and females from different contexts.

In conclusion, we partly confirmed our previous hypothesis, because our results showed that the process of IMT of learning occurs in the NPH-PH condition. This fact confirms that in older adults, the ability of motor learning is preserved and can be transferred from one upper limb to the other. Literature suggests that an active lifestyle, complemented with an exercise program can empower older adults for day-to-day tasks, providing significant improvements in the learning of motor skills. Nevertheless, more studies will be necessary to confirm the effects of exercise in the improvement of the IMT of learning.
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Effects of a Multimodal Exercise Program on the Visuomotor Memory: Study with Portuguese Older Adults of Different Contexts

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Abstract

According to the American College of Sports Medicine (1998), memory, along with attention and reaction time, is one of the aspects in the cognitive sphere that is positively influenced by regular exercise.

The current study investigated the effects of a multimodal exercise program on the visuomotor memory in two groups of older adult participants (65-92 years of age) from a psychiatric hospital center (HC), a residential care home (RCH) and a daily living center (DLC). The experimental group trained three times per week for twelve months and the control group maintained their normal activities.

The Mini-Mental State Examination and the Modified Baecke Questionnaire as well as the Visuomotor Memory Test (Thinus-Blanc, Gaunet, & Péruch, 1996) were applied to all subjects before and after the experimental protocol.

In the experimental group, the results from the RCH and the DLC showed that both genders improved their performance in the visuomotor memory for time/seconds and errors from pre- to post-training. However, in the HC no significant main effect or interactions were found (time over, gender and interaction between time over and gender). Finally, in the control group, no significant effects or interactions were found for any of the context groups.

These findings suggest that our program had a positive effect on older adults without mental disorders from different contexts. However, in older adults with mental health disorders our results contradict literature, particularly with regard to the visuomotor memory.

Keywords: aging, older adults, multimodal exercise program, visuomotor memory
Introduction

Problems in memory emerge with aging. The relationship between regular exercise and cognitive processes is a current topic of discussion where some controversy exists concerning the impact of exercise on the older adults’ cognition.

Müller and Knight (2002) state that, with aging, there is a deficit in the older adults’ spatial memory. However, when they practice certain spatial locations without any time limit, the results are as accurate and satisfactory as those of young adults.

The effects of aging on adaptive visuomotor mechanisms and behavioral responses are controversial (Etnier & Landers, 1998; Fernandez-Ruiz, Hall, Vergara, & Diaz, 2000; McNay & Willingham, 1998; Teulings, Contreras-Vidal, Stelmach, & Adler, 2002). While several studies have reported an age-related decline in spatial memory (Cooney & Arbuckle, 1997; Joanisse, Gagnon, Kreller, & Charbonneau, 2008; Park et al., 2002), others suggest that spatial memory can resist aging (Parkin, Walter, & Hunkin, 1995; Pouliot & Gagnon, 2005).

According to Izquierdo (2002), the loss of neurons and the consequent cerebral dysfunction occur with variable speed in each subject and the continuous use of memory seems to slow down or reduce the functional deficit that occurs with aging. The understanding of the etiology implicated in this process has important consequences for both determining the underlying basis for the deterioration of visuomotor mechanisms in aging and for devising new intervention procedures for new skill learning in older adult populations.

The beginning of mental changes is usually so deceptive that neither the family nor the patient can date the time of its onset. Manifestations of a special failure to orient the scheme of one's body with the surrounding space include losing one's way in familiar surroundings, inability to interpret a road map and park a car, difficulties in distinguishing right from left, setting the table and dressing (Ropper & Samuels, 2009). Visuomotor deficits are associated with poor motor function (Dancause, Ptito, & Levin, 2002) interfering with several daily tasks that rely on fast cognitive processing of sequentially ordered
movements, such as dressing, toileting, or transfers. Furthermore, previous studies indicate cognitive control processes are necessary for balance (Brauer, Woollacott, & Shumway-Cook, 2001), ambulation (Hausdorff, YogeV, Springer, Simon, & Giladi, 2005), and reaching/grasping (Carmeli & Liebermann, 2007), all motor functions that are affected by age. Overall, impaired cognition can reduce the likelihood of independent living in older adults.

Markers that are responsive to brain dysfunction can be considered as losses in the visuospatial skills. Such losses can be crucial in the possible diagnosis of dementia (Camargo & Cid, 2000).

Ahlskog, Geda, Graff-Radford, and Petersen (2011) suggest that aerobic exercise is related to a reduced risk of cognitive impairment and dementia and it may even slow dementia illness.

Aerobic exercise is responsible for promoting a higher cognitive well-being (Barella, Etnier, & Chang, 2006; Grego et al., 2005; Kramer, 2000; Lachman, Neupert, Bertrand, & Jette, 2006). Yet, no studies have examined the effects of a multimodal exercise program that is usually recommended for older adults (Garber et al., 2011) on cognition, namely on visuomotor memory (VMM).

With this research, it was our intention to investigate older adults from a wide range of the population as a whole, that is, we sought to include older adults with mental health disorders (from a psychiatric hospital center [HC] and a residential care home [RCH]) and without mental health disorders (namely, from an RCH and a daily living center [DLC]).

Thus, the aim of our study was to investigate the effects of a multimodal exercise program on the VMM of older adult men and women from different contexts.

The following hypotheses were formulated a priori: (i) a multimodal exercise program improves the VMM in older adults from different contexts, and (ii) interventions targeted by a multimodal exercise program (during twelve months in the older adults from different contexts) are effective in males and females.
Methods

Participants

A convenience sample of one hundred and thirty-six older adult participants from an HC, an RCH and a DLC participated in this study. The eligible subject pool was restricted to older adults from both genders with the following characteristics: aged ≥ 65 years; not engaged in any regular exercise training in the last year; older adults from an RCH and a DLC, lack of use of any medication known to affect the balance, postural stability and lack of any diagnosed or self-reported neurologic disorders, or orthopedic medical conditions that contraindicate the participation in exercise and testing. We point out that the older adults from the HC and the RCH (older adults with mental health disorders) were previously diagnosed with neurological deficits by neurologists, and give authorization to participate in the study.

We try to compose the sample with an identical number of older adult participants in each context according to the gender and age. However, in some circumstances this proceeding was not possible, as was the case of HC and RCH (older adults with mental health disorders), contexts where the number of subjects in each group was different.

The sample, in each context, was divided into two groups: an experimental group (EG) with practice of the multimodal exercise program and a control group (CG).

Before conducting the study, all participants received a complete explanation of the purpose, risks, and procedures of the investigation, and provided their written informed consent. However, some older adults were excluded due to medical reasons, namely: in the EG, 4 males and 2 females from the HC, 2 males and 2 females from the RCH and 4 males and 2 females from the DLC. In the CG, 1 male and 1 female from the RCH (mental health disorders), 2 males and 3 females from the RCH, and 1 female from the DLC. The characteristics of the participants of the study are shown in Table 1.
Older adults from the EG were submitted to a multimodal exercise program, for a period of twelve months while those in the CG maintained their normal physical activity routine. All measurements and the multimodal exercise program were performed by the same evaluator together with teachers graduated from the University of Porto, Portugal. We emphasize that they were the evaluators prior and after training in both groups (EG and CG).

The investigation was in full compliance with the Helsinki declaration of 1975, as revised in 2004, and all methods and procedures were approved by the Institutional Review Board.

**Training Protocol**

The twelve-month multimodal training protocol was held three times per week and each session lasted about 60 min. All sessions were accompanied by appropriate music considered relevant to the required activity and participants’ age. A physical education instructor with specialization in older adults training conducted the sessions. The exercise training was designed to promote the development of abilities, such as visuomotor coordination skills, flexibility, balance, strength, reaction time, speed of movements of the hands and feet, proprioceptive sensitivity, coincidence-anticipation, and visuomotor memory, as well as emotional and social aspects and awareness of the benefits of regular physical exercise.
Each training session included three main components: initial, a 10-min light warm-up and stretching exercises; fundamental, 45 min of light- to moderate-intensity exercises for the development of the abilities previously mentioned, such as marching in place, stepping exercise at a speed of 40–60 beats per minute using a 15-cm-high bench, heel-drops performed on a hard surface (a heel-drop consists of raising the body weight onto the toes and then letting it drop to the floor, keeping the knees locked and hips extended), muscular endurance exercises performed concentrically and eccentrically involving the upper and lower limbs; strength training performed with elastic bands and dumbbells; balance training with static and dynamic exercises (e.g., walking in a straight line, walking heel to toe, using additional resources, such as, balls, balloons, gymnastics parachutes and ribbons, hoops, ropes and sticks), flexibility training involved the major muscle groups (quadriceps, back and chest) and agility training (visuomotor coordination) aimed at challenging hand-eye coordination, foot-eye coordination, dynamic balance, standing and leaning balance, and psychomotor performance (coincidence-anticipation, proprioceptive sensitivity, visuomotor memory and reaction time) including ball games, relay races, dance movements, and obstacle courses; and finally, 5 min of stretching. For the exercises in the second part of the session, for all the abilities mentioned above, the repetitions were increased from eight to fifteen and the number of sets increased to three.

**Cognitive function assessment**

To assess the subjects’ global cognitive function, the Mini-Mental State Examination (MMSE) (Folstein, Robins, & Helzer, 1983) was applied. MMSE total score ranges from 0 to 30. According to this questionnaire, none of the participants had any cognitive impairment (RCH: mean score of 28.23 ± 2.11; DLC: mean score of 27.53 ± 2.43), except the older adults with mental health disorders of the experimental group and the control group, where the doctors confirmed pathologies like schizophrenia, dementia, and depression.
Daily physical activity assessment

In order to quantify and verify if there was any change in the daily activities of the sample during the research period, the Modified Baecke Questionnaire (1982) was completed before and after training. This questionnaire has been shown to generate valid and reliable classification scores for activity in older subjects providing a domestic, a sport, and a leisure-time activity score. The sum of the different scores gives the total activity of the subject. The questionnaires were completed by the same researcher during a personal interview. For ethical reasons, this questionnaire was not applied to all the older adults with mental health disorders of the experimental group and the control group.

Instruments

Visuomotor memory test (Thinus-Blanc, Gaunet, & Péruch, 1996). A square was used with dimensions of 78.74x78.74 inches, perfectly delimited for an off-the-ground panel measuring 74.80 inches high. For the performance of the route, three points (A, B and C) were marked in this space, with A (in the middle of the sides of the square) being the starting point, B (placed in the diagonal of the sides of the square) 7.87 inches off the left corner, and C (also placed in the diagonal of the square), 9.84 inches off the right corner.

The visuomotor memory test implies that subjects go from A to point B and thereafter to point C, and from here return to the starting point A. Figure 1 shows the route followed in this study by the older adults to assess their visuomotor memory, and Figure 2 shows the apparatus of the visuomotor memory test.
The older adults performed the route twice in order to get familiar with the visuospatial information (spatial codification) and to retain it in the memory. Both courses were performed with eyes open and later on, at the test, the route was performed with the eyes closed. The time spent in performing the route as well as the number of errors were counted and registered by the researchers. It was considered an error when the participant gets away from the target, touches the panel or uses the feet or the hands to progress along the panel. The maximum time of performance was set at five minutes, above which the test was considered null (Thinus-Blanc, Gaunet, & Péruch, 1996).
Statistical analysis

All data were analysed with Statistical Package for the Social Sciences (SPSS: version 19.0). They were checked for distribution and the means and standard deviation were calculated. Descriptive statistics and tests for normality (Shapiro-Wilks test) were performed for all outcome variables. To analyze the multimodal exercise program effect a two-way ANOVA 2x2 (time over: from pre- to post-training; gender: males and females) was used. This analysis was performed for the two groups (experimental group and the control group) and contexts (HC, RCH, DLC) separately and for each variable (time/seconds and errors). When ANOVA revealed significant interaction (time over x gender), Bonferroni post hoc tests were performed to determine differences between the initial and the final values in each group. Statistical significance was set at $p \leq 0.05$.

Results

Concerning the Modified Baecke Questionnaire data, and regardless of the exercise program, significant increases from pre- to post-training in the experimental group were found in the residential care home and the daily living center ($p < .001$). The control group maintained the level of daily physical activities from pre- to post-training: residential care home ($p = 0.148$) and daily living center ($p = 0.248$).

Figures 3 and 4 present the mean and standard deviation values of the VMM test for the experimental group (males and females) of the hospital center, the residential care home, and the daily living center, as a function of times over assessment.
**Experimental Group**

Figure 3. Experimental group. Means of seconds of the visuomotor memory (VMM) from pre- to post-training in each gender and contexts: hospital center (HC), residential care home (RCH), and daily living center (DLC). * Statistical significance $p \leq 0.05$.

Figure 4. Experimental group. Means of errors of the visuomotor memory (VMM) from pre- to post-training in each gender and contexts: hospital center (HC), residential care home (RCH), and daily living center (DLC). * Statistical significance $p \leq 0.05$. 
In the experimental group of the hospital center, no significant main effect or interactions were found. However, a significant main effect was found for time over regarding the time/seconds \( F_{1,15} = 8.729; p = .010 \) and the errors \( F_{1,15} = 6.199; p = .025 \) in the residential care home. In particular, there was a significant improvement in performance from pre- to post-training (from 27.97 ± 9.68 to 23.33 ± 6.77 seconds) and (from 8.88 ± 5.65 to 6.64 ± 4.76 errors). No other significant main effect or interactions were found.

In the daily living center, a significant main effect was found for time over according to time/seconds \( F_{1,17} = 11.968; p = .003 \) and the errors \( F_{1,18} = 9.724; p = .006 \). More precisely, there was a significant improvement in performance from pre- to post-training (from 25.78 ± 11.54 to 18.38 ± 7.82 seconds; from 9.35 ± 6.86 to 5.75 ± 2.29 errors). No other significant main effect or interactions were found.

Concerning the control group, no significant main effect and interactions were observed in the visuomotor memory for time/seconds and for errors (time over, gender and interaction between time over and gender) from pre- to post-training in all the different contexts: residential care home (older adults with mental health disorders), residential care home and daily living center.

**Discussion**

The purpose of this study was to evaluate the effects of a multimodal exercise program on the visuomotor memory (VMM) of older adults from different contexts.

In opposition to the control group, all the older adults of the experimental group from the residential care home and the daily living center improved their VMM performance (time/seconds and errors) from pre- to post-training, with the exception of the older adults from the hospital center where no significant main effect or interactions were found.

In this way, our data suggest that a multimodal exercise program is able to improve the VMM performance, in terms of time/seconds and errors, in older adult participants without mental disorders. Our results are in agreement with some studies that refer to significant improvements in the older adults' cognitive
functions after aerobic training (Lachman, Neupert, Bertrand, & Jette, 2006; Netz, Argov, & Inbar, 2009; Netz, Tomer, Axelrad, Argov, & Inbar, 2007; Williamson et al., 2009). Just as exercise increases the brain’s health and an active lifestyle improves learning, memory and depression; exercise also modulates a range of supporting systems for brain maintenance and plasticity, including neurogenesis, enhanced central nervous system in metabolism, and angiogenesis (Cotman, Berchtold, & Christie, 2007).

Likewise, our results are in accordance with another study carried out by Botelho in 2006, involving forty-six Portuguese older adults of both genders in the age group between 65 and 93 years old. Botelho (2006) found that older adults who have practiced exercise over the last five years had better results in the VMM than their counterparts (older adults who have not practiced any exercise). Our data, similar to the study of Botelho (2006), emphasizes that the practice of exercise is significant for the improvement of the VMM in both genders.

However, not only are the effects of aging on adaptive visuomotor mechanisms and behavioral responses controversial but in terms of after-training effects (a measure of visuomotor learning), the results are also confusing. Some studies, in accordance to our data, found positive effects, whereas others found no significant influence of exercise in VMM, suggesting that data is insufficient to show that the improvements in the cognitive function can be exclusively attributed to exercise (Angevaren, Aufdemkampe, Verhaar, Aleman, & Vanhees, 2008a, 2008b; Blumenthal et al., 1989; Blumenthal & Madden, 1988).

Literature points out that in healthy adults the deterioration of the hippocampus with aging leads to memory impairment (Raz et al., 2005). In a recent study with older adults without mental disorders, Erickson et al. (2011) verified that a year of regular exercise increases the size of the anterior hippocampus leading to improvements in spatial memory. So, based on these results, we can suggest that the improvements observed in our sample could be, at least in part, explained by an improvement in spatial memory, since the hippocampus is directly linked with the VMM.
However, in opposition to the literature, the older adults from the hospital center (experimental group) did not improve their performance in terms of time/seconds and errors after training. A review of twenty-seven scientific studies carried out by Eggermont and Scherder (2006) between 1974 and 2005 concluded that exercise can have a positive impact on the cognition and well-being of older adults, including beneficial effects on sleep, mood, and the functional ability in adults diagnosed with dementia. Along the same line, the meta-analysis of Heyn, Abreu and Ottenbacher (2004), concerning the effects of exercise, concluded that exercise is positively associated with beneficial results, namely, on physical function, cognitive function, and positive behavior.

A possible reason for the no-effect of training can be related with the characteristics of our hospital center group that presented adults diagnosed with schizophrenia. Literature points out that, normally these adults show great deficits in verbal learning and memory (Bowie & Harvey, 2005). And, when compared with subjects without mental disorders, unipolar patients have changes of visuomotor sequencing, immediate memory, and attention (Paradiso, Lamberty, Garvey, & Robinson, 1997).

In fact, when we observe the performance of the VMM test of the older adults from the hospital center (experimental group) we notice that they present more difficulties either in pre- and post-training assessment periods compared to the other two institutions. These results are somewhat consistent with earlier studies (Pier, Hulstijn, & Sabbe, 2004; Sabbe, Hulstijn, van Hoof, Tuynman-Qua, & Zitman, 1999) that refer to a motor retardation in depressed subjects characterized by more time and pauses and less speed in the performance of the tasks.

Nevertheless, it is important to emphasize that various studies (e.g., Bullock, 2008; Couné et al., 2012; McDougall, Becker, & Arheart, 2006) state that aging brings along a cognitive impairment including in adults diagnosed with schizophrenia and depression (Meesters et al., 2013), which can also lead to dementia (Magsi & Malloy, 2005; Rovner, Casten, Hegel, & Leiby, 2012).

In populations such as ours with neurological disorders it is more difficult to learn and to adapt to new situations and tasks. As a consequence, the
performance was inferior reflecting a neurological commitment that overlaps the regular multimodal exercise program in the VMM. However, it is necessary to carry out more studies to confirm our results.

The major limitation of our study was to find a sufficient number of older adults with mental health disorders who could perform a one-year program of regular exercise.

A key strength of our study is that, to our knowledge, there is not much information or systematic research on this subject. So we believe that our results can contribute to a better understanding of the effect of exercise in the VMM in older males and females from different contexts.

Summarizing, we confirmed partly our previous hypothesis, our program of multimodal exercise had significant effects in older adults without mental disorders from different contexts. However, it will be necessary to carry out more studies concerning older adults with mental health disorders submitted to a one-year training program, since our results contradict literature, particularly with regard to the VMM.

Acknowledgements

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Conflict of interest/financial disclosure: none.

We wish to thank the older adults who participated in this study. We also thank all the staff of the Conde de Ferreira Hospital Center in Porto, whose generous and skillful help made this work possible.

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References


Erickson, K. I., Voss, M. W., Prakash, R. S., Basak, C., Szabo, A., Chaddock, L., et al. (2011). Exercise training increases size of hippocampus and


Conclusions and final remarks

This thesis aimed to analyze the effects of a multimodal exercise program on motor fitness, functional motor asymmetry, intermanual transfer of learning and visuomotor memory in older adults of different contexts. The following tables summarize the main results of the studies involved in this thesis:

Table 1. Results summary of the variables with significant effects (pre-experimental Study 1).

<table>
<thead>
<tr>
<th>STUDY 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>TEST: Visuomotor memory (Thinus-Blanc, Gaunet, &amp; Péruch, 1996)</td>
</tr>
<tr>
<td>Motor ability: Visuomotor memory</td>
</tr>
<tr>
<td>RESULTS (significant differences $p &lt; 0.05$)</td>
</tr>
</tbody>
</table>

The results showed that (i) practitioners presented a better performance in time and the number of errors than non-practitioners of physical exercise; and (ii) gender and age did not influence the visuomotor memory performance. Results suggest that physical exercise improves the visuomotor memory regardless of gender or age.

Table 2. Results summary of the variables with significant effects (pre-experimental Study 2).

<table>
<thead>
<tr>
<th>STUDY 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>TEST: Modified Baecke Questionnaire</td>
</tr>
<tr>
<td>Assessment of physical activity</td>
</tr>
<tr>
<td>RESULTS (significant differences $p &lt; 0.05$)</td>
</tr>
</tbody>
</table>

The instruments used in the data collection were the ActiGraph GT1M accelerometer, which was applied to all participants over seven days, and the Modified Baecke Questionnaire that was filled out during an interview.

Comparing the measurements obtained from these two instruments, we verified that the correlation is high ($r = 0.665$) and statistically significant ($p < 0.01$), leading us to infer that there is a good association between the values of both assessment methods. These results show that the Modified Baecke Questionnaire is an instrument with good validity coefficients, the advantage of being practical, fast, easily understandable and one that enables the assessment of a great number of subjects, representing a great alternative to the accelerometer.
Table 3. Results summary of the variables with significant effects (experimental Study 3 - experimental group).

| STUDY 3 |
|-------------------|------------------|------------------|------------------|------------------|------------------|
| Experimental group (from pre- to post-training) | | | | | |
| TESTS | | | | | |
| Motor abilities | Motor abilities | Motor abilities | Motor abilities | Motor abilities | Motor abilities | Motor abilities |
| Manual global dexterity | Manual fine dexterity | Visuomotor coordination | Proprioceptive sensitivity | Simple reaction time | Handgrip strength | Pedal dexterity |

RESULTS (significant differences $p < 0.05$)

- **HC:** -Time (PH; NPH and BH): (from pre- to post-training): improvement with a significant effect.

- **HC:** -Time (PH and NPH): (from pre- to post-training): improvement with a significant effect.

- **HC:** -Interaction between time and gender (PH and NPH): males had slightly decreased their performance from pre- to post-training, while the females improved their performance from pre- to post-training.

- **HC:** -Time (PH and NPH): (from pre- to post-training): improvement with a significant effect.

- **HC:** -Gender (PH and NPH): males had better performance than females.

- **HC:** - Interaction between time and gender (PF and NPF): males had slightly decreased their performance with both feet from pre- to post-training, while females improved their performance with both feet from pre- to post-training.
<table>
<thead>
<tr>
<th></th>
<th>Manual global dexterity</th>
<th>Manual fine dexterity</th>
<th>Visuomotor coordination</th>
<th>Proprioceptive sensitivity</th>
<th>Simple reaction time</th>
<th>Handgrip strength</th>
<th>Pedal dexterity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RESULTS (significant differences $p &lt; 0.05$)</strong></td>
<td>RCH: - <strong>Time</strong> (PH; NPH and BH): (from pre- to post-training): improvement with a significant effect.</td>
<td>RCH: - <strong>Time</strong> (PH; NPH and BH): (from pre- to post-training): improvement with a significant effect.</td>
<td>RCH: - <strong>Time</strong> (PH and NPH): (from pre- to post-training): improvement with a significant effect.</td>
<td>RCH: - <strong>Time</strong> (PH and NPH): (from pre- to post-training): improvement with a significant effect.</td>
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<td></td>
<td>RCH: - <strong>Time</strong> (PH and NPH): (from pre- to post-training): improvement with a significant effect.</td>
<td>RCH: - <strong>Time</strong> (PH and NPH): (from pre- to post-training): improvement with a significant effect.</td>
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<td></td>
<td>RCH: - <strong>Time</strong> (PH and NPH): (from pre- to post-training): improvement with a significant effect.</td>
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<tr>
<td></td>
<td>Gender (PH and NPH): males had better performance than females.</td>
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</table>

RCH: - **Time** (PF and NPF): (from pre- to post-training): improvement with a significant effect.
### RESULTS (significant differences $p < 0.05$)

<table>
<thead>
<tr>
<th>Manual global dexterity</th>
<th>Manual fine dexterity</th>
<th>Visuomotor coordination</th>
<th>Proprioceptive sensitivity</th>
<th>Simple reaction time</th>
<th>Handgrip strength</th>
<th>Pedal dexterity</th>
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</tbody>
</table>

**DLC:**
- **Time** (PH; NPH and BH): (from pre- to post-training): improvement with a significant effect.
- **Gender** (PH): females had better performances than males.
- **Interaction between time and gender** (PH): in both gender there was an improvement of the performance from pre- to post-training and females had better performances than males.

**DLC:**
- **Time** (PH and NPH): (from pre- to post-training): improvement with a significant effect.
- **Gender** (NPH): females had better performances than males.
- **Interaction between time and gender** (NPH): (MNP): in both gender there was an improvement of the performance from pre- to post-training.

**DLC:**
- **Gender** (PH and NPH): males had better performance than females.

- **Time** (PF and NPF): (from pre- to post-training): improvement with a significant effect.

---

**Different contexts:** psychiatric hospital center (HC), residential care home (RCH), and daily living center (DLC);

**Hand preference:** preferred hand (PH), non-preferred hand (NPH), and both hands (BH);

**Foot preference:** preferred foot (PF) and non-preferred foot (NPF).
Table 4. Results summary of the variables with significant effects (experimental Study 3 - control group).

<table>
<thead>
<tr>
<th>STUDY 3</th>
<th>Control group (from pre- to post-training)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TESTS</td>
<td></td>
</tr>
<tr>
<td>Motor abilities</td>
<td></td>
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<tr>
<td>Manual global dexterity</td>
<td>Manual fine dexterity</td>
</tr>
</tbody>
</table>

RESULTS (significant differences $p < 0.05$)

- **RCH (mental health disorders):**
  - **Time (PH and NPH):** (from pre- to post-training): decrease with significant effect.

- **Gender (PH and NPH):** males had better performance than females.
<table>
<thead>
<tr>
<th>STUDY 3</th>
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<tbody>
<tr>
<td><strong>Control group (from pre- to post-training)</strong></td>
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<tr>
<td><strong>TESTS</strong></td>
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<tr>
<td><strong>Motor abilities</strong></td>
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<tr>
<td>Manual global dexterity</td>
</tr>
<tr>
<td><strong>RESULTS (significant differences p &lt; 0.05)</strong></td>
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<tr>
<td><strong>RCH:</strong> <strong>-Time</strong> (PH, NPH and BH): (from pre- to post-training): decrease with significant effect.</td>
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<tr>
<td><strong>RCH:</strong> <strong>-Time</strong> (PH and NPH): (from pre- to post-training): decrease with significant effect.</td>
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<td><strong>RCH:</strong> <strong>-Time</strong> (PH): (from pre- to post-training): decrease with significant effect.</td>
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<td><strong>RCH:</strong> <strong>-Time</strong> (PH and NPH): (from pre- to post-training): decrease with significant effect.</td>
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<td><strong>RCH:</strong> <strong>-Time</strong> (PH and NPH): (from pre- to post-training): decrease with significant effect.</td>
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<td><strong>RCH:</strong> <strong>-Time</strong> (PH and NPH): (from pre- to post-training): decrease with significant effect.</td>
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<tr>
<td><strong>Gender</strong> (PH and NPH): males had better performance than females.</td>
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<tr>
<td>STUDY 3</td>
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<tr>
<td>Control group (from pre- to post-training)</td>
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</table>

### TESTS

|--------------------------------|----------------------|-------------------|-----------------------------|--------------------------------------|----------------------------------------|-------------------|

### Motor abilities

<table>
<thead>
<tr>
<th>Manual global dexterity</th>
<th>Manual fine dexterity</th>
<th>Visuomotor coordination</th>
<th>Proprioceptive sensitivity</th>
<th>Simple reaction time</th>
<th>Handgrip strength</th>
<th>Pedal dexterity</th>
</tr>
</thead>
</table>

### RESULTS (significant differences $p < 0.05$)

- **DLC:**
  - **Time** (NPH and BH): (from pre- to post-training): decrease with a significant effect.
  - **Interaction between time and gender** (BH): In both gender, there was a decrease of the performance from pre- to post-training.

- **DLC:**
  - **Time** (PH and NPH): (from pre- to post-training): decrease with a significant effect.

- **DLC:**
  - **Time** (PH and NPH): (from pre- to post-training): decrease with a significant effect.

- **DLC:**
  - **Time** (NPH): (from pre- to post-training): decrease with a significant effect.

- **DLC:**
  - **Gender** (PH and NPH): males had better performance than females.

- **DLC:**
  - **Time** (NPF): (from pre- to post-training): decrease with a significant effect.

---

**Different contexts:** residential care home (RCH - older adults with mental health disorders), residential care home (RCH), and daily living center (DLC);

**Hand preference:** preferred hand (PH), non-preferred hand (NPH), and both hands (BH);

**Foot preference:** preferred foot (PF) and non-preferred foot (NPF).
Table 5. Results summary of the variables with significant effects (experimental Study 3 - experimental group: laterality index).

<table>
<thead>
<tr>
<th>STUDY 3 - Laterality index (LI)</th>
<th>EXPERIMENTAL GROUP (FROM PRE- TO POST-TRAINING)</th>
<th>TESTS</th>
<th>MOTOR ABILITIES</th>
<th>RESULTS (SIGNIFICANT DIFFERENCES P &lt; 0.05)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>EXPERIMENTAL GROUP (FROM PRE- TO POST-TRAINING)</td>
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<td></td>
<td>Pursuit Rotor Test</td>
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<td></td>
<td>Discrimination Weights Test</td>
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<td></td>
<td>Multi-Choice Reaction Time</td>
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<td></td>
<td>Takei TKK Digital Handgrip Dynamometer</td>
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<td></td>
<td><strong>Apparatus</strong></td>
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<tr>
<td></td>
<td><strong>Motor abilities</strong></td>
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<td></td>
<td>Visuomotor coordination</td>
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<td>Proprioceptive sensitivity</td>
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<td>Handgrip strength</td>
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<td></td>
<td><strong>RESULTS (SIGNIFICANT DIFFERENCES P &lt; 0.05)</strong></td>
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<td></td>
<td><strong>HC:</strong></td>
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<td></td>
<td><strong>-Time:</strong> there was a significant decrease</td>
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<tr>
<td></td>
<td>**of the LI from pre- (15.45 ± 14.77%) to</td>
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<td></td>
<td><strong>post-training (9.09 ± 11.13%).</strong></td>
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<tr>
<td></td>
<td><strong>RCH:</strong></td>
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<tr>
<td></td>
<td><strong>-Time:</strong> there was a significant decrease</td>
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<tr>
<td></td>
<td>**of the LI from pre- (7.19 ± 4.40 %) to</td>
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<tr>
<td></td>
<td><strong>post-training (4.24 ± 5.19 %).</strong></td>
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<td></td>
<td><strong>RCH:</strong></td>
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<tr>
<td></td>
<td><strong>-Time:</strong> there was a significant decrease</td>
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<tr>
<td></td>
<td>**of the LI from pre- (4.48 ± 3.25 %) to</td>
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<tr>
<td></td>
<td><strong>post-training (2.33 ± 2.13 %).</strong></td>
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</tr>
</tbody>
</table>
### STUDY 3 - Laterality index (LI)

#### Experimental group (from pre- to post-training)

<table>
<thead>
<tr>
<th>TESTS</th>
<th>DLC:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pursuit Rotor Test</td>
<td><em>-Time</em>: there was a significant decrease of the LI from pre- (6.58 ± 5.12 %) to post-training (2.97 ± 1.68 %).</td>
</tr>
<tr>
<td>Discrimination Weights Test</td>
<td>- <em>Interaction between time and gender</em>: in both genders there was a significant decrease of the LI from pre- (males: 10.06 ± 5.63 %; females: 4.84 ± 4.00 %) to post-training (males: 2.95 ± 1.50 %; females: 2.98 ± 1.82 %).</td>
</tr>
<tr>
<td>Multi-Choice Reaction Time Apparatus</td>
<td><em>-Time</em>: there was a significant decrease of the LI from pre- (9.76 ± 5.69 %) to post-training (3.97 ± 3.10 %).</td>
</tr>
<tr>
<td>Takei TKK Digital Handgrip Dynamometer</td>
<td><em>-Time</em>: there was a significant decrease of the LI from pre- (6.80 ± 5.42 %) to post-training (4.28 ± 3.90%).</td>
</tr>
</tbody>
</table>

#### Motor abilities

<table>
<thead>
<tr>
<th></th>
<th>DLC:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visuomotor coordination</td>
<td><em>-Time</em>: there was a significant decrease of the LI from pre- (6.58 ± 5.12 %) to post-training (2.97 ± 1.68 %).</td>
</tr>
<tr>
<td>Proprioceptive sensitivity</td>
<td>- <em>Interaction between time and gender</em>: in both genders there was a significant decrease of the LI from pre- (males: 10.06 ± 5.63 %; females: 4.84 ± 4.00 %) to post-training (males: 2.95 ± 1.50 %; females: 2.98 ± 1.82 %).</td>
</tr>
<tr>
<td>Simple reaction time</td>
<td><em>-Time</em>: there was a significant decrease of the LI from pre- (9.76 ± 5.69 %) to post-training (3.97 ± 3.10 %).</td>
</tr>
<tr>
<td>Handgrip strength</td>
<td><em>-Time</em>: there was a significant decrease of the LI from pre- (6.80 ± 5.42 %) to post-training (4.28 ± 3.90%).</td>
</tr>
</tbody>
</table>

**Different contexts**: psychiatric hospital center (HC), residential care home (RCH), and daily living center (DLC);

**Functional motor asymmetry - laterality index (LI)**.
Table 6. Results summary of the variables with significant effects (experimental Study 3 - control group: laterality index).

<table>
<thead>
<tr>
<th>TESTS</th>
<th>STUDY 3 - Laterality index (LI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control group (from pre- to post-training)</td>
<td>RCH: Interaction between time and gender: males increased the LI from pre- (2.06 ± 1.38 %) to post-training (4.26 ± 2.35 %), while females decreased the LI from pre- (5.18 ± 4.57 %) to post-training (2.18 ± 2.50 %).</td>
</tr>
<tr>
<td>Pursuit Rotor Test</td>
<td>DLC: Time: there was a significant increase of the LI from pre- (4.34 ± 3.53 %) to post-training (6.57 ± 5.15 %).</td>
</tr>
<tr>
<td>Discrimination Weights Test</td>
<td></td>
</tr>
<tr>
<td>Multi-Choice Reaction Time Apparatus</td>
<td></td>
</tr>
<tr>
<td>Takei TKK Digital Handgrip Dynamometer</td>
<td></td>
</tr>
<tr>
<td>Motor abilities:</td>
<td>RCH: Interaction between time and gender: males increased the LI from pre- (2.06 ± 1.38 %) to post-training (4.26 ± 2.35 %), while females decreased the LI from pre- (5.18 ± 4.57 %) to post-training (2.18 ± 2.50 %).</td>
</tr>
<tr>
<td>Visuomotor coordination</td>
<td>DLC: Time: there was a significant increase of the LI from pre- (4.34 ± 3.53 %) to post-training (6.57 ± 5.15 %).</td>
</tr>
<tr>
<td>Proprioceptive sensitivity</td>
<td></td>
</tr>
<tr>
<td>Simple reaction time</td>
<td></td>
</tr>
<tr>
<td>Handgrip strength</td>
<td></td>
</tr>
<tr>
<td>RESULTS (significant differences p &lt; 0.05)</td>
<td></td>
</tr>
</tbody>
</table>
Table 7. Results summary of the variables with significant effects (experimental Study 4 - experimental group).

<table>
<thead>
<tr>
<th>STUDY 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental group (from pre- to post-training)</td>
</tr>
<tr>
<td>TESTS</td>
</tr>
<tr>
<td>Motor abilities</td>
</tr>
<tr>
<td>Pedal dexterity</td>
</tr>
<tr>
<td>RESULTS (significant differences $p &lt; 0.05$)</td>
</tr>
<tr>
<td><strong>HC:</strong></td>
</tr>
<tr>
<td>- Interaction between time and gender (PF and NPF): males had slightly decreased their performance with both feet from pre- to post-training, while females improved their performance with both feet from pre- to post-training.</td>
</tr>
<tr>
<td><strong>RCH:</strong></td>
</tr>
</tbody>
</table>
| - Time (PF and NPF): (from pre- to post-training): improvement with a significant effect. | - Time (SB, DB, and TB): (from pre- to post-training): improvement with a significant effect.  
- Gender (SB, DB, and TB): males obtained a better performance in all of the three tests (SB: 14.25 ± 1.18 points), (DB: 11.83 ± 0.25 points), and (TB: 26.08 ± 1.18 points) compared to females (SB: 10.86 ± 3.23 points), (DB: 9.66 ± 4.69 points), and (TB: 20.53 ± 5.29 points). |
| **DLC:** | **DLC:** |
| - Time (PF and NPF): (from pre- to post-training): improvement with a significant effect. | - Time (SB, DB, and TB): (from pre- to post-training): improvement with a significant effect. |
Different contexts: psychiatric hospital center (HC), residential care home (RCH), and daily living center (DLC);
Foot preference: preferred foot (PF) and non-preferred foot (NPF);
Tinetti test: static balance (SB), dynamic balance (DB), and total balance (TB).

Table 8. Results summary of the variables with significant effects (experimental Study 4 - control group).

<table>
<thead>
<tr>
<th>STUDY 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control group</td>
</tr>
<tr>
<td>TESTS</td>
</tr>
<tr>
<td>Tapping Pedal Test</td>
</tr>
<tr>
<td>Motor abilities</td>
</tr>
<tr>
<td>Pedal dexterity</td>
</tr>
<tr>
<td>RESULTS (significant differences $p &lt; 0.05$)</td>
</tr>
</tbody>
</table>

RCH (mental health disorders): -Time (NPF): (from pre- to post-training): decrease with significant effect.

RCH: -Time (NPF): (from pre- to post-training): decrease with significant effect.

DLC: -Time (NPF): (from pre- to post-training): decrease with significant effect.

Different contexts: residential care home (RCH - older adults with mental health disorders), residential care home (RCH), and daily living center (DLC);
Foot preference: preferred foot (PF) and non-preferred foot (NPF).
Table 9. Results summary of the variables with significant effects (experimental Study 5).

<table>
<thead>
<tr>
<th>STUDY 5 TESTS</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Bassin Anticipation Timer</td>
<td>Bassin Anticipation Timer</td>
<td></td>
</tr>
<tr>
<td>Motor abilities</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coincidence anticipation</td>
<td>Coincidence anticipation</td>
<td></td>
</tr>
<tr>
<td>RESULTS (significant differences $p &lt; 0.05$)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PH-NPH condition</th>
<th>NPH-PH condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>EG: no significant effects:</td>
<td>EG: with significant effects:</td>
</tr>
<tr>
<td>-Time: (from pre- to post-training), gender (males vs. females), and interaction between time and gender.</td>
<td>-Time: (from pre- to post-training): there was a significant decrease of IMT percentages from pre- (66.13 ± 13.92) to post-training (45.88 ± 42.83).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CG: no significant effects:</th>
<th>NPH-PH condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>-Time: (from pre- to post-training), gender (males vs. females), and interaction between time and gender.</td>
<td>CG: no significant effects:</td>
</tr>
<tr>
<td>-Gender (males vs. females) and interaction between time and gender.</td>
<td>-Time: (from pre- to post-training), gender (males vs. females), and interaction between time and gender.</td>
</tr>
</tbody>
</table>

Experimental group (EG) and control group (CG); Hand preference: preferred hand (PH), non-preferred hand (NPH), and both hands (BH); Intermanual transfer (IMT) of learning.
Table 10. Results summary of the variables with significant effects (experimental Study 6).

<table>
<thead>
<tr>
<th>STUDY 6</th>
<th>MOTOR ABILITY</th>
<th>VISUOMOTOR MEMORY</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>EXPERIMENTAL GROUP (FROM PRE- TO POST-TRAINING)</td>
<td>RESULTS (SIGNIFICANT DIFFERENCES P &lt; 0.05)</td>
</tr>
<tr>
<td>HC: no significant effects:</td>
<td>RCH: -TIME (FROM PRE- TO POST-TRAINING): IMPROVEMENT WITH A SIGNIFICANT EFFECT.</td>
<td></td>
</tr>
<tr>
<td>-TIME: (FROM PRE- TO POST-TRAINING), GENDER (MALES VS. FEMALES), AND INTERACTION BETWEEN TIME AND GENDER.</td>
<td>DLC: -TIME (FROM PRE- TO POST-TRAINING): IMPROVEMENT WITH A SIGNIFICANT EFFECT.</td>
<td></td>
</tr>
<tr>
<td>CONTROL GROUP</td>
<td>RESULTS (SIGNIFICANT DIFFERENCES P &lt; 0.05)</td>
<td></td>
</tr>
<tr>
<td>RCH (MENTAL HEALTH DISORDERS), RCH, AND DLC: NO SIGNIFICANT EFFECTS:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-TIME: (FROM PRE- TO POST-TRAINING), GENDER (MALES VS. FEMALES), AND INTERACTION BETWEEN TIME AND GENDER.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Different contexts: residential care home (RCH - older adults with mental health disorders), residential care home (RCH), and daily living center (DLC).
Based on the results that emerged from this thesis, we emphasize the following conclusions:

(i) **Study One**, participants in multimodal physical exercise routines improved their visuomotor memory significantly (the same did not occur with gender and age level factors);

(ii) **Study Two**, the Modified Baecke Questionnaire is an instrument with good validity coefficients, suggesting its use in Portuguese-speaking older adults;

(iii) **Study Three**, the multimodal exercise program can significantly improve motor fitness, except for the simple reaction time. As for functional motor asymmetry, we observed a significant decrease of the laterality index according to: (a) the visuomotor coordination in the hospital center and the residential care home; (b) the proprioceptive sensitivity in the residential care home and the daily living center; and (c) the simple reaction time and the grip strength in the daily living center;

(iv) **Study Four**, after a multimodal exercise program, older adults improved their pedal dexterity performance significantly with both feet: (a) in the residential care home and the daily living center; and (b) in the hospital center, males slightly decreased their pedal dexterity performance with both feet while females improved their performance. Concerning balance, older adults in the hospital center, residential care home (males were better than females regarding the gender factor) and daily living center improved their performance;

(v) **Study Five**, the process of intermanual transfer of learning occurs in the non-preferred hand to the preferred hand condition; this fact confirms that the ability of motor learning is preserved in older adults and can be transferred from one upper limb to the other; and

(vi) **Study Six**, from pre- to post-training, both genders improved their performance in the visuomotor memory for time/seconds and errors in the residential care home and the daily living center; however, no significant main effect or interactions were found in the hospital center.
The main findings of the studies included in our thesis support the idea that exercise training can favourably change manual dexterity, visuomotor coordination, manual proprioceptive sensibility, hand grip strength, pedal dexterity, balance, visuomotor memory and coincidence anticipation, as well as intermanual transfer of learning in nearly all the three contexts.

On the other hand, the control group of the three different contexts decreased their performance in several abilities such as manual dexterity, visuomotor coordination, manual proprioceptive sensibility, simple reaction time, hand grip strength and pedal dexterity (with the non-preferred foot), as well as balance and visuomotor memory. Therefore, our thesis reinforces the idea that a multimodal training prevents significant age-related losses in conditional and coordinative motor abilities.

Taking into account that these motor abilities are present in most of the daily life activities of older adults, our data also reinforces the importance of fully developed motor abilities in a well-rounded exercise program. We would like to emphasize that institutionalized older adults should be encouraged to include systematic physical exercise programs in their daily routines in order to develop their motor abilities and improve their functionality and quality of life.

Our recommendations for future research include a larger sample, the use of different exercise types and different training intensities and duration.

In Study Five, it was not possible to include older adults with mental health disorders because the main task was very difficult to perform. It would be interesting in future investigations to study the differences between older adults with and without mental health disorders using an easier task.

Furthermore, it would also be important to make a longitudinal study of the Portuguese older adult population to identify from what age there is an evident decline in the manual and pedal dexterity, proprioceptive sensitivity, coincidence anticipation, balance, simple reaction time, visuomotor memory and handgrip strength in males and females, along with investigating the behavior of the functional motor asymmetry over time.
A key strength of our study is that, to our knowledge, there is little information and/or systematic research on this topic. Therefore, our results can contribute to a better understanding of the effect of a multimodal exercise program on the abilities of older males and females in different contexts.

In summary, the overall results of this thesis support the current evidence on the importance of multimodal exercise programs that allow a more autonomous life for older adults.

CONSELHO NACIONAL DE ÉTICA PARA AS CIÊNCIAS DA VIDA

RELATÓRIO E PARECER
34/CNECV/2001

sobre a

DECLARAÇÃO DE HELSÍNQUIA
Modificada em Edimburgo (Outubro 2000)

A Declaração de Helsínquia, adotada em 1964 pela Associação Médica Mundial e sucessivamente alterada em Tóquio (1975), Veneza (1983), Hong-Kong (1989) e Sommerset West (1996), é um documento oficial da organização internacional representativa dos médicos e constitui, desde a sua adoção, a magna carta da experimentação levada a cabo em seres humanos. Embora não tenha estatuto legal, é tratada e reconhecida como código de conduta à escala global da investigação médica, tendo sido nomeadamente aceite pela CIOMS (organização de pesquisa médica estreitamente ligada à OMS) e sendo referida praticamente em todos os protocolos de pesquisa ou de ensaios clínicos apresentados a comissões de ética institucionais.

Recentemente, a Associação Médica Mundial, na sua assembleia geral, realizada em Outubro de 2000 em Edimburgo, procedeu à revisão da Declaração e introduziu-lhe substanciais modificações, algumas causadoras de polémica, mas todas tendentes a garantir e aumentar a proteção dos seres humanos, sujeitos de investigação. Esta quinta emenda resultou da análise realizada durante os últimos anos, de estudos conduzidos dentro e fora da
Associação e da consulta a peritos, associações profissionais, cientistas, associações de doentes e participantes em reuniões científicas.
O Conselho Nacional de Ética para as Ciências da Vida, que desta importantíssima matéria se ocupou várias vezes (pareceres 4/CNECV/93, 9/CNECV/94 e 13/CNECV/95, comentário ao decreto-lei 97/94 (1994), não podia ficar indiferente a esta inovadora redação da Declaração de Helsínquia. Regista com satisfação o cuidado posto na clarificação de objetivos da investigação, a reafirmação da superioridade do bem estar do sujeito em relação aos interesses da ciência e da sociedade, a imposição de transparência no que concerne aos incentivos económicos dos projetos de investigação e a exigência de que, uma vez terminada a investigação, os sujeitos nela participantes não sejam privados do tratamento (ou dos meios de profilaxia ou diagnóstico) que o estudo tenha identificado como sendo os melhores.
São do maior alcance as medidas recomendadas: na prática vêm limitar o uso de placebos apenas às situações em que não existam meios eficazes e exigem a continuação do uso ("compassivo") do tratamento que se tenha revelado mais eficaz e mais seguro em todos os sujeitos do ensaio. Na sua forma actual, a Declaração propõe a publicação de todos os resultados de uma investigação ou ensaio (ou pelo menos que sejam postos à disposição do público), independentemente da sua natureza "positiva" ou "negativa".
Embora se reconheça de algumas destas disposições levantarão problemas consideráveis e trarão adicionais dificuldades à execução de investigações em seres humanos, nomeadamente quando revestem a forma de ensaios clínicos, parece justo realçar os indiscutíveis benefícios que resultarão da adopção dos princípios enunciados, sobretudo para a preservação da dignidade, saúde e bem-estar dos sujeitos da investigação, mas também para a qualidade e significado dos resultados obtidos pelos investigadores.

O Relator,
Prof. Doutor
Walter Osswald
CONSELHO NACIONAL DE ÉTICA PARA AS CIÊNCIAS DA VIDA

PARECER

Tendo em conta o relatório anexo, os seus anteriores pareceres sobre ensaios clínicos e sua avaliação (4/CNECV/93, 9/CNECV/94, 13/CNECV/95) e os princípios orientadores das disposições normativas introduzidas na Declaração de Helsínquia pela Associação Médica Mundial, o Conselho Nacional de Ética para as Ciências da Vida:

- regozija-se com a recente revisão da Declaração de Helsínquia (Edimburgo 2000), por ver nela consignados e reforçados o respeito pela dignidade e pelos direitos do ser humano sujeito de investigação, com o consequente aumento da proteção que lhe é garantida;

- recomenda às comissões de ética em saúde que tenham presentes as recomendações desta versão revista da Declaração de Helsínquia, ao procederem à avaliação dos protocolos de investigação que lhes sejam apresentados;

- recomenda que os estabelecimentos de saúde tenham na devida conta, nos seus programas curriculares, esta revisão da Declaração de Helsínquia;

- espera que a presente versão da Declaração de Helsínquia seja tomada em consideração, aquando da revisão dos decretos-leis 97/94 e 97/95, que se espera seja brevemente efectuada.

Lisboa 13 de Fevereiro de 2001

Prof. Doutor

Luís Archer

Presidente do Conselho Nacional de Ética para as Ciências da Vida
CONSELHO NACIONAL DE ÉTICA PARA AS CIÊNCIAS DA VIDA

(tradução de O Papel do Médico, corrigida por H. Carmona da Mota)

DECLARAÇÃO DE HELSÍNQUIA
modified em Edimburgo (Outubro 2000)

Associação Médica Mundial

A. INTRODUÇÃO
1. A Associação Médica Mundial promulgou a Declaração de Helsínquia como uma proposta de princípios éticos que servem para orientar os médicos e outras pessoas que realizam investigação médica em seres humanos. A investigação médica em seres humanos inclui a investigação sobre material humano ou sobre dados identificáveis.
2. O dever do médico é promover e velar pela saúde das pessoas. Os conhecimentos e a consciência do médico têm de se subordinar ao cumprimento desse dever.
3. A Declaração de Genebra da Associação Médica Mundial vincula o médico com a fórmula "velar solicitamente e antes de tudo pela saúde do meu
paciente", e o Código Internacional de Ética Médica afirma que: "O médico deve atuar somente no interesse do paciente ao proporcionar cuidados médicos que possam debilitar a condição mental ou física do paciente".

4. O progresso da medicina baseia-se na investigação, a qual em última análise, tem que recorrer muitas vezes à experimentação em seres humanos.

5. Em investigação médica em seres humanos, a preocupação pelo bem-estar destes deve ter sempre primazia sobre os interesses da ciência e da sociedade.

6. O propósito principal da investigação médica em seres humanos é melhorar os procedimentos preventivos, diagnósticos e terapêuticos, e também compreender a etiologia e a patogenia das doenças. Mesmo os melhores métodos preventivos, diagnósticos e terapêuticos disponíveis devem ser continuamente reavaliados pela investigação para que se prove que são eficazes, efetivos, acessíveis e de qualidade.

7. Na atual prática da medicina e da investigação médica, a maioria dos procedimentos preventivos, diagnósticos e terapêuticos implicam alguns riscos e custos.

8. A investigação médica está sujeita a normas éticas que servem para promover o respeito por todos os seres humanos e para proteger a sua saúde e os seus direitos individuais. Algumas populações submetidas a investigação são vulneráveis e necessitam proteção especial. Devem reconhecer-se as necessidades particulares dos que têm desvantagens económicas e médicas. Também se deve prestar atenção especial aos que não podem dar ou recusar o consentimento por si mesmos, aos que podem dar consentimento sob pressão, aos que não beneficiarão pessoalmente com a investigação e aos que têm a investigação combinada com a assistência médica.

9. Os investigadores devem conhecer os requisitos éticos, legais e jurídicos para a investigação em seres humanos nos seus próprios países, assim como os requisitos internacionais vigentes. Não se deve permitir que um requisito ético, legal ou jurídico diminua ou elimine qualquer medida de proteção para os seres humanos estabelecida nesta Declaração.
B. PRINCÍPIOS BÁSICOS PARA TODA A INVESTIGAÇÃO MÉDICA

10. Na investigação médica, é dever do médico proteger a vida, a saúde, a intimidade e a dignidade do ser humano.

11. A investigação médica em seres humanos deve conformar-se com os princípios científicos geralmente aceites, e deve apoiar-se num profundo conhecimento da bibliografia científica, noutras fontes de informação pertinentes, assim como em experiências de laboratório corretamente realizadas e, quando apropriado, em animais.

12. Ao investigar, há que prestar atenção adequada aos fatores que possam prejudicar o meio ambiente. Deve-se cuidar também do bem-estar dos animais utilizados nas experiências.

13. O projeto e o método de todo o procedimento experimental em seres humanos deve formular-se claramente num protocolo experimental. Este deve enviar-se, para consideração, comentário, conselho e, quando seja oportuno, aprovação, a um comissão de avaliação ética especialmente designada, a qual deve ser independente do investigador, do patrocinador ou de qualquer outro tipo de influência indevida. Subentende-se que essa comissão independente deve atuar em conformidade com as leis e regulamentos vigentes no país onde se realiza a investigação experimental. A comissão tem o direito de controlar os ensaios em curso. O investigador tem obrigação de proporcionar informação à comissão, em especial sobre qualquer incidente adverso grave. O investigador também deve apresentar à comissão, para que a reveja, informação sobre financiamento, patrocinadores, afiliações institucionais, outros possíveis conflitos de interesse e incentivos para as pessoas do estudo.

14. O protocolo da investigação deve fazer sempre referência às considerações éticas atinentes e deve indicar que se observam os princípios enunciados nesta Declaração.

15. A investigação médica em seres humanos só deve ser levada a cabo por pessoas cientificamente qualificadas e sob a supervisão de um médico competente. A responsabilidade pelos participantes deve ser sempre atribuída a uma pessoa com competência médica e nunca aos participantes na investigação, ainda que tenham dado o seu consentimento.
16. Todo projeto de investigação médica em seres humanos deve ser precedido de uma cuidadosa comparação dos riscos calculados com os benefícios previsíveis, para o indivíduo ou para os outros. Isto não impede a participação de voluntários sãos na investigação médica. O desenho de todos os estudos deve estar acessível ao público.

17. Os médicos devem abster-se de participar em projetos de investigação em seres humanos quando não estiverem seguros de que os riscos inerentes foram adequadamente avaliados e de que é possível fazer-lhes frente de maneira satisfatória. Devem suspender a experiência em curso se observarem que os riscos que implicam são mais importantes que os benefícios esperados ou se existirem provas concluyentes de resultados positivos ou benéficos.

18. A investigação médica em seres humanos só deve realizar-se quando a importância do seu objetivo for maior que os inerentes riscos e incômodos para o indivíduo. Isto é especialmente importante quando os seres humanos são voluntários sãos.

19. A investigação médica só se justifica se existirem probabilidades razoáveis de que a população, sobre a qual a investigação se realiza, poderá beneficiar dos seus resultados.

20. Para tomar parte num projeto de investigação, os participantes devem ser voluntários e informados.

21. Deve respeitar-se sempre o direito dos participantes na investigação protegerem sua integridade. Devem tomar-se toda a espécie de precauções para resguardar a intimidade dos indivíduos, a confidencialidade da informação do paciente e para reduzir ao mínimo as consequências da investigação sobre a sua integridade física e mental e a sua personalidade.

22. Em toda investigação em seres humanos, cada potencial sujeito deve receber informação adequada acerca dos objetivos, métodos, fontes de financiamento, possíveis conflitos de interesses, afiliações institucionais do investigador, benefícios calculados, riscos previsíveis e incomodidades inerentes à experiência. A pessoa deve ser informada do direito de participar ou não na investigação e de retirar o seu consentimento em qualquer momento, sem se expor a represálias. Depois de se assegurar de que o
indivíduo compreendeu a informação, o médico deve obter, de preferência por escrito, o consentimento informado e voluntário da pessoa. Se o consentimento não puder ser obtido por escrito, o processo para obtê-lo deve ser documentado formalmente ante testemunhas.

23. Ao obter o consentimento informado para o projeto de investigação, o médico deve ter especial cuidado quando o indivíduo estiver vinculado a ele por uma relação de dependência ou se consentir sob pressão. Em tal caso, o consentimento informado deve ser obtido por um médico bem informado que não participe na investigação e que nada tenha que ver com aquela relação.

24. Quando a pessoa for menor ou incapaz, legal, física ou mentalmente de dar consentimento, o investigador deve obter o consentimento informado do representante legal, de acordo com a lei vigente. Estes grupos não devem ser incluídos na investigação a menos que esta seja necessária para promover a saúde da população representada e esta investigação não puder realizar-se em pessoas com capacidade legal.

25. Se uma pessoa considerada legalmente incapaz, como é o caso de um menor, for capaz de dar o seu assentimento a participar ou não na investigação, o investigador deverá obtê-lo, além do consentimento do representante legal.

26. A investigação em indivíduos dos quais se não puder obter consentimento, nomeadamente por representante ou antecipadamente, só deve realizar-se se a condição física/mental que impede obter o consentimento informado for uma característica necessária da população investigada. As razões específicas pelas quais se utilizarão participantes na investigação que não possam dar o seu consentimento informado devem ser estipuladas no protocolo experimental que se apresentar para consideração e aprovação da comissão de avaliação. O protocolo deve estabelecer que o consentimento para se manter na investigação deverá obter-se com a brevidade possível do indivíduo ou de um representante legal.

27. Tanto os autores como os editores têm obrigações éticas. Ao publicar os resultados da sua investigação, o médico está obrigado a manter a exatidão dos dados e resultados. Devem publicar-se tanto os resultados negativos como
os positivos ou em alternativa estar disponíveis publicamente. Na publicação
deve citar-se a fonte de financiamento, as afiliações institucionais e qualquer
possível conflito de interesses. Os informes sobre investigações que não se
cinjam aos princípios descritos nesta Declaração não devem ser aceites para
publicação.

C. PRINCÍPIOS APLICÁVEIS QUANDO A INVESTIGAÇÃO MÉDICA
COINCIDE COM A ASSISTÊNCIA MÉDICA

28. O médico pode combinar a investigação médica com os cuidados médicos,
apenas quando tal investigação estiver justificada pelo seu potencial valor
preventivo, diagnóstico ou terapêutico. Quando a investigação médica se
combinar com a assistência médica, as normas adicionais aplicam-se para
proteger os pacientes que participam na investigação.

29. Os possíveis benefícios, riscos, custos e eficácia de todo procedimento
novo devem ser avaliados por comparação com os melhores métodos
preventivos, diagnósticos e terapêuticos disponíveis. Isso não exclui que possa
usar-se um placebo, ou nenhum tratamento, em estudos para os quais se não
dispõem de procedimentos preventivos, diagnósticos ou terapêuticos provados.

30. No final da investigação, todos os pacientes que participam no estudo
devem ter a certeza de que contaram com os melhores métodos preventivos,
diagnósticos e terapêuticos disponíveis, identificados pelo estudo.

31. O médico deve informar cabalmente o paciente qual a parte dos cuidados
exigida pela investigação. A recusa do paciente em participar numa
investigação nunca deve perturbar a relação médico-paciente.

32. Quando os métodos preventivos, diagnósticos ou terapêuticos disponíveis,
se revelaram ineficazes no tratamento do doente, o médico, com o
consentimento informado do paciente, pode permitir-se usar procedimentos
preventivos, diagnósticos e terapêuticos novos ou não provados se, na sua
opinião, houver alguma esperança de salvar a vida, restituir a saúde ou aliviar o
sofrimento. Sempre que seja possível, tais medidas devem ser investigadas a
fim de avaliar sua segurança e eficácia. Em todos os casos, essa informação
nova deve ser registada e, quando for oportuno, publicada. Devem seguir-se todas as outras normas pertinentes desta Declaração.

Morada
R. Prof. Gomes Teixeira, Edifício da PCM, 8º andar, sala 814
1399-022 LISBOA Contactos tel. 351.213927688, novo fax 351.213900032,
E.mail: cncv.etica@mail.telepac.pt www.cncv.gov.pt
Appendix 2. Authorization request to the Conde Ferreira Hospital Center – Santa Casa da Misericórdia do Porto.

Exmo. Senhor Diretor Clínico do Centro Hospitalar Conde Ferreira
Doutor José Adriano Fernandes

Assunto: solicitação de autorização para ministrar aulas de exercício físico regular aos utentes do Centro Hospitalar Conde Ferreira.

Eu, João Miguel Carvalho da Silva, doutorando da Faculdade de Desporto da Universidade do Porto (FADEUP) na área da Atividade Física para a Terceira Idade, venho por este meio solicitar a V. Exa. autorização para a colaboração dos utentes desse Hospital no sentido de integrem a amostra da minha dissertação de doutoramento.

O meu estudo, orientado pela Professora Doutora Maria Olga Fernandes Vasconcelos, do Laboratório de Aprendizagem e Controlo Motor, e co-orientado pela Professora Doutora Maria Joana Carvalho, do Centro de Investigação em Atividade Física, Saúde e Lazer, ambas Professoras Associadas da Faculdade de Desporto da Universidade do Porto, pretende avaliar o contributo do exercício físico regular na melhoria da qualidade de vida de pessoas idosas. O tema da pesquisa é “Efeitos de um programa de exercício multimodal na aptidão motora, assimetria motora funcional e transferência intermanual da aprendizagem: estudo em idosos de diferentes contextos”.

A minha intervenção, caso a autorização me seja concedida, terá um caráter voluntário e consistirá na realização de três aulas de exercício físico regular (com características essencialmente psicomotoras) por semana, com uma duração de 60 minutos cada, em horário a definir. As aulas serão administradas durante 12 meses. Salento ainda que todos os exercícios físicos a serem realizados serão adequados às características desta faixa etária.
Refiro ainda que, em contacto informal com a professora de Educação Física, Tânia Bastos (professora que, atualmente exerce funções letivas no vosso Centro Hospitalar), considerou este, um projeto viável e pertinente. Assim, mais uma vez solicito a colaboração de V. Exa. para a realização deste trabalho, o qual, em Anexo, está apresentado de forma mais pormenorizada.

Com os meus melhores cumprimentos,

Porto, 21 de Novembro de 2007

____________________________

(João Miguel Carvalho da Silva)

Exma. Senhora Diretora do Lar Nossa Senhora da Misericórdia, Isabel Matos

Assunto: solicitação de autorização para ministrar aulas de exercício físico regular aos utentes do Lar Nossa Senhora da Misericórdia.

Eu, João Miguel Carvalho da Silva, doutorando da Faculdade de Desporto da Universidade do Porto (FADEUP) na área da Atividade Física para a Terceira Idade, venho por este meio solicitar a V. Exa. autorização para a colaboração dos utentes desse Lar no sentido de integrem a amostra da minha dissertação de doutoramento.

O meu estudo, orientado pela Professora Doutora Maria Olga Fernandes Vasconcelos, do Laboratório de Aprendizagem e Controlo Motor, e co-orientado pela Professora Doutora Maria Joana Carvalho, do Centro de Investigação em Atividade Física, Saúde e Lazer, ambas Professoras Associadas da Faculdade de Desporto da Universidade do Porto, pretende avaliar o contributo do exercício físico regular na melhoria da qualidade de vida de pessoas idosas. O tema da pesquisa é “Efeitos de um programa de exercício multimodal na aptidão motora, assimetria motora funcional e transferência intermanual da aprendizagem: estudo em idosos de diferentes contextos”.

A minha intervenção, caso a autorização me seja concedida, terá um carácter voluntário e consistirá na realização de três aulas de exercício físico regular (com características essencialmente psicomotoras) por semana, com uma duração de 60 minutos cada, em horário a definir. As aulas serão administradas durante 12 meses. Saliento ainda que todos os exercícios físicos a serem realizados serão adequados às características desta faixa etária.

Assim, mais uma vez solicito a colaboração de V. Exa. para a realização deste trabalho, o qual, em Anexo, está apresentado de forma mais pormenorizada.

Com os meus melhores cumprimentos,

Porto, 21 de Novembro de 2007

Exma. Senhora Diretora do Centro de Dia Monte Espinho, Helena Córdia

Assunto: solicitação de autorização para ministrar aulas de exercício físico regular aos utentes do Centro de Dia Monte Espinho.

Eu, João Miguel Carvalho da Silva, doutorando da Faculdade de Desporto da Universidade do Porto (FADEUP) na área da Atividade Física para a Terceira Idade, venho por este meio solicitar a V. Exa. autorização para a colaboração dos utentes desse Centro de Dia no sentido de integrarem a amostra da minha dissertação de doutoramento.

O meu estudo, orientado pela Professora Doutora Maria Olga Fernandes Vasconcelos, do Laboratório de Aprendizagem e Controlo Motor, e co-orientado pela Professora Doutora Maria Joana Carvalho, do Centro de Investigação em Atividade Física, Saúde e Lazer, ambas Professoras Associadas da Faculdade de Desporto da Universidade do Porto, pretende avaliar o contributo do exercício físico regular na melhoria da qualidade de vida de pessoas idosas. O tema do estudo é “Efeitos de um programa de exercício multimodal na aptidão motora, assimetria motora funcional e transferência intermanual da aprendizagem: estudo em idosos de diferentes contextos”.

A minha intervenção, caso a autorização me seja concedida, terá um carácter voluntário e consistirá na realização de três aulas de exercício físico regular (com características essencialmente psicomotoras) por semana, com uma duração de 60 minutos cada, em horário a definir. As aulas serão administradas durante 12 meses. Saliento ainda que todos os exercícios físicos a serem realizados serão adequados às características desta faixa etária.

Assim, mais uma vez solicito a colaboração de V. Exa. para a realização deste trabalho, o qual, em Anexo, está apresentado de forma mais pormenorizada.

Com os meus melhores cumprimentos,

Porto, 21 de Novembro de 2007
(João Miguel Carvalho da Silva)
Appendix 5. Authorization request to the Residential Care Home Mãe de Jesus.

Exma. Senhora Diretora do Lar Mãe de Jesus, Rita Correia

Assunto: solicitação de autorização para realizar testes motores aos utentes no âmbito de um estudo de Doutoramento.

Eu, João Miguel Carvalho da Silva, no âmbito do Doutorado em Ciências do Desporto em Atividade Física para a Terceira Idade, ministrado pela Faculdade de Desporto da Universidade do Porto (FADEUP), venho por este meio informar que irá decorrer um trabalho de carácter voluntário, tendo como objetivo avaliar o contributo do exercício físico regular, na melhoria da qualidade de vida em pessoas com 65 ou mais anos de idade. O tema do estudo é “Efeitos de um programa de exercício multimodal na aptidão motora, assimetria motora funcional e transferência intermanual da aprendizagem: estudo em idosos de diferentes contextos”.

A Professora Doutora Maria Olga Fernandes Vasconcelos e a Professora Doutora Maria Joana Carvalho, Professoras Associadas da Faculdade de Desporto da Universidade do Porto, assumem a orientação e co-orientação, respectivamente. As linhas científicas de investigação são do Laboratório de Aprendizagem e Controlo Motor e do Centro de Investigação em Actividade Física e Lazer.

Neste estudo irá ser implementado um programa de exercício físico regular nos idosos do Centro Hospitalar Conde de Ferreira - Porto, Lar Nossa Senhora da Misericórdia - Porto e no Centro de Dia Monte Espinho - Matosinhos. No entanto, no Lar Mãe de Jesus, se possível, informamos que haverá apenas recolha de dados e não prática de exercício físico regular.

Venho por este meio pedir autorização para realizar a recolha de dados acima referida (testes motores) no Lar. Assim, peço encarecidamente a colaboração de 8 mulheres e 8 homens com idades compreendidas entre os 70 e os 80
anos. Após aproximadamente 12 meses, será novamente necessário repetir a mesma recolha de dados.
Comprometo-me, desde já, a oferecer um exemplar da Tese de Doutoramento à Instituição Lar Mãe de Jesus.
Mais uma vez, solicito, se possível, a colaboração de V. Ex.ª para a realização deste trabalho.

Sem outro assunto e com os melhores cumprimentos,

O Professor Responsável

____________________________________
(João Miguel Carvalho da Silva)

Exma. Senhora Diretora do Centro de Dia da Associação Social e de Desenvolvimento de Guifões, Gisela Santos

Assunto: solicitação de autorização para realizar testes motores aos utentes no âmbito de um estudo de Doutoramento.

Eu, João Miguel Carvalho da Silva, no âmbito do Doutoramento em Ciências do Desporto em Atividade Física para a Terceira Idade, ministrado pela Faculdade de Desporto da Universidade do Porto (FADEUP), venho por este meio informar que irá decorrer um trabalho de carácter voluntário, tendo como objetivo avaliar o contributo do exercício físico regular, na melhoria da qualidade de vida em pessoas com 65 ou mais anos de idade. O tema do estudo é “Efeitos de um programa de exercício multimodal na aptidão motora, assimetria motora funcional e transferência intermanual da aprendizagem: estudo em idosos de diferentes contextos”.

A Professora Doutora Maria Olga Fernandes Vasconcelos e a Professora Doutora Maria Joana Carvalho, Professoras Associadas da Faculdade de Desporto da Universidade do Porto, assumem a orientação e co-orientação, respetivamente. As linhas científicas de investigação são do Laboratório de Aprendizagem e Controlo Motor e do Centro de Investigação em Atividade Física e Lazer.

Neste estudo irá ser implementado um programa de exercício físico regular nos idosos do Centro Hospitalar Conde de Ferreira - Porto, Lar Nossa Senhora da Misericórdia - Porto e no Centro de Dia Monte Espinho - Matosinhos. No entanto, no Centro de Dia, se possível, informamos que haverá apenas recolha de dados e não prática de exercício físico regular.

Venho por este meio pedir autorização para realizar a recolha de dados acima referida (testes motores) no Lar. Assim, peço encarecidamente a colaboração de 8 mulheres e 8 homens com idades compreendidas entre os 70 e os 80
anos. Após aproximadamente 12 meses, será novamente necessário repetir a mesma recolha de dados.
Comprometo-me, desde já, a oferecer um exemplar da Tese de Doutoramento à Instituição Centro de Dia da Associação Social e de Desenvolvimento de Guifões.
Mais uma vez, solicito, se possível, a colaboração de V. Ex.ª para a realização deste trabalho.

Sem outro assunto e com os melhores cumprimentos,

O Professor Responsável

______________________________

(João Miguel Carvalho da Silva)
Appendix 7. Informed consent form.

Termo de Consentimento Livre e Informado

Instituição, ____________________________________.

Tendo sido convidado (a) a participar como voluntário (a) do estudo “Efeitos de um programa de exercício multimodal na aptidão motora, assimetria motora funcional e transferência intermanual da aprendizagem: estudo em idosos de diferentes contextos”, recebi do Prof. João Miguel Carvalho da Silva, professor doutorando em Ciências do Desporto em Atividade Física para a Terceira Idade, ministrado pela Faculdade de Desporto da Universidade do Porto (FADEUP), determinadas informações que me fizeram entender, sem dificuldades e sem dúvidas, os seguintes aspetos:

(i) A Professora Doutora Maria Olga Fernandes Vasconcelos e a Professora Doutora Maria Joana Carvalho, Professoras Associadas da Faculdade de Desporto da Universidade do Porto, assumem a orientação e coorientação do estudo, respetivamente. As linhas científicas de investigação são do Laboratório de Aprendizagem e Controlo Motor, do Centro de Investigação, Formação, Inovação e Intervenção em Desporto e do Centro de Investigação em Atividade Física, Saúde e Lazer;

(ii) Que irá decorrer um trabalho de carácter voluntário, tendo como objetivo avaliar o contributo do exercício físico regular, na melhoria da qualidade de vida em pessoas com 65 ou mais anos de idade;

(iii) Que a importância deste estudo será permitir que sejam observados e conhecidos, de forma segura, prática e objetiva: a) a assimetria motora funcional no controlo motor de habilidades motoras, que envolvam destreza manual, sensibilidade propriocetiva manual, precisão manual, velocidade gestual e de reação, antecipação-coincidência, coordenação óculo-manual e óculo-pedal, memorização visual a curto prazo, flexibilidade, equilíbrio e força; b) os benefícios destas funcionalidades e na qualidade de vida relacionada com a saúde dos idosos, serão obtidos pela prática de três sessões de treino por semana (segundas, quartas e sextas-feiras);

(iv) Que os resultados que se desejam alcançar são os seguintes: a) melhoria das capacidades motoras referidas anteriormente; b) melhoria da funcionalidade representada por um mais eficiente desempenho em tarefas que exijam esforço físico, mental e percetivo, como por exemplo: escrever no computador, cortar com uma faca, usar um garfo, marcar um número de telefone, pegar em moedas, inserir uma moeda numa máquina, espremer a pasta dos dentes e colocá-la na escova, descolar um penso rápido, apertar o fecho de uma saia ou calças, caminhar, atravessar ruas, levantar de cadeiras, subir escadas, entre outros; c) melhoria da qualidade de vida, relacionada com a saúde, neste estudo representada pelas seguintes variáveis: menores níveis de ansiedade, depressão e fadiga, maiores níveis de autoestima e humor positivo, entre outros;

(v) Que este estudo começará no início do mês de Setembro e terminará após 12 meses;
(vi) Que participarão neste estudo seis grupos de idosos: três grupos experimentais e três grupos controlo. Os grupos experimentais serão submetidos a um programa de exercício físico regular;
(vii) Que no programa de exercício físico regular: a) os candidatos serão recrutados através de uma declaração médica, ou seja, antes de se iniciarem qualquer tipo de atividade física, torna-se imprescindível submeter os participantes a um exame médico, a fim de avaliar a sua condição física e o seu estado de saúde; b) no nosso programa começaremos com atividades mais moderadas e iremos progressivamente aumentar a sua intensidade para eliminar os fatores de risco de lesão e estas também irão ser ajustadas ao ritmo diário dos seus participantes; c) no programa, os exercícios irão desenvolver capacidades motoras como a força, a flexibilidade, a coordenação, a resistência, entre outras; d) cada sessão terá 60 minutos de duração; e) os diferentes segmentos da aula serão sempre respeitados: uma parte inicial de aquecimento, uma parte fundamental e uma parte de retorno à calma com exercícios de respiração e relaxamento; f) espera-se que os conteúdos do programa sejam motivantes e atrativos, mas fundamentalmente serão simples, de fácil compreensão e realização. Também não devemos esquecer a segurança, no que diz respeito aos sistemas cardiovascular e locomotor; assim sendo, propomos um programa atraíve, onde serão incluídos a ginástica em grupo, jogos em grupo com carácter lúdico, a dança a pares e em grupo; g) durante as aulas será utilizado material didático diversificado, tais como, balões (feijões dentro de cada balão), pára-queda, bolas adaptadas, halteres, pedrinhas da praia, fitas, cordéis, plataformas em forma de triângulo, arcos; jogos e leitor de CD, com a finalidade de dinamizar constantemente as aulas; h) a música presente nas sessões irá ser cuidadosamente selecionada, de modo a ir ao encontro do gosto das pessoas; assim sendo, iremos utilizar principalmente música portuguesa do tipo popular; i) irá ser pedido aos participantes para alertarem o professor se sentirem eventuais sinais de mal-estar (por exemplo, tonturas, cansaço, respiração ofegante); j) antes dos participantes realizarem cada exercício da aula, o professor explica oralmente e na prática o seu objetivo principal, e serão também dadas, sempre que possível, indicações para a manutenção de uma postura correta durante a execução dos exercícios;
(viii) Que a participação de cada pessoa será acompanhada do seguinte modo: esperando-se a frequência às aulas de exercício físico regular, monitorizada através de chamadas;
(ix) Que sempre que cada participante desejar, serão fornecidos esclarecimentos sobre cada uma das etapas deste estudo;
(x) Que, a qualquer momento, cada participante poderá recusar continuar a participar no estudo, e também, que poderá retirar este consentimento sem que para isso lhe traga qualquer penalidade ou prejuízo;
(xi) Que as informações conseguidas através da participação de cada participante não permitirão a identificação dos mesmos, exceto aos responsáveis pelo estudo, e que a divulgação dessas informações só será feita entre os profissionais estudiosos do assunto.
Finalmente, tendo eu compreendido perfeitamente tudo o que me foi informado sobre a participação de cada pessoa no mencionado estudo e estando
consciente dos meus direitos, das minhas responsabilidades que a minha participação implicam, concordo em participar no mesmo e para isso dou o meu consentimento sem que para isso tenha sido forçado ou obrigado.

Assinaturas dos/ as voluntários/ as ou representante legal.

Data ___/___/___

____________________
____________________
____________________
____________________
____________________
____________________
____________________
____________________

Confirmamos ter explicado a natureza e a finalidade do estudo em causa. Declaro total disponibilidade para fornecer esclarecimentos às dúvidas surgidas antes ou durante a realização deste estudo.

Nome e Assinatura do (s) responsável pelo estudo.

Data ___/___/___

____________________
____________________

(João Miguel Carvalho da Silva)
Appendix 8. Modified Baecke Questionnaire.

**Domestic Activities**

(What are your domestic activities? How do you consider them?)

1. Do you perform any light domestic activities (making beds, washing the dishes, etc.)?
   - 0. Never (less than 1 time a month)
   - 1. Sometimes (only when I don’t have someone to help)
   - 2. Often (sometimes with the help of someone else)
   - 3. Always (alone or with help)

2. Do you perform heavy domestic activities (wash the floor or windows, wash the car, etc.)?
   - 0. Never (less than 1 time a month)
   - 1. Sometimes (only when I don’t have someone to help)
   - 2. Often (sometimes with the help of someone else)
   - 3. Always (alone or with help)

3. For how many people do you perform household chores (including yourself, "0" if you answered never in questions 1 and 2)?

4. How many rooms do you usually clean in your house, including the kitchen, bedroom, garage, attic, bathroom, etc. ("0" if you answered never in questions 1 and 2)?
   - 0. None
   - 1. 1 to 6 rooms
   - 2. 7 to 9 rooms
   - 3. 10 or more rooms

5. If you clean some, how many floors are there in your house? ("0" is never answered in questions 1 and 2)?

6. Do you cook or help someone in this kind of task?
   - 0. Never
   - 1. Sometimes (1 to 2 times a week)
   - 2. Often (3 to 5 times a week)
   - 3. Always (more than 5 times a week)

7. How many flights of stairs do you usually climb a day? (one includes 10 stairs)
   - 0. I never climb stairs
   - 1. 1 to 5
   - 2. 6 to 10
   - 3. Over 10
8. Which means of transport do you use to travel in your city? (  )
   0. I never leave home
   1. The car
   2. Public Transport
   3. The Bicycle
   4. I walk

9. How often do you leave home or go shopping? (  )
   0. Never or less than 1 time a week
   1. 1 time a week
   2. 2 to 4 times a week
   3. Every day

10. When you leave to go shopping which means of transport do you use? (  )
    0. I never go shopping
    1. The car
    2. Public Transport
    3. The Bicycle
    4. I walk

**Domestic Activity Score (DAS) = (Q1+Q2+……………Q10)/10**

**Sport Activities**
Do you practice any sports?

<table>
<thead>
<tr>
<th>Name</th>
<th>Intensity</th>
<th>Number of Hours/Week</th>
<th>Period of the Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sport 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sport 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sport 3</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Sport Activity Score (SAS) = \sum (i*a*b*c)***
Leisure-Time Activities

Do you perform any other type of physical activity?

<table>
<thead>
<tr>
<th>Activity</th>
<th>Intensity</th>
<th>Number of Hours/Week</th>
<th>Period of the Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activity 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Activity 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Activity 3</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Leisure-Time Activity Score = \( \sum (ia \times ib \times ic) \)

Questionnaire Score = DAS + SAS + L-TAS

Table of Codes for the Modified Baecke Questionnaire

Intensity:
0. Laying without load \( \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \) Code 0.028
1. Sitting without load \( \ldots \ldots \ldots \ldots \ldots \ldots \ldots \) Code 0.146
2. Sitting with movements of upper limbs \( \ldots \ldots \ldots \ldots \ldots \ldots \ldots \) Code 0.297
3. Sitting with body movements \( \ldots \ldots \ldots \ldots \ldots \ldots \ldots \) Code 0.703
4. Standing position without load \( \ldots \ldots \ldots \ldots \ldots \ldots \ldots \) Code 0.174
5. Standing position with upper limb movements \( \ldots \ldots \ldots \ldots \ldots \ldots \ldots \) Code 0.307
6. Standing position with body movements, walking \( \ldots \ldots \ldots \ldots \ldots \ldots \ldots \) Code 0.890
7. Walking, with upper limb movements \( \ldots \ldots \ldots \ldots \ldots \ldots \ldots \) Code 1.368
8. Walking, with body movements, cycling, swimming \( \ldots \ldots \ldots \ldots \ldots \ldots \ldots \) Code 1.890

Number of Hours a Week:
0. Less than 1 hour a week \( \ldots \ldots \ldots \ldots \ldots \ldots \ldots \) Code 0.5
1. 1 to 2 hours a week \( \ldots \ldots \ldots \ldots \ldots \ldots \ldots \) Code 1.5
2. 2 to 3 hours a week \( \ldots \ldots \ldots \ldots \ldots \ldots \ldots \) Code 2.5
3. 3 to 4 hours a week \( \ldots \ldots \ldots \ldots \ldots \ldots \ldots \) Code 3.5
4. 4 to 5 hours a week \( \ldots \ldots \ldots \ldots \ldots \ldots \ldots \) Code 4.5
5. 5 to 6 hours a week \( \ldots \ldots \ldots \ldots \ldots \ldots \ldots \) Code 5.5
6. 6 to 7 hours a week \( \ldots \ldots \ldots \ldots \ldots \ldots \ldots \) Code 6.5
7. 7 to 8 hours a week \( \ldots \ldots \ldots \ldots \ldots \ldots \ldots \) Code 7.5
8. More than 8 hours a week \( \ldots \ldots \ldots \ldots \ldots \ldots \ldots \) Code 8.5

Months a Year:
0. Less than a month a year \( \ldots \ldots \ldots \ldots \ldots \ldots \ldots \) Code 0.04
1. 1 to 3 months a year \( \ldots \ldots \ldots \ldots \ldots \ldots \ldots \) Code 0.17
2. 4 to 6 months a year \( \ldots \ldots \ldots \ldots \ldots \ldots \ldots \) Code 0.42
3. 7 to 9 months a year \( \ldots \ldots \ldots \ldots \ldots \ldots \ldots \) Code 0.67
4. More than 9 months a year \( \ldots \ldots \ldots \ldots \ldots \ldots \ldots \) Code 0.92
Appendix 9. Modified Baecke Questionnaire (Portuguese version).

Questionário de Baecke Modificado

Atividades Domésticas
(Quais as suas atividades domésticas? Como as considera?)

1. Realiza tarefas domésticas ligeiras (fazer a cama, lavar a louça, etc.) (    )
   1. Nunca (menos de 1 vez por mês)
   2. Por vezes (apenas quando não tem ajuda)
   3. Frequentemente (algumas vezes com ajuda)
   4. Sempre (sozinho ou com ajuda)

2. Realiza tarefas domésticas pesadas (lavar o chão e/ou janelas, lavar o carro, etc.)? (    )
   1. Nunca (menos de 1 vez por mês)
   2. Por vezes (apenas quando não tem ajuda)
   3. Frequentemente (algumas vezes com ajuda)
   4. Sempre (sozinho ou com ajuda)

3. Para quantas pessoas faz a manutenção da casa (incluindo você mesmo; “0” se respondeu Nunca nas questões 1 e 2)? (    )

4. Quantos compartimentos da casa costuma limpar, incluindo cozinha, quarto, garagem, sótão, casa de banho, etc. (“0” se respondeu Nunca nas questões 1 e 2)? (    )
   1. Nenhum
   2. 1 a 6 compartimentos
   3. 7 a 9 compartimentos
   4. 10 ou mais compartimentos

5. Se limpa alguns, por quantos pisos é que eles se dividem? (“0” se respondeu Nunca nas questões 1 e 2)? (    )

6. Cozinha ou ajuda alguém neste tipo de tarefa? (    )
   1. Nunca
   2. Por vezes (1 a 2 vezes por semana)
   3. Frequentemente (3 a 5 vezes por semana)
   4. Sempre (mais de 5 vezes por semana)
7. Quantos lanços de escada sobe habitualmente por dia? (um lanço inclui 10 escadas) ( )
   1. Nunca subo escadas
   2. 1 a 5
   3. 6 a 10
   4. Mais de 10

8. Que tipo de transporte utiliza para se deslocar na sua cidade? ( )
   1. Nunca saio
   2. Carro
   3. Transporte público
   4. Bicicleta
   5. A pé

9. Com que frequência costuma sair de casa ou ir às compras? ( )
   1. Nunca ou menos de 1 vez por semana
   2. 1 vez por semana
   3. 2 a 4 vezes por semana
   4. Todos os dias

10. Quando sai para ir às compras que tipo de transporte utiliza? ( )
    1. Nunca vou às compras
    2. Carro
    3. Transporte público
    4. Bicicleta
    5. A pé

Score da Atividade Doméstica (SAD) = (Q1+Q2+……………Q10/10)

Atividades Desportivas
Pratica Desporto?

<table>
<thead>
<tr>
<th>Nome</th>
<th>Intensidade</th>
<th>N.º de Horas/Semana</th>
<th>Período do Ano</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desporto 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Desporto 2</td>
<td></td>
<td></td>
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<tr>
<td>Desporto 3</td>
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</tbody>
</table>

Score da Atividade Desportiva (SD) = Σ (ia*ib*ic)
**Atividades de Tempos Livres**

Realiza outro tipo de atividade física?

<table>
<thead>
<tr>
<th>Nome</th>
<th>Intensidade</th>
<th>N.º de Horas/Semana</th>
<th>Período do Ano</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atividade 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Atividade 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Atividade 3</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Score da Atividade dos Tempos Livres (STL) = \( \sum (i_a i_b i_c) \)

Score do Questionário = SAD + SD + STL

### Tabela de Códigos para o Questionário de Baecke Modificado

**Intensidade:**

- 0. Deitado, sem carga .................................................. Código 0.028
- 1. Sentado, sem carga .................................................. Código 0.146
- 2. Sentado, com movimentos dos membros superiores ........... Código 0.297
- 3. Sentado, com movimentos do corpo ................................ Código 0.703
- 4. De pé, sem carga .................................................. Código 0.174
- 5. De pé, com movimentos dos membros superiores ................ Código 0.307
- 6. De pé, com movimentos do corpo, andar ........................ Código 0.890
- 7. Andar, com movimentos dos membros superiores ................. Código 1.368
- 8. Andar, com movimentos do corpo, andar de bicicleta, nadar ... Código 1.890

**N.º de Horas por Semana:**

- 0. Menos de 1 hora por semana ......................................... Código 0.5
- 1. 1 a 2 horas por semana ........................................... Código 1.5
- 2. 2 a 3 horas por semana ........................................... Código 2.5
- 3. 3 a 4 horas por semana ........................................... Código 3.5
- 4. 4 a 5 horas por semana ........................................... Código 4.5
- 5. 5 a 6 horas por semana ........................................... Código 5.5
- 6. 6 a 7 horas por semana ........................................... Código 6.5
- 7. 7 a 8 horas por semana ........................................... Código 7.5
- 8. Mais de 8 horas por semana ..................................... Código 8.5

**Meses por Ano:**

- 0. Menos de 1 mês por ano ........................................ Código 0.04
- 1. 1 a 3 meses por ano ........................................ Código 0.17
- 2. 4 a 6 meses por ano ........................................ Código 0.42
- 3. 7 a 9 meses por ano ........................................ Código 0.67
- 4. Mais de 9 meses por ano ...................................... Código 0.92
Appendix 10. Record sheet of the Bassin Anticipation Timer.

<table>
<thead>
<tr>
<th>Nome:</th>
<th>Idade:</th>
<th>Nome:</th>
<th>Idade:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grupo 1: MP → MNP</td>
<td>Grupo 2: MNP → MP</td>
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<td>30</td>
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</tbody>
</table>

Intervalo – 10 minutos (atividade cognitiva) Intervalo – 10 minutos (atividade cognitiva)

<table>
<thead>
<tr>
<th>MNP</th>
<th>MP</th>
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<tbody>
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<td>5</td>
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</tbody>
</table>
DUTCH HANDEDNESS QUESTIONNAIRE (Van Strien, 2002)

Nome: _________________________________________________________
Idade: _____ Sexo: _____ Local: ______________________________________
Data do Teste: _____/_____/_______

Em baixo está especificada uma lista de atividades, nas quais poderá usar a mão direita ou a mão esquerda. Indique a mão que normalmente usa em cada uma dessas atividades. Se não tiver a certeza em alguma das respostas, tente visualizar a atividade em questão. Se não tiver uma preferência clara, indique que usa qualquer uma das mãos.

Coloque uma cruz no quadrado que lhe parecer mais exato. Obrigado pela sua colaboração.

<table>
<thead>
<tr>
<th>Atividades</th>
<th>Esquerda</th>
<th>Direita</th>
<th>Qualquer delas</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - Qual das mãos usa para segurar uma tesoura quando recorta papel?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 - Qual das mãos usa para pegar no lápis quando desenha?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 - Qual das mãos usa para desenroscar a rolha de uma garrafa?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 - Qual das mãos usa para dar as cartas de um baralho?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 - Qual das mãos usa para segurar a escova quando lava os dentes?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 - Qual das mãos usa para lançar uma bola?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 - Qual das mãos usa para segurar no martelo quando crava um prego?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 - Qual das mãos usa para segurar a linha quando a enfa numa agulha?</td>
<td></td>
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</tr>
<tr>
<td>9 - Qual das mãos usa para pegar numa raquete de ténis?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 - Qual das mãos usa para abrir a tampa de uma caixa?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11 - Qual das mãos usa para abrir uma porta com uma chave?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12 - Qual das mãos usa para segurar a faca quando corta uma corda?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13 - Qual das mãos usa para pegar numa colher quando come sopa?</td>
<td></td>
<td></td>
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<tr>
<td>14 - Qual das mãos usa para apagar com uma borracha?</td>
<td></td>
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<tr>
<td>15 - Qual das mãos usa para segurar no fósforo quando o acende?</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
LATERAL PREFERENCE QUESTIONNAIRE (Porac, 1993)

Nome: _________________________________________________
Idade:_____ Sexo:___ Local:_______________________________________

Data do Teste: _____/_____/_______

Agora, em baixo está especificada uma lista de atividades, nas quais poderá usar o pé direito ou o pé esquerdo. Indique o pé que normalmente usa em cada uma dessas atividades. Se não tiver a certeza em alguma das respostas, tente visualizar a atividade em questão. Se não tiver uma preferência clara, indique que usa qualquer um dos pés.

Coloque uma cruz no quadrado que lhe parecer mais exato. Obrigado pela sua colaboração.

<table>
<thead>
<tr>
<th>Atividades</th>
<th>Esquerda</th>
<th>Direita</th>
<th>Qualquer delas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pé</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1- Qual dos pés usa para saltar ao pé-coxinho?</td>
<td></td>
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</tr>
<tr>
<td>2 - Qual dos pés usa para chutar uma bola?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 - Qual dos pés usa para fazer um desenho com o pé no chão?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 - Qual dos pés usa para subir para um plano superior?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 - Qual dos pés usaria se tivesse que apanhar uma pedrinha com os dedos?</td>
<td></td>
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</tbody>
</table>
## Appendix 13. Mini-Mental State Questionnaire (MMS).

### Questionário Mini-Mental State (MMS)

| NOME: __________________________ |
| IDADE: _______ Anos             |
| DATA: ______ de ______ de ______ |

1. **ORIENTAÇÃO** (1 ponto por cada resposta correta)

   Em que ano estamos? ______
   Em que mês estamos? ______
   Em que dia do mês estamos? ______
   Em que dia da semana estamos? ______
   Em que estação do ano estamos? ______
   Em que país estamos? ______
   Em que distrito vive? ______
   Em que terra vive? ______
   Em que casa estamos? ______
   Em que andar estamos? ______

   **Nota:**

2. **RETENÇÃO** (contar 1 ponto por cada palavra corretamente repetida).

   “Vou dizer três palavras; queria que as repetisse, mas só depois de eu as dizer todas; procure ficar a sabê-las de cor”.

   Pêra ______
   Gato ______
   Bola ______

   **Nota:**

3. **ATENÇÃO E CÁLCULO** (1 ponto por cada resposta correta. Se der uma errada mas depois continuar a subtrair bem, consideram-se as seguintes como corretas. Parar ao fim das 5 respostas).

   “Agora peço-lhe que me diga quantos são 30 menos 3 e depois ao número encontrado volta a tirar 3 e repete assim até eu lhe dizer para parar”.

   27____ 24____ 21____ 18____ 15____

   **Nota:**

---

LXI
4. **EVOCAÇÃO** (1 ponto por cada resposta correta).

“Veja se consegue dizer as três palavras que lhe pedi há pouco para decorar”.

<table>
<thead>
<tr>
<th>Pêra</th>
<th>_______</th>
<th>Nota:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gato</td>
<td>_______</td>
<td></td>
</tr>
<tr>
<td>Bola</td>
<td>_______</td>
<td></td>
</tr>
</tbody>
</table>

5. **LINGUAGEM** (1 ponto por cada resposta correta).

a. “Como se chama isto? Mostrar os objetos:

<table>
<thead>
<tr>
<th>Relógio</th>
<th>_______</th>
<th>Nota:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lápis</td>
<td>_______</td>
<td></td>
</tr>
</tbody>
</table>

b. “Repita a frase que eu lhe vou dizer: O RATO ROEU A ROLHA”.

<table>
<thead>
<tr>
<th>Repetiu a frase</th>
<th>_______</th>
<th>Nota:</th>
</tr>
</thead>
</table>

c. “Quando eu lhe der esta folha de papel, pegue nela com a mão direita, dobre-a ao meio e ponha sobre a mesa”, (ou “sobre a cama”, se for o caso); dar a folha segurando com as duas mãos.

<table>
<thead>
<tr>
<th>Pega com a mão direita</th>
<th>_______</th>
<th>Nota:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dobro ao meio</td>
<td>_______</td>
<td></td>
</tr>
<tr>
<td>Coloca onde deve</td>
<td>_______</td>
<td></td>
</tr>
</tbody>
</table>

d. “Leia o que está neste cartão e faça o que lá diz”. Mostrar um cartão com a frase bem legível, “FECHE OS OLHOS”; sendo analfabeto ler-se a frase.

<table>
<thead>
<tr>
<th>Fechou os olhos</th>
<th>_______</th>
<th>Nota:</th>
</tr>
</thead>
</table>

e. “Escreva uma frase inteira aqui”. Deve ter sujeito e verbo e fazer sentido; os erros gramaticais não prejudicam a pontuação.

| Escreveu a frase        | _______ | Nota: |


———

Nota:

Nota:

Nota:

Nota:

Nota:

Nota:
6. **HABILIDADE CONSTRUTIVA (1 ponto pela cópia correta).**
Deve copiar um desenho. Dois pentágonos parcialmente sobrepostos; cada um deve ficar com 5 lados, dois dos quais intercetados. Não valorizar, tremor ou rotação.

**DESENHO**

![Desenho](image)

Cópia

(Máximo 30 Pontos)  TOTAL:

---

Considera-se com Defeito Cognitivo

- Analfabetos ≤ 15
- 1 a 11 anos de escolaridade ≤ 22
- Com escolaridade superior a 11 anos ≤ 27

---

**FECHE OS OLHOS**
## Teste de Tinetti (1986) – Avaliação da Mobilidade e Equilíbrio Estático e Dinâmico (POMA – Performance-Oriented Assessment of Mobility and Balance)

### Equilíbrio Estático (Pontuação: __/16)

#### Cadeira

1. **Equilíbrio Sentado**
   - 0 - Inclina-se ou desliza na cadeira
   - 1 - Inclina-se ligeiramente ou aumenta a distância das nádegas ao encosto da cadeira
   - 2 - Estável, seguro

2. **Levantar-Se**
   - 0 - Incapaz sem ajuda ou perde o equilíbrio
   - 1 - Capaz, mas utiliza os braços para ajudar ou faz excessiva flexão do tronco ou não consegue à 1ª tentativa
   - 2 - Capaz à 1ª tentativa sem usar os braços

3. **Equilíbrio Imediato** (primeiros 5 segundos)
   - 0 - Instável (cambaleante, move os pés, marcadas oscilações do tronco, tenta agarrar algo para suportar-se)
   - 1 - Estável, mas utiliza auxiliar de marcha para suportar-se
   - 2 - Estável sem qualquer tipo de ajudas

4. **Equilíbrio Em Pés Paralelos**
   - 0 - Instável
   - 1 - Estável, mas alargando a base de sustentação (calcanhares afastados> 10cm) ou recorrendo a auxiliar de marcha para apoio
   - 2 - Pés próximos e sem ajudas

5. **Pequenos Desequilíbrios na Mesma Posição** (sujeito de pé com os pés próximos, o observador empurra-o levemente com a planta da mão, 3 vezes ao nível do esterno)
   - 0 - Começa a cair
   - 1 - Vacilante, agarra-se, mas estabiliza
   - 2 - Estável

6. **Fechar Os Olhos na Mesma Posição**
   - 0 - Instável
   - 1 - Estável

7. **Volta de 360°** (2 vezes)
   - 0 - Instável (agarra-se, vacila)
   - 1 - Estável, mas dá passos descontínuos
   - 2 - Estável e passos contínuos

8. **Apoio Unipodal** (aguenta pelo menos 5 segundos de forma estável)
   - 0 - Não consegue ou tenta segurar-se a qualquer objeto
   - 1 - Aguenta 5 segundos de forma estável

9. **Sentar-Se**
   - 0 - Pouco seguro ou cai na cadeira ou calcula mal a distância
   - 1 - Usa os braços ou movimento não harmonioso
   - 2 - Seguro, movimento harmonioso
**EQUILÍBRIO DINÂMICO** (Pontuação: _/12)

**MARCHA**

**Instruções:** O sujeito faz um percurso de 3m na sua passada normal e volta com passos mais rápidos até à cadeira. Deverá utilizar os seus auxiliares de marcha habituais.

10. **INÍCIO DA MARCHA** (imediatamente após o sinal de partida)
   0 - Hesitação ou múltiplas tentativas para iniciar
   1 - Sem hesitação

11. **LARGURA DO PASSO** (pé direito)
    0 - Não ultrapassa a frente do pé em apoio
    1 - Ultrapassa o pé esquerdo em apoio

12. **ALTURA DO PASSO** (pé direito)
    0 - O pé direito não perde completamente o contacto com o solo
    1 - O pé direito eleva-se completamente do solo

13. **LARGURA DO PASSO** (pé esquerdo)
    0 - Não ultrapassa a frente do pé em apoio
    1 - Ultrapassa o pé direito em apoio

14. **ALTURA DO PASSO** (pé esquerdo)
    0 - O pé esquerdo não perde totalmente o contacto com o solo
    1 - O pé esquerdo eleva-se totalmente do solo

15. **SIMETRIA DO PASSO**
    0 - Comprimento do passo aparentemente assimétrico
    1 - Comprimento do passo aparentemente simétrico

16. **CONTINUIDADE DO PASSO**
    0 - Pára ou dá passos descontínuos
    1 - Passos contínuos

17. **PERCURSO DE 3M** (previamente marcado)
    0 - Desvia-se da linha marcada
    1 - Desvia-se ligeiramente ou utiliza auxiliar de marcha
    2 - Sem desvios e sem mudas

18. **ESTABILIDADE DO TRONCO**
    0 - Nítida oscilação ou utiliza auxiliar de marcha
    1 - Sem oscilação, mas com flexão dos joelhos ou coluna ou afasta os braços do tronco enquanto caminha
    2 - Sem oscilação, sem flexão; não utiliza os braços nem auxiliares de marcha

19. **BASE DE SUSTENTAÇÃO DURANTE A MARCHA**
    0 - Calcanhares muito afastados
    1 - Calcanhares próximos, quase se tocam

**EQUILÍBRIO TOTAL – Pontuação Final:** _/28
Appendix 15. Record sheets of the tests used in this research.

### Purdue Pegboard – Grupo 1

Local: _________________________________    Data do Teste: _____/_____/_______

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Familiarização: Alguns.

Intervalo de descanso: 30’’ tentativas; 60’’ inter-testes
Purdue Pegboard – Grupo 2

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Familiarização: Alguns.
Intervalo de descanso: 30’’ tentativas; 60’’ inter-testes
Teste de Destreza Manual de Minnesota – Grupo 1

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MP – Mão Preferida; MNP – Mão Não Preferida

Familiarização: Alguns.
Intervalo de descanso: 30” tentativas; 60” inter-testes
### Teste de Destreza Manual de Minnesota – Grupo 2

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**MP – Mão Preferida; MNP – Mão Não Preferida**

_Familiarização: Alguns._

_Intervalo de descanso: 30’’ tentativas; 60’’ inter-testes_
Tapping Manual – Grupo 1

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Familiarização: 1 tentativa.
Intervalo de descanso: 30´´ inter-tentativas; 60´´ inter-testes
Local: _________________________________  
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Familiarização: 1 tentativa.
Intervalo de descanso: 30´´ inter-tentativas; 60´´ inter-testes
# Pursuit Rotor – Grupo 1

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**Familiarização:** 1 tentativa.  
**Velocidade:** 15 rpm.  
**Intervalo de descanso:** 20´´ inter-tentativas; 60´´ inter-blocos
Pursuit Rotor – Grupo 2

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Familiarização: 1 tentativa. Velocidade: 15 rpm.
Intervalo de descanso: 20’’ inter-tentativas; 60’’ inter-blocos
Polirreaciómetro (Tempo de Reação) – Grupo 1

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Familiarização: 2 tentativas para cada mão.
Foreperiod: 1:1; 2:2; 2:3.
 INTERVALO DE DESCANSO: 30” inter-tentativas.
Polirreaciómetro (Tempo de Reação) – Grupo 2

Local: _________________________________ Data do Teste: _____/_____/_______

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Polirreaciómetro

Familiarização: 2 tentativas para cada mão. 
Foreperiod: 1:1; 2:2; 2:3. 
Intervalo de descanso: 30´´ inter-tentativas.
Força de Preensão Manual – Grupo 1

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MP – Mão Preferida; MNP – Mão Não Preferida

Familiarização: 1 tentativa.

Intervalo de descanso: 60” inter-tentativas
**Força de Preensão Manual – Grupo 2**

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MP – Mão Preferida; MNP – Mão Não Preferida

**Familiarização:** 1 tentativa.  
**Intervalo de descanso:** 60’’ inter-tentativas
Teste de Tinetti – Grupo 1

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### Tapping Pedal – Grupo 1

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Familiarização: 1 tentativa para cada pé.
Intervalo de descanso: 120´´ inter-tentativas
### Tapping Pedal – Grupo 2

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Familiarização: 1 tentativa para cada pé.

Intervalo de descanso: 120’’ inter-tentativas
Teste de Discriminação de Pesos – Grupo 1

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Teste de Discriminação de Pesos – Grupo 2

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Teste de Memória Visuomotora – Grupo 1

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