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PHYSICAL EXERCISE AND FALL RISK IN INSTITUTIONALIZED OLDER ADULTS:
EFFECTS OF NEUROMUSCULAR AND COGNITIVE ADAPTATIONS ON MULTIDIMENSIONAL ASSESSMENTS

PhD Thesis of the Doctorate Program in Sport Sciences, Branch of Physical Activity and Health, supervised by Professors Ana Maria Miranda Botelho Teixeira, Cidalina da Conceição Ferreira de Abreu and Guilherme Eustáquio Furtado, and submitted to the Faculty of Sport Sciences and Physical Education of the University of Coimbra.

December 2022

“Sometimes we feel that what we do is just a drop in the sea. But the sea would be smaller if it lacked a drop”.
(Mother Theresa of Calcutta)

Professional Acknowledgements

The task of writing this part of my thesis is probably the most desirable and gratifying part, as I am able to express the sincerest feelings without any challenge of searching for the right or most actual bibliography or even using a citation manager software, and the most important thing, the great pleasure to thank all the people who made this journey easier and possible for me.

First and foremost, I would like to express my immense gratitude and admiration to Dra. Ana Teixeira. Thank you for all the support provided, the encouragement, and mentorship throughout this journey. Your great commitment, dynamism, passion and vision for your research to meet the highest standards, inspired and motivated me. Also, thank you for your humanity and your empathy, which make the Ph.D. journey light and pleasant.

I would also like to express my sincere appreciation to Profa. Dra. Cidalina Abreu and Prof. Dr. Guilherme Eustaquio Furtado, who always incentivize me to strive to learn and be a better researcher. Thank you both for providing me with such wonderful and enriching experiences, and for sharing your wisdom throughout this Ph.D process. It was a privilege to be able to learn with both of you.

To Prof. Dr. Eduardo Carballeira, thank you for your constant encouragement and support throughout this process. To Dra. Adriana Caldo and Ms. Fernanda Silva, who made the Ph.D experience even greater. It was a privilege to be able to share such amazing experiences with you both.

I would like to thank all the professors, staff and students at the Faculty of Sports Sciences and Physical Education and to the University of Coimbra Stadium's professionals, for all your support over the last years, your effort and hardwork make possible to me to complete this thesis. I will forever be grateful for your words of encouragement when I needed it the most.

Finally, this work would not materialize without the Institutions and the people who accepted us, and trusted in our work, so, I am especially thankful to the Caritas Diocesana de Coimbra, Centro Social de São João, Casa de Saúde "Coimbra" and to Associação Recreativa, Cultural e Social de Cioga do Monte.

Personal Acknowledgements

First, I would like to thank to God, because without faith nothing can be accomplished, or even dreamed.

I wish to acknowledge the person who is the greater support and encouragement in my life: Ana Carolina. There are no words to describe how important and decisive was to have you at my side during all this process. Thank you for being my strength when I was weak, for being my support when I fell, to believe in me when I did not even believe, thank you for being you.

To the biggest pillar of strength in my life: My mother. Mum, words cannot express the deep gratitude I have for all your support not only throughout my thesis, but my entire life and educational career. You are the epitome of strength and resilience, a characteristic I inherited from you, and which certainly came in handy during this PhD process. Thank you for your wisdom, encouragement, empathy and unquestionable love.

To my siblings whose support made this possible: Paulo, Vinicius, Monica and Luiz Gustavo. Thank you all for being my personal fans and supporters, as well as being the emotional pillars of our family. Thanks to my father, Paulo, who was taken away from us during this thesis process, however, he will ever being in our hearts, and will be proud wherever he is.

Lastly, I would like to acknowledge and dedicate this thesis to my family, specially to Luiz, Eliete, Plinio and Juliana. They always encouraged me to keep asking questions and to never stop learning. Thank you all, for all your support anytime things felt tough during these last years.

Even with the distance of living in another country, and the worries caused by these 2 years of pandemic situation, I always reminded myself to “do it for them”, and remembered that “they believe in me”, and I drew on that strength to achieve this great achievement in my life.

I miss you all, and truly wish all of you were here to see, personally, what I have accomplished. Although some of you weren’t here with us anymore, but I know you helped and guided me through this, so thank you all, one more time, and until we all meet again.

Abstract

Increasing life expectancy and the growing number of older people have also increased the number of comorbidities common in this population in the same proportion, where the risk of falling is highlighted and has been increasing in a worrying and negative way. However, the practice of physical exercise can aid the prevention and reduction of falls. In this context, this thesis presents in its introduction part an exploratory review on the evaluation, assessment, and monitoring in health and fall risk by common and the most used assessment tools divided into six categories (global health assessment, specific physical (and fitness) assessment, cognitive and psychological assessment, pharmacological assessment, fall risk specific assessment, and some complementary assessment) and try to address the theme with the objective of identifying how, which, and when physical exercise can contribute in relation to the risk of falling in the older population.

Through analysis of articles and recent reviews related to the influence of exercise (resistance/strength, power, aerobic, and multicomponent) in their various components and possible influences on the risk of falling, an exercise program proposal specific for the risk of falling in the older population was made, with adjustments in volume and intensity according to the needs of the target audience, based and improved by worldwide guidelines. Whereas health evaluative experiences and practices are essential to drive a better and specific intervention, revealing its importance and necessity was also highlighted.

Preventing falls is also part of the Portuguese National Plan for Patient Safety, and as the lack of a fall risk assessment scale for older persons in residential institutions was found, this thesis shows the semantically, conceptually, culturally, and psychometrically validation the Fall Risk Assessment Tool for the Portuguese population. The instrument demonstrating good internal consistency and correlation between the items evaluated,

could be an asset for a quick and effective assessment of the risk of falling for institutionalized Portuguese older persons.

Our studies also investigated the 40-weeks training-detraining-retraining effect of our exercise program proposal in old (≥70 years, Paper Three) and very old (≥80years old, Paper Four) population. Our paper three investigated the effect of exercise on Cognitive profile, body composition, muscle power outputs and Fall Risk tests, and showed a significant correlation between muscle power, fat-free mass and cognitive status with some fall risk assessment (Fall Risk Assessment Tool. Falls Efficacy Scale and Timed Up-and-Go test), which also demonstrated to be a good predictor/indicator for fall risk assessment. Our exercise program was able to improve muscle power, body composition, cognitive profile and fall risk status after both exercise interventions (training and retraining), still showing after the detraining phase some protective effects.

In the octogenarians' group (Paper Four), after the first training period, the exercise group improved their postural stability and decreased the estimated fall risk (7.9%), while the control group worsened their stability and increased their risk of falling (17%). In addition, the intervention was able to reduce the forward speed of postural control deterioration in octogenarians, with great increments in the first months of exercise.

Overall, our thesis' studies showed that elastic band resistance training triggered significant alterations in the participants' fall risk, which could provide independence and higher quality of life for this population.

Keywords: older adults; postural stability; strength exercise; fall risk; technology-based assessment

Resumo

O aumento da esperança de vida e o número crescente de idosos também resultaram no aumento do número de comorbidades comuns nessa população, onde o risco de queda ganha destaque e aumenta de forma preocupante e negativa. No entanto, a prática de exercício físico pode auxiliar na prevenção e redução do risco quedas. Nesse contexto, esta tese apresenta na sua parte introdutória uma revisão exploratória sobre a avaliação e monitorização em saúde e risco de queda e os possíveis instrumentos de avaliação utilizados, divididos em seis categorias (avaliação global de saúde, avaliação física específica, avaliação cognitiva e psicológica, avaliação farmacológica, avaliação específica do risco de queda e algumas avaliações complementares) e aborda o tema com o objetivo de identificar como, qual e quando o exercício físico pode contribuir em relação ao risco de queda nos idosos.

Por meio da análise de artigos e revisões recentes relacionadas com a influência do exercício (resistência/força, potência, aeróbico e multicomponente) em seus diversos componentes e possíveis influências no risco de queda, foi proposto um programa de exercícios específicos para o risco de queda nos idosos, com ajustes de volume e intensidade de acordo com as necessidades do público-alvo, baseado e aprimorado seguindo diretrizes mundiais. Considerando que experiências e práticas avaliativas em saúde são essenciais para conduzir uma intervenção melhor e específica, também foram destacadas a sua importância e necessidade.

A prevenção de quedas também faz parte do Plano Nacional de Segurança do Doente Português, e como se verificou a inexistência de uma escala de avaliação do risco de queda para idosos em instituições de acolhimento, esta tese em um de seus estudos mostra a validação semântica, conceptual, cultural e psicométrica do Fall Risk Assessment Tool para a população portuguesa. O instrumento demonstrou boa consistência interna e

correlação entre os itens avaliados e poderá ser uma mais-valia para uma avaliação rápida e eficaz do risco de queda dos idosos portugueses institucionalizados.

Nossos estudos ainda investigaram o efeito de 40 semanas de treino-destreino-retreino com o nosso programa de exercícios na população idosa (≥70 anos, capítulo cinco) e muito idosa (≥80 anos). O paper três investigou o efeito do exercício no perfil cognitivo, composição corporal, potência muscular e testes de risco de queda, e mostrou uma correlação significativa entre potência muscular, massa livre de gordura e estado cognitivo com algumas avaliações de risco de queda (Fall Risk Assessment Tool. Falls Efficacy Scale and Timed Up-and-Go test), além deles terem se demonstrado bons preditores/indicadores para avaliação do risco de queda. Nosso programa de exercícios demonstrou melhorar a potência muscular, composição corporal, perfil cognitivo e status de risco de queda após a intervenção com exercício (treino e retreino) e após a fase de destreino, também foram observados alguns efeitos protetores do exercício.

No grupo dos octogenários (Paper Quatro), após o primeiro período de treino, o grupo fisicamente ativo melhorou a estabilidade postural e diminuiu o risco estimado de queda (7,9%), enquanto o grupo controlo piorou e aumentou o risco de queda (17%). Além disto, a intervenção foi capaz de reduzir a velocidade de avanço da deterioração do controlo postural, com grandes incrementos nos primeiros meses de exercício.

No geral, nossos estudos mostraram que o treino de força com banda elástica desencadeou alterações significativas no risco de queda dos participantes, o que poderia aumentar a independência e proporcionar uma maior qualidade de vida nessa população.

Palavras-chave: idosos; estabilidade postural; exercício de resistência; risco de queda; avaliação baseada em tecnologia

Thesis Format

This thesis commences with the general introduction (Chapter One) dived in three main parts, including a general overview, which provides background and contextualization, rationale and justification for the research aims presented in this specific thesis. The second part of the introduction includes a comprehensive and didactic review published as book chapter (item 1.1) which synthesizes some of the most common ways to evaluate fall risk in older population (e.g., fall risk, loss of skeletal muscle mass, strength, and physical performance).

Chapter One also includes another published book chapter (item 1.2) that generally reviews and discusses the importance of exercise training in the risk of fall in older adults and makes recommendations of a specific elastic band resistance training to achieve the points highlighted in this chapter. Chapter One includes, in its last topic (1.3) the thesis objectives, divided into specific studies.

Chapter Two highlight our results divided in specific papers. The first paper is an "instrumental validation study" which correspond to one of our studies/objectives which was to validate the Fall Risk Assessment Tool – FRAT for the Portuguese population.

Paper Two is a crossover study focusing on how the fear of falling would be related to physical capabilities, general health status (i.e., medication use, mental assessment, comorbidity index, nutritional status), and salivary physiological biomarkers (i.e., testosterone, cortisol, DHEA, alpha-amylase). This crossover-correlational study was aimed at identifying the basis for future studies regarding falls in older population, and how multidimensional this problem is.

Paper Three is a longitudinal interventional study, which explores the relationship between age, biological sex, and training status on outcomes related to body composition, power outputs, cognitive status and a multidimensional fall risk in active and sedentary institutionalized older adults, and Paper Four is a 40-week naturalistic controlled study, where we analyze the specific effect of the intervention (16-week of training, 8 weeks of detraining, and 16-weeks of retraining) in very old adults (e.g. ≥80 years old), and its relationship with fall risk and balance outcomes measured with a sensorimotor/posturographic (Physiosensing®) platform, a new technology assessment tool. Both studies contextualize the results of our intervention studies proposal presented in Introduction, and in our Objectives (Item 1.3).

Chapter Three answers one of our objectives, which was to develop and disseminate tailored exercise programs specific for older populations. The exercise program proposal was first published in a peer-reviewed book chapter (Chapter 1, item 1.2), and now turned into an illustrated (photos and videos) multimedia package, easier to understand, and facilitate autonomous exercise practice. The exercise program package was published in the University of Coimbra, Estádio Universitário website (https://desporto.uc.pt/wp-content/uploads/2022/10/UCATIVA_treino_elastico.pdf), as a support measure to promote general health, and a healthier lifestyle, aligning our objectives in accordance with WHO, as well as the University of Coimbra objectives. The exercise program can be easily accessed by our entire community, free of charge.

Finally, Chapter Four is the general discussion that provides a synthesis and further interpretation of the findings of this thesis, including a discussion about the contributions to knowledge and its strengths, limitations, practical implications, and directions for future studies.

Abbreviations are defined at first use throughout the thesis. A full list of tables, figures and abbreviations is provided. Also, an overlap in content may occur between chapters due to the complementary nature of the studies and links between chapters. This thesis does not show a methodology-specific section, however all the proceeding are included in each specific study/paper.

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List of Abbreviations

2ST	2-Minutes Step Test
ACSM	American College Of Sports Medicine
ACT	Arm-Curl Test
ADL	Activities Of Daily Living
aPower	Absolute Muscle Power
BMI	Body Mass Index
BST	Back Scratch Test
CCI	Charlson Comorbity Index
CG	Control Group
CONSORT	Consolidated Standards Of Reporting Trials
CSEC	Comfortable Stance With Eyes Closed
CSEO	Comfortable Stance With Eyes Open
CSR	Chair Sit-And-Reach Test
CST	Chair-And-Stand Test
CV	Coefficient Of Variation
EBE	Elastic Band Exercise
EBEG	Elastic Band Exercise Group
EBRT	Elastic Band Resistance Training
EBRTG	Elastic Band Resistance Training Group
EUPHA	The European Public Health Assosciation
EuroQol	European Quality Of Life Questionnaire
FES	Falls Efficacy Scale
FFM (%)	Percentual Of Fat-Free Mass
FFM (kg)	Fat-Free Mass In Kilogram
FM (%)	Fat Mass In Percentage
FRAT	Fall Risk Assessment Tool
GDS	Geriatric Depression Scale
HADS	Hospital Anxiety And Depression Scale
HIIT	High Intensity Interval Training
HR	Heart Rate
HRmax	Maximum Heart Rate
HVLT	Hopkins Verbal Learning Test

IPAQ	International Physical Activity Questionnaire
MCI	Mild Cognitive Impairment
MMSE	Mini Mental State Examination
MoCA	Montreal Cognitive Assessment
MSE	Muscular Strength Exercise
NICE	National Institute For Health And Care Excellence
NSEC	Narrow Stance With Eyes Closed
NSEO	Narrow Stance With Eyes Open
OPAS	Organização Panamericana da Saúde (PanAmerican Health Organization)
PSE	Perceived Subject Effort
PSS	Perceived Stress Scale
RCT	Randomized Controlled Trial
RPE	Rate Of Perceived Exertion
rPower	Relative Muscle Power
RT	Resistance Training
SD	Standard Deviation
SF-36	Short-Form Health Survey
STEADI	Stopping Elderly Accidents. Death And Injuries
STS	Sit-To-Stand Test
SWLS	Satisfaction With Life Scale
TUG	Timed-Up And Go Test
VES-13	The Vulnerable Elders-13 Survey
VO2Max	Maximum Volume Of Oxygen
WHO	World Health Organization
WHOQOL-100	World Health Organization Quality Of Life Questionnaire
WHOQOL-Bref	World Health Organization Quality Of Life Abbreviated Questionnaire

Chapter 1- General Introduction

Aging: The Demographic Overview

Based on the most recent United Nation-World Population Prospects report, approximately 9.1% of the world population are over the age of 65, a number projected to rise to 11.7% in 2030 and 15.9% in 2050, where the number of very old adults (i.e., aged 80 or over) is estimated to increase to about 425 million people (United Nations, 2019). In this same report was highlighted that in 2018, for the first time in the history of the world, individuals at 65 years old and over, outnumbered children (<5 years old), and the same projections say that in 2050, the population over 65 will be twice as the population under 5, and they will outnumber the youth population (15-24 years old) as well.

Therefore, the world is undergoing an aging trend, initially manifested mainly, in prosperous regions like Europe, but in the future, this trend will also be sensed in less economically advanced countries. The 2017 United Nation-World Population Prospects report (United Nations, 2017) shows the countries on top 10 ranking with the most percentual of people aged 60 years old and over, and we can observe that those in the Europe region were predominant, and that Portugal, which was not in the top 10 of aged countries in 1980, jumped to 4th position in 2017, with the prospective to reach the 3th position on 2050 (Table 1) showing a strong trend towards aging. Nowadays, Portugal has 82.1 years of life expectancy, and 22.4% of its population is over 65 years old (United Nations, 2019).

Table 1. Ten countries with the largest share of persons aged 60 years old and over

1980			2017		2050	
Rank	**Country**	**% of people (≥60 y. old)**	**Country**	**% of people (≥60 y. old)**	**Country**	**% of people (≥60 y. old)**
1	Sweden	22.0	Japan	33.4	Japan	42.4
2	Norway	20.2	Italy	29.4	Spain	41.9
3	Channel Island	20.1	Germany	28.0	Portugal	41.7
4	United Kingdom	20.0	Portugal	27.9	Greece	41.6
5	Denmark	19.5	Finland	27.8	Republic of Korea	41.6
6	Germany	19.3	Bulgaria	27.7	China/Taiwan	41.3
7	Austria	19.0	Croatia	26.8	China/Hong-Kong	40.6
8	Belgium	184	Greece	26.5	Italy	40.3
9	Switzerland	18.2	Slovenia	26.3	Singapore	40.1
10	Luxembourg	17.8	Latvia	26.2	Poland	39.5

Adapted from (United Nations, 2017)

Although it seems to be very good news, because of the increased life expectancy (which it really is), it brings attached, or as consequence, several problems. As the life expectancy grows up worldwide, problems related to that aging trend are also increasing, which includes, but not only, problems related to social (i.e., social protection) economics (i.e., pensions) and public systems (i.e., healthcare systems) (Sadighi Akha, 2018).

The changes that constitute and influence aging are complex and include many aspects (i.e., biological, physical, psychological, social) (de Souto Barreto et al., 2016). Briefly, at the biological level, the aging process is mainly associated with the cellular and molecular damage (Nikitin & Freund, 2019), which leads to a loss of some physiological capacities, and increases the risk for some diseases, as well as the loss of physical capabilities, which can reduce mobility and independence status. Also, the aging process usually leads to social changes and loss of relationships, which strongly affects psychological health (Bailey, Ebner, & Stine-Morrow, 2021).

In this way, it is not enough just to have a longer life expectancy if these extra years are not lived with health and quality of life. In this context, the WHO defines health as a specific state related to a complete well-being (physical, mental and social) and not merely the absence of disease, and quality of life as the individual's perception of their place in life, in the context of the culture and value systems in which they live and in relation to their goals, expectations, standards and concerns (World Health Organization, 2015b).

In this context, many health organizations (WHO, OPAS, ACSM) are focusing their efforts into promoting healthy aging. Healthy aging is a continuous process of optimizing functional ability and opportunities to maintain and improve physical and mental health, promoting independence and quality of life throughout lifespans (Organização Pan-Americana da Saude, 2021).

According to OPAS

> "Healthy, independent older people contribute to the well-being of their family and community, and to describe them only as passive recipients of social or health services is to perpetuate a myth. Today, however, the number of elderly people increases exponentially, and many find themselves in complex and uncertain socioeconomic situations. Only timely interventions will make it possible to increase the contributions of this age group to social development and prevent population aging from turning into a crisis for the health and social assistance structure."
>
> (Organização Pan-Americana da Saude, 2021, p.2)

Regarding the above quote, promoting programs to answer in an assertive way to the older population needs, and helping them to regain their self-confidence, independence, and improve their health are the goals of many international organizations, such as WHO, ACSM, and OPAS (Chodzko-Zajko et al., 2009; Organização Pan-Americana da Saude, 2021; World Health Organization, 2015a).

These programs can focus in many and different objectives, as to help older adults to select fewer but more meaningful goals and activities, optimize their existing capabilities through practices and through the use of new technologies, and try to compensate the possible loss of some skills by finding other ways to accomplish tasks or even, changing the objectives, as the goals and preferences seem to be modifiable, and they can adapt to their new routine of later life, which also influence the psychosocial factors, and the subjective well-being, so the programs for these populations should respond not only to the loss of age-related characteristics, but also focus on enhancing and developping autonomy and independence (Lange & Grossman, 2018).

Autonomy is the capacity to decide, a person with autonomy is someone who decides, determines for herself. Being autonomous is being able to make your own decisions in every situation in life (Nikitin & Freund, 2019). According to WHO (World Health Organization, 2002), autonomy refers to the perceived ability to control, deal with situations and make decisions about day-to-day life, according to one's own rules and preferences. So autonomy refers to the ability to take care of themselves, to adapt to the environment, to manage their own life and be responsible for their own actions (Sequeira, 2010).

Independence, according to WHO (World Health Organization, 2002) is the ability to perform functions related to daily living and self-care, that is, the ability to live independently in the community without assistance. It can then be said that a dependent person needs help from others to meet their self-care needs and/or interact with the environment. This may be associated with a physical, psychic or intellectual limitation (Sequeira, 2010). Although dependence does not mean a change in cognitive or emotional state, in a person with changes in these dimensions, changes in dependence are likely to appear.

However, autonomy and independent are not the same. A situation of physical dependence for example, does not imply loss of autonomy, because the person can continue to make decisions about their own life, despite its physical limitations. The person who is not able to decide (autonomous), and/or is not able to perform (independent), needs support, help and guidance from others to achieve self-care (Mauk, 2018).

Regarding that, when evolution towards autonomy/independence is achieved, it is considered a health gain. The concept of health gains, according to the Brazilian Ministry of Health (Ministério da Saúde- Secretaria de Atenção à Saúde. Departamento de Atenção Básica, 2006), is seen as a positive statement of improving a person's level of health, and can be interpreted in various ways, such as reductions of diseases episodes/frequency, gains in years of life, decreased/reduction of suffering (health-related condition), and increases in psychological and physical conditions.

Aging: Frailty Syndrome and Cognitive Status in Older Populations

Current studies show aging as unavoidable, normal, dynamic, and in some ways, an irreversible process, however, the chronic and disabling conditions that surround it can be prevented, mitigated and/or delayed, both by medical interventions as well as by social, economic and environmental interventions (F. Ribeiro, Gomes, Teixeira, Brochado, & Oliveira, 2016).

In this context, in the last years some risk factors were identified that can increase the predisposition of an individual for physical and/or cognitive impairment related to aging and, among these factors stand out: age, gender, family history, educational level, smoking, nutritional aspects, stress, socialization and sedentary lifestyle (Vogel et al., 2009). With emphasis on the last three of them as they can be reversed and/or attenuated with some behavioral changes such as the start of a routine that will involve, among other things, the practice of physical exercise.

International studies report that the prevalence rates of some level of physical and cognitive impairment in people over 65 years of age reached 16.8% in 2010 and doubled in 80 years (Moraes, 2012), and the economic impact of this population was only increasing (Macklai, Spagnoli, Junod, & Santos-eggimann, 2013). For this reason, the concern of organizational entities around the world, all for the promotion of healthy and active aging, refers to the implementation of numerous programs and studies related to its efficiency.

Considering that, a more active life is involved in at least three fundamentals factors associated with this theme (stress, socialization, and sedentary lifestyle), that will contribute to the delay of many of the consequences of the aging process, such as immunosenescence, physical and cognitive frailty syndrome, and neurodegenerative diseases (Maciel, Física, & Antipoff, 2010). Placing the process of aging, and or immunosenescence with a direct association with the appearance of neurodegenerative diseases in this population (Colado et al., 2018).

Immunossenescence is defined as a dysregulated function of the immune system in older population which increase de risk/susceptibility to some diseases/infections, and it is characterized as a chronic inflammatory state, involving biomarkers such cortisol (COR), testosterone (TT), dehydroepiandrosterone (DHEA) and α-amylase (α-AMY). This pro-inflammatory process can, among other factors, accentuate the risk of falls, leading to a greater physical compromise, and reducing/limiting the level of physical activity by causing locomotor prejudice and delay the equilibrium reactions (Bauer, 2019; Siqueira et al., 2007).

However, the association between falls and salivary-related markers have not been consistently explored. Increased exposure to COR levels influence in the vulnerability to some negative effects of this hormone related to stress on general cognition health (Karlamangla, Friedman, Seeman, Stawksi, & Almeida, 2013). Some authors also have found preliminary results suggesting that the diurnal COR cycle influence the hypothalamic-pituitary-adrenal axis, which is one of the main stress-related systems (Weller et al., 2014). Prefrontal cortex, which is known for its importance in decision-making and attention status related to executive functions, may also be affected (Funahashi, 2017).

The importance on several sensory-motor skills such as decision-making and attention, and its influence on fall risk have been explored in some studies (Cuevas-trisan, 2019; Filaire, Ferreira, Oliveira, & Massart, 2013; Sungkarat, Boripuntakul, Chattipakorn, Watcharasaksilp, & Lord, 2017). However, in addition to the influence of COR, α-AMY is a good measure of attentional demand, with a significant influence on postural control

(Akizuki & Ohashi, 2014). As a result, this influence would cause physiological and neurological changes (Lupien, McEwen, Gunnar, & Heim, 2009), as well as a direct impact on mental and physical health, lowering the life satisfaction (Puvill, Lindenberg, De Craen, Slaets, & Westendorp, 2016).

Another studies identified that high levels of cortisol were associated with falls and fractures in older population (Greendale, Junger, Rowe, & Seeman, 1999), which cortisol being also characterized as an independent predictor for bone fracture (Izawa et al., 2022). Similarly, other researchers discovered that salivary α-AMY is an effective tool for assessing attention status, reaction time, and postural control (Akizuki & Ohashi, 2014). All of which are strongly associated with falls in the older population (Cuevas-trisan, 2019; Rodrigues et al., 2022). Other hormones, such as TT also showed relationship with falls (Benichou & Lord, 2016), primarily related to TT's influence on functional fitness of body composition (Bain, 2008), and showing influence on muscle strength and resistance as well (Orwoll, 2006).

The lack of physical activity can trigger the early development of some physical and neurodegenerative diseases in older adults leading to the development of sarcopenia and dynapenia (Cruz-Jentoft et al., 2019; Macklai et al., 2013). The latter phenomena are part of what has been called the frailty syndrome, which is conceptualized as a clinical syndrome and involves involuntary loss of weight, exhaustion, weakness, decreased gait speed and balance, which leads to a even more decreased physical activity level, and accentuate the problems even more (Fried et al., 2001).

Frailty can also be defined as a multidimensional syndrome characterized by the high vulnerability to stressors and its reduced physiological capacity to deal with that (Boyle, Buchman, Wilson, Leurgans, & Bennett, 2010; Panza et al., 2011), and has several types of characterization, such as physical (i.e., Fried's phenotype criteria (Fried et al., 2001)), multidimensional models criteria (i.e., Frailty Index (Rockwood & Mitnitski, 2007)), and biopsychosocial model (Gobbens, Luijkx, Wijnen-Sponselee, & Schols, 2010).

Based in some recently published meta-analysis, this syndrome affects around 15% of older adults (over 65 years old) in Europe (O'Caoimh et al., 2018), and is still increasing, mainly linked to sedentary lifestyle and insufficient social support (Marshall, Nazroo, Tampubolon, & Vanhoutte, 2015). The frailty syndrome has always been linked to physical characteristics, and its evaluation, most of the time, includes factors such obesity, physical inactivity, strength assessment, cardiovascular evaluation, gait speed, as well as alcohol consumption and self-related health state (E. Dent et al., 2019). This syndrome is also more predominant in persons with lower educational level, lower economic position, and in women (E. Dent et al., 2019)

Usually, the older person is diagnosed with frailty syndrome when 3 out of 5 conditions are met (i.e., weak muscle strength, unintentional weight loss, slow gait speed, exhaustion, and low physical activity levels) (Fried et al., 2001). Since, the frailty syndrome looks to affect more than just the physical aspects, many researchers (Avila-Funes et al., 2012; Gray et al., 2013; Kojima, Taniguchi, Iliffe, & Walters, 2016; Panza et al., 2015) have suggested the use of a more multidomain evaluation, including diseases, clinical deficits, cognitive assessment, and psychosocial risk factors (i.e., delirium, falls).

However, independently of the model or criteria of frailty used, it is associated with increased risk factors for some adverse health related outcomes (i.e., falls, disability, hospitalizations and mortality) (Gill, Gahbauer, Allore, & Han, 2006; Graham et al., 2009). In the same way, current evidence has shown strong relationships between frailty syndrome and cognitive impairment. Frailty apparently may increase the risk of future mild cognitive impairment, and appears to be related to vascular dementia as it shows some possible common physiological pathways (Buchman, Boyle, Wilson, Tang, & Bennett, 2007; Buchman et al., 2014). The physical frailty, when diagnosed together with some cognitive impairment, is called cognitive frailty (Kelaiditi et al., 2013). Besides that, the debate about the associations and its magnitude is still undergoing, and in some longitudinal studies (Avila-Funes et al., 2012; Gray et al., 2013; Solfrizzi et al., 2013) associations were found between vascular dementia and frailty, and in some others, the cognitive association was retrospectively identified (Buchman et al., 2014; Panza et al., 2011; Song, Mitnitski, & Rockwood, 2014). The frailty status (physical and cognitive) was also linked to an increase in the number and severity of falls in older adults (Kearney, Harwood, Gladman, Lincoln, & Masud, 2013).

The fall can be conceptualized as an unintentional body displacement to a lower level than the initial position, determined by multifactorial circumstances that compromise stability (Rapp, Becker, Cameron, König, & Büchele, 2012). Aging plays a central role as it affects the afferent sensory system (i.e., proprioception, vestibular and visual system), the central neurologic control system (i.e., cognition, attention, fear of falling), and finally, the efferent neuromotor system (i.e., physical function, muscle strength, balance, and stability) (MacKinnon, 2018; Nnodim, 2015). In addition, diseases, drugs, and environment modulate the age-associated changes in the fall risk pathway.

In this scenario, there are intrinsic causes (deterioration of physiological and neuromuscular changes of aging, muscle dysfunctions, pathologies, medications) and extrinsic causes (environmental hazards, architectural and furniture inadequacies, stairs, high heel shoes) of fall occurrence (Almeida, Abreu, & Mendes, 2013).

The interaction between intrinsic and extrinsic factors compromises the perceptive and neuromuscular systems related to postural stability and balance control, affecting the functionality, independence level and quality of life of the older adults (Menezes & Bachion, 2008), being an essential aspect of morbidity and mortality and the leading cause of fatal and non-fatal injuries among older adults (Bergen, Stevens, & Burns, 2016).

In 2020, more than 24 million falls incidents were registered in the United States according to a Behavioral Surveillance and Risk System survey, affecting around 26% of its adult population (Center of Disease Control and Prevention, 2021a), and in the year before (Center of Disease Control and Prevention, 2021b), more than 34 thousand death-related to falls were recorded. This number is still growing, and the projections expect an increase to 30% by the year of 2030, which corresponds to 7-deaths-related-to-falls per hour only in United States (Center of Disease Control and Prevention, 2019). Besides this sad and warning data, this events were also overreaching the health system, generating a cost of more than 50 billion dollars annually in medical care (Center of Disease Control and Prevention, 2018, 2019).

In Europe, the results were not different. In 2017 the Western region registered more than 8 million events related to falls in older adults only in medical centers (Haagsma et al., 2020), and this scenario is even worst in older adults living in healthcare institutions (i.e., nursing homes) as they are at much higher risk of fall because the prevalence of frailty in these homes is around 50%, beside the 40% of them who are characterized as pre-frail individuals (Kojima, 2015).

Also, the percentage of people who fall, changes as their age advance, going from about 26% in older people aged between 65 and 74 years olde to almost 30% in older people between 75 and 84 years old (Cuevas-trisan, 2019). For very old people (i.e. over 84 years old) the percentage of fall incidents can increase almost to 37% given this population' specificity and high vulnerability, which must be better explored (Gotzmeister, Zecevic, Klinger, & Salmoni, 2015).

Specifically related to frailty and its consequences, such as fall risk, there is much potential for reversion or at least control, mainly at early phases (Gill et al., 2006; Lang, Michel, & Zekry, 2009; Rockwood & Mitnitski, 2007). In this context, the early evaluation and assessment, and adequate intervention are important factors that must be considered for both healthcare policy makers and healthcare providers, mainly in order to achieve the health gains wanted (Elsa Dent et al., 2017; Rodríguez Mañas et al., 2018; Woo, 2017). In fact intervening on aging-related issues through effective interventions may change the aging trajectories and its cascade' effect in many individuals who can go from the possible "pathological aging" pattern to some health gains, with improved quality of life and achieving the desirable "successful aging" (Kelaiditi et al., 2013)(4).

The successful aging concept in a combination of many definitions related to aging and its health concerns (Cosco, Prina, Perales, Stephan, & Brayne, 2014; Urtamo, Jyväkorpi, & Strandberg, 2019). It can go from the simple concept of physical, social and psychological well-being in old age (without major health problems), to the coverage of others aging-related concepts, such as "productive aging", "aging well", "active aging", or "healthy aging" (Fernández-Ballesteros, R., Benetos, A., & Robine, 2019). Therefore, successful aging is a concept that includes all fields related to a good and happy aging, in all areas and its relationships (Urtamo et al., 2019) as we can see in the Figure 1 below.

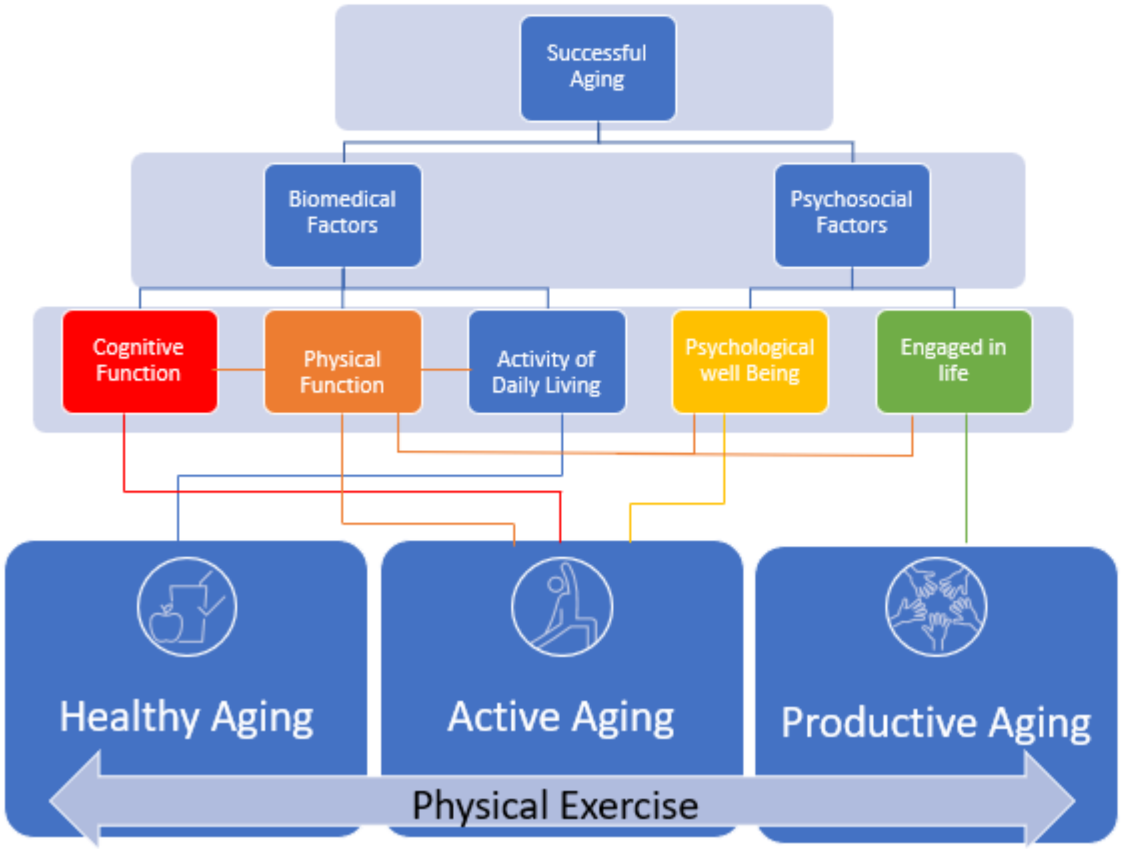

Figure 1. Successful aging process

Adapted from (Urtamo et al., 2019)

As we can observe, the physical functioning aspects are related to both biomedical and psychological aspects in its subcategories, directly or as it supporting role, as the physical activity can promote not only physical gains related to activity of daily living, but also promote well-being, psychological improvements, and cognitive changes, which in its turn can make people more "healthy", more "productive", and is directly associated with "active aging" (Nikitin & Freund, 2019; Urtamo et al., 2019). Therefore, in order to promote these health gains and the successful aging, focused on independence and autonomy maintenance, prevent physical and cognitive frailty, mainly related to physical conditions and fall risk, the WHO has emphasized the importance of physical exercise and in being active as a way to combat and reduce physical deterioration and the loss of independence, as well as other factors related to the aging process.

The WHO (Bull et al., 2020), as well as the American College of Sport Medicine (ACSM) (American College of Sports Medicine (ACSM), 2021), aware of the importance of the fight against a sedentary lifestyle in the aged population, has published some guidelines and recommendations for health maintenance, and includes a detailed and multidimensional evaluation assessment, as well as minimum dose of physical exercise recommendations, including multicomponent exercise focusing on balance and strength, to improve the functional capacity, promote independence and prevent falls (Bull et al., 2020).

In this context, the next two topics (1.1, and 1.2) explain in detail the most common health and fall risk assessments for older population, as well as the use of physical exercise as a fall prevention strategy for older population based in the WHO (Bull et al., 2020) and the ACSM (American College of Sports Medicine (ACSM), 2021) guidelines and recommendations.

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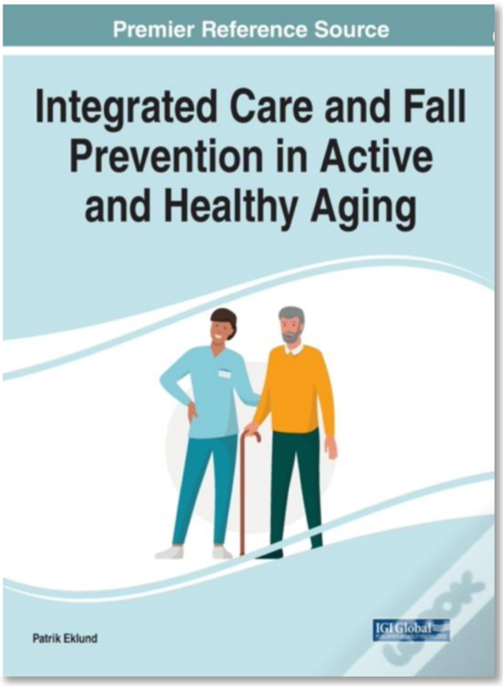
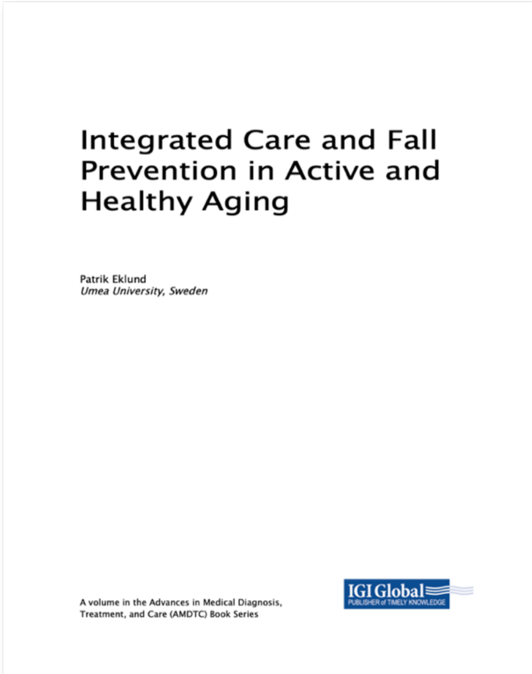
1.1. Health and Fall Risk Monitoring Within Common Assessments

The following book chapter appears as published in IGI Global:





Nogueira Rodrigues, R., Caldo, A., Silva, F. M., Abreu, C. C., Furtado, G. E., & Teixeira, A. M. (2021). Health and Fall Risk Monitoring Within Common Assessments. In P. Eklund (Ed.), *Integrated Care and Fall Prevention in Active and Healthy Aging* (pp. 182-199). IGI Global. https://doi.org/10.4018/978-1-7998-4411-2.ch010

ABSTRACT

This chapter presents an exploratory review on the evaluation, assessment, and monitoring in health and fall risk by common and the most used assessment tools. The main discussion of this chapter of evaluation in health and fall risk is divided into six categories—global health assessment, specific physical (and fitness) assessment, cognitive and psychological assessment, pharmacological assessment, fall risk specific assessment, and some complementary assessment—which show information and how to access. Whereas health evaluative experiences and practices are essential to drive a better and specific intervention, revealing its importance and necessity was also highlighted.

Chapter 10
Health and Fall Risk Monitoring Within Common Assessments

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ABSTRACT

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DOI: 10.4018/978-1-7998-4411-2.ch010

DEMOGRAPHICS OF HEALTH AND FALL RISKS IN THE ELDERLY

In the last years an increased attention towards falls prevention and management has been not surprising since falling has been recognized worldwide as a major health risk for older people. The number of falls is increasing each year and is the leading cause of injury (fatal and nonfatal) in older adults in Europe and in USA. Approximately 30% of people over 65 years old, and 50% of those over 80, fall at least once a year, and approximately 33% of these are repeated fallers (Bergen, Stevens, & Burns, 2016; Cuevas-trisan, 2019)

One-third of falls requires medical attention, including serious fractures (2-10%), being also the leading cause of hospitalization, and resulting in about 36.000 deaths per year in Europe (EUPHA, 2009). In the USA, the situation is similar, with 28.7% of older adults reporting falling at least one time in the past 12 months, which amounts to 29 million falls a year (Center of Disease Control and Prevention, 2018). The severity of injuries can vary, but 2.8 million of them were treated in hospital and 25% of these individuals were hospitalized subsequently, resulting in approximately 27.000 deaths (Bergen et al., 2016; Cuevas-trisan, 2019). Also, it is known that older people who lie for an hour or more unattended after falling, are less likely, than those who get up or are helped up to make a good recovery. More than 50% of those who remain on the floor for over an hour will die within 6 months, even though not directly injured by the fall (Blain, Bernard, Boubakri, & Bousquet, 2019).

Populations who report poor health have significantly higher fall-related injuries than the ones who report excellent health. Women are more likely to report falling and fall injuries, and this can be explained by the reduced muscle strength that is found when compared to men, with sex and age being two factors associated with reduced muscle mass (Cuevas-trisan, 2019; Nevitt, Cummings, & Hudes, 1991; Rapp, Becker, Cameron, König, & Büchele, 2012). Also, the percentage of caucasian older adults who report falls is greater than that among black persons, however, only a few studies on racial and ethnic differences had been published, and these differences could also be related to health behavior and/or culture (Bergen et al., 2016; Nicklett & Taylor, 2014)

In USA, the approximate costs related to falls among older people were estimated at 31.3 billion dollars annually in 2016 (EUPHA, 2009), and when applying this number to the expected at risk of falling older population, who is deemed to increase 55% by 2030, this cost could reach around 50 billion dollars annually in order to support the predicted 48,8 million falls and the 11,9 million fall injuries, with this increase in cost being similar worldwide (Hartholt et al., 2012). And what is more alarming about this data, is that does not include persons in long-term care facilities who are at higher risk for falls (Rapp et al., 2012; Vlaeyen et al., 2015), so these numbers could be even greater.

The ageing process itself contributes to falls because of the association with several psychological and physiological changes, the decline of gait and balance, the increase in sedentarism, use of medication and the presence of several chronic conditions, all are risk factors for falls.

However, the good news is that falls in older adults are preventable, and health care professionals can play an important role in it, by discussing about falls prevention with the elderly, providing good and clear information, as well as promoting appropriate interventions (Gillespie et al., 2012). Some studies showed that correct interventions were able of reducing the incidence of falls in more than 20%, which is very significant.

Some guidelines, as those from the American and British Geriatrics Societies, and NICE recommend an approach that includes activities like talking about falls, assessing and reviewing medications, balance, and the level of vitamin D, for example (AGS/BGS Clinical Practice Guideline, 2011; National

Institute for Health and Care Excellence, 2013). A three step guide was also developed to address the patient in an initial visit: 1) ask patients if they have fallen in the past year, feel unsteady, and/or worry about falling; 2) review medications and stop, switch, or reduce the dosage of drugs that are linked to fall risk; and 3) recommend daily vitamin D supplementation (to improved bone, muscle, and nerve health).

Briefly, many factors, such as physical (musculoskeletal and nerve condition, strength/weakness, gait, balance, sarcopenia), psychological (depression, self-esteem, self-confidence), pharmacological (medication), physiological (diabetes, uremia, vitamin deficiency, hypotension, irregular heart rate), health history (diseases), pain and vision impairment are involved in the cause of falls. The very fear of falling can play a crucial role because the greater the fear, the greater self-restricted activities (reduction in social interactions and physical activities), and the greater the risk of falls. However, to address it correctly, and avoid falls and their possible consequences (serious injury, loss of independence, and even death)(Rapp et al., 2012; Salzman, 2011), the health care professionals are essential, and play an important role by screening and monitoring older adults at risk.

Basically, opportunities to make fall prevention a routine part of clinical practice and reduce the barriers to providing services that can prevent falls among older adults, should be created. As mentioned above, fall risk is a multicomponent problem and therefore a multifactorial assessment is need in order to be effective.

1. GLOBAL HEALTH ASSESSMENT

Definition and Characterization

The Global Health Assessment includes an individual's physical, mental, and social health. The measures are generic and global, rather than disease-specific, and often use an "In General" item context as it is intended to globally reflect the subjects' perception of their own health. It should include the patient history, some physical, nutritional, pharmacological, psychological and social assessments (Cuevas-trisan, 2019; King et al., 2019).

1.1. Patient History

Patient history is a set of documents and reports about his health status at different stages of life. It gathers historical information on current, past, family-affecting illnesses and health care provided, physical evaluation, testing and treatments. Gathering information about illness, habits, appointments, tests and treatments, this anamnesis is one of the foundations for providing effective care. For signaling risk factors, this document is also used as a support in preventing pathologies and health conditions. These and other aspects reveal the need for different health professionals to deepen their knowledge of the patient's history. This history should include specific questions about falls and its risk factors (Almeida, Abreu, & Mendes, 2013; Oliveira et al., 2015).

1.2. Initial Assessment of Fall Risk

The STEADI (Stop Elderly Accidents, Death & Injuries) proposes 3 must ask questions to include in a routine part of the exam: 1) Have you fallen in the past year? 2) Do you feel unsteady when standing or walking? 3) Do you worry about falling? If the answers to any of these questions is "yes", the persons are considered at increased risk of falling, and further assessment is recommended (Bergen et al., 2016)

If possible, family members should participate in some of the initial screening to give additional important information that the individual may have dismiss or downplayed. Questions about the environment and its hazards should also be included, like rugs, high clutter areas, electrical cords, steps, poor lighting, stairways, slippery surfaces, etc. The initial assessment should always include a specific screening of the ability to perform basic activities of daily living (Cuevas-trisan, 2019).

1.3. Common Subjective Assessments

WHOQOL-100: The WHOQOL (World Health Organization Quality of Life) instrument assesses quality of life in a variety of situations and population groups. The WHOQOL-100 has 100 questions to assess important aspects of quality of life, which is defined by the organization as an individual's perception of their position in life in the relation to their culture and value systems and in relation to their goals, expectations, standards and concerns. It is a broad ranging concept affected in a complex way by the person's physical health, psychological state, personal beliefs, social relationships and their relationship to salient features of their environment. The questions about quality of life were drafted on the basis of statements made by patients with a range of diseases, health professionals, and by healthy people as well, in a vast variety of countries and cultures (WHO, 2012).

WHOQOL-Bref: WHOQOL-BREF is an abbreviated generic Quality of Life Scale which were developed through the World Health Organization. It is an abbreviated version of WHOQOL-100, and it is composed by 26 questions (WHO, 2012).

Charlson comorbity index: The CCI is a predicting mortality index which classifies/weights comorbid conditions and has been widely utilized by health researchers to measure burden of disease. It has an index based on 17 comorbid conditions that has been shown to predict mortality (1 to 10 years) (Charlson, Szatrowski, Peterson, & Gold, 1994). A recent study aimed to update the index with 12 new comorbidities showed adequate discrimination in predicting and classifying comorbidities and included data from six countries (Quan et al., 2011).

The Vulnerable elders-13 Survey (VES-13): is a 13-item function-based tool designed to screen older patients at risk for health deterioration, with a higher overall score indicating greater vulnerability and decreased function (Arora et al., 2007; Min et al., 2009).

EuroQol (EQ-5D): It is a health-related quality of life measuring instrument that allows to generate an index of an individual general health state. Based on a classification system, it describes health in five dimensions: mobility, personal care, usual activities, pain/malaise, and anxiety/depression. Each dimension has three levels of severity corresponding to the following: level 1 – no problems; Level 2- some problems; and Level 3- extreme problems, experienced, lived or felt by the individual (EuroQol Group, 1990).

SF-36: It is a 36-Item Short Form Health Survey, a set of generic and easily administered quality-of-life questionnaire. It is a patient self-reporting and are widely utilized for routine monitoring and assessment of care outcomes in adult patients (Ware & Sherbourne, 1992).

2. SPECIFIC PHYSICAL (AND FITNESS) ASSESSMENT

Definition and Characterization

The most common cause of falls and increased fall risk, frequently leading to injury and disability, are gait and balance disorders (Salzman, 2011). Balance is defined as an even distribution of weight enabling someone or something to remain upright and steady, gait refers to locomotion and human locomotion/ gait is defined as bipedal, biphasic forward propulsion of the center of gravity. Gait and balance are composed by interaction of physiological and cognitive elements, that should allow a precise and fast response to perturbation (fall risk), avoiding any risk at the very moment (i.e., reaction time). Gait and balance disorders are usually complex and multifactorial, and include among others, – medical conditions, pain, fear of falling and cognitive disorders, and it requires a very comprehensive and extensive assessment to determine the factors involved in order to make possible target interventions. The prevalence of gait and balance disorders increases with age and is higher in institutionalized elderly (Cuevas-trisan, 2019; Salzman, 2011).

Common Assessments

8-foot-up-and-go-test: It measures power, speed, agility and dynamic balance. The test involves getting out of a chair, walking 8 feet towards and around a cone, and returning to the chair in the shortest time possible (Rikli & Jones, 2013b).

Timed-up-and-go test: Almost the same as the test above. It starts in a seated position, stands up upon command, walks 3 meters, turns around, walks back to the chair and sits down. The time stops when the person is seated. The use of an assistive device is allowed, but it must be documented (Podsiadlo & Richardson, 1991).

Short physical performance battery: This battery includes balance, gait and chair stand tests, with possible scores range between 0 to 12 points (4 maximum points for each test), and where 0 to 3 points means incapable, 4 to 6 points indicates poor performance, 7 to 9 points moderate performance and 10 to 12 good performance (Guralnik et al., 1994).

Balance test: i) Side-by-Side Stand: The participant is instructed to remain still with parallel feet for 10 seconds without moving the feet with a score between 0 and 1; ii) Semi-Tandem Stand: With the heel of one foot placed next to the hallux of the other foot, needing to reach the pre-set time of 10 seconds. Thus, 1 point if it is done, if not, 0 points; iii) Tandem Stand: to stand with one foot in front of the other for 10 seconds.

Gait and speed test: This walking speed test has two variations, one that includes walking a 3-meter course and registering the time taken to do it, and another one, that uses a 4-meter course. The participants can do two attempts and the shortest time is the one written down.

Chair stand test: Participants are instructed to cross their arms across the chest and get up from the chair and sit down for 5 consecutive times as quickly as possible but remaining standing at the end of the 5th round. The total time is registered.

Sarcopenia Assessment: Sarcopenia is defined as a generalized and progressive loss of skeletal muscle mass and strength, and is a risk factor for physical disability, poor quality of life, and even death. Its diagnostic criteria can differ depending on different studies, however, all of them include a body composition evaluation (DEXA. Bioimpedance, skin folds, hydrostatic weight) and strength and/

or physical tests (lower and upper body strength, 1Maximum Repetition, walking test, TUG, etc.). With a prevalence of around 1/3 in those older than 60 years of age and still increasing as the percentage of the very old continues to grow (Cruz-Jentoft et al., 2010) it runs along frailty, being one of the frailty criteria that in its initial phase can still be reversed. The fight against sarcopenia in older adults can potentially stop or at least slow down the progressive risk of falls, disability and physical dependency (Delmonico et al., 2007).

Frailty Assessment: The identification of the frailty phenotype is made by assessing five dimensions: 1) Changes in body composition - self-reported loss of four pounds or more of body mass in the last year; 2) Exhaustion and / or low stress resistance (verified through the Fatigue Impact Scale); 3) Physical activity level (quantification of daily and weekly expenditure (five days) through accelerometers or the use of the IPAQ); 4) Slow walking (time taken to travel a distance of 4.6 m at comfortable speed, adjusted for height and gender); 5.) Weakness / Muscle strength (hand-held dynamometer grip test, adjusted for gender and body mass index (BMI)) (Bieniek, Wilczyński, & Szewieczek, 2016; Fried et al., 2001; Macklai, Spagnoli, Junod, & Santos-eggimann, 2013).

Katz Index - The Katz index of independence in activities of daily living (ADL) is an instrument to assess functional status as a measurement of the older person's ability to independently perform daily life activities. The Katz index assess the adequacy of people's performance in six specific functions (bathing, dressing, toileting, transferring, continence, and feeding). There are yes/no questions for independence in each of these six categories. A maximum score (5 to 6) indicates full function, a score of 3 to 4 indicates moderate impairment, and 2 or less indicates severe functional impairment (Buurman, Van Munster, Korevaar, De Haan, & De Rooij, 2011; Katz, Downs, Cash, & Grotz, 1970)

The Lawton-Brody instrumental activities of daily life: is an 8-item tool designed to evaluate functioning, where a higher summary score represents greater levels of Independence (Chong, 1995; Lawton & Brody, 1969)

Strength Assessment: The Center of Disease Control and Prevention of United States recommends using TUG, the 30-s chair stand, and the 4-stage balance test to identify people with gait/strength/balance disturbances (Department of Health and Human Services, 2015). Also, there are specific tests for upper and lower body strength, namely:

Lower Body Strength Test: "30second's chair-and-stand-test" (CST): which consists of calculating the total number of times the subject can sit and get up from the chair, with arms crossed at chest height, completed in 30 seconds (Rikli & Jones, 2013b).

Upper Body Strength Test: hand-held dynamometer grip test: It is designed to replicate the grip strength, using a dynamometer which measures grip strength in kilograms and/or pounds. The test requires to squeeze the dynamometer with maximal effort (as hard as possible). Keep squeezing for at 3 to 5 seconds. It should be done 2 to 3 attempts, recording the best one (Macklai et al., 2013), 2013). "30 seconds Arm-curl test" (ACT) that measures the total number of arm curls executed in the 30-s.

Senior functional battery - The Senior Fitness Test battery includes the following tests: 1) lower body strength test, determined with the "*30 second's chair-and-stand test*" (CST); 2) the upper-body strength test, determined with the "*30 seconds Arm-curl test*" (ACT); 3) aerobic test, determined with the "2-minute step test"(2ST); 4) lower- body flexibility, with the "*chair sit-and-reach test*" (CSR) and; 5) upper-body flexibility, determined with the "*back scratch test (BST)*". For the above mentioned each test, there is cut-off values adjusted for sex and age, which is analyzed as continuous variables (Rikli & Jones, 2013a).

Complementary Information:

"*2-minute step test"* (2ST) that measures the number of full steps completed in 2 min, raising each knee to a point midway between the patella (kneecap) and iliac crest (top hip bone). Score is the number of times the right knee reaches the required height

"*chair sit-and-reach test"* (CSR) measures the maximum reach as forward as possible toward or past the toes.

"*back scratch test (BST)"* that measures the distance of overlap or between the tips of the middle fingers of the back

3. COGNITIVE & PSYCHOLOGICAL ASSESSMENT

Definition and Characterization

Cognitive functions influence almost every factor related to falls (gait, balance, strength, depression, quality of life, activities of daily living, etc), and besides the diagnosis, a cognitive impairment is always a risk factor (Kearney, Harwood, Gladman, Lincoln, & Masud, 2013). Some studies showed that an increase in cognitive impairment increased the prevalence of falls in older adults when compared with their cognitively intact peers (Booth, Harwood, Hood, Masud, & Logan, 2016). The population diagnosed with mild cognitive impairment (MCI) is at a higher risk for a significant number of comorbidities, including functional decline, and consequently, falls, which in turn will also contribute to cognitive and functional decline through hospitalization, lower confidence, deconditioning from injuries and reduced activity level, starting a cyclic problem.

In this scenario, cognitive assessment is a very strong tool to anticipate the risk, and try to minimize, or even stop its development at an early stage. However, there is no clear guidance on how to respond to these individuals needs because recommendations are not clear and documented yet (National Institute for Health and Care Excellence, 2013).

In the same situation, psychological disorders, can contribute to increase sedentarism, once the elderly are more susceptible to depression. And psychological assessment can help understanding, also intervene in problems such as loneliness, isolation, dementia and depression. As well, can help in the design and implementation of health management and monitoring systems to prevent and treat pain and diseases (OPP, 2015).

Common Assessments

Mini mental state examination (MMSE)- The mini mental state examination (MMSE) was designed to assess five areas of cognition: orientation, immediate recall, attention and calculation, delayed recall and language. The maximum possible score is 30 points. Scores below 24 points are considered abnormal and used for dementia and MCI screening (de Melo & Barbosa, 2015). It usually classifies participants by cognitive profile as a category variable, following the criteria: (a) severe cognitive impairment (01 to 09 points), (b) moderate cognitive impairment (10 to 18 points); (c) Mild Cognitive Impairment (19 to 24 points); (d) normal cognitive profile (25 to 30 points). The MSSE also showed to be sensitive to the effects of exercise in an older population (Folstein, Folstein, & McHugh, 1975).

Hopkins verbal fluency test - The Hopkins verbal learning task (HVLT) is one of the most commonly used memory tests in older adults. It is used to assess verbal episodic memory, including immediate memory (Folstein et al., 1975). It is a 4-min test, easy to administer, to score, and is well tolerate even by significantly impaired individuals. This test requires recall of a series of 12 words (nouns) from 3 semantic categories (precious stones, animals, and human dwellings) over 3 learning trials (De Jager, Hogervorst, Combrinck, & Budge, 2003). Scores between 15.5 and 24.5 on this test indicate a risk of dementia or MCI (Dellagi et al., 2019; Rieu, Bachoud-Lévi, Laurent, Jurion, & Dalla Barba, 2006).

Montreal cognitive assessment (MoCA) - The MoCA is a cognitive screening test designed to assist Health Professionals in the detection of mild cognitive impairment (MCI). This tool was designed to assess short term memory, visuospatial abilities, executive functions, attention, concentration and working memory, language, and orientation to time and place. MoCa has a 0 to 30 possible points scale, and has the ability to assess several cognitive domains, that have and has been proved to be a useful tool for screening many illnesses, such as: Alzheimer's, Parkinson's and Huntington's disease, Stroke, Fronto-temporal dementia, Brain metastasis, Sleep behavior disorder, multiple sclerosis, head trauma, depression, schizophrenia, heart failure, substance abuse, etc (Charbonneau, Whitehead, & Collin, 2005).

Rosenberg Self Esteem Scale – It is a 10-item scale which measures global self-worth by measuring feelings (positives and negatives). All items are answered using a 4-point Likert scale which range from "strongly agree" to "strongly disagree". To the items 1, 2, 4, 6, and 7, a reverse value of scores is done. The global self-esteem is represented by the sum of all scores and gives results between 10 and 40 points, where higher values represent higher levels of global self-esteem (Rosenberg, 1965).

Perceived Stress Scale - The perceived stress scale (PSS) is a 14-item scale that assesses the perception of stressful experiences by asking the participant to rate the frequency of feelings and thoughts related to events and situations that occurred over the previous month. 7 out of the 14 items of PSS-14 are negative and the remaining 7 are positive, representing perceived helplessness and self-efficacy, respectively (Trigo, Canudo, Branco, & Silva, 2019). For items 4, 5, 6, 7, 9, 10, and 13, a reversal of the scores is done. Final scores vary from 14 to 70 points. A higher score indicates greater stress (Remor Bitencourt, 2006).

Falls Efficacy Scale - The falls efficacy scale (FES) contains questions about the possibility of falling during the performance of 10 daily activities (Tinetti, Richman, & Powell, 1990). The trust that the elders have to perform the activities without falling is represented on a 10 points scale ranging from "No confidence" (1 point) to "Completely confident" (10 points). The score of the FES is the sum of the scores obtained in each of the 10 items. The minimum score possible is 10 and the maximum is 100 (Morgan, Friscia, Whitney, Furman, & Sparto, 2013).

Hospital Anxiety and Depression Scale (hads) – It is a 14-item questionnaire designed to assess anxiety and depression, 7 of the items relate to anxiety and 7 relate to depression. Items are rated on a 4-point severity scale. The HADS produces 2 scales, one for anxiety and one for depression. Scores of greater than or equal to 11 on either scale indicate a definitive case (Snaith & Zigmond, 1983)

Geriatric Depression Scale (GDS)- It is a "yes" or "no" questionnaire. Simple enough to ensure that the scale can be used in cognitively impaired individuals, for whom a more complex set of answers may be confusing or lead to inaccurate recording of responses. A point is assigned to each answer and its cumulative score is ranked on a scoring grid. The scoring grid sets the results as 0-9 as "normal", 10-19 as "mildly depressed", and 20-30 as "severely depressed" (Yesavage et al., 1982).

Geriatric Depression Scale (GDS) short version- GDS-15, consisting of 15 direct questions with yes or no answers, considers that with 5 or more points, we are in the presence of mild depressive symptoms and above 11 in the presence of severe depressive symptoms (Yesavage et al., 1982).

Bradburn Scale of Psychological Well-Being: assesses happiness, where a higher score indicates greater psychological well-being (MCDOWELL & PRAUGHT, 1982; Mechanic & Bradburn, 1970).

Satisfaction with life: The satisfaction with life scale (SWLS) is a short five-item instrument designed to measure global cognitive judgments of satisfaction with one's life. The scale requires around 2 min to be completed by the participants. It uses a seven-point Likert scale, which indicates the participant's level of agreement with each item by choosing the appropriate number on the line regarding that item. Results range between 1 and 35 points, with higher values representing higher levels of life's satisfaction (Parker, Strath, & Swartz, 2008).

4. PHARMACOLOGICAL ASSESSMENT

Definition and Characterization

Some specific classes of medication, especially those affecting central nervous systems (benzodiazepines, diuretics, vasodilators, opioids, muscle relaxants, beta blockers, tricyclic antidepressants, sleeps aids, and other drugs which cause sedation and delirium), and the use of 4 or more medication need to be observed with caution because of the side effects that these could have, altering elderly's reaction time, memory, brain perfusion, gait, balance, and influencing the risk of fall (Leipzig, Cumming, & Tinetti, 1999).

Its al so recognized that using many medications can generate some iatrogenic problems (from side effects of drugs interactions). Antiplatelet agents and anticoagulants, for example, are common medication in the elderly because of associated cardiovascular ailments, which add another layer of complexity, potentially making falls catastrophic (Cuevas-trisan, 2019). Some common side effects include hypotension and dizziness, all associated with falls. In a study, tapering and discontinuation of psychotropic medications (benzodiazepines, neuroleptic agents, antidepressants) over a 14-week period was associated with a reduction around 39% in the rate of falling (Campbell, Robertson, Gardner, Norton, & Buchner, 1999)

The control and managing medication side effects with other medications, was a common response in clinical setting, but rarely justified and, a new concept is taking place, the concept of medication reconciliation, which is the reviewing process of all medication prescribed by all physicians, and after a review, the professionals should always consider replace or discontinuing some original medication before adding another to treat undesirable side effects (Musich, Wang, Ruiz, Hawkins, & Wicker, 2017). The concept of medication reconciliation has become standard of practice, and successful components of these interventions include review and reduction (in possible) of medications (Cuevas-trisan, 2019; Musich et al., 2017).

5. FALL RISK SPECIFIC ASSESSMENT

Definition and Characterization

Health Professionals are often unaware of the many existing scales specifically for identifying fall risk and are uncertain about how to select an appropriate one. Nowadays there are more than 30 fall risk assessments were some focus on institutionalized, and others are more functional assessment scales. The majority of the scales were developed for elderly populations, characteristics assessed are quite similar across them, and sensitivity can varied from 38% to 100% (Perell et al., 2001). Therefore, a substantial number of fall risk assessment tools are readily available and assess similar patient characteristics. Although their diagnostic accuracy and overall usefulness showed wide variability, there are several scales that can be used with confidence as part of an effective fall prevention program.

FRAT - Fall Risk Assessment Tool: It is a 4-item falls-risk screening tool for sub-acute and residential care. It has three sections: i) falls risk status; ii) – risk factor checklist; iii) action plan. These 3 parts are a complete falls risk assessment tool. However, section 1 can be used as a falls risk screen (Stapleton et al., 2009), which also includes the Abreviated Mental Test Score (Hodkinson, 1972).

Posturography Plataform PhysioSensing – Fall Risk Test - This fall risk test allows the identification of potential fall candidates. The protocol assesses static balance under four conditions, each lasting 40 seconds: 1. comfortable posture with eyes open; 2. Comfortable posture with eyes closed; 3. Narrow posture with eyes open; 4. Narrow posture with eyes closed (Bigelow KE and Berme N. 2011) (Pajala, S. et al. 2008). After performing all protocol conditions, the value of the oscillation speed index for each of the conditions appears.

The Hendrich II Fall Risk Model: It determines the risk of falling based on sex, mental and emotional status, (possible) symptoms of dizziness, and by the categories of medications taking that could increase risk. This tool screens for fall risk and is integral in a post-fall assessment for the secondary prevention of falls (Hendrich, Bender, & Nyhuis, 2003).

6. COMPLEMENTARY ASSESSMENT

Environmental Assessment (and modifications) -An effective prevent falls program should include some environmental assessment, and some modification if necessary. However, the experience of the professional who is performing the assessment and proposing some recommendations are a very important factor, so this professional should be well trained and prepared. The common recommendation includes removal of rugs, the use of non slip bath mats, lightning at night, safer footwear, and to add stair rails. (Tinetti, 2003). Although nonspecific advice about this changes in home hazards are directly targeted, an assessment and a follow up by a an occupational therapist is the most recommended, and these changes was associated with a 20% reduction in fall risk (Gillespie et al., 2012; Sherrington et al., 2017). Some scientific evidence supports the idea of environmental modification being beneficial in individuals in risk, mainly in those with history of falls. And the public environmental should be adapted as well. The NICE guidelines (National Institute for Health and Care Excellence, 2013) recommend modifications such as "age-friendly" transportation to help older people in daily life, and these kind of modification and the implementation of a fall prevention program can reduce fall, and fall-related injury by 20 to 40% in community dwelling people, and are cost effective.

Visual Assessment - Visual impairment is recognized to be an important risk factor, but it is not well studied. Vision impairments increase as we age, and sometimes it is overlooked because the process of decreasing vision is often slow and may even be unnoticeable (Cuevas-trisan, 2019). A glaucoma for example, is associated with fear of falling, which contributes to a decrease in mobility (Zhang, Shuai, & Li, 2015). Therefore, improving vision can have some advantages. A review also showed that a cataract surgery can reduce the rate of falls(Gillespie et al., 2012). However, it should be made with extra attention because some studies showed that these kind of interventions could increase the rate of falls because with an improved vision leads to a behavior changes, and increase the elderly's exposure to fall risk situation (Grue, Kirkevold, Mowinchel, & Ranhoff, 2009). Also, a combinations of intervention can be more effective than a visual intervention alone, so a combined interventions (eg, exercise and vision) is more effective in preventing falls in older people (Zhang et al., 2015).

Hypotension, Cardiac Pacing, rhythm and frequency – A health evaluation is only complete when obtaining vital signs, and when it is assessed appropriately, postural hypotension is identified in almost 1/3 of older people, besides some of elderly do not report dizziness, or some other symptoms related. Elderly usually have some cardiovascular issue, such as arrhythmias which can lead to falls, also a special attention should be taken around orthostatic hypotension and hearing problems, which can lead to syncope. A review article showed that people with carotid sinus hypersensitivity who had pacemakers had the rate of falls reduced (Gillespie et al., 2012). Therefore, a use of pacemaker must be considered when falls are associated with condition that make changes in heart rate and blood pressure (Booth et al., 2016).

Pain: Persistent pain, reduced mobility and function, and reduced general quality of life are some common experiences associated with musculoskeletal conditions in the ageing process. However, musculoskeletal pain usually limited the people's ability to make lifestyle changes to be more active. A strong relationship exists between painful musculoskeletal conditions and a reduced capacity to engage in physical activity, and it can result and/or generate frailty, functional decline, independence loss, and increased fall risk. In a group of community-dwelling adults (^{3}88 years), joint pain was reported as the most common contributor to gait problems (Bloem et al., 1992), showing the importance of pain in the fall risk. However, pain still being a very hard to assess, control, and reduce, being necessary a multi professional approach.

Posture – Posture, mainly the body's center of gravity, related to changes in neck limited extension, shift significantly in older people, contributing to postural imbalance, and limited field of vision, collaborating to increase the risk of fall. Therefore, the postural evaluation, e correction e strengthening can reduce the risk and incidence of falls in older people (Cuevas-trisan, 2019).

Proprioception – Neurologic exams to detect or identify deficits such as weakness and possible sensory problems, mainly in proprioception should be included whenever possible because it is capable to show some specifically and treatable problems which can cause balance impairments. One sensitive marker of abnormal proprioception is the decrease in vibration sense, as well the worse balance problems with closed eyes (Tinetti, 2003). The evaluator should always include tone and coordination assessments to have a better conclusion.

Osteoporosis (Risk) – The prevalence of osteoporosis is higher in those who fall, and it is very common is elderly, and worst in those with sarcopenia (Gillespie et al., 2012). The STEADI and NICE guidelines recommend giving calcium and vitamin D supplements to all, besides their risk of fall, but taking extra attention, and performing some exams to evaluate bones and muscles to determine more specific recommendation and proceeding to a more specific treatment (Jang et al., 2016; Kearney et al., 2013)

7. FINAL CONSIDERATIONS

Falls and their associated injuries are we could see are common in the elderly and usually result from multiple factors interactions, and many of them may be modifiable or, at least, more adequate. In this scenario, the knowledge of the existent tools to assess the different levels and factors associate with fall risk is mandatory and can play a critical role in reducing fall risk factors among the older population.

Additionally, most guidelines recommend at least an annual general screening with an objective to identify people at increased risk, targeting to understand the risk and trying to manage/modify the fall risk factors identified. Also, understand the perspective of the older adults, and their involvement (or not) in some prevention activities can be critical to have success.

Falls Prevention Educational Programs as The NICE guidelines (National Institute for Health and Care Excellence, 2013) also recommend to talk about falls, and increase the knowledge of older people to enhance their "fall awareness". In the same way, the STEADI (Bergen et al., 2016) and ProFound group (ProFound, 2015) developed and disseminate best practices in fall prevention, producing even documents to influence policy, and trying to reach all sectors – NGOs, commercial sector, and the general public as well. However, these educational programs alone showed to not been able to decrease the rate of falls in older adults significantly.

Therefore, as fall risk is multidimensional, and has multiple cause, an equal multiple intervention, with a multidisciplinary staff, and multiple screening tool is needed to address it in the best way.

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KEY TERMS AND DEFINITIONS

Cognitive Assessment: A specific kind of evaluation focusing on a general or specific component of cognition.

Environmental Assessment: The kind of tool designed to evaluate information from de environment in some specific, or general component.

Fall Risk Assessment: A group of specific tools used to verify the risk of fall in specific population and/or groups.

Health Assessment: A group of tools used scientifically to assess health parameters.

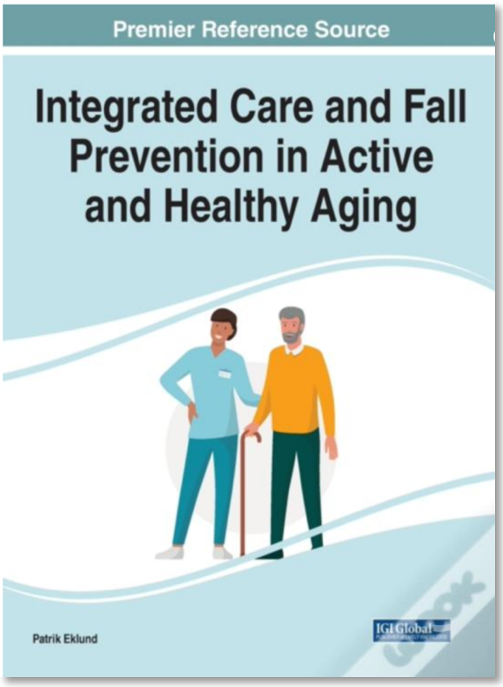
Pharmacological Assessment: A kind tool to access pharmacological information from an specific person or group.

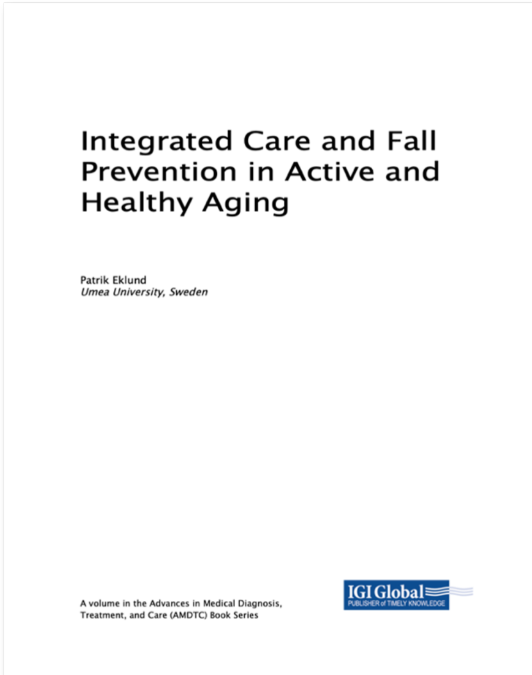
Physical Assessment: A specific kind of evaluation focusing on physical and/or fitness level in a general or specific component.

Psychological Assessment: A group of tools designed to specifically assess psychological background.

1.2. Fall Risk and the Use of Exercise as Fall Prevetion Strategy

The following book chapter appears as published in IGI Global:





Nogueira Rodrigues, R., Carballeira, E., Silva, F. M., Caldo, A., Ceschini, F., Giráldez-García, M. A., Abreu, C. D., Furtado, G. E., & Teixeira, A. M. (2021). Fall Risk and the Use of Exercise as a Fall Prevention Strategy. In P. Eklund (Ed.), *Integrated Care and Fall Prevention in Active and Healthy Aging* (pp. 130-156). IGI Global. https://doi.org/10.4018/978-1-7998-4411-2.ch007

ABSTRACT

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Chapter 7
Fall Risk and the Use of Exercise as a Fall Prevention Strategy

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DOI: 10.4018/978-1-7998-4411-2.ch007

INTRODUCTION

Despite the known benefits of physical activity on health and physical function with aging, the proportion of older adults meeting recommended physical activity remains low, being around 30% or below (Dipietro et al., 2019; Guthold, Stevens, Riley, & Bull, 2018). Therefore, in the last two decades, considerable evidence (including a significative number of guidelines) has emerged regarding the relative benefits of various modes or combinations of physical activity, such as progressive resistance training, multicomponent exercise, dual-task training, tai chi, yoga, dance, and balance for fall-related injury prevention and for specific physical function outcomes (e.g., strength, gait speed, balance, activities of daily living [ADL] function) (Erickson et al., 2019; Europeia, 2008; Jakicic et al., 2019).

Falls are partly a consequence, and to a great part cause of physical inactivity in older adults. Falls are defined as involuntary events that make you lose your balance and hit the body on the ground or another firm surface that stops it (Windle, Hughes, Linck, Russell, & Woods, 2013). Falls are the main cause of fatal and nonfatal injuries among the elderly according to a survey by the Behavioral Risk and Surveillance System, which was analyzed by the US Centers for Disease Control and Prevention (Center of Disease Control and Prevention, 2018). In this survey, in 2014, about 28.7% of older people reported falling at least one time in last year, what resulted in 29.0 million falls and about 7.0 million fall injuries only in United States (Bergen, Stevens, & Burns, 2016).

Moreover, the percentage of older people who fall increases with age, from 26.7% among people aged 65 to 74, to 29.8% among people aged 75 to 84, to 36.5% among older people over 85 years old (Florence et al., 2018). Of the older adults who fall, half have recurrent falls and 50% will fall again in the same year (Rebelatto, Castro, & Chan, 2007). The fall event is, therefore, a risk factor for suffering further falls. According to the Brazilian Ministry of Health, approximately one third of the elderly population suffers multiple falls each year (DATASUS, 2009) and in the USA one in each four elderly falls every year, these falls being the major and most common cause of fatal injuries and hospitalizations (Center of Disease Control and Prevention, 2018).

The severity of the fall injury can advocate the early onset of morbidity and mortality. From the total number analyzed by the US, 2.8 million were treated at emergency units for fall-related injuries and approximately 800.000 of those treated, were subsequently hospitalized, and approximately 27.000 died, with women being more likely to report falls and a fall injury than men (Bergen et al., 2016; Florence et al., 2018). These numbers kept growing, between 2007 to 2016, the falls related occur by 2030, which is pretty death in USA increasing by 30%. Within this scenario around 7 deaths/hour will dramatic and highly costly. And Europe goes in the same way, with the Western region with 8.4 million older adults attended in medical centers due to fall-related injuries in 2017 (Haagsma et al., 2020).

Also it should be emphasized that falls are the most common cause of traumatic brain injury in older adults (Center of Disease Control and Prevention, 2018). That can produce an increment in cognitive impairment and contribute to the acceleration of the loss of functionality and an increase of sedentary behaviors through the emergence of fear-of-falling (Erickson et al., 2019; Freiberger, Häberle, Spirduso, & Rixt Zijlstra, 2012).

Prevention of falls and injuries is not easy due to the combination of intrinsic impairments (e.g., decreased muscle mass; deterioration of nerve, musculoskeletal, vestibular and visual systems; loss of tactile sensitivity to pain; memory loss, depression and anxiety) and extrinsic or environmental hazards (e.g., uneven ground surface, loose carpets, inadequate lighting, high beds, low toilet, inappropriate footwear, etc.) (Silva et al., 2016). Knowledge of preventive factors for falls in the older people might lead to a reduction in this personal and public health problem. In a large number of occasions falls in the elderly lead to fractures of the hip and/or femoral bones, that situation increases the level of dependence and elevates the institutionalization rates with the consequent rise in socioeconomic cost (Teixeira, Oliveira, & Dias, 2006). Furthermore, older adults institutionalized are even at greater risk of falls, concisely they are three times more likely to fall because its higher physical and cognitive impairment, and 39.8% of then being between 80 and 89 years old, showing even more vulnerability (Florence et al., 2018; Hartholt et al., 2012).

The institutionalized elderly usually have singular characteristics, such as sedentary habits, decreased autonomy and, in many cases, family abandonment, which contribute to the increase and prevalence of related to morbidities and comorbidities, especially falls, as it is one of the most relevant (and preventable) health issues in aging, due to the high social and economic cost (Ribeiro, Souza, Atie, Souza, & Schilithz, 2008).

Institutionalized elderly have different needs, requiring attention, support and specialized services, as the vast majority are considered frail, presenting physical and/or mental morbidities, which makes them more prone to health problems, conceptualizing the frailty syndrome (E. J. Kim et al., 2015; Vlaeyen et al., 2015).

The concept of frailty refers to the heterogeneous syndrome that is found in older people, characterized by physical frailty concomitant with cognitive impairment (Fried et al., 2001). Among the features of the syndrome, the loss of functional physical capabilities such as muscle strength (due to possible sarcopenia), resistance (due to possible sedentary behavior), as well unintentional weight loss, can lead to an increased risk of accidents (Cai, Chan, Yan, & Peng, 2014; Bothania Hassan et al., 2016).

AGE-RELATED BIOLOGICAL CHANGES PREDISPOSING TO FALL EVENTS

Before the design of an intervention program to reduce the risk of falling through physical exercise, the health professional has to analyze and understand the changes related to age that increase the risk of falls.

Loss of Muscle Mass

Originally, the loss of muscle mass has been considered as an inherent phenomenon to the aging and determining process in increasing the risk of falls. Since the age of 25 to 30, there is a progressive loss of muscle mass that could reach up to 30% at the age of 80 (Center of Disease Control and Prevention, 2003). However, the ratio of muscle mass loss is not the same between men and women and among the upper and lower members. Older men lose muscle mass in arms at a rate of ~ 0.29 kg/decade and women ~ 0.19 kg/decade, however this loss is greater in the lower limbs, reaching values of ~ 0.63 vs. ~ 0.49 kg/decade for men and women respectively (Janssen, Heymsfield, Wang, & Ross, 2000). In addition, the anatomical cross-sectional area may be overestimated if the noncontractile tissue is not deducted, which usually represent a higher percentage in the elderly (Overend, Cunningham, Paterson, & Lefcoe, 1992). Taking into account all this information, it is expected that the older adults have a reduced amount of contractile tissue that harms functionality and increases the risk of falls. To this reduction in the muscle mass produced during the process of aging and unrelated to the presence of other circumstances (e.g., cancer, accident immobilization) has been called Sarcopenia (Rosenberg, 1989). This denomination marked a before and after research on the decline of muscle mass and its relationship with functionality in older people. However, we now know that functionality, understood as the ability to perform movements required in daily life, and in which we could frame walking or getting up from a chair without falling, depends on other factors in addition to the amount of muscle mass. In this sense, more than four decades ago that dissociation between muscle mass and the force applied in a gesture (Moritani & DeVries, 1979) is reported. In fact, the concept of sarcopenia has evolved, and, in many consensus scientific articles, the deterioration of force, power or functionality have been included within the definition (Cruz-Jentoft et al., 2019). In this sense, in the last decade, the use of the term Dynapenia has been proposed to refer to the deterioration of muscle strength, power and functionality (Manini & Clark, 2012), arguing that this new paradigm can mark the means used for evaluation and the intervention in the improvement of functionality.

Loss of Strength and Power

The rate of decline in muscle strength is greater than muscle mass during the aging process. Results of cross-sectional studies report a difference in maximum isometric force of 30%-50% between young people and older adults (~70 y). Muscle strength reaches its peak between the second and third decades of life, is maintained or slightly reduced between the fourth and fifth decades, and then progressively declines sharply at a rate of ~ 1.0 to ~ 1.5% per year (12%/decade), especially this reduction accelerates from 65 to 70 years (Booth, Harwood, Hood, Masud, & Logan, 2016; Chen et al., 2019). The rate of loss of strength, like the age-related muscle mass loss, is faster in the lower limbs than in the upper limbs (Booth et al., 2016; Chen et al., 2019). In addition, women have less absolute strength throughout the life cycle, which leads them to reach the dependency threshold at an earlier age. This makes strength training in women a priority to prevent dependency and the risk of falling. A deterioration in the ability to exert force and to contract fibers at high velocity has its origin in the atrophy that occurs over the years in muscle fibers, especially in the fast velocity contraction fibers or type-II fibers, the reduced muscle thickness and pinnation angle, slower formation of actin-myosin cross bridges, the deterioration of the recruitment capacity of high-frequency motor units and the reduction in voluntary activation. The reduction in force and velocity that experiments older people leads to a critically affected ability to generate muscle power or the ability to perform movements that require a manifestation of force at a certain speed. Two decades ago, muscle power was believed necessary to improve performance in sports activities, however, during the last ten years it has been known that it is also an essential component in the performance of certain activities of daily life and that is closely linked with improved functionality (Raj, Bird, & Shield, 2010). An adequate level of neuromuscular power will help older people to decelerate their movement to change their spontaneous direction of gait or stop their movement in a situation that poses a certain risk of falling, it will also allow them to rebalance in the face of an external disturbance (e.g., a stone in the road, a boost on the bus, etc.). Indeed, it has been suggested that muscle power is a more discriminating predictor of functional performance in older adults than muscle strength (Baltasar-fernandez et al., 2021). In a study carried out with women in good physical condition in which two age groups were compared (18 to 30 vs. 65 to 74 years), it was reported that the muscular power measured in the unilateral leg press exercise was 61% lower in older women (Macaluso & Vito, 2004). This difference was determined by a 52% reduction in optimal force and a 21% reduction in optimal velocity, resulting in a 22.1% reduction in the ratio between peak power and maximum isometric voluntary contraction (Macaluso & Vito, 2004). The importance of introducing power training in exercise programs that seek functional improvement in older people and the consequent reduction in the risk of falls seems unquestionable. There are an increasing number of studies that have applied high-speed training in older adults (Jaque et al., 2020; Ramirez-campillo, Castillo, De, & Campos-jara, 2018) and have shown that exercise interventions aimed at improving muscle power of the lower extremities are well tolerated, safe and effective even among frail older adults.

Decrease of Force Steadiness

The normalized amplitude (coefficient of variation, CV) of force fluctuations measured when a person attempts to sustain a constant force during submaximal isometric activation or the standard deviation (SD) of anisometric (eccentric, concentric) force activation is called force steadiness (or force variability) (de Luca, LeFever, McCue, & Xenakis, 1982; Enoka et al., 2003; Enoka & Farina, 2021). In general, older individuals are less steady (greater CV during isometric activation or greater SD during anisometric activation) than young individuals when they applied force at levels generally lower than 40% (Enoka & Farina, 2021). Force steadiness has been moderately associated with standing balance (Davis et al., 2020; Kouzaki & Shinohara, 2010) and risk of falls in older individuals (Carville, Perry, Rutherford, Smith, & Newham, 2007). For instance, Carville et al. (2007) have observed that older adults (>70 y) with a history of falls presented 31% lower levels of force steadiness compared to those older adults who did not have a history of falls, moreover this observation was independent of their maximal muscle strength. It has been suggested that the dominant factor influencing the amplitude of the fluctuations in force (<10 Hz) is the variance in the modulation of discharge times within the force bandwidth, which represents only the slow oscillatory variability in motor unit discharge times (Enoka & Farina, 2021). Even though it remains unclear why the variability in the neural drive to muscle during a submaximal isometric or anisometric activation can explain significant amounts of the variance in tests of motor function it has been stated that the CV for force during steady contractions can explain more of the variance in motor performance than can measures of muscle strength (Enoka & Farina, 2021).

Brain and Cognitive Deterioration

The aging process, besides the association with locomotor system, is also strongly associated with changes in cognitive abilities (Seidler et al., 2010). In fact, daily life activities need the combination of executive/cognitive and functional abilities (locomotor system) (Faulkner et al., 2007), with the progressive deterioration of the capacity to perform simultaneous (dual) tasks, also referred as cognitive-motor interference, starts to be a major risk for falls (Wollesen & Voelcker-Rehage, 2014).

A recent study (Wollesen, Wildbredt, Schooten, Lim, & Delbaere, 2020) has shown three important factors of executive function which are of special relevance to daily life activities:

(i) inhibitory control (ability to stay focused, without distraction);
(ii) working memory (ability to hold/manipulate information, priorities, and action plan);
(iii) cognitive flexibility (ability to adjust/change attention, set-shifting, task-switching).

The executive functions need to be trained and improved to prevent fast deterioration, and increased risk of fall (Wollesen et al., 2020). Furthermore, as an additive effect specific higher-order cognitive processes may moderate efficacy of exercise via adherence (Best, Nagamatsu, & Liu-Ambrose, 2014). Adhering to exercise training is a must precondition to take benefits that regularly practice of exercise offers. Therefore, it may be important to assess and consider internal self-regulatory cognitive processes at baseline to determine optimal strategies for promoting adherence to exercise recommendations for preventing falls in non-supervised programs. For example, those with executive dysfunction may require more frequent contact and in-person support versus those without executive dysfunction, and strategies as exergames training could be an more than optimal option to reduce fall risk and to work executive capacities (Gschwind et al., 2015; J. M. Cisneros Herreros & G. Peñalva Moreno, 2010).

PHYSICAL ACTIVITY AND FALL RISK

The above discussed about the decline in functional capacity results in part from neuromuscular changes such as muscle denervation, atrophy, and selective loss of muscle fibers (especially type II fibers) with reduced total muscle mass and decreased muscle strength and power, negatively affecting the balance and functional mobility of the elderly by reducing the effectiveness of postural adjustment and motor control mechanisms (Sherrington et al., 2019), and contributing to this increased risk of falls and fractures. This risk is particularly high in institutionalized elderly, since, among other factors, functional fitness levels are lower than in non-institutionalized elderly, which may partially explain the higher prevalence of falls with femur fracture that has been observed in this segment of population (Bergen et al., 2016; Florence et al., 2018).

Loss of muscle and functionality are only part of the age-related changes in the body (Milte & Crotty, 2014). Causes of physical and cognitive impairment include cardiometabolic disease, chronic kidney disease, insulin resistance, sleep disorders, chronic inflammation and obesity (A. King et al., 2019; Kraus et al., 2019; Salminen, 2020). Some of the predisposing factors underlying sarcopenia (e.g., oxidative stress, inflammation) are also associated and may explain the common etiological factor, which is potentiated by physical inactivity (Jensen, Hasselbalch, Waldemar, & Simonsen, 2015).

As well, the increase in the older population and the high levels of physical inactivity that occur in several countries in this population, predict the increased prevalence and incidence of falls in this population. Thus, physical exercise may play a key role in maintaining balance, functional mobility and consequently preventing falls in the elderly (A. King et al., 2019).

In this context, physical exercise appears as a non-pharmacological tool against consequences related to the risk of falling, as well as syndromes that may contribute to a greater predisposition to falling, or to the risk of falling. During exercise, various substances outside the central nervous system have the ability to communicate with the brain, including various types of cytokines. Some systemic inflammatory cytokines, such as TNF-α and IL-1β, have direct catabolic effects on skeletal muscle and brain functions during and after prolonged exercise (Trappe, Standley, Jemiolo, Carroll, & Trappe, 2013). Observations of the beneficial effects of physical exercise on physical and cognitive performance, particularly in the elderly, were made experimentally by several researchers.

However, regardless of gender, older people's participation in exercise programs promotes increased muscle mass, muscle strength and balance, reducing the risk of falls and consequently fractures (Stokes, 2009). The ACSM, in their 2018 Physical Activity Guidelines (A. King et al., 2019) provides strong evidence that physical activity reduces around 30-40% the risk of fall-related injuries in older people, and this includes severe falls requiring medical care or hospitalization.

Thus, the effectiveness of physical activity/exercise programs that emphasize combinations of moderate-intensity balance, strength, aerobic, gait, and physical function training for risk reduction has significant public health relevance in older age, due to the high prevalence of falls and fall-related injuries and fractures among older adults, as well as the consequent morbidity, disability and reduced quality of life (Erickson et al., 2019; Kraus et al., 2019).

Strength-Power Training and Fall Risk

As a fall has a strong connection with muscle weakness and the loss of muscle mass, the kind of exercise that fights it, is strength training, is one of the most recommended type of physical activity for older populations (Cruz-Jentoft et al., 2010; de Souto Barreto et al., 2016; Bothaina Hassan et al., 2016; A. King et al., 2019).

Studies that associate strength exercises and the possible effects on fall risk and quality of life are scarce, but have been increasing its number in the last 5 years (Chupel et al., 2017; Cuevas-trisan, 2019; A. King et al., 2019). In some of the studies, it was observed that strengthening exercises promoted significative improvements in muscle strength, increasing, or maintaining (or, at least, reducing the speed of loss of) muscle mass, as it plays a key role in maintaining balance and functional mobility, which are important factors for reducing and controlling the risk of falling in the elderly (Blain, Bernard, Boubakri, & Bousquet, 2019; Chodzko-Zajko et al., 2009; Cruz-Jentoft et al., 2010; Dipietro et al., 2019).

Also, the strength training programs were able to improved psychological well-being, stress levels and cognitive functioning (Kearney, Harwood, Gladman, Lincoln, & Masud, 2013; Salzman, 2011) which could help the individuals keep their adherence to exercise programs. Moreover, strength training based on perceived exertion has been shown to be an effective method for improving health-related quality of life in some subscales (vitality, functional capacity, general health, and mental health) as well in reducing depressive symptoms (Cuevas-trisan, 2019; A. King et al., 2019).

In some studies (Baltasar-fernandez et al., 2021; Rodriguez-lopez et al., 2021) were compared the power and strength training in different ways. Using traditional resistance training, focused on strength capacity, and some high-speed resistance training, focusing in the development of power as well. Over the 12-week training period, both groups showed significant improvements, and were effective in improving functional capacity, muscle performance and quality of life in older women, but the high-speed resistance training program induced in a greater way, the improvements in muscle power and functional capacity (Ramirez-campillo et al., 2018), showing another interesting way for interventions.

Briefly, the programs that emphasizes in the use of strength and power training were able to improve muscle strength by 6% to 60% in older people and were effective in reducing the fall rate by 22% to 35% (Cadore, Rodríguez-Mañas, Sinclair, & Izquierdo, 2013).

Balance and Fall Risk

Recent studies have shown that exercise programs with at least 3 hour/duration/week, with some levels of balance challenge, and balance-specific training could reduce around 21% the rate of falls in community-dwelling older people (Chou, Hwang, & Wu, 2012; Hauer et al., 2001). This studies also showed that all exercise programs had a fall prevention effect in community-dwelling people with some level of cognitive impairment and Parkinson's disease. However, among stroke survivors and recently hospitalized elderly, the fall prevention effect, was not found with the same physical exercise program.

In another study (Binder et al., 2002) was compared the frequency of falls in 91 institutionalized frail elderly, divided in three different groups: i) Vitamin D supplementation; ii) low-frequency exercise and

iii) combination of both. The intervention iii) (i.e., combination of both) showed to be the most effective for the reduction of falls among institutionalized frail elderly individuals, showing the importance of the vitamin D supplementation, beyond the importance of physical exercise.

A recent meta-analysis (based on 18 RCT studies) (Huang, Feng, Li, & Lv, 2017) that analyzed the influence and use of Tai Chi, showed some evidence of its beneficial issues, mainly, in improving balance, and therefore reducing fall risk. Another review evaluating outcomes of these kind of interventions revealed that programs targeting at least two of these components (strength, endurance, flexibility, and balance) were able to improve balance capacities between 5% to 80% in older adults, and reduce the rate of falls significantly, with the rate of fall, and fall risk reduction above 55% (Cadore et al., 2013; Casas & Izquierdo, 2012).

Aerobic Exercise and Fall Risk

As the aging process is always associated with a cardiorespiratory capacity decline, the use of aerobic exercise has been recommended to counteract this process (Carrick-Ranson et al., 2020; Valenzuela, Maffiuletti, Joyner, Lucia, & Lepers, 2020). The aerobic/endurance/cardiorespiratory training usually include treadmill walking, step-ups, stair climb, cycling (usually, stationary cycling), and walking, with changes in pace and time duration (Freiberger et al., 2012; H. K. Kim et al., 2012; Zhang et al., 2016).

In a review investigating the effect of exercise interventions (Cadore et al., 2013), the outcomes of aerobic exercise showed improvements in maximum rate of oxygen consumption (VO_{2max}) around 13% in older adults, after 3 months of practicing walking exercise ate 70-75% of maximal heart rate (HR) intensity, with progression starting in 20 minutes to 60 minutes duration. However, older persons with severe functional decline, most of times, are not able to perform this kind of exercise interventions, in a way to recover their cardiorespiratory capacities, or to promote significative changes (Cadore et al., 2012; Izquierdo et al., 2001).

Although, aerobic capacity is a very important characteristic of physical capacity, and should be included in an exercise training routine, there may be a need to strengthen the muscular system, or to use some method for controlling the adequate intensity for cardiorespiratory tolerance, previously the starting of an aerobic training, in order to achieve significant changes and adaptations (Izquierdo et al., 2001).

Some studies (Cadore et al., 2012; Izquierdo et al., 2001) have demonstrated that has a positive association between strength and aerobic capacity, recommending the use of multicomponent interventions (Freiberger et al., 2012; García-Molina et al., 2018; H. K. Kim et al., 2012; Wang et al., 2018; Zhang et al., 2016), which have shown improvement not only in physical capacities, but also in cognitive functions of the participants, including reaction time, gait speed, balance, memory, mood and general well-being (Meurer, Benedetti, & Mazo, 2009). As well in a study by Chupel et al (2017) where aerobic capacity was correlated with cognitive performance and positive effects were noted in the trained group.

Multicomponent Exercise and Fall Risk

The "multicomponent" term refers to physical exercise programs which are composed by more than an only one mode of physical activity, being a mix of some of most common types such as strength training, aerobic exercise and stretching training, for example.

A review (Cadore et al., 2013) on the use of this kind of exercise training, concluded that multiple-component group exercise programs reduced the rate of falls and risk of falling, in both individually or group prescribed, home-based or physically present exercise programs in a very significant way.

In the same way, the American College of Sports Medicine (ACSM) 2018 Guidelines report convincing evidence related to the greater benefits of multicomponent exercise when compared to a single-mode of exercise alone (strength, aerobic, balance, etc.), in the prevention/reduction of fall-related injuries, and fall risk, by improvements in physical function in older adults. It has become the most recommended type of exercise program (A. King et al., 2019) with a rate of fall prevention around 31% in frail older adults (Cadore et al., 2013).

Moreover, multicomponent exercise programs, as well as the multi-task activities (that which combine cognitive and physical task together) have shown to be an important and better option to daily live routine, being a positive alternative to the single, structure and regular exercise programs.

Dual-Task and Fall Risk

Dual-task activities refers to the combination of some cognitive task with some physical/locomotor activity (e.g., walking while counting backwards) (Wollesen & Voelcker-Rehage, 2014).

A recent meta-analyses has shown general dual-task activities improved significativly the level of global cognition and executive functions as well, in many and different types of exercise, its intensity, and the intervention settings, with some heterogenity, but all being positivi in some ways (Wollesen et al., 2020). Therefore, the review suggest that the studies where long interventions was choosen, had more benefits and improvents in general cognition

Also, the domains of cognitive function that are influenced by this kind of training are vast and significant, going of inhibitory control to attention and mental shifting skills (Faulkner et al., 2007; Wollesen & Voelcker-Rehage, 2014). In this way, the use and promotion of new technologies may be a helpful tool to complement some kind of home-based and/or not supervised program for older adults, as they can, in some level, independently perform interesting and more diverse training sessions (Wollesen et al., 2020).

RECOMMENDATIONS, PREVENTION AND MANAGEMENT STRATEGIES

Adding to the above discussed benefits, physical exercise exceed fall prevention and the reduction of fall risk, being beneficial to general health and well-being and able to reduce the risk of disease onset, also managing chronic conditions such as arthritis, diabetes, heart and respiratory conditions, which are very common and related to aging process (Mendes, Sousa, & Barata, 2011).

Taking into account, the general recommendation from the ACSM (Jakicic et al., 2019), the European Union (European Union, 2014), the World Health Organization (Bull et al., 2020) and The National Program for Health and Physical Activity from Portugal (Direcao Geral de Saude, 2017) on physical activity to prevent fall converges in many point, highlighting that older adults should perform a varied multicomponent exercise at moderate to high intensity, that should include:

i) Around 30 minutes/day of moderate intensity aerobic exercise, 3 to 5 days a week; or do vigorously intense aerobic exercise, for 20 minutes/day, 3 to 5 days a week.
ii) Around 8 to 10 strength training exercises, with 10 to 20 repetitions, 2 to 3 times per week.

iii) Include balance exercises in the physical activity plan, as they can prevent fall in both, high risk groups and the general population.

These general recommendations of physical exercise to older adult population include the incorporation of physical activities focusing on maintaining and/or increasing/improving physical capabilities, such as muscle mass, flexibility, balance, endurance, and gait speed (A. King et al., 2019).

Some studies (Albornos-Muñoz et al., 2018; García-Molina et al., 2018; Hamed, Bohm, Mersmann, & Arampatzis, 2018; Pimentel & Scheicher, 2009; Sosnoff et al., 2015) also highlight the importance of effectively challenge balance with specific exercises that are conducted whilst standing, and participants should be encouraged, among other things, to:

i) stand with their feet closer together or on one leg;
ii) minimize the use of their hands to assist balance;
iii) practice controlled movements of the body's center of mass/gravity.

However, the prescription of the exercise and its difficulty must be guided taking account the individual's capacities and limitation, and the safety conditions. When balance, or any other physical capacity is mastered in a safe, stable and positive manner without any other support, it should be progressed to increase challenge and continue the progression rate (A. King et al., 2019; Kraus et al., 2019).

Specific ways to increase intensity of balance training for example, should taking to account the progressively difficulty of postures in different bases of body support, such as semi-tandem, tandem, and one leg stands, as well the movements which perturb the body's gravity center, like circle turns, stepping over obstacles and tandem walk, and activities with reduced sensory output (eyes closed, walking or at least stand in unstable surfaces). Specific strength training exercises should also be included to improve balance, such as hip abduction and heel and toe stands (de Souto Barreto et al., 2016).

In addition to that, high doses of exercise (more than 50 hours – 2 session of 1 hour/ week, for 6 months) have been shown to even have bigger effects on fall prevention. It is almost mandatory that exercise needs to be ongoing to have a lasting effect on fall rates. Therefore programs should offer ongoing exercise, or encourage people to undertake ongoing exercise at the end of a short-term formal program as recommended by the ACSM (A. King et al., 2019).

A study including 54 randomized controlled trials (Sherrington et al., 2011) indicates that the better options of exercise programs for preventing falls is those containing these three characteristics:

i) Exercises specific to challenge balance;
ii) High volume of exercise;
iii) Low volume of walking program.

These three characteristics combined resulted in a rate of falls reduction by 38%. On the other hand, the exercise programs that have included walking resulted in a rate of fall reduction by 21%. According to the authors, this "apparently" lower effect around walking programs, may be related to one or more of these indicators:

i) Elevated exposure to threats, contributing to increase fall risk with walking;

ii) The walking activity taking time away from exercises more indicated (balance training and/or strength training) and/or;
iii) Confounding results (as the walking programs were more frequently prescribed to high-risk populations-institutionalized elderly, the beneficial effects of exercise in this population are less marked, and progress slower, even a reduction in the speed of capacities degradation can be understood as an improvement).

However, while walking appears not to be an effective strategy for fall prevention, there are other benefits in walking for aged people (Kraus et al., 2019; Mendes et al., 2011). In general, it was suggest that walking training may be add into a fall prevention program as long it does not take the place of balance training for example, and people at higher risk should not do brisk walking programs due to the increased risk with this activity (Grue, Kirkevold, Mowinchel, & Ranhoff, 2009; Kraus et al., 2019; Rapp, Becker, Cameron, König, & Büchele, 2012; Wu & Lu, 2017).

Additionally, the use of dual task programs should also be encouraged, with different kinds of combination, such as memory task and gait training or balance exercise, balance/walking exercises and hand-eye coordination, tandem walk with cognitive tasks, counting backward when weightlifting, and balance itself can be considered a coordination task, since it involves ongoing postural adjustments in different moments and conditions (standing, sitting, walking to a new base of support, or seat) (Wang et al., 2018).

Also, research aimed at studying if older adults were able to learn a specific movement ("tuck-and-roll") which could reduce impact during a fall, when the participants were trained and performed, in a standardized way, sideway falls (Moon, Bishnoi, Sun, Shin, & Sosnoff, 2019). The results showed significant decrease in the hip impact force, showing preliminary evidence that this kind of training has potential effect in reducing the severity of an unpredictably fall in older adults, and could be included in specific programs.

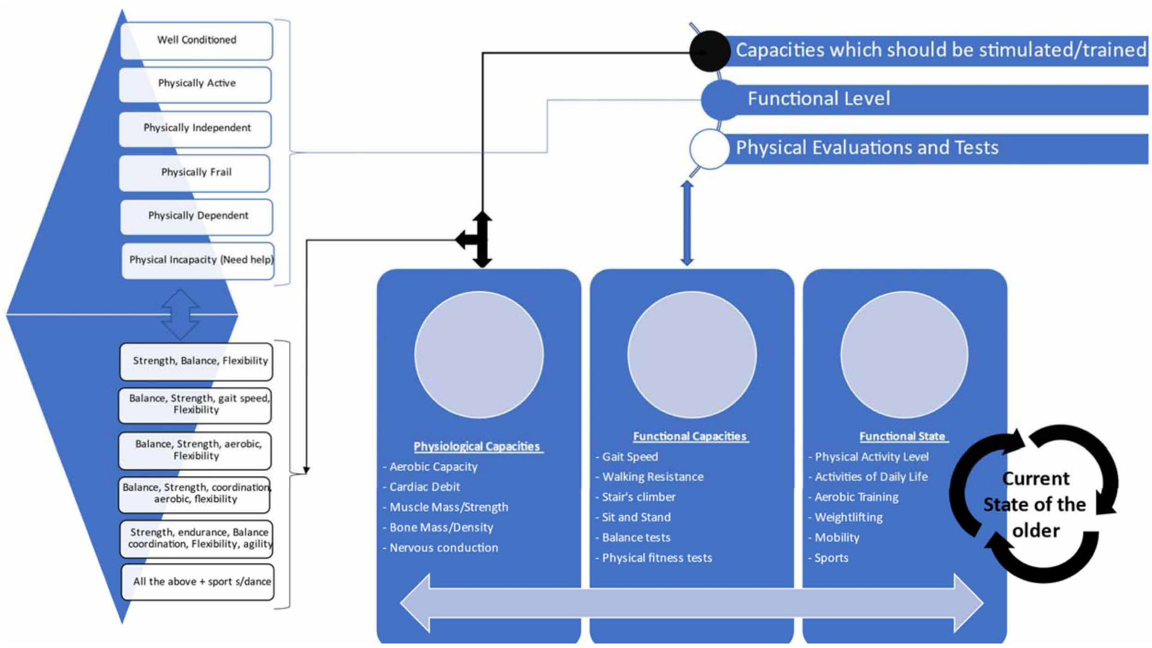
The exercise program also must include and respect the gradual approach to increase and increment the physical activity (types and time duration) over time (de Vries et al., 2012; Jakicic et al., 2019; A. King et al., 2019). Muscle strength training and weightlifting exercises are very important for older adults due to their specific role in preventing loss of muscle and bone mass overtime (de Vries et al., 2012; Jakicic et al., 2019; A. King et al., 2019). A significative number of studies (Chan et al., 2015; Ferreira, Ferreira, & Escobar, 2012; García-Molina et al., 2018; Padoin, Gonçalves, Comaru, & Silva, 2010; Pimentel & Scheicher, 2009; Ramalho et al., 2018; Sherrington et al., 2019) showed that exercise has important and consistent effects in reducing fall risk in older adult populations, mainly when prescribed at the very correct progression rate and intensity (Chou et al., 2012).

Besides some emphasis on the importance of balance and its training, the strength training is also gaining space/importance since strength capacities declines strongly after the age of 35-40 years (Blain et al., 2019; Cruz-Jentoft et al., 2010; Gielen et al., 2012), and impaired lower limb strength has been identified as an important fall risk factor (Menezes & Bachion, 2008; Ramalho et al., 2018). So, physical activities focusing on strengthening the lower limb muscle groups (Gillespie et al., 2012; Ramalho et al., 2018), muscles of the ankles, and feet (Spink et al., 2011) have been observed in successful fall prevention programs (Dipietro et al., 2019).

Moreover, the older adults who has some medical issues where therapeutic exercise should be performed in a specific manner to treat the condition, should engage in activities in a very specific way to prevent and reduce some of the risk involved, and the risk of developing any other diseases (Kraus et al., 2019).

In summary, exercise programs which focus on balance and strength activities, providing continuous exercise, are showing to be effective in preventing falls. Exercises targeting the muscles of ankles and feet are considered important components of a successful fall prevention program (Spink et al., 2011). Also, the exercise programs design should meet the needs (Graph 1) and abilities of the targeted population to provide exercises which are safe, motivational, and challenging.

Figure 1. Elderly Needs



The "functional state" is defined as the current state of the first evaluating moment, in summary, what he/she is capable in terms of training capability. This "functional state" is dependent on the "functional capacities", which is the capacity of to do/to perform daily life activities. This "capacities" being determined by their "physiological capacities", that is, the physiological capacity of nervous system transmission to muscle fibers, cardiac debit, muscle strength and proprioception.

Therefore, the "physiological capacity" determines the "functional capacity" that determines the "functional state", which is, the current state of the older person, so with correct physical evaluations and tests, addressing the correct functional level, we should be capable to recommend the most adequate kind of exercises to achieve the expected adaptation in the "physiological capacities", to improve de "functional capacities" and level-up the "functional state", keeping the circle working as good as possible.

In addition, some other activities such as aerobic classes, dancing, and specific sports have not been used in studies about fall prevention and its context, possible due to their difficulty, however as they are activities in which coordination, balance, and body control are required, they may be beneficial in maintaining balance and physical fitness status, but only for older people who are more able and active (at the top of the pyramids in Table 1), or middle age groups. For older people with poor physical status and postural control, these activities can be more dangerous, and increase fall risk (Gillespie et al., 2012; Tinetti, 2003).

CONSIDERATION FOR CLINICAL GROUPS

Most guidelines (de Souto Barreto et al., 2016; European Union, 2014; A. King et al., 2019) declare that is safe to (almost) all individuals (even sedentary ones) to start a moderate-intensity exercise program, and they have some assessment screening to know and clarify about any specific medical conditions and recommendations for older adults. However, they also state that if any older person wants to start a moderate physical exercise, and is apparently healthy, with no special condition to address, medical screening is not necessary, but is still recommended, and if the older one wants to start a vigorous physical exercise program, medical screening is strongly recommended.

On the other hand, older persons with some known disease (cardiac, pulmonary or metabolic) or any other factors which increase or influence the risk of adverse effects should undergo medical screening prior the beginning of any exercise programs. In addition, immediate cessation of physical exercise and a fast medical review is strongly recommended if they have any symptom or experience dizziness, chest pain, difficulty of breath (Dipietro et al., 2019). Taking that to account, the intensity of exercise should also be progressive with time, but in a much more tailored way, identifying individual tolerances, difficulties and preferences (Chodzko-Zajko et al., 2009; de Souto Barreto et al., 2016).

When prescribing exercise to people aged over 85 years, with or without any chronic disease, like functional limitation, Parkinson and previous stroke, for example, it is very important to be aware that they are at a substantially increased risk of falls (Erickson et al., 2019; A. King et al., 2019; Kraus et al., 2019). Meanwhile, the evidence about the potential to prevent falls using well-design exercise program even in high-risk populations is well established, taking only extra attention to safety, ensuring that exercise is well supervised by well-trained professionals (Albornos-Muñoz et al., 2018; Barnett, Smith, Lord, Williams, & Baumand, 2003).

However, further studies are still necessary to better explain the most correct approach to prevent falls in older persons in some of these special conditions, since the scientific evidence about this is limited (Dipietro et al., 2019; Hill et al., 2011; Pimentel & Scheicher, 2009). In the same way, exercise programs designed for cognitively impaired populations, and its relation to fall and fall risk outcomes are scarce. However, it is expected that these populations will benefit from carefully, specifically prescribed and well monitored exercise programs.

For older persons with other kinds of medical conditions, some extra precautions may be required to ensure safe and effective exercise participation. Elderly with asthma and/or hearth disease may need some medication (Kraus et al., 2019), the diabetics may require the use of additional carbohydrate before or even during exercise (Foscolou et al., 2019; Hsu et al., 2011), and all of this can have a direct or indirect effect on exercise execution.

Additionally, some guidelines (Bull et al., 2020; Dipietro et al., 2019; Jakicic et al., 2019) recommend extra attention, and the possibility of an extended period for a cool down activity, after physical exercise, to reduce the possibility syncope, hypotension, or even arrhythmias during the post-exercise period. The hydration status is also a concern since dehydration is more likely to occur in older persons (and some of them take diuretics to hypertension control, for example), so intake of mainly water is highly recommended, before, during and after exercise (Picetti et al., 2017; Scherer, Maroto-Sánchez, Palacios, & González-Gross, 2016).

PRACTICAL PROPOSAL AND TIPS

The programs should all be supervised by an exercise expert, since some studies have shown that older people who exercise without a professional supervision, have the same benefits as the ones who do not exercise (Steele et al., 2017). The program proposed below of structured exercises performed with a chair to help and ensure the safety of the participants, consists of a progressively increased intensity employing elastic bands in 7 to 10 exercises per session (Table 1). Intensity progression was fixed according to the OMNI table for bands progression (Colado et al., 2018).

These exercises and its progression (and periodization) were adjusted to the recommendations from the guidelines mentioned above. The intensity of the proposed program was indirectly calculated using the Karvonen's formula to predict target heart rate (HR), with HR_{max} being calculated using a specific formula for older populations (Target Heart Rate = (HR_{max}−resting HR) x %Intensity) + resting HR (Tanaka et al., 2001). During the exercise programs, to assess the internal load, cardiac frequency could be monitored with heart rate monitors and the rate of perceived exertion (RPE) with the Borg scale (Borg, 1982) for example.

The exercise program proposed here consisted of 3 to 4 session/week, with 7 to 10 exercise plus some level of aerobic and stretching exercising, of 2-3 sets of 10-20 repetitions, starting using only the body weight (just doing the movements) first, and goes on with a light intensity band during the adaptation period and progressed to 2-3 sets of 10-20 repetitions with a higher intensity elastic band for 2-3 weeks and increasing to 2-3 sets of 10-20 repetitions for another 2-3 weeks. Keeping this same system of progression for the following weeks, with the increase happening every 2-3 weeks, or, to the point that the supervisor believes it should happen. Finally, when the elastic band reach the green or blue colour (using Thera-band® colour-weight system), meaning they have been exercising for at least for 2 months, some extra exercises for balance (e.g. taking more time in the stand position than seated at the chair, stand in one foot, walking in a straight line, etc.), some free weights and shin guards could be added in, preferable in a circuit format, which will allow a more intense and diversified range of exercises. Some gym exercises, and specific classes like yoga or tai-chi, to increase the variety of exercises could also be added.

The exercise program dynamics consisted of performing muscle groups alternated, with the approximate cadence of 2 seconds concentric phase and 3 seconds' eccentric phase, and the frequency of 2-3 times week, in alternated days, to allow appropriate recovery. Also, the use of music can be helpful to help then to warm-up, do exercises, and cooldown in a better way (Ziv & Lidor, 2011).

The program could start using the simple sequence of doing some warm-up exercise for 5min, and exercise 1, 2, 4, 6, 7, 8 and 9, without the elastic band, using only the body weight, with 2 sets of 10-15 repetitions, with 30 seconds resting interval, for a week or two (3-6 training session), and in the following week, the same, with the first elastic band (yellow). The following increment could be to include exercise 3, during 1-2 weeks with the yellow band, and going on to the red one. In the next step, exercise 10 could be addressed, and in this 1st week, start with the yellow band, just to adapt, and go on to the red for another 2 weeks. In the following steps, using all 10 exercises proposed, starting with the red elastic band, 2 sets of 10-15 repetitions, being increased in the following week to 3 sets of 20 repetitions.

Table 1. Protocol of Multicomponent Exercise Program

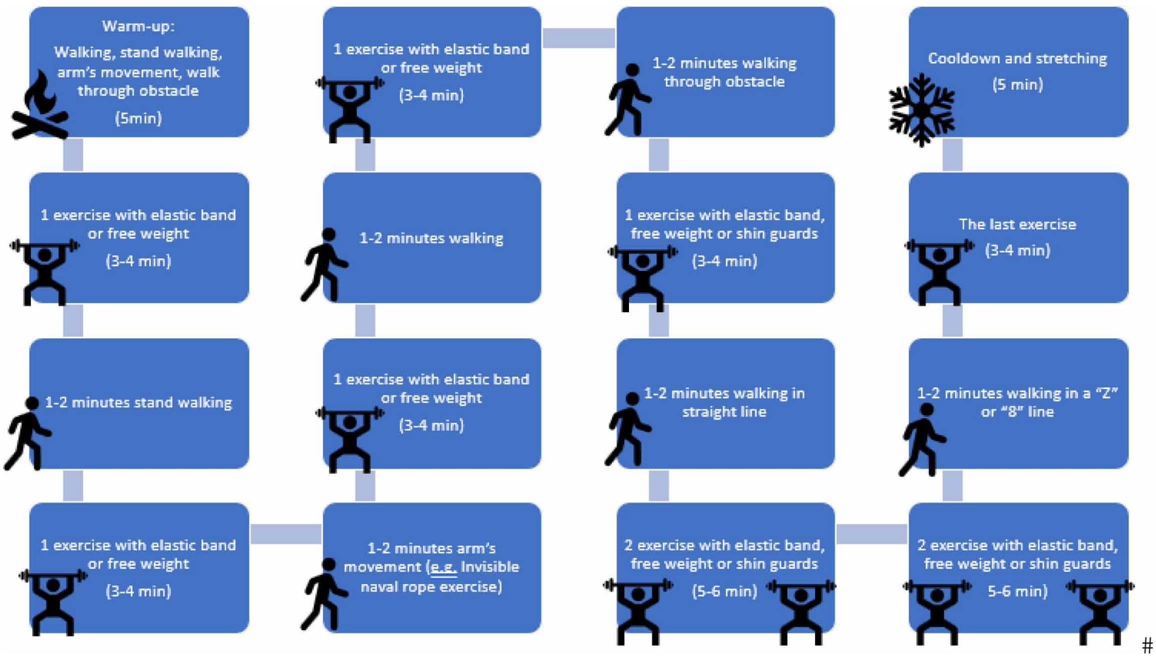
Warm-up 5-10 minutes PSE 4-6 Stand walking/Walking/Arm's movements					
Exercises (7-10)	**Sets**	**Repetitions**	**Cadence**	**Interval**	**PSE**
1. Front squat (with a chair for beginners)	2-3	10-20	1:2	30 seconds	4 to 7
2. Chair Bench over row (with flexion)	2-3	10-20	1:2	30 seconds	4 to 7
3. Chair unilateral hip flexion	2-3	10-20	1:2	30 seconds	4 to 7
4. Chest Press (stand and/or chair)	2-3	10-20	1:2	30 seconds	4 to 7
5. Bench over row unilateral (Stand)	2-3	10-20	1:2	30 seconds	4 to 7
6. Chair (or stand) frontal total raiser	2-3	10-20	1:2	30 seconds	4 to 7
7. Chair (or Stand) reverse fly	2-3	10-20	1:2	30 seconds	4 to 7
8. Shoulder Press/twist arm front position	2-3	10-20	1:2	30 seconds	4 to 7
9. Chair (or Stand) Biceps arm curl	2-3	10-20	1:2	30 seconds	4 to 7
10. Chair (or Stand) Overhead triceps extension	2-3	10-20	1:2	30 seconds	4 to 7
Cooling down 5-10 minutes PSE 1-3 Upper and Lower body's stretching (seated and/or standing)					

Table 2. Progression and Intensity of Elastic Bands (by color and weeks)

Week	Exercises	Elastic band/weighs/shin guards	Sets/Repetition
1	1, 2, 4, 6, 7, 8, 9	Body weight	2x 10-15
2	1, 2, 4, 6, 7, 8, 9	Body weight	2x15-20
3	1, 2, 4, 6, 7, 8, 9	Yellow	2x10-15
4	1, 2, 3, 4, 6, 7, 8, 9	Yellow	2x10-20
5	1, 2, 3, 4, 6, 7, 8, 9	Yellow/Red	3x15-20
6	1, 2, 3, 4, 6, 7, 8, 9, 10	Yellow	2x10-15
7	1, 2, 3, 4, 6, 7, 8, 9, 10	Red	2x10-15
8	1, 2, 3, 4, 6, 7, 8, 9, 10	Red	2x10-20
9	1, 2, 3, 4, 6, 7, 8, 9, 10	Red	3x15-20
10	All 10	Red	2x10-15
11	All 10	Green	2x10-20
12	All 10	Green	3x15-20
13	All 10 in a Circuit format	Red	2x10-20
14	All 10 in a Circuit format	Green	3x10-15
15	All 10 in a Circuit format	Green	3x15-20
16	All 10 + Circuit format + Free weight	Green	2x10-20
17	All 10 + Circuit format + Free weight	Green + free weight (exercises 1, 5, 8)	3x10-15
18	All 10 + Circuit format + Free weight	Green + free weight (exercises 1, 5, 8)	3x15-20
19	All 10 + Circuit format + Free weight	Green + free weight (exercises 1, 5, 6, 8, 10)	2x10-20
20	All 10 + Circuit format + Free weight	Blue + free weight (exercises 1, 5, 6, 8, 10)	3x10-15
21	All 10 + Circuit format + Free weight	Blue + free weight (exercises 1, 5, 6, 8, 10)	3x15-20
22	All above + Shin guards	Blue + free weight (ex. 1, 5, 8) + shin guards (ex. 3)	2x10-20
23	All above + Shin guards	Blue + free weight (ex. 1, 5, 6, 8, 10) +shin guards (ex. 3)	3x10-15
24	All above + Shin guards	Blue + free weight (ex. 1, 5, 6, 8, 10) +shin guards (ex. 3)	3x15-20

This system (Table 2) can go on for a long period of time, with some and different levels of increment in one of the three exercise categories (quantity and difficulty, color/intensity of elastic band, and the number of sets and repetition) each 1 to 2 weeks, and a general “level up” at each 3 to 4 weeks, which shows progression in an easy and safety way, which could (should) be adapted to the personal needs of the “participants” according to the examination of the professional in charge, who will be the one deciding the best way to progress during exercise sessions, as well in the circuit training example proposed (Figure 1).

Figure 2. Example of a Circuit Training



FINAL CONSIDERATIONS

Since de first guidelines were published, significant scientific evidence has emerged and showed, in some details, the benefits of a variety of types of exercise (aerobic, strengthening, balance) and its combinations and/or composed activities (Tai Chi, Yoga, multicomponent exercise, HIIT, Dance, dual-task training) in physical functions (gait, balance, ADL, muscular strength, muscle mass) and fall-related injuries (Dipietro et al., 2019; Jakicic et al., 2019).

In spite of the benefits of physical exercise on health and physical function throughout life and during aging being well known, the proportion of older adults meeting the recommended levels of physical activity remains very low, being not above 27% in USA (Dipietro et al., 2019), 36% in Brazil (DATASUS, 2009) and 30% in Europe (WHO, 2018). Also, low levels of physical exercise usually walk side-by-side with chronic diseases, which have a big impact in physical function decline. Some evidence shows that a sedentary lifestyle is one of the strongest indicators of disability in older population, which will also increase fall risk and for consequentely mortality (Dipietro et al., 2019; Erickson et al., 2019; Jakicic et al., 2019)

In the opposite way, a more active lifestyle with regular physical activity/exercise, meeting the minimum recommendation of aerobic, strength training, and/or multicomponent exercise seems to have a very strong relationship with improved physical capacities and health in the elderly, as well in those suffering of some chronic disease, so, these kinds of activities may improve, or at least delay the processes of decreased mobility, frailty status, fall risk, and consequently the loss of independence during the aging process (Dipietro et al., 2019).

However, evidence on long-term exercise, aided by nutrition, is still scarce in this population. Supplementation of branched chain amino acids has been studied and used as an alternative to try to combat / alleviate the process of musculoskeletal degradation and may be an important agent in the control of falls in the elderly (Mitchell et al., 2012).

Thus, the role of adequate physical exercise programs in targeting these events must be highlighted, and fall prevention programs must be established with priority, including not only exercise programs (effective single prevention strategy), but also environmental modifications and multifactorial interventions(M. King et al., 2002).

In this perspective, appropriate interventions by health professionals are important in order to provide better conditions for a good quality of life and to prevent the increase of disabilities, which are the earliest causes of institutionalization, and one of the causes for an increased risk of fall, showing the need and importance of multifactorial interventions, which will be more effective than any single intervention (Cuevas-trisan, 2019).

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1.3. Thesis Objectives

This Ph.D thesis general objectives are focused on the study of the effects of exercise on fall risk related to neuromuscular changes, global cognition, and physical fitness levels in older adults at different times (after training, detraining/washout, retraining) . The specific objectives are divided into studies as follows:

Objective/Study 1 - Perform the psychometric validation of the instrument entitled Falls Risk Assessment Tool (FRAT) by Stapleton et al. (2009) for the Portuguese older population.

The Results obtained from the objective/study 1 are included on Paper 1.

Objective/Study 2 - Identify possible correlations between health outcomes, nutritional status, physiological biomarkers, and physical fitness assessments related to fear of fall in aged people to serve as basis for future studies related to this topic.

The Results obtained from the objective/study 2 are included on Paper 2.

Objective/Study 3 - To study the effect of resistance training and its influence on parameters of muscle power, body composition and cognitive status related to the risk of falls in institutionalized older population.

The Results obtained from the objective/study 3 are included on Paper 3.

Objective/Study 4 - To study the effect of exercise training, and its influence on fall risk parameters evaluated through a sensorymotor posturographic platform (Physiosensing, SensingFuture®) on a very old (> 80 years old) institutionalized population.

The Results obtained from the objective/study 4 are included on Paper 4.

Objective/Study 5 – To identify, develop, promote, and divulgate a specific exercise program focused on the reduction of fall risk in older adults.

The Results obtained from the objective/study 5 are included on Chapter Three.

Paper 1- Fall Risk Assessment Tool (FRAT) Validation for the Portuguese Population

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The following paper appears as Accepted for publication in Springer Special Edition:
Proceedings of the 10th Congress of the Portuguese Society of Biomechanics:
"Portuguese version of the Fall Risk Assessmente Tool (FRAT) for older population"

Portuguese version of the Fall Risk Assessment Tool (FRAT) For Older Population

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Abstract. Preventing falls is a strategic objective of the Portuguese National Plan for Patient Safety. However, Portugal lacks a validated fall risk assessment scale specifically designed for the older population residing in social-assistance institutions (SAI). The aim of this study was to validate the Fall Risk Assessment Tool (FRAT) semantically, conceptually and culturally. Data was collected from 131 older adults (79.64 ± 7.61 years) residing in SAI. To assess the fidelity of the instrument, Cohen's Kappa (0.765) and Cronbach's Alpha coefficient (0.743) were tested, along with the internal consistency of its components: Recent Falls (α=0.619), Medication (α=0.657), Psychological (α=0.727), and Cognitive State (α=0.639). Correlations between the four questionnaire items were calculated, revealing significant intercorrelations between "Recent Falls" and "Medication," as well as between "Medication" and "Cognitive State" (p=0.01). No correlations were found between "Psychological" and "Recent Falls" or between "Medication" and "Psychological". Concurrent criterion validity was also assessed, showing a positive correlation between the FRAT and the Timed-Up-And-Go Test, as well as a negative correlation between the FRAT and the Falls Efficacy Scale. These findings demonstrate that both instruments align in assessing the risk of falling, providing convergent validity and indicating a similar direction of risk assessment. in the institutionalized older population in Portugal.

Keywords: Risk of Falls, Active Aging, Prevention, Balance, Walking Speed test, ensure health and well-being.

1 Introduction

According to the Joint Declaration of the European Stakeholders Alliance for Active Aging through Falls Prevention [1], “falls are the biggest indicator of increased frailty, loss of independence and mobility.

One third of the population over 65 who live in the community fall each year and this proportion rises to 50% at age 80 and over” [2,3]. The World Health Organization reports that in residential institutions for older adults, 30 to 50% of them fall at least once per year, and about 40% experience more than one fall (4). It is noteworthy that in terms of data from the national notification system, 21% of all reported incidents are related to falls. This statement shows that despite many health and well-being constraints for older people, falls are considered one of the major causes of morbidity, disability, and premature death.

Falls are a serious public health problem in society at a global level and it results in devastating consequences for the elderly, affecting them physically, psychologically, and socially [5]. Falls have also economic impact for health institutions, with the cost of falls being estimated at €281 per person, which, in general terms, would mean an estimated average cost of 25 billion euros per year if we consider the entire European Union region [5-6].

According to Stapleton et al (2009), in residential institutions there are elderly people with or without dementia who fall frequently and, therefore, there is a need to assess the risk of falls to adopt preventive measures [7]. Some assessments, such the Morse scale is more suitable for hospital and health center environments, however, the Falls Risk Assessment Tool (FRAT) scale is be more suitable for residential structures, as it is a brief instrument that is easy to apply to this population, and does not need special training or equipment [5,8]. There is also a need to have a fall risk assessment tool in residential institutions for the elderly to mitigate falls and, in this way, contribute to their safety [8]. Corroborating the above presented and contributing to the dissemination of an institutional culture of risk of falls assessment, we consider it relevant to validate the FRAT scale for the population in Portuguese residential institutions.

This study aims to validate the FRAT [7] semantically, conceptually, and culturally for Portuguese older population and analyze the psychometric properties of FRAT for this specific sample.

2 Methodology

The FRAT was obtained in its English version from the Department of Health & Human Services, Melbourne, Victoria, Australia [8]. Authorization was requested from the authors for translation and data collection, and it was granted.

To ensure methodological rigor, all translation procedures deemed scientifically correct in the literature were followed to characterize the phenomenon of falls in residential institutions for the older population, taking into account Portuguese culture. This process involved five steps: Translation, Synthesis of procedures, Retroversion, Panel of experts, and Testing of the pre-final version of the FRAT [9–11].

2.1 Participants

The sampling technique employed in this study was a non-probabilistic convenience process. The inclusion criteria consisted of individuals aged 65 years and older who were residing in institutionalized settings at the time of data collection.

Exclusion criteria encompassed individuals under 65 years of age and those not living in institutions. Data were collected from 9 residential institutions. The final sample comprised 131 older adults, with a mean age of 79.64 (±7.61) years, with 75.57% of participants being female. This sample size meets the recommended minimum requirement for instrument validation, which suggests a minimum of 10 individuals per item - the FRAT consists of 4 items. [7,11]. Prior to the administration of the FRAT, visits were made to each participating location during the two months preceding the study. Relevant documentation and specific information were provided to the involved parties, and continuous communication was maintained to address any additional information needs.

2.2 Study Protocol

After receiving detailed information about the study, each participant was requested to provide informed consent by signing a Free and Informed Consent Form. This ensured data confidentiality and the participants' right to withdraw from the study without any negative consequences.

The assessment instrument was administered independently. The data collection period took place from February 10 to June 15, 2019. To facilitate data collection and obtain a comprehensive sample characterization, a specific form with two parts was utilized. The first part gathered basic sociodemographic information about the participants, including age, sex, and marital status. The second part consisted of the actual FRAT questionnaire [7].

To ensure content validity, the study followed the recommended guidelines for the translation and cross-cultural adaptation of instruments [10–12]. Following this stage, the administration of the questionnaires commenced with the aim of conducting the psychometric validation. Alongside the FRAT instrument, two commonly used instruments related to falls, namely the Falls Efficacy Scale International (FES) [13–14], and the Timed-Up-and-Go Test (TUGT) [15,16], were administered to a smaller subset of participants (n = 51).

The FES, which has already been validated for the Portuguese population, comprises evaluative questions regarding the level of confidence older adults have in their ability to perform 10 daily activities without the fear or risk of falling [14]. Confidence levels are measured on a 10-point scale, ranging from "Not confident" (1 point) to "Fully confident" (10 points). The FES score is derived from the sum of scores obtained for each of the 10 items.

The TUGT involves the participant being seated, standing up upon request, walking a distance of 3 meters in a straight line, turning around, returning to the chair, and sitting back down. The time taken is recorded once the person is seated again, and the use of assistive devices for walking or balancing is allowed, but must be documented [15].

2.3 - Instrument Validation Steps

The validation process of the FRAT was conducted in two phases. In the first phase, after obtaining authorization from the authors, the instrument underwent semantic, conceptual, and cultural validation. The implementation of this validation process involved the following steps [17]:

2.3.1 Translation by two bilingual experts

Initially, the FRAT was translated from English into Portuguese by two independent and proficient bilingual translators who were not involved in the field of the scale's theme. These translators were qualified and experienced in translating scientific and healthcare-related documents.

2.3.2 Synthesis of the procedures of the translations

Subsequently, the translations were compared and synthesized with the translators themselves to ensure minimal differences between them.

During this process, specific terms and phrases were carefully reviewed and discussed. For instance, in the title, one translator used the term "instrument" while the other used "tool." After thorough discussion, the term "instrument" was chosen, resulting in the final title as "Fall risk assessment instrument." Additionally, there was a variation in the translations where one used the term "introspection" while the other used "reasonableness." Following extensive discussion, the term "introspection" was selected. Ultimately, the most appropriate semantic, conceptual, and culturally adjusted terms for the Portuguese population and scientific community were accepted [18].

2.3.3 Retroversion

The final Portuguese version of the instrument was back-translated and compared to the original version, revealing minimal discrepancies. For example, the translation of the "Medication" parameter differed slightly, with the research team choosing the version that clarified "Not taking any of these medications."

Similarly, in the "Cognitive State" parameter, the back translation used "moderately impaired" instead of "mod impaired," providing clearer conceptual and semantic terms. Although these were the most notable differences, the research team deemed them to be minor and ensured a reliable translation from the beginning.

2.3 Expert Panel

A panel of experts validated the semantic, conceptual, and cultural equivalences between the original and final versions of the instrument.

The panel, consisting of two experts, engaged in extensive discussions and made adjustments to the instrument. One particular challenge was understanding the meaning of the expression "esp re" in the original scale. After consulting the authors, it was clarified as "especially referring to mobility," and this clarification was incorporated into the instrument. Taking into account all the suggestions from the expert panel, the Fall Risk Assessment Instrument for elderly individuals in residential institutions was finalized [19].

2.4 Teste of the pre-final version of the instrument

The pre-final version of the instrument was tested by seven nurses from the Long-Term Integrated Continuing Care Unit. One nurse suggested changing the column heading in the "Cognitive State" parameter from "AMTS 9 or 10/10(…)" to "intact (…)" for ease of use.

However, the researchers decided to maintain the original format of the FRAT instrument. The remaining nurses found the instrument easy to understand and simple to complete. They emphasized the importance of having a fall risk assessment tool in residential institutions for the elderly due to the high incidence of falls. Following the completion of the pre-final version, the final instrument was prepared and presented in Table 1.

In the second phase of the study, the instrument was applied according to the established criteria. The reliability of the construct was assessed, yielding an Intraclass Correlation Coefficient (ICC) of 0.95. This high ICC indicates that there is no need to remove or modify any item in terms of clarity, coherence, and back-translation analysis. In terms of the sample's characteristics, the study included participants with an average age of 79.64 ± 7.61 years, with 75.57% of the participants being female.

Following the initial phase, the Portuguese version of the Fall Risk Assessment Tool, known as FRAT-P, was developed (Table 1). Subsequently, the second phase of the study involved the application of the instrument based on the established criteria. In terms of construct reliability, an Intraclass Correlation Coefficient (ICC) of 0.95 was obtained, indicating that no modifications or removal of items were necessary in relation to clarity, coherence, and back-translation analysis. Noteworthy is the sample characterization, with participants having an average age of 79.64 ± 7.61 years and a female representation of 75.57%.

2.5 Statical analysis

In the process of cultural adaptation, the recommendations outlined in the original FRAT were meticulously followed. To assess the psychometric properties of the instrument, a reliability study was conducted using the Intraclass Correlation Coefficient (ICC) and Cronbach's α. In terms of stability, the inter-observer reliability was determined using Cohen's Kappa concordance coefficient, with a minimum value of 0.70 adopted as the criterion [11].

To examine the correlation between the FRAT instrument and the assessment of fall risk based on two other similar instruments (TUGT and FES), as well as the associations among the individual questions/domains within FRAT-Portugal itself, the Pearson's correlation coefficient was utilized. The collected data were processed using SPSS, version 23.0, which allowed for the appropriate statistical analyses to be conducted.

3 Results

Table 1. Fall Risk Assessment Tool Portuguese Version (Instrumento de Avaliação do Risco de Queda - FRAT-P).

Instrumento de Avaliação do Risco de Queda

Fator de Risco	Nível	Pontuação de Risco
Quedas Recentes (Para pontuar complete o historial de quedas, no verso da folha)	Nenhuma nos últimos 12 meses ……………........... Uma ou mais entre os últimos 3 a 12 meses ……….... Uma ou mais nos últimos 3 meses ……………….... Uma ou mais nos últimos 3 meses enquanto paciente/residente………...……………………...........	**2** **4** **6** **8**
Medicação (Sedativos, Antidepressivos, Anti-Parkinson, Diuréticos, Anti-hipertensivos, hipnóticos)	Não toma nenhum dos medicamentos……………… Toma um …………………………………………… Toma dois ………………………………………….. Toma mais do que dois …………………………..	**1** **2** **3** **4**
Psicológico (Ansiedade, Depressão, Cooperação, Introspeção ou Julgamento **esp re*** mobilidade) *especificamente referente à mobilidade	Não aparenta ter qualquer um destes ……………….. Aparenta ligeiramente afetado por um ou mais .... Aparenta moderadamente afetado por um ou mais …. Aparenta severamente afetado por um ou mais ….......	**1** **2** **3** **4**
Estado Cognitivo (AMTS – Pontuação do Teste Mental Abreviado de Hodkinson)	AMTS 9 ou 10/10 **OU** intacto ……………...... AMTS 7-8 ligeiramente alterado...... AMTS 5-6 moderadamente alterado. AMTS 4 ou menos severamente alterado......	**1** **2** **3** **4**
(Baixo Risco : 5-11 Médio Risco: 12-15 Alto Risco: 16-20) **Pontuação de Risco:**		**/20**

Estado Automático de Alto Risco: (se selecionado então circunde risco **ALTO** em baixo)
☐ Mudança recente no estado funcional e/ou medicação afetando a mobilidade segura (ou antecipada) ☐ Tonturas / Hipotensão postural
Estado do Risco de Quedas: *(Circundar):* **Baixo / Médio / Alto**

To assess the reliability of the instrument, we examined the overall Cohen's Kappa coefficient (0.76) and Cronbach's Alpha coefficient (α= 0.74). Additionally, we calculated the alpha coefficients for each individual item: Recent Falls (α= 0.62), Medication (α= 0.66), Psychological (α= 0.73), and Cognitive State (α= 0.64), as shown in Table 2.

Table 2. Descriptive Statistics, Corrected Item-Total Correlation and Cronbach's Alpha (Total and Excluding Item) from FRAT-P

Item Portuguese (English)	**M**	**SD**	Corrected Item-Total Correlation	Cronbach's Alpha (Excluding Item)
Recent Falls Quedas recentes	3.25	1.13	0.68**	0.62
Medication use Uso de medição	2.62	0.76	0.67**	0.66
Psychological Psicológico	2.59	1.96	0.29*	0.73
Cognitive State Perfil Cognitivo	2.31	1.02	0.67**	0.64
Alpha de Cronbach - Total			0.74	
Cohen's Kappa			0.76	

M= Mean; SD= Standard Deviation; ** $p \leq 0.01$; * $p \leq 0.05$

The Cronbach's Alpha value obtained indicated substantial internal consistency of the scale, in accordance with previous studies [18]. Analyzing the correlation of each item with the total scale, we found that only one item had a correlation value below 0.6. However, this value was still greater than 0.2, suggesting that all items are generally good indicators of the instrument's validity [19]. Correlations were calculated between the four items of the questionnaire, revealing significant intercorrelations between "Recent Falls" and "Medication," as well as between "Medication" and "Cognitive State," with a significance level of 0.01.

Table 3. Intercorrelations between FRAT-P scales using Pearson's correlation coefficient (r).

Item Portuguese (English)	**1**	**2**	**3**	**4**
1. Quedas Recentes (Recent Falls)	--	0.323**	0.142	0.191*
2. Medicação (Medication)	--	--	0.139	0.373**
3. Psicológico (Psychological)	--	--	--	0.187*
4. Estado Cognitivo (Cognitive State)	--	--	--	--

** $p \leq 0.01$; * $p \leq 0.05$

Additionally, significant correlations were observed between "Recent Falls" and "Cognitive State," and between "Psychological" and "Cognitive State," with a significance level of 0.05. However, no significant correlation was found between "Psychological" and "Recent Falls," nor between "Medication" and "Psychological," as shown in Table 3 (above).

To evaluate the effectiveness of the Fall Risk Assessment Tool (FRAT) in assessing the risk of falling, we compared it with two other commonly used instruments that are part of the objective assessment of fall risk in the elderly population [5]. The Timed-Up-and-Go Test (TUGT) measures the time taken to complete the task, where a shorter time indicates a lower risk of falling [15], similar to the FRAT [7]. Conversely, the Falls Efficacy Scale (FES) measures self-perceived confidence in performing activities without the fear of falling, where a higher score indicates a lower risk of falling [14].

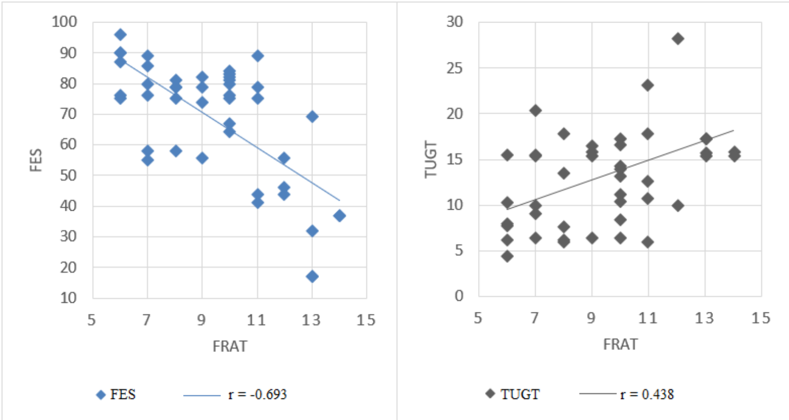

Fig. 2. Scatter Graph and Correlation Line between the FRAT and FES, and FRAT and TUGT.

The correlation between the FRAT, TUGT, and FES instruments is depicted in Figure 1. We found a significant positive correlation between the FRAT and the TUGT, indicating that both instruments assessed fall risk in a similar manner. Additionally, there was a significant negative correlation between the FRAT and the FES, suggesting that higher scores on the FRAT corresponded to lower perceived self-efficacy in avoiding falls. These findings demonstrate that the assessment of fall risk across these instruments aligned consistently and in the same direction.

4 Discussion

There is a significant lack of objective instruments that are easy and quick to administer in the institutionalized older population in Portugal [20]. This shortage can have consequences in terms of early detection and the development of intervention/prevention plans at various levels, which may compromise the health and well-being of this population [5]. A simple solution to address this situation is to utilize adapted instruments that are already available in other countries, languages, and cultures, and have been used with diverse populations [13].

Moreover, the translation and validation procedures are also valuable in facilitating cross-cultural studies, which contribute to a better understanding of clinical conditions, risk levels, and their specificities in different cultures and populations [9-10]. The translation and adaptation of a foreign instrument follow a similar process to constructing a new assessment tool, aiming for maximum equivalence between the original and adapted or translated version to minimize distortions [11-12].

In this study, the process of adapting the FRAT for the Portuguese population strictly followed the guidelines proposed in the literature [10-12]. This included translation, retroversion, possible corrections in the initial linguistic adaptation, application of the first version with subsequent adjustments, implementation of the instrument in a significant sample of the target population, analysis of psychometric characteristics, evaluation of equivalence between the original and adapted versions, and, if necessary, contact with the instrument's developers. Final revisions and adjustments were made to finalize the Portuguese version.

Regarding the equivalence between the original instrument and its adapted version, several authors [11-12] have presented models for evaluating equivalence, considering different levels such as conceptual, item, semantic, operational, measurement, and functional. Following these criteria, it is evident that the process of adaptation and validation of the FRAT for the Portuguese older population rigorously addressed these different levels. Consequently, it can be concluded that the Portuguese version of the FRAT is equivalent to and in agreement with the original version. Furthermore, a moderate to strong [21] and significant correlation was found between the FRAT and other instruments assessing fall risk, demonstrating its effectiveness in evaluating and characterizing fall risk. Specifically, a moderate level of correlation was observed between FRAT and TUGT ($r= 0.44$, $p=0.01$), while a strong negative correlation was found between FRAT and FES ($r= -0.69$, $p=0.01$).

This discrepancy in correlation may be attributed to the distinct characteristics and specificities of each test. The TUGT involves a practical physical assessment that requires participants to move and mobilize [16]. On the other hand, the FES is an informative theoretical tool that evaluates individual confidence in performing certain activities [14]. In this regard, the FES aligns more closely with the evaluative nature of the FRAT, which also incorporates informative theoretical aspects by gathering subject information, including a cognitive test [7]. These factors may explain the stronger correlation between FRAT and FES.

4.1 Strengths and limitations

The rigorous process followed the recommended guidelines, including translation, expert panel validation, and psychometric analysis, ensuring the instrument's reliability and validity. The study also highlighted the equivalence between the adapted version and the original instrument. Furthermore, the correlation analysis with other established fall risk assessment tools demonstrated the effectiveness of the FRAT. However, a limitation of the study was the convenience sampling method, which may affect the generalizability of the findings. Nonetheless, the study provides valuable insights into fall risk assessment for the Portuguese older population.

5 Conclusion

This study validates the Fall Risk Assessment Tool (FRAT) for the Portuguese population, enhancing the repertoire of assessment methods for fall risk in institutionalized older individuals.

The rigorous validation process ensured semantic, conceptual, and cultural equivalence with the original scale. Psychometric analysis demonstrated substantial internal consistency, interobserver reliability, and good item correlations. The validated FRAT instrument can be utilized in clinical practice as a reliable, fast, and cost-effective measure for assessing fall risk in institutionalized older adults. Its adoption in residential institutions can contribute to fall prevention and enhance the safety of this population. Future research can further explore falls in the context of residential institutions for older adults.

Furthermore, this study contributes to the fulfillment of the United Nations Sustainable Development Goals [22]. This aligns with SDG 3's objective of ensuring healthy lives and promoting well-being for all ages. The use of the FRAT instrument can lead to early detection of fall risk, enabling timely interventions and the formulation of tailored prevention plans. Ultimately, this study supports the improvement of health outcomes and enhances the well-being of older individuals in residential institutions, thereby contributing to the achievement of SDG by United nations.

Author Contributions: Rodrigues and Furtado work on conceptualization, methodology, and writing - original draft preparation. Rodrigues and Direito work focuses on the methodological conception and was responsible for data collection. Brito-Costa worked on statistical analysis. Teixeira, Vaquinhas and Abreu assisted in the review, editing, coordination process and raised funding for the project. All authors have read and agreed to the published version of the manuscript.

Competing interests: *All authors declare that they have no competing interests.*

Acknowledgments: Guilherme Furtado" thanks the National funding by FCT- Foundation for Science and Technology, P.I., through the institutional scientific employment program-contract (CEECINST/00077/2021).

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Paper 2- Association of High Fear of falling with lower functional fitness status, higher cortisol, and lower DHEA levels in older women

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The following paper appears as Submitted for publication in BMC Geriatrics:

Abstract

Introduction: Fear of falling (FOF) is a common and natural phenomenon that most people experience during lifetime and is thought to be caused by a previous fall that possibly caused psychological trauma, resulting in the development of intense fear. Some other aspects can also contribute to increase the prevalence of this fear, such as dizziness, general health status, depression, and physical problems. However, the association between fear of falling (FOF) and salivary biomarkers such as Cortisol (COR), Testosterone (TT), Dehydroepiandrosterone (DHEA) and α-amylase, have not been consistently explored. A recent study showed that high levels of DHEA were associated with a lower fall risk, and a reduced rate of recurrent falls in older population, with greater influence in women. **Objective:** The purpose of this study was to explore the relationship between FOF, general health status, physical function, and salivary-related stress biomarkers in institutionalized older women. We hypothesize that older women with higher levels of FOF have lower levels of functional fitness, salivary TT and DHEA, and higher levels of salivary COR. **Method:** 178 older women were assessed and grouped as having Higher FOF or Lower FOF according to Falls efficacy Scale score**. Results:** The comparison between FOF subgroups showed that salivary levels of COR and DHEA were significantly different, as well the physical functions, and depression status. The correlation analysis significantly demonstrated a relationship between FOF and COR, DHEA, and physical functions. The regression analysis showed the influence of physical functions, DHEA, and depression status on FOF. **Conclusion:** Older women with a lower FOF seem to have higher physical performance, higher DHEA levels, and lower levels of stress. The possible influence of biochemical indicators appears to be novel in the literature.

Keywords: aging, fall risk, physical exercise, physical exercise, hormones.

Introduction

Fear of falling (FOF) is a common and natural phenomenon that most people, mainly the older ones, experience in varying degrees of severity (Legters, 2002). It can also be referred to as a phobia syndrome called basophobia and may be associated with astasia-abasia, or the fear of standing and/or walking (Suzuki, Ohyama, Yamada, & Kanamori, 2002). During the 1980s, it was thought that FOF was caused by a previous fall that caused some psychological trauma, and the fallers developed intense fear, not just of falling (Delbaere et al., 2010). It also affects walking and even standing, resulting in walking disorders (Rapp, Becker, Cameron, König, & Büchele, 2012). This was dubbed post-fall syndrome, and the FOF was found to be a key component of the problem (Murphy & Isaacs, 1982) .

Since then, FOF gained some attention as a health issue, specifically in older adults, as it was also observed in older adults who had not fallen yet (Friedman, Munoz, West, Rubin, & Fried, 2002). The prevalence of FOF varies from 20% to more than 80% in some individuals (Huang, Mao, Lee, & Chi, 2022), increases with age, and is more prevalent in women (Rebelatto, Castro, & Chan, 2007). Some other aspects can also contribute to increase this prevalence such as dizziness, health status, depression, physical problems (Huang et al., 2022). As a result, the risk of falls and FOF have a multifactorial origin (Arfken, Lach, Birge, & Miller, 1994; Nascimento et al., 2022; Wang et al., 2022).

Several health organizations consider the FOF a major health problem as it can be the leading factor to physical and psychosocial disturbances (Bull et al., 2020; Scheffer, Schuurmans, van Dijk, van der Hooft, & de Rooij, 2008). Many activities, such as regular physical exercise are avoided or restricted by older adults who are afraid of falling (Canning et al., 2015). Also, increase of FOF in advanced aging was associated to a progressive functional decline, and consequently decrease ability to perform instrumental and independent daily life activities (Choi, Jeon, & Cho, 2017; G E Furtado et al., 2019). It is important to note that these two types of activities require light, moderate, and vigorous levels of physical activity (PA) (Delbaere et al., 2010). As a result, reducing both instrumental and independent activities tends to compromise PA levels, and vice versa (Oliveira, Nossa, & Mota-Pinto, 2019).

Over the last few years, some researchers have identified new FOF related risk factors (Muanjai, Namsawang, Satkunskienė, & Kamandulis, 2022; Nascimento et al., 2022; Turnbull, Cherdsakul, Chanaboon, Hughes, & Tudpor, 2022; Wang et al., 2022). These factors include some non-modifiable characteristics such as sex, age and fall history (Lavedán et al., 2018; Park & Kim, 2017; Scheffer et al., 2008), as well as some modifiable risk factors that can be regulated through lifestyle interventions, primarily related to physical capacities such as gait and balance capabilities (Curcio et al., 2020). Psychological factors (i.e., depression, anxiety, stress) are were also identified as main FOF risk factors, and have the potential to increase the risk of falls in older individuals due to their inverted interaction with physical and functional health components (Park & Kim, 2017). As a result, some studies have found a strong link between FOF and physical function measures such as strength, gait speed, and balance in different and complementary ways (Brouwer, Musselman, & Culham, 2004; Deshpande et al., 2008; Rochat et al., 2010; Sapmaz & Mujdeci, 2021).

Despite the findings discussed above, the understanding of FOF, which is primarily related to physiological factors, has yet to be thoroughly investigated. The association between FOF and salivary biomarkers such as Cortisol (COR), Testosterone (TT), Dehydroepiandrosterone (DHEA) and and α-amylase (α-AMY), for example, have not been consistently explored. Increased exposure to COR levels influence in the vulnerability to some negative effects of this hormone related to stress on general health cognition (Karlamangla, Friedman, Seeman, Stawksi, & Almeida, 2013). Some authors also have found preliminary results suggesting that the diurnal COR cycle influence the hypothalamic-pituitary-adrenal axis, which is one of the main stress-related systems (Weller et al., 2014). Prefrontal cortex, which is known for its importance in decision-making and attention status related to executive functions, may also be affected (Funahashi, 2017).

The importance on several sensory-motor skills such as decision-making and attention, and its influence on fall risk have been explored in some studies (Cuevas-trisan, 2019; Filaire, Ferreira, Oliveira, & Massart, 2013; Sungkarat, Boripuntakul, Chattipakorn, Watcharasaksilp, & Lord, 2017). However, in addition to the influence of COR, α-AMY is a good measure of attentional demand, with a significant influence on postural control (Akizuki & Ohashi, 2014). As a result, this influence would cause physiological and neurological changes (Lupien, McEwen, Gunnar, & Heim, 2009), as well as a direct impact on mental and physical health, lowering the life satisfaction (Puvill, Lindenberg, De Craen, Slaets, & Westendorp, 2016).

Another study identified that high levels of cortisol were associated with falls and fractures in older populations (Greendale, Junger, Rowe, & Seeman, 1999), with cortisol also being characterized as an independent predictor for hip bone fracture (Izawa et al., 2022). Similarly, other researchers discovered that salivary α-AMY is an effective tool for assessing attention status, reaction time, and postural control (Akizuki & Ohashi, 2014). All of which are strongly associated with falls in the older population (Cuevas-trisan, 2019; Rodrigues et al., 2022). Other hormones, such as TT also showed relationship with falls (Benichou & Lord, 2016), primarily related to TT's influence on functional fitness and body composition (Bain, 2008), and showing influence on muscle strength and resistance (Orwoll, 2006).

The FOF is also related to TT levels, with a fear-reducing property in older people with higher levels (van Honk, Peper, & Schutter, 2005). On the other hand, low levels of TT were independently associated with the incidence of falls in older men (Kurita et al., 2014), and associated aspects related to fear (i.e., anxiety, motivation) also appear to have a relationship with TT levels, and influence the subcortical affective pathways of the brain (van Honk et al., 2005).

Some antiglucocorticoids showed effects on fear-conditions, the adrenal steroid DHEA appearing to act as one, apparently producing the same effect/pattern as an adrenalectomy (Fleshner, Pugh, Tremblay, & Rudy, 1997; Prall & Muehlenbein, 2018). In this sense, DHEA's action can influence not only fear-conditions, but it can also mediate memory and learning processes (Maninger, Wolkowitz, Reus, Epel, & Mellon, 2009; Sripada et al., 2013). Some researchers analyzed specifically the influence of DHEA in the health related fall's condition (Carrer et al., 2019; Ohlsson et al., 2018). A recent study identified that high levels of DHEA were associated with a lower fall risk, and a reduced rate of recurrent falls in older population, with greater influence in women (Carrer et al., 2019). Another, concluded that this reduction of fall risk may be related to some apparently influence of high levels of DHEA on muscle mass, muscle strength, and balance capabilities (Ohlsson et al., 2018).

Despite the few studies on these themes, recent studies have attempted to elucidate the relationship between maintaining physical-functional capacities and contributing to a good balance of COR, TT, DHEA and α-AMY levels (Guilherme Eustáquio Furtado et al., 2021; Marques et al., 2017; Rieping et al., 2019). Understanding the possible relationship between FOF, functional fitness, and salivary-related stress markers, on the other hand, may help health professionals identify which domains are more relevant and, as a result, propose more efficient interventions that will target the FOF more effectively. Therefore, the purpose of this study was to explore the relationship between FOF, physical-functional status and salivary-related stress markers in institutionalized older women. We hypothesize that older women with higher levels of FOF have lower levels of functional fitness, TT and DHEA, and higher levels of COR. Furthermore, we believe that some salivary markers have an influence on the existing relationships between FOF and functional fitness.

Material and Methods

Study design and sample

This study was a characterized as a prospective cross-sectional involving older population who live in social and health care centers (SHC) and is part of a study protocol previously published (ref.). An analysis of the statistical power of this study was performed on G*power 3.1.9.2 and the power was determined to be 0.99 (Faul, Erdfelder, Buchner, & Lang, 2009). The initial sample consisted of 319 participants (≥ 60 years old). After applying the inclusion and exclusion criteria, 141 participants were excluded for disability, mental disorder and hearing or visual severe deficit; need of palliative health care or special nutritional support; refused to participate (listed below). The final sample size analyzed consisted of 178 older women (Figure 01).

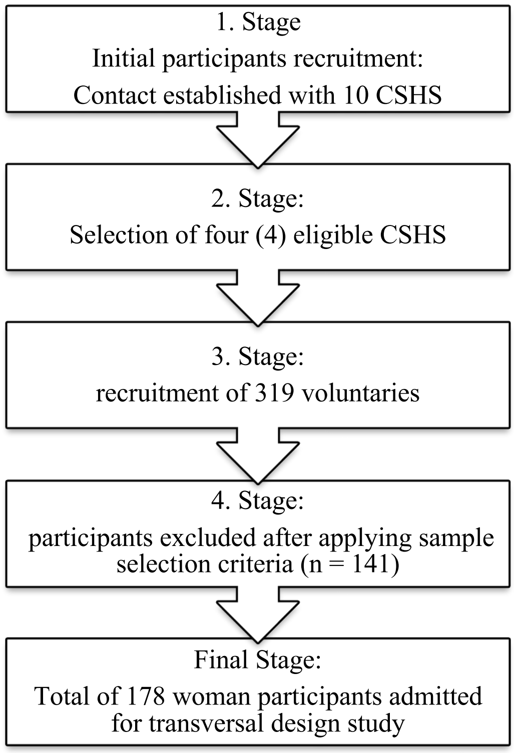

Figure 1 - Schematic diagram of study sample flow

Sample selection criteria

The participants were selected using a non-probability convenience sample based on the geographical area of Coimbra, Portugal and specific inclusion criteria were applied: a) women, b) aged over 60 years, c) living in the SHC, d) clinical condition/drug therapy controlled according to medical information, e) take part in the study spontaneously. Exclusion criteria were also applied: a) presence of any type of health condition (i.e., severe cardiopathy, hypertension, uncontrolled asthmatic bronchitis, musculoskeletal conditions) that might prevent testing, according to medical decision; b) severe cognitive impairment (mini-mental state exam score of 9 and lower) or clinical diagnosed with mental illness; c) morbid obesity (a body mass index of ≥ 40).

Ethical aspects

Consent forms were distributed and signed by the SHC's directors, all participants and their legal representatives. This study was approved by the Ethical Committee of the Faculty of Sport Science and Physical Education (Reference code CE/FCDEF-UC/0002020213), University of

Coimbra, and respected the Portuguese Resolution (Art. 4st; Law nº 12/2005, 1st series) and complied with research guidelines in humans of the Helsinki Declaration (Petrini, 2014).

Measurements

The quality of data was assessed using scores of internal consistency reliability (ICR). The FOF was analyzed centrally, and variables (sociodemographic, anthropometric, nutritional status, mental health, comorbidities) shown to be significantly associated with the FOF in previous studies (Pena et al., 2019) were considered as co-variates in the correlation and regression models due to the potential confounding effect that these variables could exert on the results (de Vries et al., 2011; Formiga et al., 2007). The indicators of physical-functional fitness, cognition and salivary biomarkers were analyzed as secondary outcomes.

Fear of falling

Tinetti Falls Efficacy Scale (FES) was used to measured fear of falling, where individuals are asked to rate, in a 0-to-10-points-scale, their concerns about the possibility of falling when performing 16 activities of daily life, that included, but not only, “cleaning the house”, “going to shop”, “walking around the neighborhood”, “visiting a friend/relative”, “walking on a uneven surface” (Tinetti, Richman, & Powell, 1990). The FES has been shown to have a good correlation with measures related to balance and gait capacities (Morgan, Friscia, Whitney, Furman, & Sparto, 2013) and has good power to predict falls and functional decline (Alves Marques-Vieira, Alves Caldeira Berenguer, Mota de Sousa, & Ribeiro de Sousa, 2018). The FES has also been shown to have a positive sensitivity to intervention targeting the fears of falling directly. The FES scores range from 10 to 100 points, with a lower score indicating a high self-efficacy and little fear of falling (Tinetti et al., 1990). Specifically, to analyze our sample, the modal value was identified and used to create two study subgroups: i) High FES, characterized by the ones who had more than 41 points in the FES, and ii) Low FES, characterized by the ones who had 40 or less points in the FES

Functional Fitness status (FFS)

To access the FFT, the Senior Fitness Test battery was used, and included the assessment of: i) lower body strength, determined by the '30 second's chair-and-stand test' (30s-CS), which measures the number of total stands from a chair that are completed in 30 seconds; ii) The upper body strength, determined by the '30 seconds arm-curl test' (30s-AC) that measures the total number of arm curls executed in 30 seconds; iii) The lower-body flexibility, determined by the 'chair sit-and-reach test' (CSR) that measures the distance in centimeters of the overlap or between the tips of the middle fingers when the arms are reaching up in the middle of the back as far as possible, iv) the upper-body flexibility (shoulder girdle), determined by the 'back Stretch' test (BST), that assesses the distance in centimeters of approach between the middle fingers when one hand reaching over the shoulder and one up the middle of the back; v) Agility and Dynamic Balance, determined by the '8-foot-up and go test' (FUG), that assesses the time needed for the subject to get up from the chair, walk as quickly as possible around either side of a cone placed 244 centimeters away and sit back down in the chair again; vi) aerobic resistance, determined by the "2-minutes step test" (2m-ST) that consisted in the number of full steps completed in two minutes, raising each knee to a midway point between the kneecap and iliac crest (Rikli, R.; Jones, 2013) . In addition, to have a more complete FFS, the Tandem Stance Balance test (TSB) was used to assess the static balance. This test consists of the subject maintaining the standing position with eyes opened and one foot in front of the opposite foot for a maximum of 30 seconds. The score of 10 seconds or less are indicative of very poor static balance (Cho, Scarpace, & Alexander, 2004). Three repetitions of each functional test mentioned above were performed and the best score was considered for analysis

Biomarkers of saliva samples

Saliva samples were collected between 10h00 to 12h00 am in order to avoid circadian effects. These were collected by passive drool for 2minutes, by allowing the participant saliva to collect on the mouth's floor, then dribble into a polypropylene tube. The participants were also instructed to wash their mouth with water 20 minutes before de sample collection to remove any kind of residues. Saliva samples volume was measured and samples stored at −20°C until further analysis. The determination of the salivary levels of COR, TT, and DHEA were done by competitive ELISA (Salimetrics UK, 2017), and the α-AMY was analysed by a kinetic assay (Salimetrics UK, 2017), according to the manufacturer instructions.

Sociodemographic

Sociodemographic information about chronological age (continuous variable); marital status (assessed as a four categories variable: single, married, widowed, and divorced) and educational level (assessed as a continuous variable) was collected by a questionnaire.

Anthropometric

Body mass weight was determined using a portable scale (Seca®, model 770, Germany) with a precision of 0.1 kilograms. Stature was determined using a portable stadiometer (Seca Body meter®, model 208, Germany) with a precision of 0.1 centimeters. Body mass index (BMI) was calculated according to the formula [BMI = weight/height^2]. The standardized procedures previously described were followed for screening anthropometric measures (Chumlea, W., Baumgartner, 1989).

Comorbidities and daily medication use

To assess the comorbidities the Charlson Comorbidity Index (CCI) was used. The CCI, is a method of predicting mortality by classifying or weighting comorbid conditions based on 19 comorbid conditions. The CCI score can be combined and/or adjusted with age and gender to form a single index. In the CCI, 1-point is added to its initial score to each 10 years, as was shown to predict 1-year and 10-year mortality (Charlson, Szatrowski, Peterson, & Gold, 1994).

To assess medication use, question number six of the Mini Nutritional Assessment (MNA), that asks the participant if she takes more or less than 3 prescription drugs per day (Guigoz, 2006) was used. To confirm medical use, the participants' medical records were provided by the health professional team in order to verify the accuracy of the information provided by the participants.

Reporting of polypharmacy was done according to the Portuguese Classification System of Human Medicine (M. Santos & Almeida, 2010).

Nutritional status

The Mini Nutritional Assessment (MNA) was used to assess nutritional status and consists of 18 questions which a 30-points maximum score. The MNA classifies the participants as: well-nourished subjects (24 to 30 points), at risk of malnutrition (17 to 23.5 points) or as malnourished (> 17 point) (Guigoz, 2006).

Mental health

The Mini Mental State Exam (MMSE) and Center of Epidemiologic Studies for Depression Scale (CES-D) was used to assess mental health. The MMSE assesses five areas of cognition (i.e., orientation, immediate recall, attention and calculation, delayed recall, and language) (Folstein, Folstein, & McHugh, 1975). MMSE was included because recent studies showed that low cognition profile can affect the trainability and consequently, affect significant gains in physical fitness (Uemura et al., 2013), and it is also related to falls (Muir, Gopaul, & Montero Odasso, 2012). The MMSE has a 30-points maximum score. A result below 24 points is already considered abnormal. The MMSE is also used for dementia and mild cognitive impairment (MCI) screening (Melo & Barbosa, 2015). The MMSE was used to classify participants according to the following cut off values: i) severe cognitive impairment(1 to 9 points); ii) moderate cognitive impairment (10 to 18 points); iii) mild cognitive impairment (19 to 24 points); and iv) normal cognitive status (25 to 30 points) (Mungas, 1991).

The CES-D is a 20-item scale and rates how often (past week), the participants experienced symptoms related to depression (i.e., poor appetite, loneliness, restless sleep), reflecting major facets of this state. The scale response ranges from 0 to 3 (0 = Rarely or None of the Time, 1 = Some or Little of the Time, 2 = Moderately or Much of the time, 3 = Most or Almost All the Time), and scores range from 0 to 60 with lower scores indicating lower depressive symptoms. The CES-D has a cut-off score of 16-point (Gonçalves, Fagulha, Ferreira, & Reis, 2014).

Statistical analysis

The assumption of normality was checked by using Shapiro Wilk tests and visual inspection of plots. Continuous data was described by their mean and standard deviation. In this study, the FOF (by FES) was assumed as a dependent variable. The comparison of continuous variables between the two FOF sub-groups was performed using T-Student or Mann-Whitney-U test, depending of assumption of data. Standardized differences between means for comparisons analysis were reported using Cohen’s d values, interpreted as follows: <0.20 (trivial), 0.20 to 0.59 (small), 0.60 to 1.19 (moderate), 1.20 to 1.99 (large), 2.0 to 3.9 (very large), and > 4.0, extremely large. (Batterham & Hopkins, 2006b). Spearman's rank correlations (SRC) and their partial corresponding were computed to test the association between FOF (continuous variable), salivary and physical fitness outcomes, controlling for the covariates that presented statistical differences in the comparison analysis. The FFS and SBM that exposed stability in significance after SRC controlling for covariates were taken from the regression analysis, respecting the statistical assumption (Jeong & Jung, 2016). A multivariate hierarchical stepwise regression analysis was used to explore the power of FFS, SBM variables to explain FOF variation, controlling for co-variates. The degree of the associations was discussed according to the magnitude of the correlations, which are understood as robust ($r = 0.7–0.8$), strong ($r = 0.5–0.7$), moderate (r from 0.3 to 0.4), small (0.1–0.2), and trivial ($r < 0.1$) (Batterham & Hopkins, 2006a). The software R 3.3.1 and IBM SPSS 22.0 were used for all statistical treatments. The statistical significance level adopted in this study was $p < 0.05$.

Results

Characteristics of the Participants

As shown in Table 1, a total of 178 female participants were evaluated. There were 76 participants with Higher FOF and 102 with Lower FOF among the 178 participants. The participants' average age was 81.94 (± 7.92) years. No statistical differences between groups for sociodemographic and anthropometric characteristics were found. In the general health assessment, significant statistical differences were also found for CES-D (p = 0.01, *ES* = 0.61) and MNA (p = 0.01, *ES* = 0.53) with strong *ES* for both variables. The group of higher FOF presented scores of 68.17 (±16.04) points, while lower FOF subgroup showed 24.06 (± 16.04) points. Regarding functional fitness variables, participants with Lower FOF showed better performance than those with Higher FOF in the 30-seconds seat-to-stand (p = 0.05, *ES* = 0.46), 30-seconds arm-curl (p = 0.04, *ES* = 0.52), 2-minutes step test (p = 0.05, *ES* = 0.38), Tandem Stance Balance (p = 0.03, *ES* = 0.39), and 8-foot-up and go tests (p < 0.001; *ES* = 0.54), with the magnitude of the *ES* ranging from moderate to strong. Salivary COR levels were higher in the High FOF (p = 0.01 with strong *ES* = 1.16) while the salivary DHEA levels were lower (p = 0.03, with moderate *ES* = 0.50). TT and α-AMY levels showed no significant differences between the groups.

Correlation Coefficients Outcomes

Keeping in mind that the FES is the central outcome (and dependent variable), figure 2 depicts the coefficients of the correlation matrix. In the functional fitness, the FOF scale showed a negative and small correlation with agility/dynamic balance assessed by the FUG test (r = - 0.202, p = 0.029); negative and moderate with 30-s CS (r = - 0. 331; p = 0.000), negative and small with and 2m-ST (r = - 0.212, p < 0.05), and negative and small with 30s-AC (r = - 0.260, p < 0.01). Regarding salivary biomarkers, FOF presented a negative and small correlation with DHEA (r = - 0.365, p = 0.033) and a positive and moderate correlation with COR (r = - 0.201, p = 0.031). For the other variables, no significant interactions were observed.

Table 1. Characterization of participants and comparison analysis by fear of falling subgroups for all studied variables.

	Total sample (n = 178)		**Higher* Fear of falling (n = 76)**		**Lower* Fear of falling (n = 102)**		***p*-value**	***Cohen's d ES***
Sociodemographic	M	SD	M	SD	M	SD		
Chronological age (years)	81.94	7.92	82.61	7.32	81.51	8.29	0.45	0.14
Level of education (degree)	3.66	2.74	3.52	2.88	3.76	3.05	0.66	0.08
Anthropometric								
Weight (Kilos)	65.46	12.63	66.42	14.16	64.84	11.61	0.52	0.12
Height (centimeters)	1.51	0.08	1.50	0.06	1.52	0.08	0.17	0.28
Body mass index	28.48	5.06	29.34	5.81	27.94	4.48	0.16	0.27
General Health Status								
Medication use per day (unit)	3.01	1.46	3.00	1.35	3.02	1.54	0.91	0.01
Charlson Comorbidity index (0-10 points)	7.44	1.84	7.82	1.55	7.19	1.97	0.07	0.35
Mini Mental State Exam (0-30 points)	19.64	5.49	18.60	5.83	20.30	5.19	0.12	0.31
Depression of CES-D (0–60 points)	21.93	8.03	24.86	8.55	20.05	7.12	**0.01**	0.61
Mini-nutritional assessment (0-30 points)	24.35	2.32	23.53	2.57	24.78	2.07	**0.01**	0.53
Falls efficacy Scale (0-100 points)	41.26	25.58	68.17	16.04	24.06	12.09	<0.001	3.10
Functional Fitness								
8-foot-up and go test	16.64	10.83	13.56	6.43	18.96	12.50	<0.001	0.54
Chair Seated and Reach (centimeters)	34.82	14.54	34.45	17.74	35.05	12.19	0.68	0.04
Back Stretch Test (centimeters)	48,31	22.23	44.80	17.65	50.20	24.55	0.16	0.25
30-seconds Chair Seated and Stand (per time)	8.55	3.55	7.54	3.82	9.19	3.23	**0.05**	0.46
30-second arm curl (per time)	10.72	4.29	9.41	3.63	11.56	4.49	**0.04**	0.52
2-minute step test (per time)	34,73	15.48	31.21	15.05	36.98	15.43	**0.05**	0.38
Tandem Stance Balance (seconds)	4,05	7.10	2.51	4.70	5.09	8.18	**0.03**	0.39
Salivary biomarkers								
Cortisol (µg/mL)	0.28	0.14	0.31	0.09	0.23	0.13	**0.01**	1.16
Dehydroepiandrosterone (pg/mL)	32.08	11.53	24.59	15.47	37.87	34.16	**0.03**	0.50
Testosterone (pg/mL)	65.22	29.59	61.83	27.92	65.38	30.60	0.32	0.12
α-Amylase (U/mL)	60.23	40.20	56.39	39.44	62.68	81.15	0.67	0.10

Notes: Depending on the data assumptions, the Student's or Mann-Whitney-U test was used to compare Fear of Falling Subgroups; M = mean; SD = standard deviation; ES = Effect size; CES-D = Center for Epidemiologic Studies for Depression

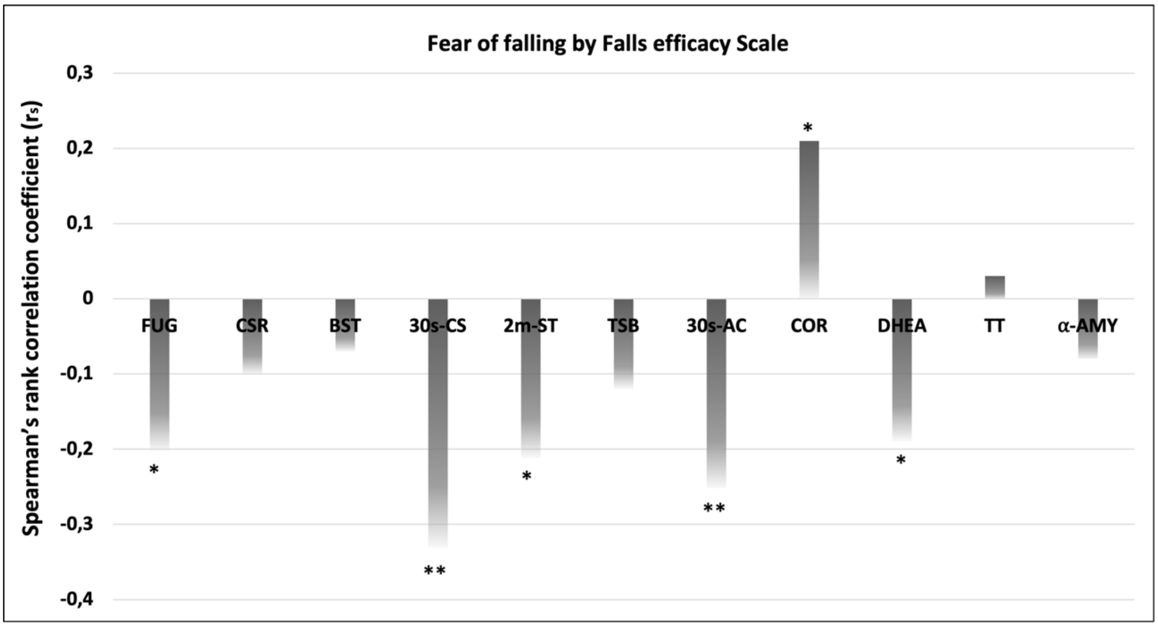

Figure 2. Spearman's Ranking Correlation among fear of falling by Falls efficacy Scale, functional fitness, and salivary biomarkers; significant for $^{**}p \leq 0.01$; $^{*}p \leq 0.05$; FUG = Eight foot-up and go test; CSR = Chair Seated and Reach; BST = Back Stretch Test; 30s-CS = 30-seconds Chair Seated and Stand; 2m-ST = Two-minute step test; TSB = Tandem Stance Balance; 30s-AC = 30 seconds arm-curl test; COR = cortisol; DHEA = Dehydroepiandrosterone; TT = Testosterone; α-AMY = α-Amylase.

Regression analysis

Table 2 presents a multiple linear regression analysis generated to assess associations between functional fitness and salivary biomarkers variables with FOF. Firstly, the multivariate models were built using a stepwise backward regression analysis. All FFS variables (FUG, 30s-CS, 2m-ST, 30s-AC) that showed statistically significant correlations with FOF were included in the first analysis. Following this statistical procedures, two statistically significant models emerged, however the model that included FUG (β = - 0.442; t = 9.148; p = 0.012; 95% CI: -0.842 – -0.002) and 30s-CS (β = - 1.664; t = 1.192; p < 0.001; 95% CI: -2952 – 0.376) tests was the one that better explained the 13% of FOF variance (F [2.114] = 5.365; $R^2 = 0.131$; $p < 0.001$).

Secondly, a model 2 was generated introducing nutritional and depression status by CES-D as a co-variate. The results showed two statistical significant models ($p < 0.001$). However, a change of the significant values for FFS variables occurred, and only the co-variate CES-D influenced significantly both blocks of adjusted model 2 ($p < 0.001$). Finally, the entry of the salivary COR and DHEA levels as a co-variate in model 3 did not change the significant values of both two blocks of adjusted model 3 ($p < 0.001$). However, DHEA demonstrated that it could outperform the FOF prediction within this model. Figure 2 shows the schematic representation of multiple regression analysis, in order to clarify the possible relationships between the indicators studied in the various models.

Table 2 - Multiple linear regression analysis among FOF, functional fitness and salivary biomarkers.

	Fear of falling*								
	Unadjusted model 1			**Adjusted model 2§**			**Adjusted model 3‡**		
	R^2	β	*p*	R^2	β	*p*	R^2	β	*p*
Block 1									
30-s chair seated-and-stand	0.06	- 1.690	0.012	0.16	- 0.907	0.175	0.09	- 0.213	0.021
Block 2									
30-s chair seated-and-stand	0.13	- 0.178	0.049	0.19	- 0.928	0.163	0.12	- 0.210	0.021
Eight- foot-up-and-go		- 0.442	0.012		- 0.294	0.164		- 0.179	0.047

Notes: *Falls efficacy scale; §Adjusted model 2 controlling for mini-nutritional status (MNA) and state of depression (CES-D); ‡Adjusted model 3 controlling for cortisol (COR) and dehydroepiandrosterone (DHEA).

Figure 3 shows the schematic representation of multiple regression analysis, in order to clarify the possible relationships between the indicators studied in the various models. The study of associations between FFS, subjective FOF, and the possible influence of salivary biomarkers appears to be novel in the literature.

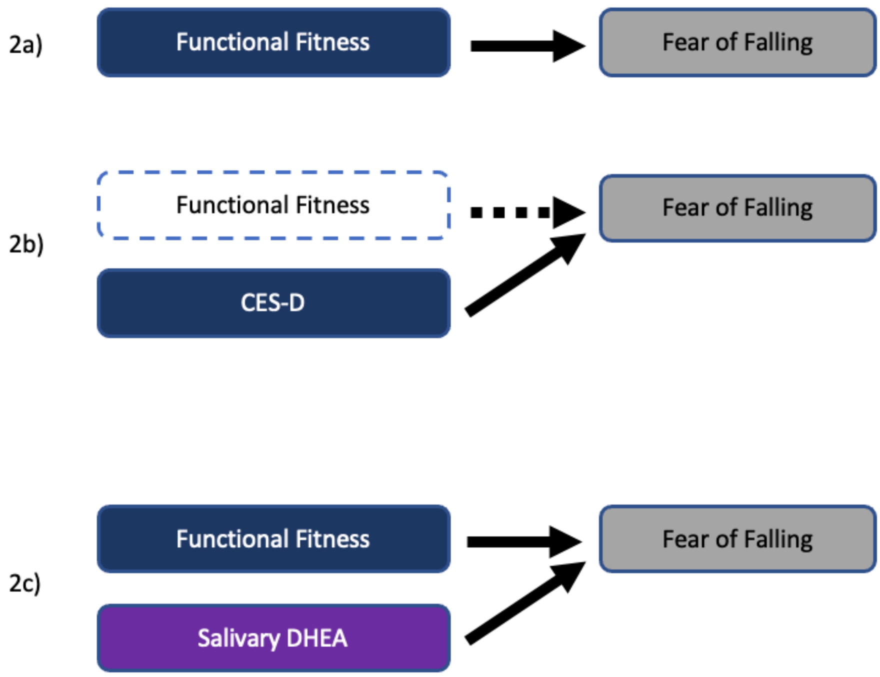

Figure 3 – Graphical representation of multiple regression analysis. 2a) Functional fitness variables predict variation in fear of falling independently; 2b) The insertion of covariates explains the impact of depressive state, which reduces the effect of functional fitness for insignificant values; 2c) The addition of salivary biomarkers as covariates had no effect on the predictive power of functional fitness indicators. DHEA, on the other hand, emerges as a contributing indicator to explain the FOF variation.

Discussion

Our study investigated the association between fear of falling assessed using the Falls Efficacy scale with general health indicators (i.e., Medication use, CCI, CES-D, MNA, MNES), functional fitness (i.e.,30s-ES, 30s-AC, CSR, BST, FUG, and 2m-ST), and salivary biomarkers (i.e., Testosterone, DHEA, cortisol, α-amylase) in a sample of older women. The study of associations between physical fitness indicators, subjective fear of falling, and the possible influence of biochemical indicators appears to be novel in the literature.

Subgroups Comparison

In the present study, our initial hypothesis was partially confirmed. We found significant differences between groups divided by the FOF (Higher FOF and Lower FOF) for the general health status (CES-D and MNA), for Physical Function (FUG, 30s-CS, 30s-AC, 30s-ST, 2m-ST, and tandem Stance Balance), and salivary biomarkers (i.e., cortisol and DHEA).

The association between FOF and the general health outcomes are in concordance with three previous related studies (Bjerk, Brovold, Skelton, & Bergland, 2018; N.-T. Chang, Chi, Yang, & Chou, 2010; Davis, Marra, & Liu-Ambrose, 2011), where differences and relationship around health-related quality of life and falls-related self-efficacy were found. Our study accounts for similar control variables and comparable results, including the unnecessary experienced fall of the participants. The study of Chang and colleagues included fallers and non-fallers, and FOF was analyzed by a simple dichotomic (yes/no) question (N.-T. Chang et al., 2010). Unlike our study and that of Davis and colleagues (Davis et al., 2011), they did not compare physical or psychological status. However, both studies showed that FOF was independently associated with almost all variables assessed, being an important factor related to quality of life and poor physical function.

These studies also significantly associated the physical functions, activities of daily life subscales related to quality-of-life assessments (i.e. FS-36, HRQOL) with hormones like DHEA and COR (Bjerk et al., 2018; J. Y. Chang et al., 2011; Davis et al., 2011). The association of FOF with DHEA, COR, and functional fitness outcomes where also found by Liu et al., (2018) and Smith et al., (2019), where older adults with a lower FOF demonstrated to have higher physical performance, higher DHEA levels, and lower salivary COR comparatively to older adults with Higher FOF.

In general, this present study found changes in general health status, physical fitness, and salivary biomarkers related to FOF in the sample evaluated. In this way, and based in recent meta-analysis (Lusardi et al., 2017; McKinnon, Connelly, Rice, Hunter, & Doherty, 2017; Oikawa, Holloway, & Phillips, 2019), interventional programs involving social integration, continuous and oriented physical exercise may be effective methods to counteract all the relations observed, reducing the cumulative effects of stress-related markers (i.e., cortisol), muscle quality and strength indicators (i.e., DHEA, 30s-AC), and general functional fitness levels (i.e., FUG, 30S-CS, 2m-ST) on physical, mental, and physiological health outcomes. Besides the differences between groups, relationships between the variables where also found.

Relationships and Associations

We also investigated the relationship between all the variables and found negative and significant associations (small to moderate) between FOF and physical fitness assessed by FUG, 30s-CS, 2m-ST, and 30s-AC. Associations between FOF and salivary biomarkers were also found between FOF and cortisol (positive-small) and DHEA (negative-small). A possible explanation for the small-to-moderate correlation coefficients may be related to the fact that FOF is caused by multifactorial causes (Alves Marques-Vieira et al., 2018) resulting from physical, psychological, and physiological factors.

Therefore, physical fitness indicators such as FUG, 30s-CS, 30s-AC and 2m-ST can influence the FOF. It is also important to highlight that some hormones such as DHEA and COR have influence on physical performance (Izquierdo et al., 2001; Ohlsson et al., 2018), besides the influence of COR on psychological (P. B. dos Santos, Kuczynski, Machado, Osiecki, & Stefanello, 2014), and physical condition outputs (Hsu et al., 2011). However, it should be noted that both indicators are part of a set of factors contributing to the increased/decreased FOF (Fleshner et al., 1997). Moreover, the analysis pointed to a positive and significant association between FOF and COR and a negative with DHEA, which is in line with previous studies (Maninger et al., 2009; Rieping et al., 2019; Sripada et al., 2013). On the other hand, we did not find a significant result between FOF and TT or α-AMY, even tough, the Lower FOF group had improved levels for these salivary biomarkers than the Higher FOF group, but not statistically significant.

Even though TT levels have been directly related to physical fitness performance in some studies (Kurita et al., 2014; Orwoll, 2006), when analyzing it alone, to see the possible correlation with FOF in our sample, no significance was found. This finding was highlighted by a low and nonsignificant correlation coefficient between FOF and TT, the same occurring between FOF and α-AMY (see Figure 2 for an overview).

Predictive Exploration Analysis

We also partially confirm our second hypothesis on the basis of the significant results revealed by the multiple linear regression analysis. Thus, except for the TT, α-AMY salivary levels and the stretches tests (CSR and BST) measures, all other tests proved to be FOF predictors. It was found that the higher performance of the physical fitness tests FUG, 30s-CS, 3s-AC and 2m-ST were associated with lower odds of FOF and, therefore, with a protective effect capable of reducing the felling of fear related to falls.

In the older population, physical capabilities such as gait speed, balance, and muscle strength are one of the most critical to maintain an independent life (Ramalho et al., 2018). Therefore, the indicators related to these capabilities are important, mainly to maintain stability (Wiesmeier, Dalin, & Maurer, 2015), and demonstrated to have direct influence on FOF.

The concept of stability itself is defined by the system's behavior related to minimal perturbations (Bruijn, van Dieën, Meijer, & Beek, 2009), therefore, after a disturbing situation, the system should be able to remain stable as it tries to recover the previous state of balance, in static or dynamic situations (Herssens et al., 2018). Thus, understanding the importance of gait speed and balance may help estimate the possible fall risk, and its influence on FOF, since they are very closely related (Nascimento et al., 2022; Osoba, Rao, Agrawal, & Lalwani, 2019).

Therefore, muscle weakness, mainly in the lower limbs, can potentiate postural instability, increasing the risk of falling (Cattagni, Scaglioni, Laroche, Gremeaux, & Martin, 2016), and consequently, increasing the FOF. However, although this suggests that muscle would be the main player related to body balance and stability, postural instability has multidimensional characteristics (Cuevas-trisan, 2019)c, as well as the fall risk (Rodrigues et al., 2022) and FOF (Nascimento et al., 2022).

This same pattern was observed for the salivary biomarkers DHEA, were association with lower odds ratio of FOF and a protective effect was found. Some studies have also linked DHEA with improvements in muscle strength (Ohlsson et al., 2018) and performance (Cherniack, Flores, & Troen, 2007). On the other hand, a high COR level was not significantly associated with an increase in FOF by multiple regression analysis in our sample. However, studies (Peeters et al., 2007) concluded that high levels of cortisol were negatively associated with physical performance in healthy older population, mainly explained by its influence on balance capabilities, which in its turn, and by this way, agree with our results, that demonstrated that COR levels were positively associated with FOF while physical function was negatively associated.

Another point to consider is that CES-D and MNA, although not showing correlations, were significantly different between groups, and in the regression model, CES-D (state of depression) significantly influence FOF. In this regard, studies (Caldo-Silva et al., 2021) highlight the psychological and nutritional importance for physical and physiological factors, mainly in older women, and this relationship regarding body balance, fall risk, and FOF should be further studied.

Limitations and future perspectives

Some limitations should be noted. First, because of the cross-sectional design, caution is suggested in generalizing the results regarding changes over time. Second, it is known that among older adults, physical activity levels are related to all physical functions outcomes, thus, considering that our analysis did not control the participants level of physical activity and that the sample was recruited from different locations in the region, older adults may have unequal physical conditions. Therefore, this may have resulted in further interindividual differences in the values of the variables studied.

Third and finally, although the FOF is known by its strongly association with the risk of fall (Asai et al., 2022), we did not evaluate the incidence of falls, nor considered the context of older adult mobility or cognitive functioning, so our results must be interpreted as correlations involving FOF, and should be used for basis of future studies.

Our findings may also provide important information to help understand the mechanisms related to older adults FOF and its relationship with hormones such as cortisol and DHEA, physical performance related to gait, balance, and muscle strength and power, as well as its influence on body stability, postural control, and cognitive status. Thus, our information can serve as a basis for comparative analyses of future studies. More research is needed to explore this issue, in order to contribute to not only to physical and mental well-being, but also to the maintenance of individual independence and autonomy.

Conclusion

This study was able to confirm several associations between physical performance variables, hormone salivary levels, and the felling of fear, specifically the fear of falling. The variables studied may also be a predictor of FOF when used alone. Moreover, the findings can help health professionals to organize and plan adequate interventional programs that may be capable of targeting, preventing or even minimizing the FOF, and consequently the incidence of falls itself and the sequelae related to it.

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Paper 3- Elastic Band Resistance Training on Multiple Description Fall Risk, Power Outputs, Body Composition and Cognitive Status in Older Fallers with Mild Cognitive Impairment: A 40-week Controlled Trial

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The following paper appears as Submitted for publication in Sports Medicine - Open:

This paper's partially results were presented in the following Congress:

Rodrigues, R.N.; Caldo, A.; Silva, F.; Furtado, G.; Neves, R.; Abreu, C.; Teixeira, A.M. (2021) Efeitos do exercício físico e da suplementação com aminoácidos de cadeia ramificada (BCAA) na composição corporal de mulheres idosas institucionalizadas. School of Education of Viseu, Portugal; ACES ACES Dão Lafões (Org.). Proceedings of the "5o Congresso de Envelhecimento Ativo: Atividade Física e Saúde"; 2021 Feb 27; Virtual Congress (Anexx A).

Abstract

Background: Physical inactivity will potentiate muscle function and mass loss, leading to an increase in the number and risk of falls in the older population. Still, it is accepted that regular exercise programs can benefit older persons, preventing and reducing the speed of muscle loss and the evolution of cognitive decline and aging-related comorbidities, consequently contributing to and possibly decreasing the risk of falling. However, the fall risk process involves multiple causes, so a multifactorial assessment should be done. **Objective:** to investigate the effects of a 40-weeks training-detraining-retraining intervention based on elastic band resistance training (EBRT) on fall risk and cognitive status in older fallers with mild cognitive impairment living in nursing homes. **Methods:** The study consisted of a prospective nRCT with two arms of EBRT intervention, and experimental (intervention-wash-out-intervention) design. The participants (≥70 years old) were divided into two groups: i) EBRT group (n = 20), and no-treatment control group (n = 22). Cognitive profile, body composition, muscle power outputs and multifactorial Fall Risk screening [(physical: Timed Up-and-Go Test; psychological: Fear of falling by Falls Efficacy Scale (FES), and multidimensional Fall Risk Assessment Tool (FRAT); base-technology sensorimotor: posturographic platform)] were concomitantly evaluated at four different time-periods: baseline (T1), after 16 weeks of intervention (T2), after a subsequent eight weeks of detraining (washout period, T3), and finally, after an additional 16-week intervention (T4). **Results:** At baseline, significant correlations between muscle power, fat-free mass and cognitive status with 3 fall risk assessments (FRAT, FES and TUG) was found, making them good predictors/indicators for fall risk. Improvement of muscle power, body composition, cognitive profile and fall risk status were found for the EBRTG after both exercise interventions periods. After the detraining phase, protective effects of exercise were also observed. **Conclusion:** Overall, the study showed that EBRT triggered significantly alterations in the participants fall risk assessment by improving muscle power, body composition and cognitive status, which could provide independence and higher quality of life for this population. Trial registration number NCT04376463. Registered 13 April 201, https://www.clinicaltrials.gov/ct2/show/NCT04376463?cond=NCT04376463&draw=2&rank=1.

Keywords: Resistance Training, Fall Risk, Aging, Cognitive Impairment, Muscle Power; Innovative base-technology assessment.

Key Points

1. Elastic-Band Resistance Training reduces fall risk, and concomitantly tends to improve cognitive status in older persons.
2. Interventions focused on fall risk prevention should include balance-challenging static and dynamic strength physical exercise
3. In order to prevent/reduce fall risk, the exercise training should be regular.

BACKGROUND

The increased life expectancy is changing the dynamic and progression of aging. Functional, hemodynamic, morphological, and psychological changes associated with aging reduce the individual's functional and cognitive reserve leading to an increase in the vulnerability to internal and external stressors and age-related disease (1). Around 67% of older adults are sedentary (2,3), which potentiates the early development of neurodegenerative diseases and the loss of muscle mass, strength, and power, which are associated with the development of sarcopenia and dynapenia (4,5), and strongly related to physical and cognitive frailty (6). All these changes increase the risk of disability in older individuals, decrease mobility, raise hospitalization rates, and even escalate death risk, with falls events often a direct contributing factor (7,8). Also, low physical capacities such as low gait speed and loss of muscle power are common and strongly associated with fall risk (8–10). Muscle power (speed x strength) and postural sway are two of the determinants of fall risk and are also related to reduced mobility (11,12).

In the same way, the central nervous system and, in consequence, cognitive functioning also face changes as people get older, with almost 100% of older adults aged 80 and over showing some sensorial (i.e., hearing, vision) impairment, and at least 15% of them, aged 70 and over, being diagnosed with dementia (13). Some studies (14) also show that losses in the neuronal system, including loss of neurons can start as early as the third decade of life. These losses can result in cognitive performance decline, with some cognitive functions more susceptible to senescence (i.e., attention, memory, and executive functions) (3,15), key components linked to daily living activities' impairment (16). Several studies (17,18) have shown associations between cognitive functions and several functional capacities, such as balance and gait speed, as well as between postural control and stability, which may increase the number and risk of falls (18). However, other associations between cognitive status and muscle power or postural stability assessed by multidimensional fall risk tests, are less studied (1).

Besides, postural stability is a very complex skill that depends on both cognitive and sensorimotor systems. The sensory and motor systems are necessary to perceive the environmental stimuli (its condition) and to respond (as fast as possible) to possible perturbations of body control movement (19,20). It is connected to neurological processes and cognition that are required in order to improve attention, plan movements, and respond to changes within the environment (21,22).

Previous research (2) has shown that physical exercise plays a role in retarding and reducing certain aspects of aging linked to postural stability, muscle power, cognitive abilities, anxiety and depression, and fall risk in older adults. It has been shown that physical exercise can attenuate cognitive deterioration processes, their evolution and rate of occurrence, and in some cases, even reverse them in some ways (23–25). Recent studies (26,27) have demonstrated that cognition has a crucial role in maintaining and regulating balance and gait capacities demonstrating that several cognitive domains, including attention, visuospatial ability, and memory, can contribute to falls (3,28,29), with exercise consequently decreasing the fall risk among older adults (10,24,30).

Several studies have shown that resistance training (RT) increases muscle mass, gait speed, and strength capacities in institutionalized older adults, and different and specific protocols have been used to elicit these possible beneficial effect of physical exercise on body composition, muscle power, and fall risk (2,31–33). Therefore, it is not surprising that people with mild cognitive impairment (MCI) have poor balance, gait disorders, and a high incidence of falls (34). A recent study showed improved results in cognitive functions in seniors on an aerobic training program (35). On the other hand, resistance training improve body composition as it increases muscle mass, and strength capacities in institutionalized older adults (23,36) and may positively influence cognitive abilities, functional performance and frailty status (3).

In order to attend to this specific population, different protocols have been used to show the possible beneficial effect of exercise training on physical and cognitive frailty (2,31,32). However, there are still doubts about the training protocols to be used and the follow-up periods, as well as about the detraining effects, important to evaluate if the effects of the interventions after their end, and how it impacts or not, the cognitive function and fall risk.

Considering this scenario, the present study aimed to evaluate the effects of a 40-weeks- (training-detraining-retraining) elastic band resistance training (EBRT) intervention on cognitive status, body composition, power output, and fall risk using multidimensional assessment methods in older fallers with cognitive impairment. Our research group hypothesised that exercise will positively influence muscle power, body composition, and cognitive status, and that this improvement will be reflected in a possible reduction in the fall risk outcomes assessed by multidimensional methods. Also, we believe that the inclusion of a detraining phase through the withdrawal of the exercise program will allow the study of the protective effects of regular exercise.

MATERIALS AND METHODS

Study Design

This is a 40-week prospective, naturalistic, controlled clinical trial (treatment vs. care) involving both sexes of institutionalized fallers with mild cognitive impairment. This study was divided into 3 phases (i.e., training, detraining, and retraining conducted between January 2019 and January 2020 using a two-group design and four repeated measures. As figure 1 shows, the evaluation took place in four moments: baseline assessment (pre-intervention, T1); after sixteen weeks of exercise training (post-intervention I, T2); after eight weeks of detraining (exercise training withdraw, T3); and after sixteen weeks of exercise training in the second period (post-intervention II, T4).

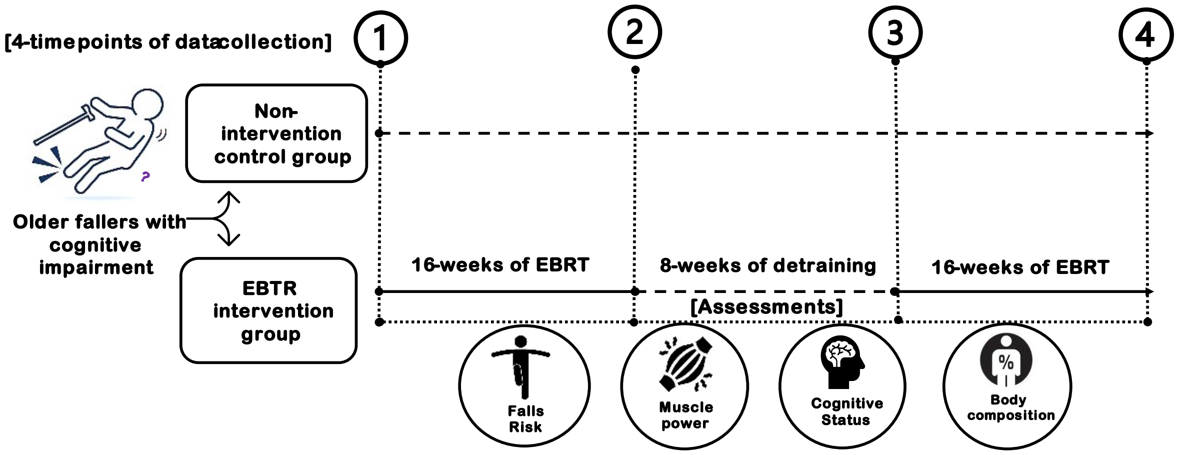

Figure 1. Graphical representation of the study design.

Participants' selection criteria and settings

Potentially eligible participants were institutionalized-dwelling older adults living in healthcare and social support centers (HSC) in the city of Coimbra – Portugal, and surrounding areas. Suitable HSC were contacted first by telephone and e-mail, and a presential meeting with the HSC's director/representative was appointed for the ones that had interest, followed by a meeting with the possible participants, where the first screening (eligible criteria) was done.The eligibility criteria at the time of first screening were: (i) having a history of one or more fall between the last three to twelve months, determined by the Fall risk assessment tool (FRAT) (37,38); (ii) having a score less than 22 points (mild cognitive impairment) on the MOCA's assessment of cognitive profile (39)); (iii) 70 years or more; (iv) clinically stable with their drug therapy updated; (v) being able to perform the Timed Up and Go test in ≤50s, indicating mobility independence (40); (vi) not having participated in other structured exercise intervention in the last six months; (vii) not presenting any type of health condition or use of medication that might prevent the test performance (such as severe cardiopathy, uncontrolled hypertension, uncontrolled asthmatic bronchitis or severe musculoskeletal conditions) and/or attention impairment; (viii) not presenting mental, hearing or visual impairments that could prevent the evaluations and activities proposed, according to the institution medical staff; (xv) not presenting morbid obesity (BMI ≥ 40 kg/m^2).

Participants assigned

The estimated sample size was calculated using G*Power software, version 3.1.9.7 (41). Based on our calculations, for an effect size of 0.30, a sample size of 26 achieves 95% statistical power to detect differences among the means using an ANOVA test with an α-level of 0.05. We have employed a non-probability convenience sampling of 42 older adults (14 men, 28 women; 84±6.08 years old) living in social support centers. Consent forms were distributed and were signed by the institution's directors and the older adults or their legal representatives before testing and intervention. The participants were assigned and distributed into two groups: the Elastic Band Resistance Training group (EBRTG, n= 20; women = 15; men= 5) that performed an elastic band resistance training (EBRT) program, and a control group (CG, n= 22, women = 13; men= 9), who received the usual care. The exercise program consisted of 16 weeks of EBRT program + 8 weeks of detraining + 16 weeks of EBRT program. Both first and second EBRT interventions were divided into 32 sessions each, with two sessions (duration: 45 min) per week on non-consecutive days. The Transparent Reporting of Evaluations with Nonrandomized Designs (TREND) was followed to guide this study purpose (42).

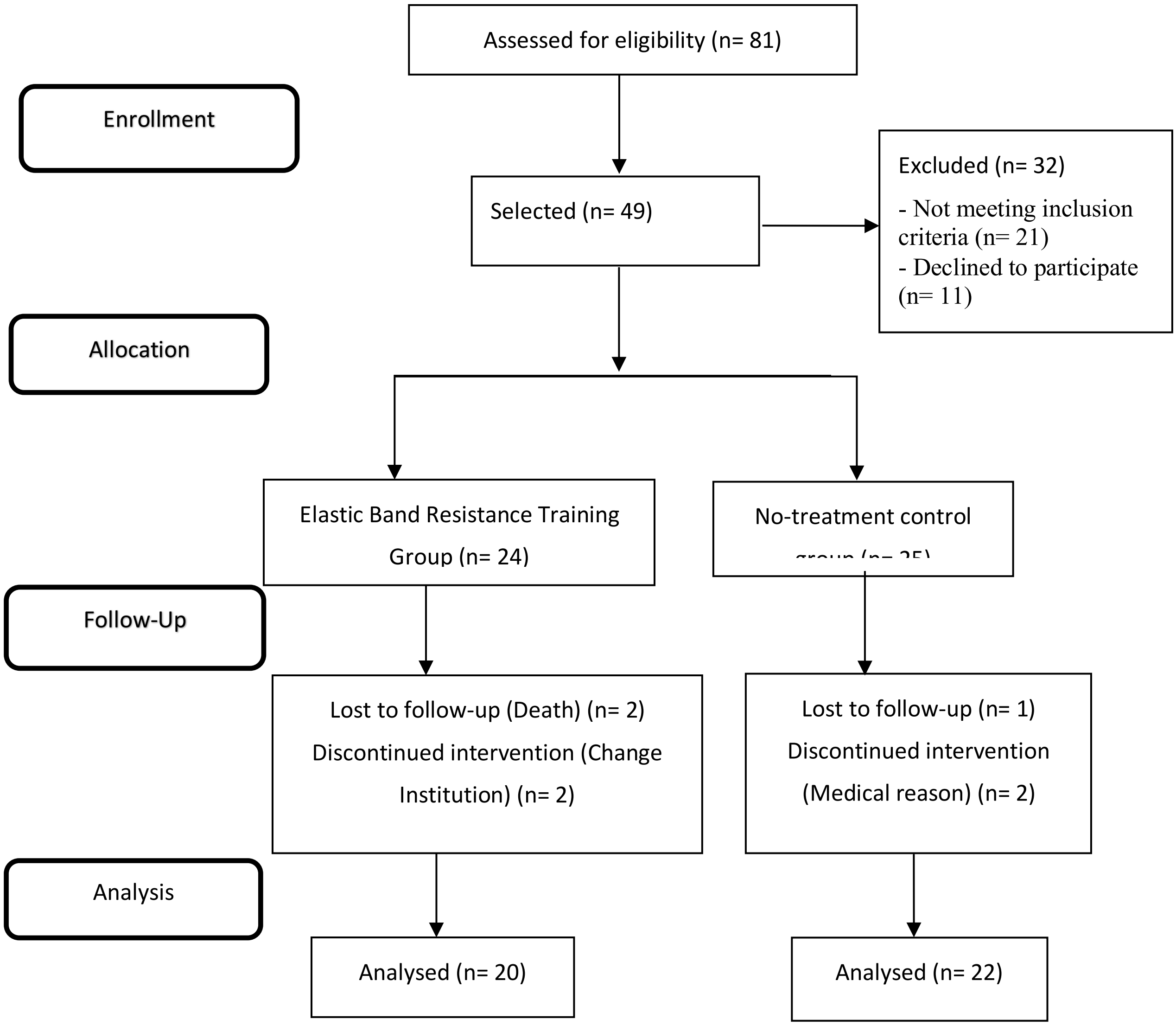

Figure 2. Flow Chart of Study design

Ethical statement

This study was approved by the University of Coimbra, Faculty of Sport Science and Physical Education Ethical Committee (reference number: CEFCDEF/0028/2018), respecting the Portuguese Resolution (Art. 4^{th}; Law no. 12/2005, 1^{st} series) on ethics in human research (Braga, 2013), follows the guidelines for ethics in scientific experiments in exercise science research (44), and complies the Helsinki's Declaration (45). This study was registered adequately on clinicaltrials.gov, registration code NCT04376463.

INTERVENTIONAL PLAN

Elastic Band Resistance Training Exercise Protocol

The EBRT programs were all supervised by an exercise expert, consisting of planned and organized exercises performed with a chair to help ensure the safety of the participants. Exercise prescription was adjusted according to the American College of Sports Medicine (ACSM) guidelines, and training was periodized according to the exercise prescription guidelines for older adults (46,47). During the exercise programs, participants internal load was monitored with heart rate monitors (Polar, model M200, Polar Electro Oy, Kempele, Finland) and rate of perceived exertion (RPE) with the Borg scale (0-10) (48). Participants completed two sessions of 45 minutes per week, separated by at least 48h between sessions for 16 weeks and 16 weeks more after eight weeks detraining period. The EBRT program consisted of 7 to 10 exercises per session of progressively increased intensity, employing elastic bands of TheraBand®. Intensity progression was fixed according to the OMNI table which has a specific relationship between elastic band colour (progression) and RPE (25). Each session was divided into 3 phases, namely: warm-up (5 minutes), exercises with an elastic band (35 minutes), and cooldown/stretching (5 minutes).

The exercise protocol consisted initially of 2 sets of 10-20 repetitions performed using a light intensity band during the adaptation period and progressing gradually in sets, repetitions, and to a higher intensity elastic band each 2 to 3 weeks. For the last four weeks, besides the exercises with Thera-band®, some free weights were added in a circuit format, which allowed for a more intense and diversified range of exercises. The exercise program dynamics consisted of engaging muscle groups alternated, with the approximate cadence of 2 second- concentric phase, and 3 second- eccentric phase. All the EBRT program was conducted with specific music to help keep the exercise cadence (49). Music was chosen according to the participants taste and used to increase adherence, make them comfortable and attracted to the exercise program. We opted for days such as Monday and Thursday, or Tuesday and Friday, for the interval between weekly sessions to be as close as possible and to try to minimize possible errors allowing for an appropriate recovery of the subjects. A total of 64 sessions were offered (32 in the first training period and 32 in the retraining period), and the adherence values in different moments were reported as a percentage. An adherence of 80% or more was necessary to include the participant in the analysis.

Detraining-retraining period

Our study design included an 8-week detraining period, with detraining defined as the suspension of the exercise program. The exercise program was stopped, and the participants were instructed to return to their normal routine (which previously did not include any professionally supervised physical activity). After the 8-weeks of detraining, the retraining started for another 16-weeks following the same program explained above, including the possibility of continuous exercise-load (elastic band) progression.

No-treatment control group

Participants from CG were not exposed to any experimental manipulation or intervention. However, the HSC has its own schedule of activities for all its patients but did not include any kind of oriented physical exercise program.

OUTCOME MEASURES

The older participants completed all assessments between 10 am, and 11:45 am to avoid possible bias. To reduce differences in data collection procedures all functional fitness tests were carried out by two researchers, while the questionnaires were administered by a single investigator in a face-to-face setting. The exercise session instructors did not participate in the data collection procedures. By staggering the class schedule, it was possible to avoid interaction between individuals from the physical exercise group. The research team conducted all of the tests and made contact with the participants without mentioning the exercise program.

Fall Risk Assessment

Falling, is generally known to be caused by various risk factors (21), and therefore, in order to identify the fall risk in a more diverse way, the fall risk assessment included four specific tests.

Sensorimotor assessment

This is an innovative and base-technology testing protocol that measured 45 seconds of static balance in 4 pre-established conditions. Each participant stood barefoot on a stabilometer board (Physiosensing v19002, Sensing Future®, Coimbra, Portugal) without moving in an upright position and directing their gaze to a point located 2 meters away (20,37). Four conditions were used to evaluate the influence of the visual and proprioceptive information: a) Comfortable stance with eyes open (CSEO); b) Comfortable stance with eyes closed (CSEC); c) Narrow stance with eyes open (NSEO); d) Narrow stance with eyes closed (NSEC).

The oscillation speed index value for each condition obtained was recorded as well as the speed index value, which was calculated as a value based on the velocity (i.e., distance travelled in the sagittal plane divided by the test time, 45 seconds, units: mm/s) and the participant height, normalized by the natural logarithm function. This quantification of the participant postural sway velocity is used to predict the risk of fall since sway velocity can be described as the speed of an individual's center of gravity sway as the balance is maintained (37), thus higher velocities are indicative of postural control deficits when indications are given to be as stable as possible.

A "composite velocity" (i.e., mean velocity for all four conditions) is calculated to represent fall risk prediction. Therefore, the results are interpreted as higher scores indicating higher fall risk. The Physiosensing Fall Risk test protocol was based on research from the University of Dayton (38) and the University of Jyväskylä in Finland (37).

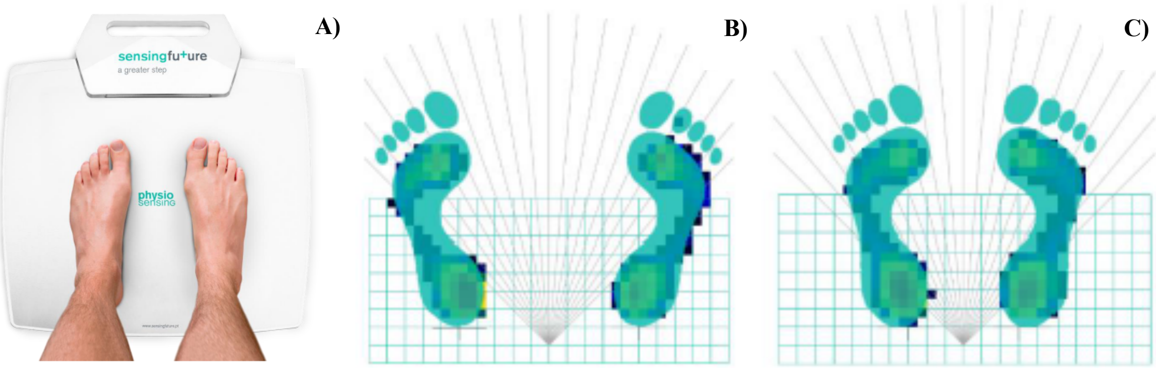

Figure 3. Illustration of Physiosensing v19002® balance and plantar pressure platform (A) with example of foot position and computer interface of Fall Risk protocol at comfortable (B) and narrow stance (C). Retrieved from Sensing Future - Technology for Healthcare, Physiosensing v19002 manual.

Fall Risk Assessment Tool - FRAT

The FRAT-p is a paper-based 4-item fall-risk screening tool for sub-acute, residential and HSC individuals (50). It has four fall risk specific sections: i) recent falls, ii) medication, iii) psychological indications, and iv) cognitive status assessed by the Abbreviated Mental Test Score (51). All the sections are based on specific scoring related to each specific domain. The overall score ranges from 5 to 20, where 5 to 11 indicates lower fall risk, 12 to 15 indicates moderate fall risk, and 16 to 20 higher fall risk. The assessment also has an "extra question/statement" that has 2 possible checkboxes. These statements are i) recent change in medication that directly affects the secure mobility, and

ii) dizziness/postural hypotension. If some of them are checked, it indicates automatically higher fall risk (50).

Timed Up-and-Go Test – TUG

As the prevalence of abnormal gait speed increases with age, and is one of the most common indicator of fall risk in older adults (21), a specific test to evaluate this capacity was be performed. The timed up-and-go test (TUG) consist of the timing of the completion of the following task: the subject starts in a seated position, stands up upon command, walks 3 meters, turns around, walks back to the chair, and sits down. The time stops when the person is seated. The use of an assistive device is allowed, but it must be documented (52).

Fear of falls by Fall Efficacy Scale – FES

The Portuguese version of FES contains questions about the perception of falling during the performance of ten daily activities (53). The older adult confidence to perform the activities without falling is represented on a 10-point scale ranging from “no confidence” (1 point) to “completely confident” (10 points). The score of the FES is the sum of the scores obtained in each of the ten items. The minimum score possible is 10, and the maximum is 100, and lower scores indicate higher fear of falling/fall risk (54).

Cognitive Status

The Portuguese version of Montreal cognitive assessment (MoCA) was used to assess cognitive status (39). MoCA consists of a one-page protocol whose application time is approximately 10 minutes of a cognitive screening test designed to assist health professionals in the detection of mild cognitive impairment (MCI). This tool assesses short-term memory, visuospatial abilities, executive functions, attention, concentration, working memory, language, and orientation to time and place. Participants can obtain from 0 to 30 points. This test can assess several cognitive domains and has been proved to be a valuable tool for screening many illnesses. In this study, the MoCA score refers to the total gross score without correction by educational level since all the population screened had the same educational level (55).

Muscle Power

We estimated muscle power by the equation proposed by Alcazar et al. (56) that employs data from the five times sit-to-stand test (5xSTS) (57). The 5xSTS consists of sitting and standing five times on a standardized armless chair (height: 0.49 meters). After the command to start, the participants performed these five repetitions as fast as possible, from sitting to knee extended standing position, with arms crossed over the chest. The test finished when they sat on the chair after the fifth repetition. The time recorded, the repetitions done, the chair height, and the body mass and height of the participants were used to calculate STS mean velocity, STS mean force, STS mean power, and the relative STS mean power (68, 69):

$$\text{STS mean Velocity} = \frac{(Height\ x\ 0.5 - chair\ height)}{STS(time)\ x\ 0.1}$$

$$\text{STS mean Force} = Body\ Mass\ x\ 0.9\ x\ g$$

$$\text{STS mean Power} = \frac{Body\ mass\ x\ 0.9\ x\ g\ x\ (Height\ x\ 0.5 - chair\ height)}{STS(time)\ x\ 0.1}$$

$$\text{Relative STS mean Power} = \frac{0.9\ x\ g\ x\ (Height\ x\ 0.5 - chair\ height)}{STS(time)\ x\ 0.1}$$

$g = 9.81 m/s^2$

Anthropometric and Body Composition Assessment

The participants body mass was determined using a portable scale (Seca®, model 770, Hamburg, Germany) with 0.1 kg of precision. Height was determined using a portable stadiometer (Seca Body meter®, model 208, Hamburg, Germany) with 0.1 cm of precision. Body mass index (BMI) was calculated according to the formula (BMI = body mass/height^2). Percentual of Fat mass ($FM_{\%}$), and percentual ($FFM_{\%}$) and kilogram of fat-free (FFM_{kg}) mass were assessed by tetrapolar bioimpedance (Akern®, model BIA 101, Berlim, Germany).

Sociodemographic screen

Sociodemographic information such as age, sex, educational level, and marital status was collected and the ones that showed significant difference between groups were added as covariables in the statistical analysis. Age was treated as continuous variable, sex was based on individual self-identification (female and male), educational level was assessed according to Portuguese Education System (58), and the marital status was defined as a binary variable (yes or no answer).

Statistical analyses

The normality was previously verified by the Shapiro-Wilk test and were logarithmically transformed when appropriate. The descriptive data at baseline (T1) and its follows-up (T2, T3, T4) assessments are presented as mean and standard deviation (SD). Intercorrelation and multiple regression models were used to identify possible mediators on the fall risk indicators. To compare baseline and post-intervention data, repeated measure ANOVA (2x4, group vs. moment) and repeated measures mixed models were performed with pre-values as covariable. Post-hoc test was performed for paired comparisons of means, with Holm-Bonferroni correction, and the delta percentual of variations, when significant interactions were found. The magnitude of intercorrelation and the pre-post interventions Cohen's *d* (effect size, *ES*) measures was classified following the standards: trivial [$r \leq 0.3$]; moderate [$0.3 < r \leq 0.5$]; strong [$0.5 < r \leq 0.7$], and robust [$r \geq 0.7$] (59). An alpha level of 0.05 was used in all analyses. For all statistical analyses the Statistical Package for the Social Sciences version 24.0 was used (Armonk: NY, IBM Corporation).

RESULTS

A total of 42 participants were screened and followed all the intervention, completing the 40-weeks trial. The simple effects analysis of baseline values revealed that the EBRT and CG groups were very similar and did not present significant differences in almost all assessed variables of sociodemographic, anthropometric, cognitive status, Fall Risk screen (incidence of falls, sensorimotor index), and body composition ($FM_{\%}$, $FFM_{\%}$, FFM_{kg}). However, the TUG ($p = 0.018$) and FRAT ($p = 0.004$) assessments revealed statistical differences between groups, with the EBRTG obtaining high scores marks than the CG for both variables (Table 2).

Table 1. Baseline characteristic of the participants and its initial comparisons

Variables	EBRTG M(SD)	CG M(SD)	p value
	N = 20	N = 22	
SOCIODEMOGRAPHIC			
Male	5 men	9 men	
Female	15 women	13 women	
Chronological age (years)	83.5 (5.2)	81.2 (7.2)	0.192
ANTHROPOMETRIC			
Height (meters)	1.56 (0.77)	1.56 (0.10)	0.128
Weight (kilos)	69.2 (2.8)	68.1 (2.7)	0.785
Body mass index	28.3 (1.0)	28.0 (1.0)	0.882
MUSCLE POWER			
aPower (watts)	91.4 (35.1)	83.2 (37.6)	0.467
rPower (watts/kilos)	1.30 (0.4)	1.18 (0.39)	0.336
FALL RISK			
Incidence of falls (last 3 to 12 month)	1.45(0.51)	1.57(0.59)	0.426
FRAT (05 to 20 points)	8.40 (2.08)	10.45 (2.3)	0.004*
FES (10 to 100 points)	74.15 (14.67)	62.45 (23.13)	0.06
Sensorimotor (index)	9.55 (2.56)	10.5 (2.1)	0.193
TUG (per time, seconds)	10.92 (6.54)	15.15 (4.47)	0.018*
COGNITION			
MoCA (0 to 30 points)	17.95 (3.83)	16.9 (4.37)	0.419
BODY COMPOSITION			
FFM_{kg}	45.14 (7.62)	46.84 (9.88)	0.395
$FFM_{\%}$	66.36 (9.35)	68.55 (7.10)	0.539
$FM_{\%}$	34.6 (13.28)	31.45 (7.08)	0.337

Notes: M = Mean; SD = standard deviation; EBRTG = Elastic Band Resistance Training Group; CG = Control Group; aPower.= Absolute Muscle Power in watts, rPower = Relative Muscle Power in watts/kg, FRAT= Fall Risk Assessment Tool, FES= Falls Efficacy Scale, Sensorimotor= Posturographic platform, TUG = Timed-up-and-go Test, MoCA = Montreal Cognitive Assessment, $FM_{\%}$ = fat mass in percentage, $FFM_{\%}$ = percentual of fat-free mass, FFM_{kg}= fat-free mass in kilogram. *The mean difference is significant at the 0.05 level

In order to identify possible interactions between the fall risk variables (FRAT, FES, Sensorimotor and TUG) and the muscle power outputs (aPower and rPower), cognitive status (MoCA), and Body Composition status of FFM_{kg}, $FFM_{\%}$ and $FM_{\%}$, a Pearson intercorrelation test with baseline data was also performed. For the FES, we found a moderate correlation ($r = 0.32$, $p < 0.05$) with FFM_{kg}, a strong correlation with rPower and aPower, of $r = 0.55$ ($p < 0.01$), and $r = 0.54$ ($p < 0.01$), respectively. A robust correlation with MoCA ($r = 0.77$, $p < 0.01$) also were found. For the FRAT, the muscle power outputs showed an inverse correlation of $r = - 0.46$ ($p < 0.01$) and $r = - 0.48$ ($p < 0.01$) for aPower and rPower, respectively. A moderate and inverse correlation ($r = 0.35$, $p < 0.05$) with FFM_{kg}, and a strong inverse correlation with MoCA ($r = 0.58$, $p < 0.01$) were found. TUG also showed significant inverse and moderate correlations with aPower ($r = - 0.41$, $p < 0.01$), rPower ($r = - 0.49$, $p < 0.01$), and MoCA ($r = - 0.38$, $p < 0.05$)

After the intercorrelation analyses, supported by the evidence presented, these four variables were included, in the multiple regression models to identify the possible mediator effects of muscle power (aPower and rPower), FFM_{kg}, and cognition status (MoCA) on the fall risk indicators (Sensorimotor, FES, FRAT and TUG). The multiple regression showed no interaction regarding all variables and the sensorimotor indicator, so it was not included in Table 2.

Table 2. Linear Multiple Regression of aPower, rPower, MoCA, and FFM_{Kg} related to FES, FRAT and TUG at baseline.

	FES			FRAT			TUG		
	B	**β**	**t**	**B**	**β**	**t**	**B**	**β**	**t**
aPower	0.30	0.55***	4.15	-0.03	-0.46**	-3.25	-0.06	-0.41**	-2.87
rPower	2.77	0.54***	4.11	-2.89	-0.48***	-3.43	-7.31	-0.49***	-3.6
MoCA	3.78	0.77***	7.62	-0.34	-0.58***	-4.54	-0.55	-0.38**	-2.63
FFM_{Kg}	0.73	0.32*	2.13	-0.09	-0.35*	-2.34	-0.11	-0.16	-1.07

Notes: aPower.= Absolute Muscle Power, rPower = Relative Muscle Power, FRAT= Fall Risk Assessment Tool, FES= Falls Efficacy Scale, Sensorimotor= Posturographic platform, TUG = Timed-up-and-go Test, MoCA = Montreal Cognitive Assessment, FFM_{kg}= fat-free mass in kilogram. *=p≥0.05; **=p≥0.01; ***=p≥0.001

In the FES interactions, cognitive status assessed by MoCA demonstrated to be the best predictor, but when analyzed together, the best predictor model for FES included also rPower, and resulted in the following model [F(2,39) = 36,731; $p \leq 0.001$; $R^2 = 0.632$]. The same pattern was observed for FRAT [F(2,39) = 13,373; $p \leq 0.001$; $R^2 = 0.376$]. For TUG, the rPower was the most effective indicator showed in the table above, as well in the best predictor model [F(1,40) = 12,947; $p \leq 0.01$; $R^2 = 0.226$].

In relation to the main effect of time*group, the rPower demonstrated a significant main effect ($F_{1,216} = 6.771$, $p < 0.01$), as well as the fall risk assessment by Sensorimotor variable ($F_{1,990} = 5.401$, $p < 0.01$), and the cognitive status assessed by MoCA ($F_{1,902} = 4.504$, $p < 0.05$). Meanwhile, the body composition main effect related to $FM_{\%}$ and $FFM_{\%}$ showed effect of time*group ($F_{2,055} = 3.928$, $p < 0.05$ and $F_{2,361} = 5.807$, $p < 0.01$; respectively). To specifically analyse the differences pointed above, the following figures show the mean differences between the moments of evaluation, for each variable and group.

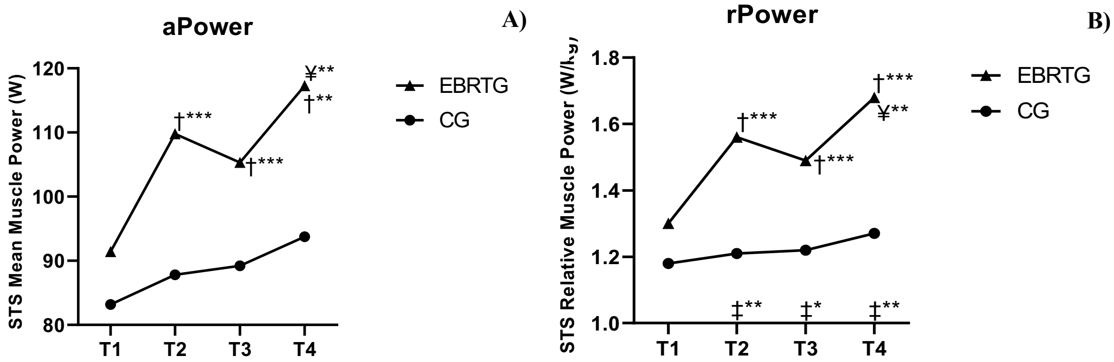

Figure 3. Graphical representation of Muscle Power by groups in each moment; (A) aPower.= Absolute Muscle Power; (B) rPower.= Relative Muscle Power; EBRTG = Elastic Band Resistance Training Group; CG = Control Group; †= difference versus previous moment of evaluation; ¥= difference after all interventions period (T1 vs. T4); ‡= difference between groups at specific moment; *= p ≤ 0.05; **= p ≤ 0.01; ***= p ≤ 0.001.

Looking at the muscle power outputs in Figure 3, the aPower, in the EBRTG, showed significant improvements after both exercise intervention periods of training (T1 vs. T2, $p < 0.001$, *ES* = 0.47) and retraining (T3 vs. T4, $p = 0.002$; *ES* = 0.28), with a statistically significant decrease during detraining (T2 vs. T3, $p = 0.001$; *ES* = 0.10). The same occurred for the rPower, where the EBRTG kept the same pattern. The CG kept stable for both, aPower and rPower. In the rPower, the difference between groups (EBRTG vs.CG) where significant after training (T2, $p = 0.009$; *ES* = 0.54), detraining (T3, $p = 0.039$, *ES* = 0.38) and retraining (T4, $p = 0.008$, *ES* = X0.52).

Regarding the fall risk assessments illustrated in Figure 4, the FRAT outputs related to EBRTG showed smaller mean values in all phases, with a trend for improvement (lower results), but without statistical significance. Meanwhile, the CG showed a worsening (higher scores) trend, with a significant result after T2 vs. T3 ($p = 0.01$, *ES* = 0.48). In the case of the FES evaluation, the results showed that the EBRTG kept the same pattern during all phases, without significant changes, while the CG worsened (lower scores), significatively in all phases – training, retraining, detraining, and throughout the entire intervention (T1 vs. T4, $p = 0.01$, *ES* = 0.26).

Regarding the sensorimotor assessment, the CG had greater scores in all phases (which indicated worse conditions for postural control and fall risk), attaining significant values after T2 (T1 vs T2, $p = 0.003$, *ES* = 0.52), and after the entire intervention period (T1 vs. T4, $p < 0.001$, *ES* = 0.92). The EBRTG kept its scores during the entire intervention, with no significant changes. The difference between both groups after each moment of the intervention was also significant (T2, $p = 0.01$, *ES* = 0.84; T3, $p = 0.004$, *ES* = 0.95; T4, $p = 0.001$, *ES* = 1.13).

In relation to the TUG test, the EBRTG showed significant changes after the training, and retraining phases, with significant ($p = 0.04$, *ES* = 0.38; and $p = 0.04$, *ES* = 0.51, respectively) improvements, however, the withdraw of the exercise program (detraining) resulted in a significant worse result ($p = 0.01$, *ES* = 0.68). Meanwhile, the CG kept a non-significant worsening trend.

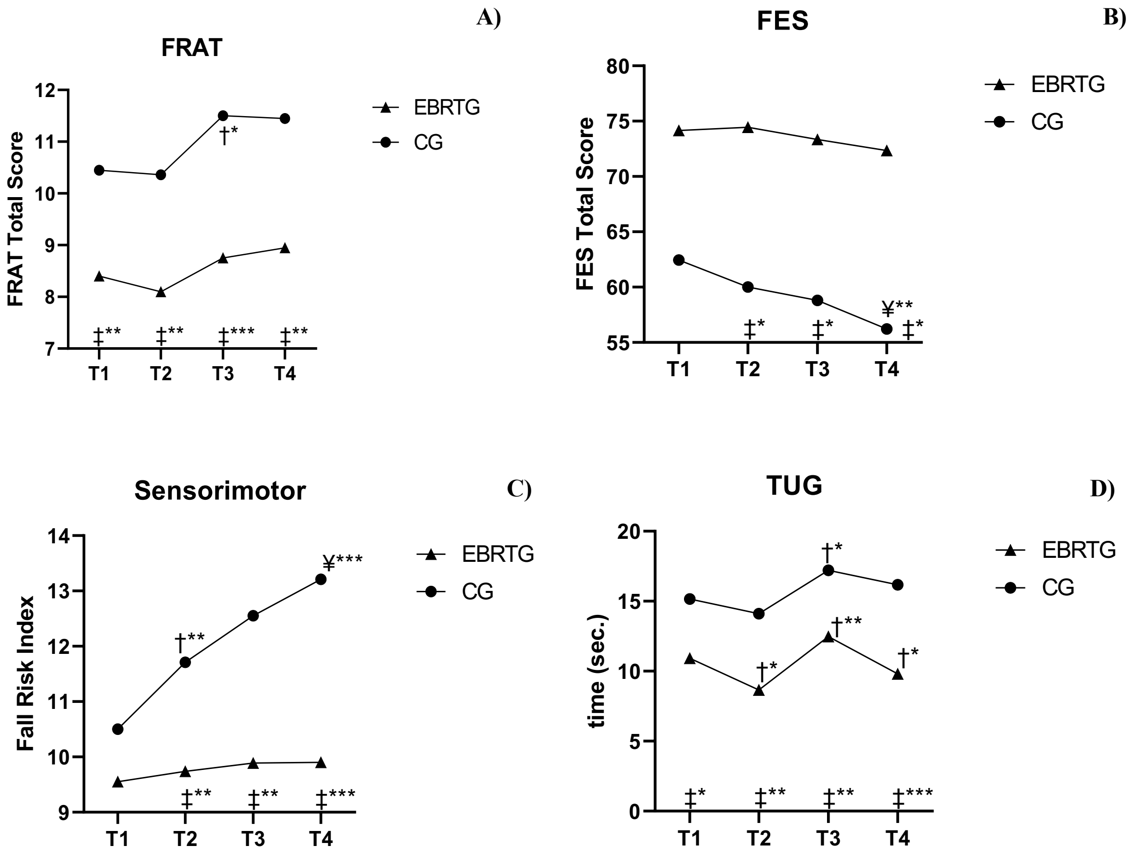

Figure 4. Graphical representation of Fall Risk by groups in each moment**;** (A) FRAT= Fall Risk Assessment Tool; (B) FES= Falls Efficacy Scale; (C) Sensorimotor= Posturographic platform; (D) TUG= Timed-up-and-go Test; EBRTG = Elastic Band Resistance Training Group; CG = Control Group; †= difference versus previous moment of evaluation, ¥= difference after all interventions period (T1 vs. T4), ‡= difference between groups at specific moment, *= p ≤ 0.05; **= p ≤ 0.01; ***= p ≤ 0.001.

For body composition measurements (Figure 5), the $FM_{\%}$, in the EBRTG decrease after the training period, and increased after detraining, followed by a new decrease after retraining, with a significant difference for the entire intervention (T1 vs. T4, p = 0.04, *ES* = 0.38). On the other hand, CG kept increasing the fat mass (%), however without a statistical significance. For the $FFM_{\%}$, the results were almost the same but in the opposite sense, with the CG decreasing its fat-free mass (%), and the EBRTG increasing significantly during the training period (T1 vs. T2, p = 0.04, *ES* = 0.27), and after the entire intervention period (T1 vs T4, p = 0.002, *ES* = 0.36), with a small decreasing trend after detraining. These results also matched those for FFM_{kg}, where the EBRTG had a significant increase when analysing the entire program (T1 vs. T4. P = 0.003, *ES* = 0.25), the CG keeping a similar level to the baseline.

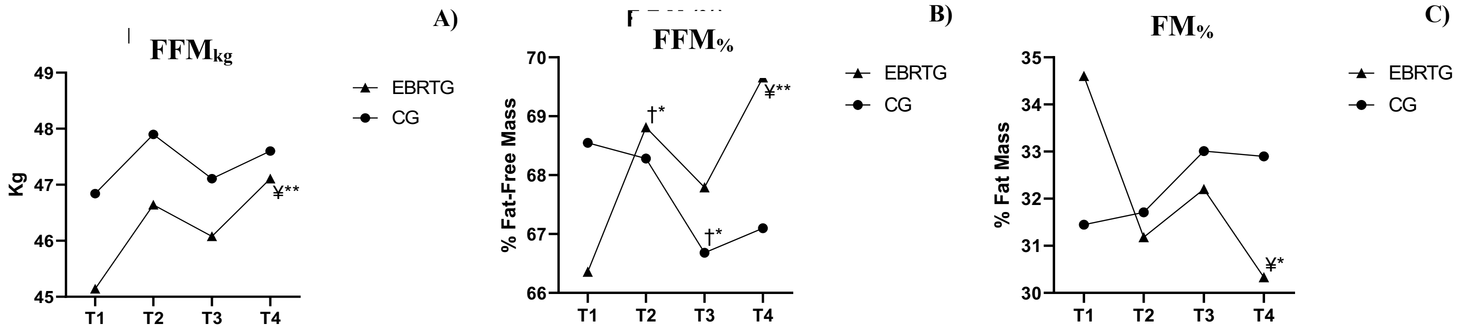

Figure 5. Graphical representation of Body Composition by groups in each moment**;** (A) FFM_{kg}= fat-free mass in kilogram; (B) $FFM_{\%}$= percentual of fat-free mass; (C) $FM_{\%}$= Percentual of fat mass; EBRTG = Elastic Band Resistance Training Group; CG = Control Group; †= difference versus previous moment of evaluation, ¥= difference after all interventions period (T1 vs. T4), ‡= difference between groups at specific moment, *= $p \leq 0.05$; **= $p \leq 0.01$; ***= $p \leq 0.001$

Figure 6 shows the graphical representation of the MoCa scores before-after 40 weeks of intervention. The EBRTG group showed a significant change after the training (T1 vs. T2, p = 0.01, *ES* = 0.39) intervention, but did not have any other significant changes, therefore, keeping a positive/improved trend while the CG group had a negative/decreased trend throughout the intervention, with statistical significance during the detraining period (T2 vs. T3, p = 0.01, *ES* = 0.26).

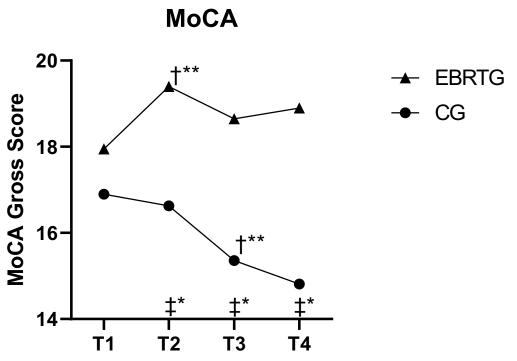

Figure 6. Graphical representation of Cognitive Status (MoCA) by groups in each moment**;** MoCA= Montreal Cognitive Assessment; EBRTG = Elastic Band Resistance Training Group; CG = Control Group; †= difference versus previous moment of evaluation, ¥= difference after all interventions period (T1 vs. T4), ‡= difference between groups at specific moment, *= $p \leq 0.05$; **= $p \leq 0.01$; ***= $p \leq 0.001$

DISCUSSION

This study aimed to evaluate the effects of a 40-weeks intervention of training-detraining-retraining of an EBRT program in muscle power, body composition, cognitive status and in fall risk of older adults, through different and multidimensional assessments methods. Our findings contribute to the growing body of evidence that physical exercise improves physical and cognitive function in older adults with and without cognitive impairment (3,12). Specifically, this study provides evidence that physical exercise training can improve and/or stop/delay the rate of impairment of cognitive capacities and physiological measures associated with falls risk in institutionalized older adults.

Cognitive status

Some exercise training programs have already showed significant improvement in cognitive health on older populations (60), although still not well understood which area of cognition are more related and influenced by exercise, or which kind of physical exercise is the most important for this improvement (61).

However, some studies suggest that the greatest benefits from exercise is related to memory and/or executive function (14,60), which are closely related to problem-solving capacities, and that aerobic training seems to have the greatest effect (62), but in some others (60), the resistance training showed to have a greater impact, while in a recent meta-analyses (61), the training type did not show significant implications on cognitive improvements, and in fact, they recommend to use, instead of one model, both aerobic and resistance training which could result even in a greater cognitive health, as our exercise program, characterized as multicomponent elastic band resistance training that demonstrated to have improvements in total MoCA score.

As it remains unclear why and how the exercise type could influence some cognitive areas, however, in animal models, the aerobic training have demonstrated to act in 3 different domains (63): i) Hippocampal neurogenesis, creating new neurons, ii) Cerebral angiogenesis, creating new blood vessels in the brain, iii) Changes in inflammatory markers. While the resistance training seems to act increasing IGF-1 signaling, which stimulates hippocampal neurogenesis (64). However, in human studies both types of exercise seems to improve brain function (65,66), and plasticity (64,67), and cognitive status, where some studies support the idea of exercise training being reliable for both global cognition and domain-specific, irrespective of which type of exercise is performed (61).

Some studies also shows that female participants have greater benefits than man, in human and animal models (62,68), which were not seen in our results, where no difference between sex were observed. However, the importance of sex in this context should be inquiry further to better understand this relationship.

Briefly, our findings about cognitive status shows that EBRTG improved their performance on MoCA test, with greater effects during the first period of training compared to the second (retraining). Meanwhile, the CG kept worsening their cognitive abilities throughout time. The task-specific requirements of the designed exercise program, mainly in executive function, such as movement recall, movement switching and planning, and visuomotor processing, could explain the obtained results that are consistent with previous studies and show the importance of a multicomponent exercise program (69,70).

Muscle power outputs

In this same way mentioned above, the EBRT exercise program also improved the muscle power outputs. The EBRTG showed a significant improvement in absolute and relative muscle power after training, followed by a modest loss after the 8 weeks detraining period, that was regained and improved after the retraining process. Besides the difference within group, in relation to aPower, the difference between groups was also significant. Importantly, the training-induced improvements in muscle power were preserved during the detraining phase, during which only a small decrease was observed, being in concordance with Henwood & Taaffe, 2008 (71), where the muscle power and strength followed the same pattern as in our study, resulting in the promotion of physical independence and autonomy.

Body composition

As well as the muscle power discussed above, some authors (72) also suggest the importance and the influence of body composition, specifically in the ageing process, as it usually declines. Among the reasons for the age-related decline in muscle power outputs, is the body's fat mass, that usually increases with age, and creates a passive mass that burden the muscle power. Specifically in our subjects, the increase in fat mass did not show direct relationship with power outputs.

Briefly, we found that power outputs can affect the performance related to chair-rising, and both aPower and rPower declines with age, however, this process can be reversed with exercise, which also improves body composition.

Fall risk psychometric screen

According to some reviews (73,74) the practice of physical exercise have positive effects on postural control and stability, and in the risk of falls, providing an increase in balance capacity, functional ability, mobility, strength and coordination (75). In this scenario, some studies (76,77) with the same objective as ours, compared older adults with increased levels of physical activities with those who did not practice, and its influence in fall risk. They observed that many older adults are prone to falls in both groups (active and non-active ones), and individuals with at least a moderate risk of falls were found. However, those who practiced physical activity regularly showed a higher level of mobility and less propensity to fall, when compared to the physically inactive group.

Also, similarly to the results found by some researches (78), we observed that physically inactive older adults presented, according to the sensorimotor evaluation, a greater propensity to falls when compared to active older adults. Studies (79,80) have shown that there is an increased risk of falls in people with physical and functional deficits. In our study, after the first intervention period (T2), the EBRTG had decreased the fall risk, possibly due to the increased physical activity levels and functional abilities stimulated by the resistance exercises, such as muscle power and balance while the CG had significantly increased it.

The analysis of the fall risk assessments, mainly by the Sensorimotor platform, shows that our EBRT exercise program was able to maintain the older adults' stability and fall risk over time, while the absence of physical stimuli increased de fall risk more rapidly, as found in the CG. These results also building on other studies that have demonstrated that exercise can prevent falls (12). It is likely that some characteristics that were emphasized in our exercise program, such as sequential movements, with alternate flexion and extension of lower limb joints, changing direction of limb movements, static and dynamic weightlifting and shifting, and single limb support may be responsible for the possible gains in proprioception and strength, and as consequence, the decrease (or the maintenance) in postural sway (instability) (9,32,76,79).

Although no significant changes in the retraining period were found for the EBRTG, they were able at least maintain the level of postural control and fall risk, showing the protective effect of exercise, which was not found in the group who did not exercise. The concern with function decline with aging has mobilized health professionals not only to establish measures, but to delay the consequences of chronic-degenerative diseases as well (81,82), and most of these studies defend the importance of exercise, and in being active as a method of prevention, like we found in our study, where even after the detraining period, when both groups showed worsened scores in some of the variables studied, the range and severity of it was much lower in the active group (EBRTG), showing the protective effect of exercise over time.

The concern is that normally, sedentary older adults have decreased functional capacity, which increases the incidence of falls, that are directly related to impaired balance and poor postural control, impaired instrumental activities, limitation/lack of mobility, gait and muscle strength (83). Therefore, exercise programs focused in stimulating these capacities have shown positive results (24,78,82,84,85)

In the same context, the TUGT evaluations showed that both exercise interventions (Training, and Retraining) were able to improve its performance, reducing the time of the test. The opposite occurred when the exercise program ceased, increasing the time for the test conclusion. The same occurred in the CG, which increased the TUGT time in all moments, showing that maintenance of exercise is necessary for its positive influence on physical capacities and fall risk reduction, in concordance with studies from (77,86,87), where exercise was positively correlated with improvements in gait and balance capacities.

The improvement in reaction time, and speed of walking complements the findings of faster processing speed and greater attention manifest in the cognitive tests and may be one mechanism for the improvement in executive function, which could explain, in some (but restrictive) way, the improvement in cognitive status showed by the MoCA tests after training (88,89).

Concomitant, the FES, demonstrated similar results, with improved scores related to the exercise program, while the subjects who did not exercise continued to worsen their scores, showing higher insecurity in performing daily life tasks. This highlights the importance of the general physical condition for older adults to feel safer in the execution of some of their daily live activities and more independent (90,91).

However, it is arguable that the practice of exercise alone can reduce the risk of falls (92,93) because even after the second exercise intervention (Retraining phase), the differences between both groups were not significant, and also, there were cases of older adults in the EBRTG whose score was worse, showing once again the multifactorial nature of each case. For example, the FRAT scale did not show any changes in fall risk for our specific active population (EBRTG), however, as it is a multidimensional assessment, this may be related to other variables not analysed in this study, such as medicine interactions.

Also, we should address to the promising results of this study, since some previous studies have found no significant improvements in cognitive function (94,95) physical performance, or falls after exercise specific interventions (96,97), and several study-related factors may account for these differences. A systematic review (98) report that some interventions, such as Tai Chi program, should compromise twice-weekly programs, of at least 45 minutes duration, for 12 weeks (or longer) in order to achieve balance improvements. The WHO in its last guideline (99) recommends even more (to perform at least 150-300 minutes of light to moderate physical activity, or 75-150 minutes of moderate to vigorous physical activity per week, including multicomponent exercise, preferable focusing on balance and strength capacities). Study characteristics such as participant age, frailty, fall risk level and differing adherence of each participant may affect the effectiveness of each program, and the non-significant findings in some trials have also been attributed to the lack of sensitivity of some outcome measures (100). However, in our study, extra attention was taken to strengthen and maximizing accurate adherence, and the EBRT program design appears to have facilitated learning and program adherence.

Also, care was taken to exclude factors that differentiated the sample, seeking a homogeneous sample without statistical differences like age, sex, ability to perform activities of daily life (ADL) independently, and without a history of diseases that could directly affect the balance. Therefore, this study was able to observe that muscle power outputs and cognitive status demonstrated a significant relationship (correlation) with fall risk indicators such as TUG, FRAT and FES, and showed to be a good predictor for those same fall risk indicators. In this same way, the FFM_{kg} showed significant relationship (correlation) with fall risk indicators such as FRAT and FES, and can also be a good predictor for these two fall risk indicators.

Briefly, the practice of resistance training with elastic band showed a significant improvement in muscle power (absolute and relative), body composition, and consequently in fall risk status, during training and retraining in the active group, and its effects was also observed in the detraining phase, demonstrating some protective effect. The cognitive status also appears to be positively influenced by our exercise program. The scores from the cognitive assessment after training and retraining period were better than its previous assessment, only after de detraining phase, the result was worse, but even that, do not at the baseline level, showing some protective status promoted by exercise

Relationship between improvements on cognition and physical outcomes

Exercise is well known by its improvements-induced related to physical functions, and in cognitive functions in some ways, but the neural underpinnings and the temporal aspect of this connexions are not yet well established (61). However, physical and cognitive functions are related in some common factors that is influenced and improved by exercise (2,15).

In this context, our results appear to provide some evidence that exercise-induced improvements in physical and cognitive function are connected, and can be explained by Liu-Ambrose et al (101) in his central benefit model where the cognition and neural plasticity are an significant mechanism influenced by exercise, and promote mobility, and therefore, reducing the fall risk (61,102).

Our study was able to observe that muscle power outputs and cognitive status demonstrated a significant relationship (correlation) with fall risk indicators such as TUG, FRAT and FES, and showed to be a good predictor for those same fall risk indicators. Also, the improvement in reaction time, and speed of walking complements the findings of faster processing speed and greater attention manifest in the cognitive tests and may be one mechanism for the improvement in executive function, which could explain, in some (but restrictive) way, the improvement in cognitive status showed by the MoCA tests after training (88,89).

Briefly, the practice of resistance training with elastic band showed a significant improvement in muscle power (absolute and relative), body composition, and consequently in fall risk status, during training and retraining in the active group, and its effects was also observed in the detraining phase, demonstrating some protective effect. The cognitive status also appears to be positively influenced by our exercise program. The scores from the cognitive assessment after training and retraining period were better than its previous assessment, only after thee detraining phase, the result was worse, but even that, do not at the baseline level, showing some protective status promoted by exercise

Although our study agrees with some others (103), and provides some evidence that regular exercise promotes cognitive improvements, we cannot conclude that these improvements from the exercise program are the primary mechanism by which physical function (or cognition) improves.

Limitations, Constraints, and Directions for Future Studies

There are, however, some limitations to this study, namely, the reduced number of participants, not gender balanced (small number of men), and the possible influence of some covariable such as pharmacological use, depression, and falls history. As far as the strengths are concerned, there are not many studies with exercise long-term programs and its influence on cognitive status and multiple description fall risk, using new technology as our posturographic test by Physiosensing® platform to address it. Therefore, more research with a larger number of participants should be done to verify these results, mainly in specific domains of cognitive status, and considering the influence of other factors such as nutrition, number and type o medicine taken, and falls history as example.

Practical Applications.

The EBRT showed to be a good and safe option of intervention, even for institutionalized older adults, who are at greater risk for physical and cognitive frailty. The EBRT also showed significative improvements in some physical and cognitive indicators, which may reflect in some aspects as mobility safety, as these older adults need to walk, sit, stand up, between other things, so our intervention could bring some kind of autonomy and independence, even in a lower scale, however, could be significative for these people, and also for the caregivers and health professional, who can see their workloads reduced or facilitated.

This study showed that an EBRT program was effective in stopping, and/or reducing the forward speed of deterioration in body composition, muscle power, postural control, cognitive status and fall risk in older adults, with a great increment occurring in the first months of exercise, the benefits of it lasting longer, even after a detraining period, when compared to a sedentary group where a downward trend was present throughout time for all the outcomes.

Taking into account the vulnerability of this population, reducing the speed of evolution of several age-related process can also be satisfactory. Our results also suggested that physically inactive older adults have a higher risk of falls and that the regular practice of physical activity interferes in this specific risk. Also, good physical capacity was shown to be linked to the confidence of performing daily life activities, highlighting the importance of being active to be independent.

CONCLUSION

This study supports the premise that EBRT for older adults at a frequency of two times per week for 16 weeks was able to significantly improve cognitive function and physical performance, resulting in a moderate reduction in fall risk. These results can only be maintained if exercise is done regularly, however as the exercise stopped (detraining), some protective effects was observed, as well as the benefits that came back when exercise restart (retraining). Specific associations of fall risk in different methods of evaluations were also identified, that could be used to facilitate the early identification of fall risk and increasing the chance of successful interventions.

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Paper 4- The Effect of a Resistance Training, Detraining and Retraining Cycle on Postural Stability and Estimated Fall Risk in Institutionalized Older Persons: A 40-Week Intervention

The following paper appears as published in Healthcare:

Rodrigues RN, Carballeira E, Silva F, Caldo-Silva A, Abreu C, Furtado GE, Teixeira AM. The Effect of a Resistance Training, Detraining and Retraining Cycle on Postural Stability and Estimated Fall Risk in Institutionalized Older Persons: A 40-Week Intervention. *Healthcare*. 2022; 10(5):776. https://doi.org/10.3390/healthcare10050776

This paper's partially results were presented in the following Congresses:

Rodrigues, R.N.; Silva, F.; Caldo, A.;Teixeira, A.M.; Abreu, C.; Furtado, G. (2021). Influência de 16 semanas de exercício Físico na função cognitiva em octogenários. In Desouzart G (Coord.), Proceedings of the 2nd International Congress of Health and Well-Being Intervention – ICHWBI2021 and the 1st International Conference on Human Kinesiology – 1st ICOHK; 2021 May 28-29; Viseu, Portugal. ISBN (e-book): 978-989-759-154-9 (Annex B)

Rodrigues, R.N.; Caldo, A.; Silva, F.; Neves, R.; Abreu, C.; Teixeira, A.M.; Furtado, G. (2021) Influência de 16 semanas de exercício físico no risco de queda em octogenários: uma comparação entre homens e mulheres. School of Education of Viseu, Portugal; ACES ACES Dão Lafões (Org.). Proceedings of the "5o Congresso de Envelhecimento Ativo: Atividade Física e Saúde"; 2021 Feb 27; Virtual Congress (Annex C).

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The Effect of a Resistance Training, Detraining and Retraining Cycle on Postural Stability and Estimated Fall Risk in Institutionalized Older Persons: A 40-Week Intervention

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Special Issue
Exercise Evaluation and Prescription in Older Adults

Edited by
Dr. Eduardo Carballeira, Dr. Guilherme Furtado and Dr. Rubens Vinícius Letieri

MDPI

https://doi.org/10.3390/healthcare10050776 healthcare

Article

The Effect of a Resistance Training, Detraining and Retraining Cycle on Postural Stability and Estimated Fall Risk in Institutionalized Older Persons: A 40-Week Intervention

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Abstract: Physical inactivity and low levels of muscle strength can lead to the early development of sarcopenia and dynapenia, which may increase the number and risk of falls in the elderly population. Meanwhile, exercise programs can stop or even revert the loss of muscle mass, strength, power, and functional capacity and consequently decrease the risk of falls in older adults. However, there is a lack of studies investigating the effect of strengthening programs in octogenarians. The present study investigates the effects of 40 weeks of a training-detraining-retraining cycle of muscle strength exercise program on postural stability and estimated fall risk in octogenarians. Twenty-seven institutionalized participants were allocated into two groups: the muscular strength exercise group (MSEG, n = 14) and control group (CG, n = 13). After the first training period, the MSEG improved postural stability and decreased the estimated fall risk by 7.9% compared to baseline. In comparison, CG worsened their stability and increased their risk of falling by more than 17%. No significant changes were found between groups in the detraining and the retraining period. This study demonstrated that strength exercise effectively improved postural control and reduced fall risk scores. In addition, the interventions were able to reduce the forward speed of postural control deterioration in octogenarians, with great increments in the first months of exercise.

Keywords: older adults; postural stability; strength exercise; fall risk; technology-based assessment

Citation: Rodrigues, R.N.; Carballeira, E.; Silva, F.; Caldo-Silva, A.; Abreu, C.; Furtado, G.E.; Teixeira, A.M. The Effect of a Resistance Training, Detraining and Retraining Cycle on Postural Stability and Estimated Fall Risk in Institutionalized Older Persons: A 40-Week Intervention. *Healthcare* **2022**, *10*, 776. https://doi.org/10.3390/healthcare10050776

Academic Editors: Giovanni Morone and José Carmelo Adsuar Sala

Received: 20 February 2022
Accepted: 20 April 2022
Published: 22 April 2022

1. Introduction

Life expectancy is growing worldwide, and consequently, many health problems related to the aging process have been drawing greater attention, with the physical, psychological, and physiological degenerative processes standing out. The increase in sedentarism linked to aging is a global health problem [1]. The lack of physical exercise can trigger the early development of some physical and neurodegenerative diseases in older adults leading to the development of sarcopenia and dynapenia [2,3]. The latter phenomena are part of what has been called the frailty syndrome [4], which has been linked to an increase in the number and severity of falls in older adults [5].

The World Health Organization, aware of the importance of the fight against a sedentary lifestyle in the aged population, has published some minimum dose recommendations for health maintenance [6]. These recommendations are to perform at least 150–300 min of moderate physical activity, or 75–150 min of vigorous physical activity per week, including multicomponent exercise focusing on balance and strength, to improve the functional capacity and prevent falls [6].

The fall is conceptualized as an unintentional body displacement to a lower level than the initial position, determined by multifactorial circumstances that compromise stability [7]. Aging plays a central role as it affects the afferent sensory system (i.e., proprioception, vestibular and visual system), the central neurologic control system (i.e., cognition, attention, fear of falling), and finally, the efferent neuromotor system (i.e., physical function, muscle strength, balance, and stability) [8,9]. Changes in central neural system connectivity have been observed in areas related to the integration of information and in areas associated with motor and sensory information processing, providing evidence of the complex multidimensionality of the neural underpinnings of falls [10]. In addition, diseases, drugs, and environment modulate the age-associated changes in the fall risk pathway.

In this scenario, there are intrinsic causes (deterioration of physiological and neuromuscular changes of aging, muscle dysfunctions, pathologies, medications) and extrinsic causes (environmental hazards, architectural and furniture inadequacies, stairs, high heel shoes) of fall occurrence [11]. The interaction between intrinsic and extrinsic factors compromises the perceptive and neuromuscular systems related to postural stability and balance control, affecting the functionality and quality of life of the older adults [12], being an essential aspect of morbidity and mortality and the leading cause of fatal and non-fatal injuries among older adults [13].

According to a Behavioral Surveillance and Risk System survey, about 26% of older adults reported falling at least once in the last 12 months, resulting in 24.96 million falls in 2020 [14]; likewise, in 2019 [15], more than 3 million fall injuries and more than 34,000 deaths related to falls were recorded, generating an approximate cost of 50 billion dollars in medical care in the USA [15,16]. Sadly, these numbers kept growing and are projected to increase 30% by 2030, resulting in around seven deaths/hour in the USA [16]. Similarly, in Europe, the Western region saw 8.4 million older adults in medical centers due to fall-related injuries in 2017 [17]. In this scenario, institutionalized older people are at a higher risk of falling since the prevalence of frailty in nursing homes is 50%, and approximately 40% are pre-frail individuals [18]. Furthermore, the percentage of fallers increases from 26.7% in older people between 65 and 74 y/o to 29.8% in older people between 75 and 84 y/o [19]. For people over 84 years old, their incidence of falls increases up to 36.5% [19]. Furthermore, this effect in octogenarians is still not well understood, given this population's difficulty, specificity, and high vulnerability [20].

Meanwhile, some studies have shown that physical exercise can attenuate the speed of evolution of some neurodegenerative processes, such as sarcopenia, dynapenia, and frailty, contributing to balance control and postural stability [21–23]. Regular exercise has been proven to reverse the frailty status and decrease the fall risk among older adults, even in those who live in nursing homes or social care institutions [9,18]. Recent studies have shown that institutionalized older adults had lower scores in physical fitness and higher scores for depressive symptoms and comorbidities, with a significant correlation between frailty, fear, and risk of falling and physical fitness [21,24–27]. It has been demonstrated that professional-oriented multicomponent training for eight weeks has positive outcomes; specifically, it has been indicated that shorter and high-intensity dynamic exercise can be an effective way of improving performance, gait, and balance capacities in older adults at risk of fall [28].

A meta-analysis has shown that exercise-only interventions had a practical effect on fall risk in institutionalized and non-institutionalized older adults, significantly reducing the number of falls [29]. However, this same meta-analysis showed a high percentage of drop-out ratio in the population studied, making it difficult to draw conclusions from this study. This, taken together with the lack of works focused on people over 80 years old, indicates the need to study the chronic adaptations in very old populations after exercise interventions. The benefits of exercise are transient and last as long as it is being performed; thus, the necessity of adherence and progression is crucial [3,6,18,21]. However, adherence is an unresolved matter when training older persons, especially those institutionalized, who interrupt their training programs, for example, when spending holidays with families and other diverse circumstances. Therefore, the study of evolution/involution of neuromuscular adaptations after training-detraining may help prescribe exercise with more prolonged residual effects to overcome detraining periods [30,31]. In this way, some authors have analyzed the effects of the detraining process [32]. Detraining can be defined as training reduction or cessation, which implies temporary discontinuation or complete abandonment of systematic programmed physical exercise, which may cause a partial or complete loss of training-induced adaptations (anatomical, physiological, psychological, and functional performance) produced during a previous training period [33]. Some authors studying this process have indicated that after 12 weeks of detraining, the benefits of exercise started to decline, and even after another 12 weeks of detraining, some of the muscular endurance and strength parameters reduced by ~15% [30]. In another detraining study, strength and gait speed were reduced after 16 weeks of no training but did not return to their baseline values [34]. These data point to a lasting protective effect from exercise, even when these capabilities decline due to the aging process [35]. In fact, as people age, muscle power deteriorates faster than muscle strength [36].

Muscle strength is the amount of tension that a muscle or muscle group can generate in a specific movement; meanwhile, muscle power is the tension generated at a specific velocity [37]. In this context, neuromuscular adaptations and deteriorations, mainly at the level of muscle-tendon units (i.e., reduced tendon stiffness), muscular structure (i.e., reduced number of muscular units, and atrophy of fast-twitch fibers), and neural changes affect strength capabilities [cite] and power output [38]. However, since muscle power is more strongly associated with daily life activities, more attention must be paid to exercise strategies that contribute to power development in older adults.

In this scenario, the specific use of elastic bands in exercise training programs has been shown to improve muscular capacities such as strength, balance, and functional capabilities in older adults, even in the institutionalized ones [22], including those characterized as frail or pre-frail [23]. Considering the reasons given, we aimed to evaluate the effects of forty weeks of a training-detraining-retraining cycle of muscle strength exercise (MSE) program with elastic bands on institutionalized octogenarians and its influence on postural control and estimated fall risk status.

2. Materials and Methods

We have employed a non-probability convenience sampling of octogenarian dwelling older adults living in nursing homes. The institution's directors and the older adults' legal representatives revised and signed the consent form before the first testing session. The estimated sample size was calculated using the G*Power software (version 3.1.9.7) [39]. Based on our calculations, for an effect size of 0.30, a sample size of 26 achieves 95% statistical power to detect differences among the means using an ANOVA test with an α-level of 0.05. The sample consisted of 27 participants (7 males, 20 females) aged over 80 (86.37 $\pm$ 3.59) years old, institutionalized in nursing homes or social care centers of Coimbra (Portugal). This study is designed as a prospective, naturalistic, controlled clinical trial (treatment vs. care) composed of 3 phases, i.e., training, detraining, and retraining. The participants were stratified randomized into two groups: the muscular strength exercise group (MSEG, n = 14, 4 male and 10 female), who performed an elastic band strength exercise program, and the control group (CG, n = 13, 3 male and 10 female) who continued their usual routine, which does not include any kind of programmed and supervised physical exercise.

The eligible criteria for the participants in this study were that, at the time of first screening, participants had to be: (i) 80 years old or more; (ii) clinically stable with their drug therapy updated; (iii) not participating in another structured program of physical exercise in the last six months; (iv) not presenting any type of health condition or use medication that might prevent the functional self-sufficiency test performance or attention impairment (such as severe cardiopathy, uncontrolled hypertension, uncontrolled asthmatic bronchitis or severe musculoskeletal conditions); (v) not presenting mental disorders or hearing/visual impairment that could prevent the evaluations and activities proposed, according to the institutional medical staff.

Additionally, we should address that in this study, care was taken to exclude as much as possible the factors that differentiated the sample, seeking a homogeneous sample without statistical differences in age, sex, the ability to perform daily life activities independently, and without a history of diseases that could directly affect the balance so that the results are as accurate as possible.

The intervention consisted of a first period of sixteen weeks of resistance training with elastic bands, followed by eight weeks of detraining and a second training period of sixteen weeks. Participants performed a total of 64 sessions, 2 sessions/week of 45 min each on non-consecutive days distributed between the two training periods.

To avoid any bias, all the participants completed the evaluation protocol at the same time period, between 10 am to 11.45 a.m. That protocol was repeated on four occasions: pre-intervention (PRE), postintervention after 16 weeks of training (POST16), after eight weeks of detraining (POST24), and postintervention after 16 weeks of training in the second period (POST40) (Figure 1). The evaluation protocol assessed anthropometric values and estimated fall risk through an index based on the posturography platform (Physiosensing® v.19002, Sensing Future, Coimbra, Portugal) test with four specific conditions (please see details below).

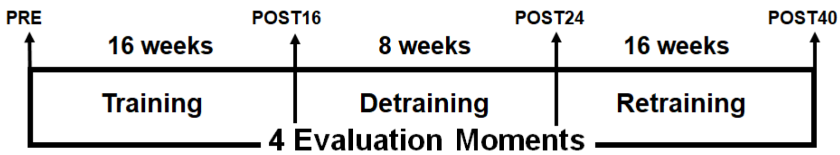

Figure 1. Graphical representation of the study design.

This study was approved by the Faculty of Sport Science and Physical Education, University of Coimbra Ethics Committee (reference number: CEFCDEF/0028/2018) respecting the Portuguese Resolution (Art. 4th; Law no. 12/2005, 1st series) on ethics in human research [40] and the Helsinki Declaration. Clinical trial register number NCT04376463.

2.1. Postural Stability and Fall Risk Assessment

The fall risk assessment allows the identification of potential fall candidates. The protocol employed in the present study, the Physiosensing® Fall Risk test, has been validated and described elsewhere [41,42]. Postural stability assessment was performed employing a specialized force platform (Physiosensing® v.19002, Sensing Future, Coimbra, Portugal) that measured the participants' sway center of pressure. Each participant stood barefoot on the force platform and tried to be as stable as possible in a static upright position, directing their gaze to a point located at 2 m, for 45 s under four pre-established conditions [41,42]: (1) comfortable stance with eyes open (CSEO); (2) comfortable stance with eyes closed (CSEC); (3) narrow stance with eyes open (NSEO); and (4) narrow stance with eyes closed (NSEC).

Data were stored and analyzed with commercial software (Physiosensing® v.19.0.1.0) that calculated the speed index for each condition to estimate fall risk. The speed index is calculated as the displacement velocity of the center of pressure (i.e., distance traveled in the sagittal plane divided by the test time (mm/s), normalized by the participant's height, and transformed with the natural logarithm function [1]. The fall risk estimation is based on the assumption that an increment in the participant's sway velocity denotes a postural control deficit. The software also calculates the composite speed index score as the mean of the scores obtained in the four conditions. The higher scores in the composite index and within each of the four conditions indicate higher fall risk.

2.2. Muscular Strength Exercise Protocol

An exercise expert supervised the MSE program. Exercise prescription was based on the recommendations of the American College of Sports Medicine guidelines and previously published exercise prescription guidelines for older adults [43,44]. Furthermore, participants from the MSE group could choose their preferred music to increase the adherence rate [45].

The sessions comprised five minutes of a general warm-up with mobility exercises, and the main part involved resistance exercises with an elastic band for 35 min (see the detailed program in Table 1). At the end of the session, participants completed a cooldown with stretching exercises for 5 min. The program consisted of organized and planned exercises performed with a chair to ensure the safety of the participants. The intensity of the resistance training program was controlled by a rate perceived exertion (RPE) scale (Borg 0–10 scale [46]). During the exercise sessions, participants wore a heart rate monitor (Polar, model M200, Polar Electro Oy, Kempele, Finland), and heart rate (HR) was estimated using Karvonen's formula where HRmax was calculated using a specific formula for older populations [47]. Heart rate was controlled jointly with the observation of facial flushing or hyperventilation to identify possible adverse events during exercise training. The MSE program consisted of 9 elastic bands exercises per session of progressively increased intensity (TheraBand, Akron, OH, USA). The exercises' execution targeted truncal musculature, so the proposed exercises, when possible, were executed safely and correctly in stand positions, adding some balance and stability needs, leading to a higher stimulation of the proprioceptive system.

The progression intensity was based on the OMNI table [48], which indicates the intensity progression throughout a colored band progression (soft-to-hard). The exercise protocol consisted initially of 2 sets of 10 to 20 repetitions with a light intensity band during the adaptation period and progressed gradually every 2 to 3 weeks. Finally, for the last four weeks, some free weights (dumbbells and ankle weights) were added to exercises, which allowed for a more intense and diversified spectrum of exercises. The participants performed all exercises in sequential order within each set and employed a cadence of 2 s in the concentric phase and 3 s in the eccentric phase of the movement. A minimum of two days between sessions was provided to ensure sufficient recovery.

The minimum adherence to be considered for analysis was set up to 80% of training sessions. When participants missed two consecutive sessions, a researcher contacted them and offered help to return to the group class; in case of a negative response, they were excluded from the analysis.

2.3. Anthropometric Assessment

Participants' body mass and stature were measured in a portable scale (Seca, model 770, Hamburg, Germany) with 0.1 kg of precision and a portable stadiometer (Seca Body meter®, model 208, Hamburg, Germany) with 0.1 cm of precision, respectively. Body mass index (BMI) was calculated as the body mass in kilograms divided by the square of height in meters. Standardized procedures were followed as previously recommended [49].

Table 1. Protocol for the muscular strength exercise program (MSE).

Warm-Up (Dynamic Flexibility and Walk around the Room): 5 min and RPE 3–5								
Exercises	**Sets**	**Reps**	**Cadence**	**Resting Interval**	**RPE**	**Progression**	**Weeks**	**Intensity ***
Front squat	2–3	10–20	2:3	30″	6 to 7	3×10^{-15}	2	Yellow
Unilateral hip flexion (chair)	2–3	10–20	2:3	30″	6 to 7	3×15^{-20}	2	Yellow
Row (with flexion) (chair)	2–3	10–20	2:3	30″	6 to 7	3×10^{-15}	2	Red
Chest Press (stand/chair)	2–3	10–20	2:3	30″	6 to 7	3×15^{-20}	2	Red
Reverse fly (stand/chair)	2–3	10–20	2:3	30″	6 to 7	3×10^{-15}	2	Green
Shoulder Press/twist	2–3	10–20	2:3	30″	6 to 7	3×15^{-20}	2	Green
Frontal raiser (stand/chair)	2–3	10–20	2:3	30″	6 to 7	3×15^{-20}	2	Blue
Biceps curl (stand/chair)	2–3	10–20	2:3	30″	6 to 7	4×15^{-20}	2	Blue
Overhead triceps extension	2–3	10–20	2:3	30″	6 to 7			
Circuit format								
Multidirectional walk around the room with an obstacle, cones, etc.				3–5 min	4 to 7			
Balance/ agility/motor coordinator exercises				3–5 min	4 to 7			
Cooling down								
Upper and Lower body's static stretching (seated and standing)				5 min	2 to 3			

Reps = repetitions; RPE = Rating of Perceived Exertion of Borg Scale; min = minutes. * Based on Thera-band grade of elastic resistance.

2.4. Statistical Analyses

All descriptive data are presented as estimated marginal means and the 95% confidence interval (CI). Normality was assessed through standard distribution measures, visual inspection of Q–Q plots and box plots, and the Shapiro–Wilk test. Changes within and between groups were analyzed by employing mixed models for repeated measures designs with the module GAMLj [50], which uses the R formulation of random effects as implemented by the function lme4, an R package, in Jamovi software (The jamovi project, v1.6, 2021). GAMLj estimates variance components with restricted (residual) maximum likelihood (REML), producing unbiased estimates of variance and covariance parameters, unlike earlier maximum likelihood estimation. The inter-subject factor group (MSE and CG), the intra-subject factor time (i.e., PRE, POST16, POST24, and POST40) and condition (i.e., CSEO, CSEC, NSEO, NSEC; when appliable), and the interaction (group × time) were set as fixed effects. Sex and age were not introduced as a fixed factor and covariate, respectively, because these variables did not improve the model (i.e., parsimonious method), as evaluated by the Akaike information criterion (AIC). The participants' intercepts were set as a random effect. Time slope was not included as a random coefficient since this factor's variance was small in composite scores and speed index by condition.

Within-subject and between-subject changes were evaluated by ANOVA F omnibus test employing the Satterthwaite approximation of degrees of freedom and estimating the coefficients with their 95% confidence intervals for the fixed effects in the mixed model. When a significant interaction was detected, paired and independent comparisons were made with a t-test with the Bonferroni–Holm correction for within-subject and between-group changes, respectively. Furthermore, the variance of the random coefficients was obtained. Simple effects analysis was applied with ANOVA (type III sums of squares) and the Kenward-Roger method for degrees of freedom calculation. The level of significance was established at $p < 0.05$.

3. Results

Simple effects analysis revealed that MSEG and CG groups participants did not present significant differences in the anthropometric variables, age, sex distribution, and any postural control conditions and composite index (Table 2) at baseline.

Table 2. Sample characteristics, postural control, and composite index outcomes at baseline (i.e., PRE).

Variables	MSEG ẋ ± SD	CG ẋ ± SD	*p*-Value
Total of participants	14	13	
Male	4	3	
Female	10	10	
Chronological age (years)	86 ± 3	87 ± 4	0.589
Height (cm)	155 ± 7.4	152 ± 10.2	0.389
Weight (kg)	70.4 ± 15.3	69.4 ± 11	0.845
Body mass index	29.1 ± 5.2	30 ± 4	0.616
Postural Control:	ẋ [95%CI]	ẋ [95%CI]	*p*-value
(i) CSEO	10.2 [8.6 to 11.7]	10.8 [9.2 to 12.4]	0.566
(ii) CSEC	10 [8.5 to 11.6]	10.3 [8.7 to 11.9]	0.801
(iii) NSEO	9.4 [7.8 to 10.9]	10.4 [8.8 to 12]	0.353
(iv) NSEC	9.6 [8 to 11.1]	10.7 [9.1 to 12.3]	0.308
Composite Index	10.1 [8.9 to 11.4]	10.5 [9.2 to 11.8]	0.665

Values are estimated marginal means with 95% confidence intervals (CI). Simple effect analysis is employed to obtain *p*-values. MSGE = Muscular Strength Exercise Group; CG = Control Group; ẋ = Mean; SD = Standard deviation; CSEO = Comfortable Stance Eyes Open; CSEC = Comfortable Stance Eyes Closed; NSEO = Narrow Stance Eyes Open; NSEC = Narrow Stance Eyes Closed.

Body mass index did not change from the baseline to POST16, POST24, and POST40 weeks of intervention (p = 0.477). The composite index evolution and its percentual delta changes are presented in Table 3. The percentual delta changes (Δ%) represent the comparison with the precedent moment of measurement.

Table 3. Composite index (i.e., fall risk estimation) for both groups in each moment of measurement.

Condition and Moment	MSEG ẋ [95%CI]	MSEG Δ%	CG ẋ [95%CI]	CG Δ%
Composite Index—Baseline, PRE	10.1 [8.9 to 11.4]		10.5 [9.2 to 11.8]	
Composite Index—Training, POST16	9.3 [8.1 to 10.1]	−7.9%	12.3 [11 to 13.6]	17.2% *
Composite Index—Detraining, POST24	9.9 [8.7 to 11.1]	6.4%	12.6 [11.4 to 13.9]	2.4%
Composite Index—Retraining, POST40	9.6 [8.4 to 10.8]	−3.1%	12.9 [11.6 to 14.2]	2.3%

Values are estimated marginal means with 95% confidence intervals (CI). MSEG = Muscular Strength Exercise Group; CG = Control Group. * Significant differences in comparison to Baseline (p < 0.01).

In relation to the composite index, we found a main effect of group ($F_{1,25}$ = 7.80, p = 0.010), moment ($F_{3,399}$ = 15.15, p < 0.001) and interaction of group by moment ($F_{3,399}$= 31.75, p < 0.001). Estimated difference between MSEG vs. CG was −2.35 a.u. (95%CI [−4.0 to −0.7]), p = 0.010), and the difference between groups (i.e., MSEG vs. CG) in changes of POST16 vs. PRE (β = −2.6, 95%CI = −3.3 to −1.9, p < 0.001), POST24 vs. PRE (β = −2.4, 95%CI = −3.0 to −1.7, p < 0.001) and POST 40 vs. PRE (β = −2.9, 95%CI = −3.6 to −2.3, p < 0.001) indicate lower composite index in MSEG than CG during the entire intervention. Mainly, CG progressively increased their composite index throughout the intervention period (Table 3 and Figure 2).

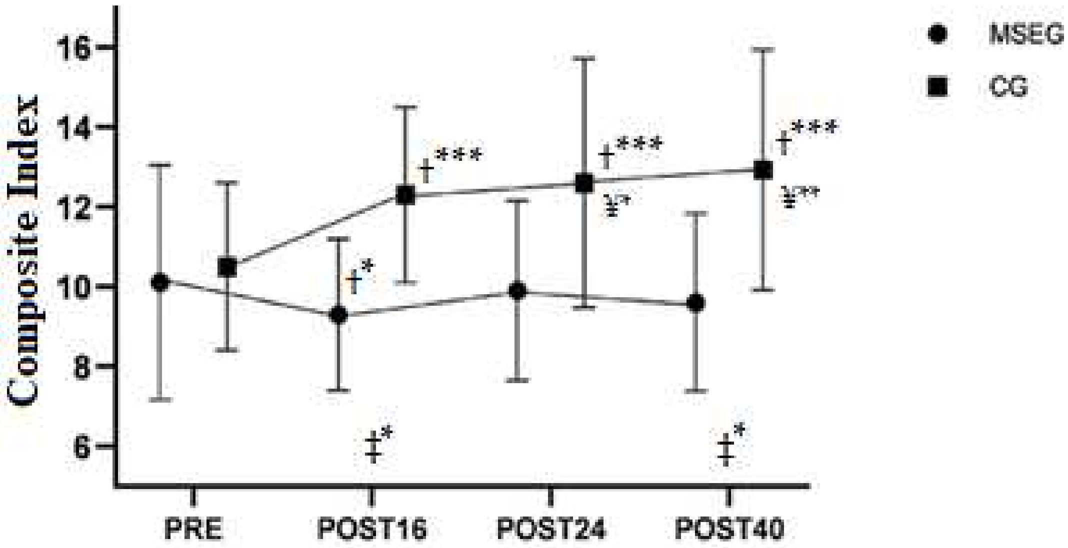

Figure 2. The composite index in the four moments of measurement. PRE: pre-intervention test; POST16: after sixteen weeks of intervention; POST24: after eight weeks of detraining; POST40: after the second training period (retraining). ‡ = difference between groups at that specific time; † = difference versus PRE; ¥ = Difference versus MSEG-POST16. * = $p < 0.05$, ** = $p < 0.01$; *** = $p < 0.001$.

Mean and individual responses to every moment of postural control conditions (CSEO, CSEC, NSEO, NSEC) are illustrated in Figure 3. We observed a significant difference in postural control between groups ($F_{1,25} = 6.44$, $p = 0.018$), moments ($F_{3,375} = 6.52$, $p < 0.001$), conditions ($F_{3,375} = 9.16$, $p < 0.001$) and moment x group ($F_{3,375} = 11.34$, $p < 0.001$). There was no triple interaction group x moment x condition ($F_{9,375} = 0.53$, $p = 0.853$). However, simple effects analysis of group moderated by moment and condition revealed that eyes closed conditions (CSEC and NSEC) showed differences between MSEG and GC (−2.4 a.u., 95%CI = −4.6 to −0.1; and −2.8 a.u., 95%CI = −5.0 to −0.5; respectively), conversely to eyes open condition (CSEO and NSEO). Moreover, differences between groups were evident ($p < 0.05$) in POST24 and POST40 in all conditions. The random intercept (i.e., participants intercept) presented higher variance ($\sigma^2 = 5.30$) than residual variance ($\sigma^2 = 3.08$), which justifies the employment of setting participants as clustered random component. Individual and mean responses can be seen in Figure 3.

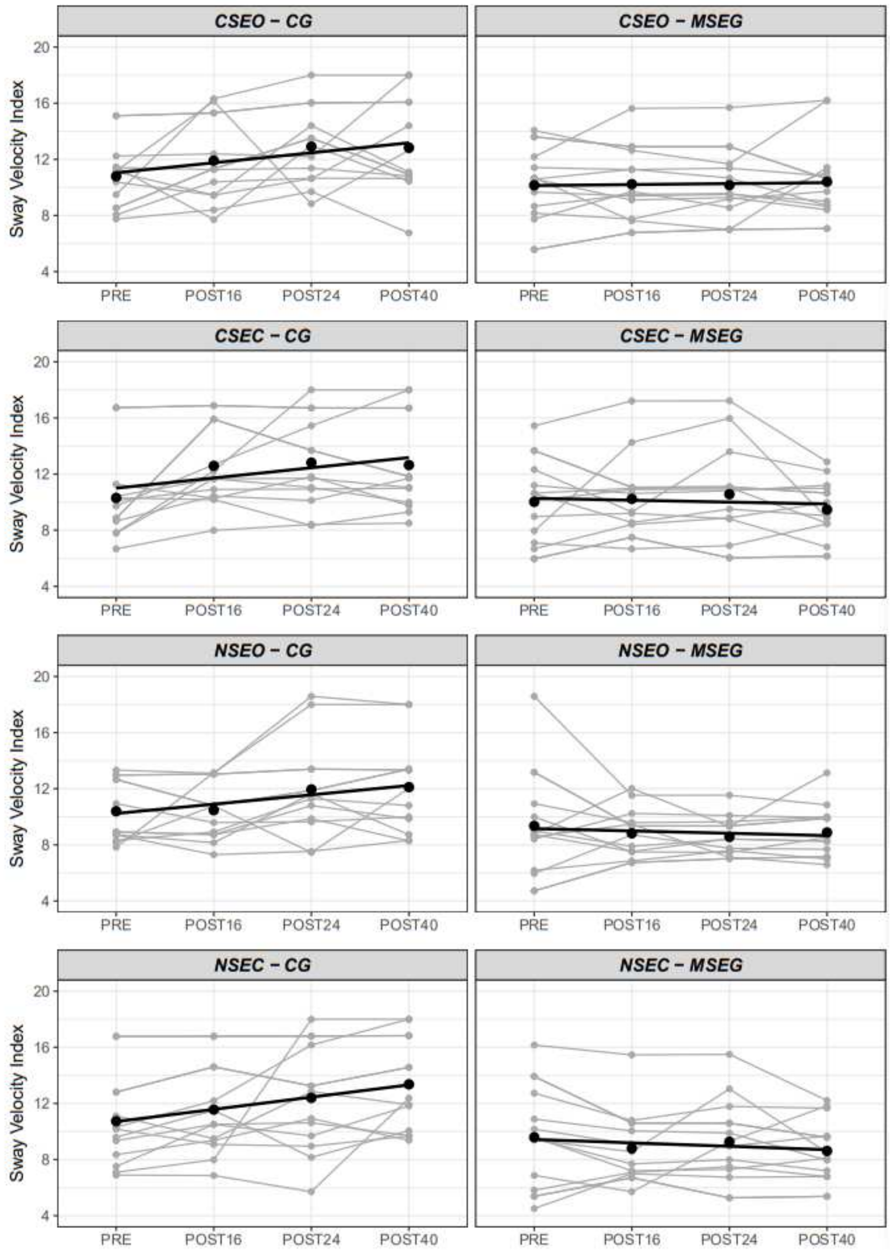

Figure 3. Individual and mean sway velocity index in the four conditions by the group. CSEO = Comfortable Stance Eyes Open; CSEC = Comfortable Stance Eyes Closed; NSEO = Narrow Stance Eyes Open; NSEC = Narrow Stance Eyes Closed.

4. Discussion

The main findings of this study can highlight that (1) 16 weeks of training were sufficient to improve body control in octogenarians, (2) 8 weeks of detraining were sufficient to observe reductions in the improvements see after the training period, but not strong enough do not return to baseline values, (3) retraining process was able to start reverting the reduction seen after detraining, promoting improvements, and (4) the lack of exercise in the CG led to a trend in a decrease/worsen in all body control parameters.

In this way, the main findings of this study can contribute to the growing body of evidence signaling the protective benefits of strength exercise in the very old populations [30,51]. Our results showed that very old adults performing 45 min of muscular strength exercises, two times a week, for 16 weeks could improve stability and body control, represented by a reduction of 7.9% in the composite index. Moreover, even after the performance decline observed after the detraining process, an increment of 6.4% in the composite index was still present, the exercise program showing a protective effect and avoiding returning to baseline values. Additionally, the MSEG increased their stability, reducing 3.1% their composite index, during the retraining process; meanwhile, CG showed a very marked increase of instability after the first 16 weeks (17.1%) followed by a more gradual increase during the subsequent measuring moments (2.4% at POST24, and 2.3% at POST40). These results agree with those reporting an association between lack of physical activity or regular exercise training with a decrement of postural control and a concomitant worsening in the performance of gait and instrumental activities [52,53].

Therefore, exercise programs have shown positive results, especially those focused on increasing strength combined with functional exercise [21,51,54,55]. Accordingly, in a similar design study [28], it has been reported a 14% improvement in balance after a training period, a reduction of stability of 7% after the detraining period, and a new improvement of 18% after retraining. Taken together, these results confirm a positive effect of strength training over the postural control of older adults [56,57]. Moreover, older adults who did not exercise (CG) increased their sway velocity and the composite index, which is interpreted as an increment of their risk of falls.

We also observed that the CG presented a substantial increment of their sway velocity composite index (17.1%) at POST16, when on the other hand, MSEG presented a 7.9% decrease of sway velocity composite index, indicating an improvement in the estimated risk of falls after that period. A similar pattern was observed in the postural control (in the four conditions (Figure 3), with the CG always showing a worsening trend when compared to the MSEG. It has to be emphasized that MSEG trained resistance exercise with elastic bands for two sessions per week, with similar training configurations producing similar results, showing that groups who performed physical exercise demonstrate a trend to decrease de fall risk by improving their balance [24,57].

In this scenario, other studies comparing older adults who practiced physical activities with those who did not practice [54,55] observed that many older adults were prone to falls in both groups. However, those who practiced physical activity regularly showed a higher level of mobility and less propensity to fall when compared to the inactive group.

After the first training period (POST16), we observed the biggest difference between groups in CSEC ($p < 0.001$) and NSEC ($p < 0.001$), these evaluates postural control when visual capacity was taken off, indicating the positive effects of exercise on proprioception, sensorial information, and the vestibular system. Therefore, our results are in line with the study [58] where they found that physical exercise was able to improve significantly the proprioception related to sensorial status in older persons, which is also closely related to the risk of fall [59] and to another study [60] where the practice of exercise apparently was helpful to attenuate the deleterious effect of eye closure on postural control.

After the detraining phase, we expected that the physical capacities of the participants would worsen because of the withdrawal of the exercise program, and consequently, they would diminish their postural control and stability, increasing the risk of fall [19]. However, our study was also able to identify some possible protective effects of exercise because the postural control of the stability test barely varied from POST16 to POST24 in MSEG (0.53%, 0.43%, 0.01%, and 0.09% for CSEO, CSEC, NSEO, and NSEC, respectively). In comparison, percentual increments in instability were observed in CG (10.3%, −1.02%, 9.89, and 0.05% for CSEO, CSEC, NSEO, and NSEC, respectively). These results show a possible protective effect of the exercise program delaying the expected age deterioration of neuromuscular system controlling posture when aging.

In this way, a study [31] observed significant reductions in strength and power after six weeks of detraining, but balance and neuromuscular function did not return to the baseline levels. Therefore, health professionals and researchers have pointed out the relevance of putting their efforts into establishing strategies to delay the aging process or at least maintain the quality of life of people cushioning the consequences of chronic degenerative diseases [22,57,61]. These authors suggested that strength training programs are essential for maintaining muscle strength, balance, functional performance, and independence in older adults.

The results of the present study, when indicating a significant difference in postural stability and fall risk, agree with several studies [24,31,54,62], where physical activity contributes to a lower incidence of falls in older persons. Among the strategies to reduce the action of risk factors for falls, the practice of exercise, like in our study, has been proven as an effective intervention proposal [34,63]. Moreover, most of these studies defend the importance of physical activity and exercise and being active as a method of prevention [6,64,65].

Even if arguing that only the practice of physical activities can reduce the risk of falls by improving body stability and postural control is inconsistent [66,67] because even in the second exercise intervention (retraining), the difference between both groups was not significant, and also, there were cases of older adults in MSEG in whom the score was worse even after the exercise program, this only helps to highlight the multifactorial nature of the process involved. Medications, psychological condition, or even nutritional status, all can affect the risk of fall.

5. Conclusions

Our study revealed that sixteen weeks of two 45 min sessions/week of a resistance training program with elastic bands effectively improved balance control and exerted a protective effect reducing fall risk in very old adults (i.e., > 80 y/o).

During the retraining period, both groups did not change significantly in any variable. However, the MSEG obtained better stability outcomes during this period compared to PRE values. Meanwhile, the CG kept a worsening trend during the eight weeks that this period lasted. The delayed beneficial effects produced on the stability of the MSEG group during the first training period meant that at the end of the detraining period, the participants of this group were at a lower risk of falls than the CG. In addition, we should highlight that we observed greater improvements in CSEC and NSEC conditions, where the visual capacity was taken off during the evaluation, showing a possible positive effect of exercise concerning proprioception and the vestibular system, which should be further studied.

Our results indicate that a band-based resistance training program can positively affect postural stability and the risk of falls, providing an increase in balance and postural stability, which can positively ameliorate the functional ability and mobility of older adults. Additionally, the stability trends observed during the detraining period highlight the need to develop better and more specific physical activity programs for very older people (i.e., >80 years) to ensure adherence to training programs and avoid the detrimental effect of being inactive.

Our study has some limitations that should be reported. We did not measure the participants' daily physical activity levels, which could influence the results. However, since they were older adults living in nursing homes or social care centers, certain stability can be expected in carrying out their usual physical activities since they were prescribed by the different institutions of origin. In this study, we did not control the incidence of falls prospectively in a follow-up period that would allow us to study the effects of the intervention on the incidence of falls. In future studies, it should be considered to include a follow-up period after intervention with different doses of strength training and functional activities to determine those training configurations that most favor the reduction of falls. In addition, other variables that may affect falls (changes in the medication regimen, aspects related to the context of the participants, psychometric evaluations . . .) must be recorded to analyze holistically the determining factors that reduce the number of falls in octogenarian adults.

Author Contributions: Conceptualization: R.N.R., G.E.F., C.A. and A.M.T. Methodology: R.N.R., A.C.-S. and G.E.F. Software: R.N.R. and E.C. Validation: R.N.R., E.C. and F.S. analysis: R.N.R. and E.C. Investigation: R.N.R., F.S. and A.C.-S. Data curation: R.N.R., F.S. and E.C. Writing—original draft preparation: R.N.R., E.C., G.E.F. Writing—review and editing: F.S., A.C.-S., Cidalina Abreu, A.M.T. Supervision: C.A., G.E.F. and A.M.T. Project administration: A.M.T. Funding acquisition: E.C., G.E.F. and A.M.T. All authors have read and agreed to the published version of the manuscript.

Funding: Financed by the Portuguese Foundation for Science and Technology (CIDAF- UID/DTP/04213/2020).

Institutional Review Board Statement: This study was approved by the University regional committee (reference number: CEFCDEF/0028/2018) respecting the Portuguese Resolution (Art. 4th; Law no. 12/2005, 1st series) on ethics in human research (Braga, 2013) and the Helsinki Declaration. Clinical trial register number NCT04376463.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to [restrictions e.g. their containing information that could compromise the privacy of research participants].

Conflicts of Interest: The authors declare no conflict of interest.

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Chapter 3. Exercise Program Propusal and Divulgation

In the context of divulgation and giving back to society, a specific book chapter (Chapter 1, subitem 1.2) was written to give examples of a specific exercise program focused on improving balance and reduce fall risk in older adults.

This specific exercise program was also accepted and included in the department of sports of University of Coimbra as a specific exercise program for adults and older adults as it matches the University of Coimbra's ambition of a healthier society.

The department of sports of University of Coimbra is called Desporto UC and has the mission to make the University of Coimbra and its community healthier, and for this purpose, develops many kinds of initiatives related to sports and physical activity. Desporto UC offers to the University of Coimbra community, through its University Stadium and its initiatives, a large sports infrastructure that generates information and opportunity to local courses, stimulates sports participation and practice, helps to develop competitive and non-competitive sports games, and the opportunity to practice many kinds of physical activity and sports through the UC+Ativa program (i.e.: tennis, table tennis, badmintons, functional training, laboral exercises, swimming, walk and run activities, etc.) which is Desporto UC' greatest focus, as well as to give support for student-athletes.

In this context, Desporto UC has asked to within the purpose of this thesis to prepare a specific poster with detailed images/photos and instructions of exercises, as well as a video to demonstrate all exercises, to be part of UC+Ativa program and available for all those who wants to improve their health through exercise.

The poster was illustrated with photos and information about the exercises, is order, and followed by a proposal of progression and planning for different objectives: for those who want a faster and practical exercise at home, and for those who want a more continuous and moderate to vigourous exercise program, including the possibility of circuit training.

Also, a short video was produced and published on the Desporto UC YouTube channel (Figure 2) and can be watched by everyone.

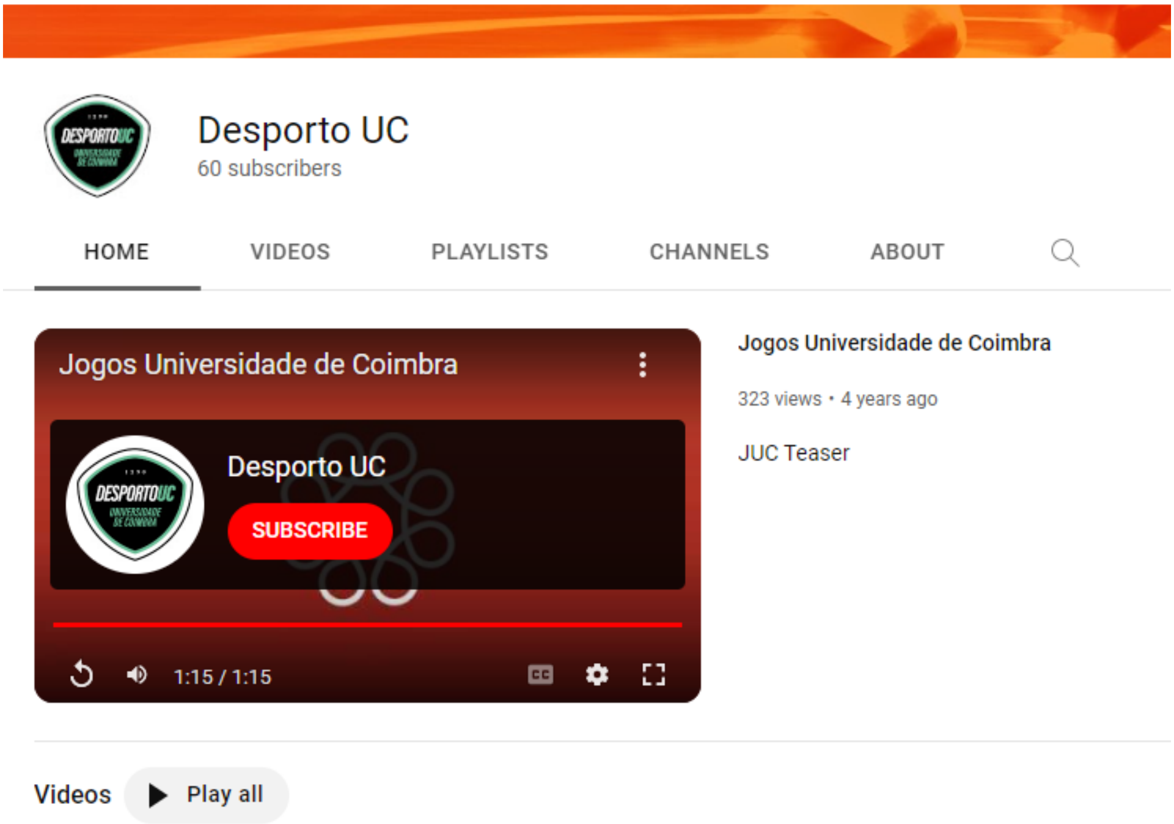

Figure 2. Desporto UC Youtube Channel

The exercise program was accepted as part of UC+Active program, under the subprogram Functional Training, and inside the area of autonomous training. The specific video, and poster was produced in a partnership with Desporto UC, in its UC+Active program, and University of Coimbra, and was submitted under the name of UC+Active: Functional Training with Elastic Band. The program and its content can be found on this thesis chapter 1, subitem 1.2, the video of demonstration, ca be easily accessed by everyone following the weblink: https://youtu.be/R82uhrHD2BI.

The video has 5 minutes and 7 seconds duration, and shows all the proposed exercises, some variations (i.e., sitting or standing position), how to use the elastic band, a warmup indication (figure 3), the specific elastic band exercise (figure 4), and cool down (stretching) part (figure 5).

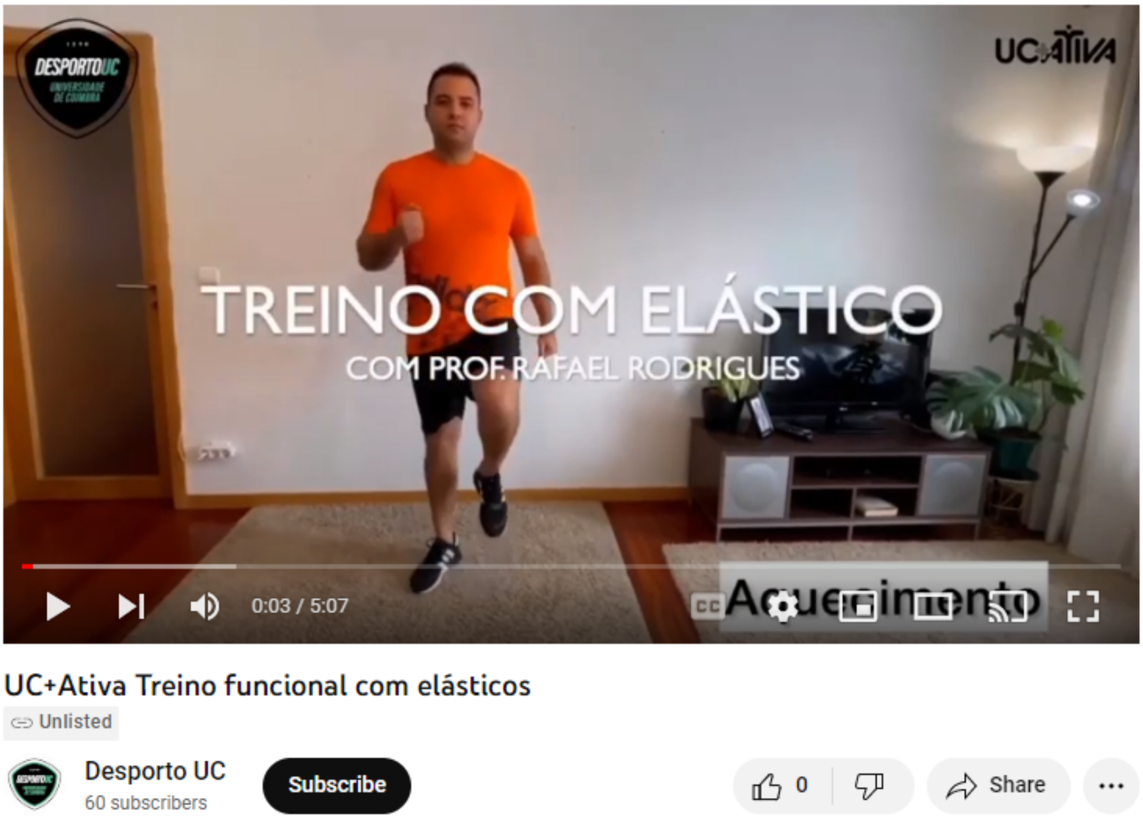

Figure 3. UC+Active: Functional Training with Elastic Band – warm-up

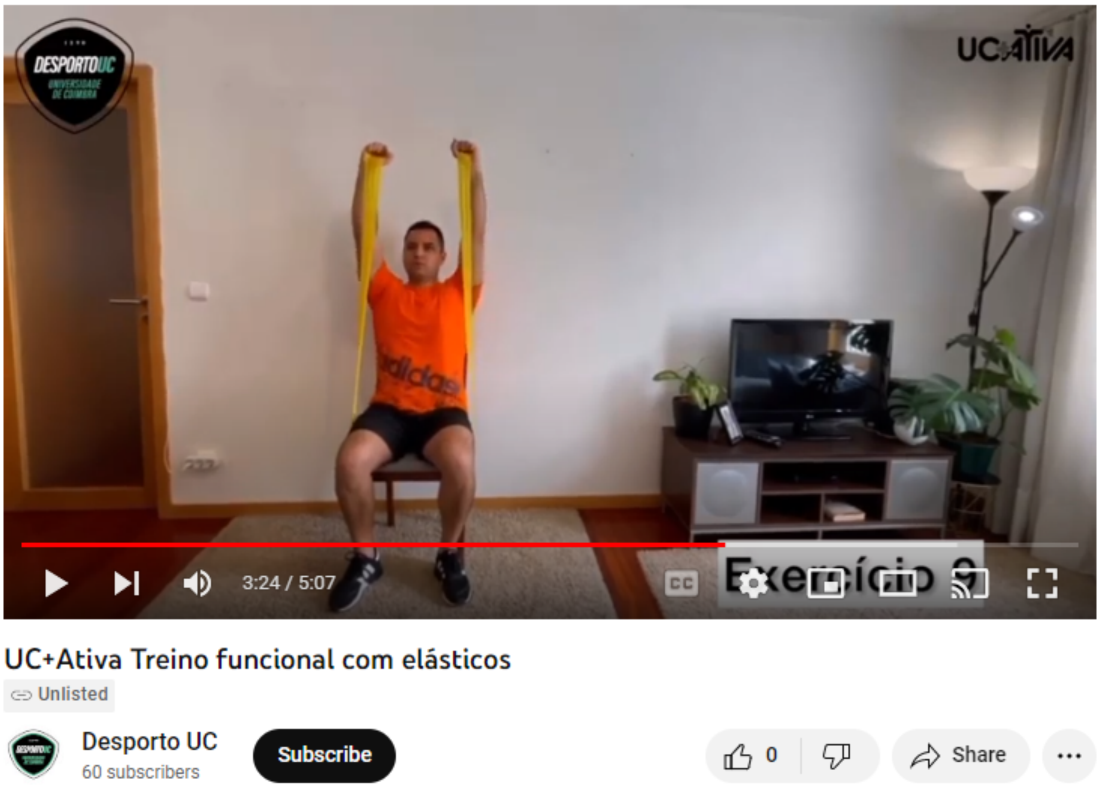

Figure 4. UC+Active: Functional Training with Elastic Band – elastic band exercise

Figure 5. UC+Active: Functional Training with Elastic Band – cool down/stretching.

The following poster is divided in two parts (figure 6 and figure 7) just for thesis adjustment, but it is a unique poster. The direct link for all the information is also published on Desporto UC website, under the menu “Atividades” → “UC+Ativa”.(https://desporto.uc.pt/wp-content/uploads/2022/10/UCATIVA_treino_elastico.pdf).

Figure 6. UC+Active: Functional training with elastic band – part 1/2.

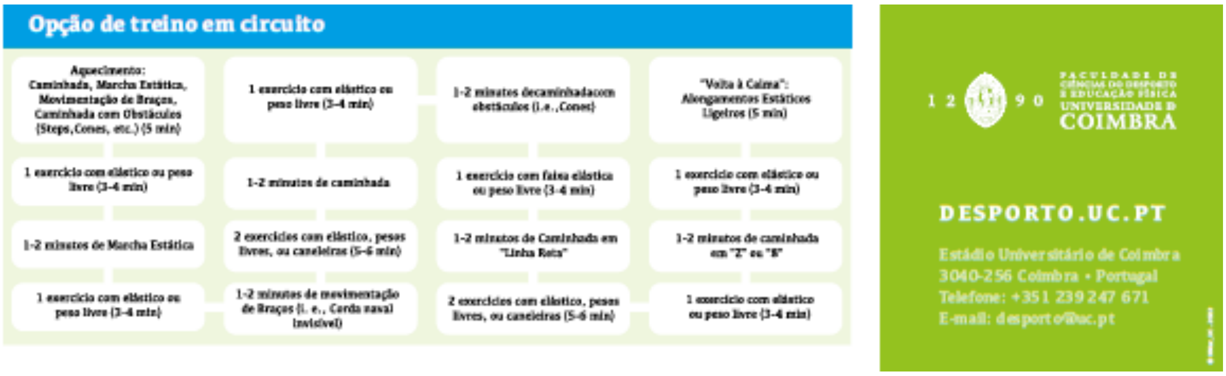

Figure 7. UC+Active: Functional training with elastic band – part 2/2.

Chapter 4. General Discussion

4.1 Summary of key findings

The overall aim of this thesis is part of an overarching relationship between aging aspects, mainly related to fall risk (e.g., balance, specific fall risk tests, body composition, muscle power and cognitive status) and the practice of elastic band resistance training exercise in a cohort of old individuals.

To address this, a comprehensive literature review was initially presented in its general aspects (Chapter One), and as two published book chapters (Chapter One, item 1.1 and 1.2) showing the overview of health and fall risk issues linked to the aging process, the importance of its evaluation in a continuous way, and the influence of physical exercise and its characteristics.

During the process of production of Chapter One and its two published book chapters some methodological and scientific gaps were identifies, which include:

1. Large heterogeneity between studies
2. Failure to propose a fall-risk reduction specific training protocol
3. The necessity of a more simple and fast fall risk test for Portuguese population
4. Lack of information about the influence of physical exercise related to fall risk in very old population (i.e., >80 years old)
5. The importance of new technologies to assess fall risk in a faster and reliable way
6. The use of physical exercise programs that may not be suitable for a 'fall risk' reduction or control (e.g., too much walking, too little strength or balance training).

These methodological and scientific gaps were further emphasized in the four studies and the multimedia package produced as a result of this thesis, which includes the validation of FRAT for the Portuguese population (paper 1) in order to try to fill the necessity of a simpler and more specific test to address fall risk, one crossover study, focused on the some relationships around fear of falls, and two studies related to our intervention proposal.

The first study was conducted in order to understand the influence of our elastic band resistance exercise program in the multidimensional fall risk test, and specific physical and cognitive capabilities and indicators, such as body composition, muscle power and cognitive status. The main finding of this study (paper 3) was:

i) Muscle power outputs showed a significative relationship (correlation) with fall risk indicators such as TUG, FRAT and FES. The muscle power outputs also showed to be a good predictor for those same fall risk indicators.

ii) The FFM(kg) showed significative relationship (correlation) with fall risk indicators such as FRAT and FES, but weaker if compared to muscle power outputs. It was also showed to be a good predictor for these two (FRAT and FES) fall risk indicators.

iii) Cognitive status showed significative relationship (correlation) with fall risk indicators such as FES, FRAT and TUG. This relationship was stronger when cognitive and behavioural status were used to characterize the fall risk, like in the FES and FRAT assessments. The cognitive status also showed to be the best predictor for fall risk when compared to the other predictors (FFM, aPower, rPower). Congnition was also the best predictor for fear of falling (FES).

iv) The practice of resistance training with elastic band showed a significant improvement in muscle power (absolute and relative) during training and retraining in the active group. This difference was also significant between groups for the aPower variable during training, detraining and retraining, showing the influence of our intervention.

v) In the Fall Risk indicators, FRAT showed very stable results for the active group, that was able to keep the same fall risk status while the CG kept worsening, increasing its risk of fall significantly. The Sensorimotor assessment showed an increased trend in the fall risk status for the CG, while the exercise group was able to kept basically, the same baseline results for all 40 weeks. The TUG test showed a more ondulatory trend, which has followed the intervention. After the training period, the exercise group improved its results significatly, and worsened in a significant way, even worse than the baseline result when the exercise was taken out (detraining), but it significatively improved again after the retraining period, showing the effect of our resistance training in this specifically fall risk evaluation.

vi) Our resistance exercise program was also able to improve body composition status. The exercise group gained FFM (kg and %) in the training and retraining phases. This group also lost FM, however, during the detraining phase, the opposite trends were observed.

vii) The cognitive status also appears to be positively influenced by our exercise program. The scores from the cognitive assessment after training and retraining periods were better than its baseline assessments, only after de detraining phase, the result was worse, but even then, not at the baseline level, showing a protective status promoted by exercise. Meanwhile the CG worsened, and kept this trend thought time.

Overall, this study (paper 3) found that in a cohort of institutionalized older adults, exercise significantly contributed to reduce the fall risk indicators, improved general cognitive status, muscle power, and some of the sarcopenia indicators such as lean body mass.

The 4th paper based in our elastic band resistance training program explored the relationship between exercise and fall risk outcomes measured with a posturografic/sensorimotor platform in very old adults (i.e., >80 years old). The study showed that after 16 weeks of training, the active older octogenarians reduced their fall risk score based in the posturografic test, and during the 8 weeks-detraining process, some protective effect of exercise could be observed as the physical active group had improved results even with the withdraw of exercise when compared to its sedentary peers. Also, the retraining process demonstrated some improvements in the fall risk test for exercise group. On the other hand, the control group kept worsening its results.

The finding of these two studies (Paper 3 and 4), support the main hypothesis that resistance training exercise program with elastic band would influence the improvements related to body compositions, skeletal muscle power, cognitive status, and fall risk analyzed by different and multidimensional methods.

Whereas per the hypothesis, a resistance exercise training provided and performed twice weekly, resulted in significant decrease in fall risk mediated by significant increases in muscle power, FFM (kg) and cognitive status in the exercise group.

In order to facilitate the comprehension of this thesis, this final chapter summarizes the main findings from the previous studies here presented, mainly in terms of the main outcomes explored throughout this thesis process: Skeletal muscle mass (body composition), skeletal muscle power (absolute and relative), cognitive status and multidimensional fall risk.

Therefore, findings from all included chapters are summarized within each topic mentioned above and build on their individual discussions which include the main variables explored throughout this thesis (e.g., physical activity, fall risk, age etc.).

This summary of the findings was built on the current knowledge, and some explore potential mechanisms, also aim to connect all chapters here presented, followed by discussing the research strengths, limitations, and recommendations for future research/practice.

4.1.1. Body Composition Outcomes

Skeletal muscle mass is a very dynamic tissue which is constantly in turnover states (1). This tissue is strongly affected by the aging process, and this age-related decline is also observed in skeletal muscle strength and power. This process occurs mainly related to physical inactivity and the disruption of muscular protein balance (2).

In this way, there is evidence (3,4) that physical exercise is an important component in any kind of intervention to increase skeletal muscle mass, fat free mass, muscle strength and power, and reduce the age-related changes related to body composition, physical function and performance (3). Therefore, the current literature indicates the use of exercise programs, mainly focused on strength training, which promote long term adaptations and cause hypertrophy, enhance skeletal muscle mass, strength and power, and consequently improve body composition (5–7).

Our findings (Paper 3) showed a significant improvement in body composition status related to FFM during both exercise periods (training and retraining), with a greater improvement during the first training period than during retraining. The exercise group was also able to keep the added FFM during the detraining process, or at least, to have a slower decrease in FFM values when compared to the CG, that in contrast, had reductions in FFM during the training, detraining and retraining period.

The difference between individuals was not present at the baseline assessment, showing similarity between all subjects and groups, and demonstrated the effect of the exercise intervention. Therefore, the difference observed in body composition [i.e., FFM (% and Kg), FM] is largely governed by the performance of the exercise program as discussed in Paper Three.

4.1.2. Skeletal Muscle Power Outcomes

Some research indicates that muscle power assessment would be a better indicator than strength, for clinical purposes, in active older adults, because of it faster decline (8). Although even gait speed is usually used to address muscle power (8,9),it has little relevance to performance measures in exercising older groups (10). Furthermore, muscle power outputs have been found to correlate well with several fall risk tests in our study, as well as in others (11).

In this specific study, there was an increase in absolute and in relative power during the training and retraining phase, as well as some protective effect during the detraining phase in the exercise group. This same result was not observed in the control group.

For example, Villanueva (13) observed in its 22 recreationally active males, a significant synergistic effect on relative muscle power, with a 38% increase versus a 5% observed in control group. However, Villanueva (13) also included a protein intake in its subjects, which is consistently known to help in muscle gains, and can influence muscle power, especially in the lower limbs [64]. This group that was composed only by men, and our groups included both sexes, with female predominance.

In the Caldo-Silva study (14), where the same populational group was included, with protein intake only, no significant differences in muscle power were found. However, the active group had its result improved or at least maintained, which can also be good in this population, who is most of the time characterized by the natural aging effect, and consequently loss of muscle power.

Furthermore, the loss of muscle power is connected not only to muscle atrophy or body composition changes, but it also related to the loss of certain types of muscle fiber, mainly the type II fast-twitch (8), as already demonstrated by Lexell et al (15)

Nonetheless, the test used to measure muscle power in this thesis, as well as the mathematical equation to calculate the muscle power results, have been shown to be simple, valid, and a reliable way to measure muscle power in older populations. The five-times-sit-to-stand test also mimics similar physical challenges that older adults undertake daily (i.e.: climb stairs, get out of a chair/bed/sofa/car) (16,17). Therefore, assessing muscle power in older adults using this method is simple, cheap, fast and reliable.

4.1.3. Cognitive Outcomes

Some exercise training programs have already showed significant improvements in cognitive health in older populations (18), although still not well understood which area of cognition are more related and influenced by exercise, or which kind of physical exercise is the most important for this improvement (19).

However, some studies suggest that the greatest benefits from exercise are related to memory and/or executive function (18,20), which are closely related to problem-solving capacities (21), and that aerobic training seems to have the greatest effect (22). However in some others (18), the resistance training showed to have a greater impact. In a recent meta-analyses (19), the training type did not show significantly different implications on cognitive improvements, and in fact, they recommend to use, instead of one model, both aerobic and resistance training which could result in even greater cognitive health, such as our exercise program, characterized as multicomponent elastic band resistance training, that was able to cause improvements in total MoCA score.

Although it remains unclear why and how the exercise type could influence some cognitive areas in humans, in animal models, aerobic training has been shown to act in 3 different domains (23): i) Hippocampal neurogenesis, creating new neurons, ii) Cerebral angiogenesis, creating new blood vessels in the brain, iii) Changes in inflammatory markers. The resistance training seems to act by increasing IGF-1 signaling, which stimulates hippocampal neurogenesis (24). However, in human studies, both types of exercise seem to improve brain function (25,26), plasticity (27–29), and cognitive status. Several studies support the idea of exercise training being a reliable strategy for improving both global and domain-specific cognition, irrespective of the type of exercise performed (19).

Some studies also show that female participants have greater benefits than man, in human and animal models (22,30). This was not seen in our results, where no differences between sexes were observed. However, the importance of sex in this context should be further studied to better understand this relationship.

Briefly, our findings on cognitive status showed that EBRT improves the performance on MoCA test, with greater effects during the first period of training compared to the second. Meanwhile, the inactive group kept worsening their cognitive abilities throughout time. The task-specific requirements of the designed exercise program, mainly in executive function, such as movement recall, movement switching and planning, and visuomotor processing, could explain the obtained results that are consistent with previous studies and show the importance of a multicomponent exercise program (28,31–33).

4.1.4. Fall Risk Outcomes

Exercise has many positive benefits in older adults, mainly related to physical function (34), and some reviews (35,36) have demonstrate that the practice of physical exercise has positive effects on postural control and stability, and in the risk of falls, providing an increase in balance capacity, functional ability, mobility, strength and coordination (37).

However, a recent meta-analysis demonstrated that the largest effects of exercise (i.e., resistance training, aerobic training, multicomponent training) are on body strength and functional capacities, plus a small improvement in flexibility and balance, with no significance on gait speed, or even in fall risk (19).

In this scenario, some other studies (38,39) with the same objective as ours, tried to identify and discuss more about the influence of exercise in fall risk by comparing older adults submitted to an exercise program (with increased levels of physical activities) with those who did not practice exercise. They observed that many older adults are prone to falls in both groups (active and non-active ones), and individuals with at least a moderate risk of falls were found. However, those who performed physical exercise regularly showed a higher level of mobility and less propensity to fall, when compared to the non-exercising group.

We also observed that our control group showed, according to the sensorimotor/posturographic test, a greater propensity to falls compared to the exercise group, being in concordance with similar studies (38,40,41). Other studies have also shown an increased risk of falls in people, of different ages, with physical and functional deficits, that is even greater as people age (42,43).

Specifically in our study, after the first intervention period (training), the exercise group had decreased its fall risk, possibly due to the increased physical activity levels and functional abilities stimulated by our elastic band resistance training program. The analysis of the fall risk assessments, in all psychometric fall risk assessments, showed that our EBRT program was able, at least, to maintain the older adults stability and fall risk over time, while the absence of physical stimuli increased the fall risk more rapidly, showing, like other studies, that exercise can be a useful tool to prevent falls (44).

It is likely that some characteristics that were emphasized in our exercise program (i.e., sequential movements, alternate flexion/extension of lower limb joints, changing direction of limb movements, static/dynamic weightlifting and shifting, and single limb support) may be related to these gains in postural sway, and consequently reducing fall risk (38,42,45,46).

Although no significant changes in the retraining period were found, the older adults who did our exercise program were able to maintain the level of postural control and fall risk, demonstrating some protective effects of exercise, which did not happen in the non-exercising group. Some authors (47,48) also highlight the importance of exercise to be ongoing, not only because its possible benefits, but also because the importance of functional capacities in later life, for maintaining independence, and reducing the probability of frailty development.

This concern with function decline with aging mobilizes health professionals not only to establish measures, but to try to delay the consequences of chronic-degenerative diseases as well (49–51), and most of these studies defend the importance of exercise, and in being active as a method of prevention. As we found in our study, even after the detraining period, when both groups showed worsened scores in some of the variables studied, the range and severity of those was much lower in the active group, showing the protective effect of exercise over time.

In the same context, the TUG evaluations showed that both training and retraining interventions were able to improve its performance, with the opposite occurring with the exercise withdraw, in concordance with several studies (39,52–55), where exercise was positively correlated with improvements in gait and balance capacities, which also is related to falls (56)

The concern is that normally, sedentary older adults have decreased functional capacity, which increases the incidence of falls, that are directly related to impaired balance and poor postural control, impaired instrumental activities, limitation/lack of mobility, gait and muscle strength (57,58). Therefore, exercise programs focused in stimulating these capacities have shown positive results (41,51,59–63)

In the same way, the FES, demonstrated similar results, with improved scores related to the exercise program. This highlights the importance of the general physical condition for older adults to feel safer in the execution of some of their daily live activities and increasing independence (64,65). Hence, it is plausible to say that our EBRT is both a preventive strategy, as it showed some influence on maintaining physical functions in older adults, and also an intervention, as it was able to improve significatively some physical and cognitive aspects related to fall risk.

4.1.5. Relationship between improvements on cognition and physical outcomes

Exercise is well known by its induced improvements related to physical functions, and some studies have demonstrate that exercise is also related to cognitive functions in many ways, but the neural underpinnings and the temporal aspect of this connexions are not yet well established (19). However, physical and cognitive functions are related by some common factors that are improved by exercise, such as IGF-1 (66,67).

In this context, our results appear to provide some evidence that exercise-induced improvements in physical and cognitive function are connected, and was explained by Liu-Ambrose et al (68) in his central benefit model where cognition and neural plasticity are significant mechanisms influenced by exercise, and promote mobility, and therefore, reduce the fall risk (19,69)

Also, we should address to the promising results of this study, since some previous studies have found no significant improvements in cognitive function (70,71) physical performance, or falls after exercise specific interventions (72,73), and where several study-related factors may account for these differences. Study characteristics such as participants age, frailty, fall risk level and differing adherence of each participant may affect the effectiveness of each program, and the non-significant findings in some trials have also been attributed to the lack of sensitivity of some outcome measures (74,75). However, in our study, extra attention was taken to strengthen and maximizing accurate adherence, and the EBRT program design appears to have facilitated learning and program adherence.

Therefore, this study was able to observe that muscle power outputs and cognitive status demonstrated a significant relationship (correlation) with fall risk indicators such as TUG, FRAT and FES, and were shown to be good predictors for those same fall risk indicators. Also, the improvement in reaction time, and speed of walking complements the findings of faster processing speed and greater attention manifested in the cognitive tests and may be one mechanism for the improvement in executive function, which could explain, in some (but restrictive) way, the improvement in cognitive status assessed by the MoCA tests after training (76,77).

Briefly, the practice of resistance training with elastic band showed a significant improvement in muscle power (absolute and relative), body composition, and consequently in fall risk status, during training and retraining in the active group, and its effects were also observed in the detraining phase, demonstrating a protective effect. The cognitive status also appears to be positively influenced by our exercise program. The scores from the cognitive assessment after training and retraining period were better than its previous assessment, only after the detraining phase, the results worsened, but even then, not returning to the baseline level, also showing some protection promoted by exercise

Although our study agrees with some others (78), and provides some evidence suggesting that physical exercise promotes cognitive improvements, we cannot conclude, specifically from our results that these improvements are the main mechanism by which physical function improves.

4.2. Thesis Contributions

This thesis provides evidence that support: i) the effect of our exercise program appears to impact muscle power, body composition, and global cognitive function, ii) the effect of our exercise program, by improving several physical and cognitive aspects, appears to reduce fall risk in old (≥ 70 years old) and very old (≥ 80 years old) populations, iii) our exercise program showed to be beneficial in maintaining older adults' health (physical and cognitive).

In this context, the findings from this thesis have some implications for researchers who are interested in health and performance outcomes in older (i.e.: >65 years old) and very old adults (i.e.: >80 years old), for health professionals working within this population (e.g., sports specialist), and for the older adults themselves, and their relatives.

The first implication in the research field of older adults within a clinical setting is that active older adults who regularly engage in physical activity do not have the same outcomes compared to its peers who do not engage in physical activity, and it allows researchers to understand the real physical, cognitive or even the physiological impact their intervention may have.

Secondly, the knowledge of the baseline physical and cognitive profile of older adults may provide to researchers a preliminary understanding of the influence of being active or not.

In relation to health professionals who work with older adults, this thesis provides some insights to consider (e.g., age, training, fall risk, cognition influence) when implementing exercise and fall risk control interventions. Furthermore, it also highlights the use (and the need for a continuous development) of technologies as well as simple and cheap ways to assess and control the fall risk.

Finally, this thesis also provides insights for older adults themselves and the next generations of older adults, as the study participants (>70 years old) make up a very considerable proportion of Portugal's population and of the global population (79), and the next cohort of older adults are also predicted to live much longer than the previous generations (80). This new generation of older adults has been shown to have higher expectations for wellness and independence in later life (81) which motivated the production and divulgation of the guide and video, so that the population has easy access to some simple but instructive materials on how to improve their quality of life and preserve it through physical activity and exercise.

Hence, the biggest benefits of our elastic band exercise program are that it helps to improve, or at least, to maintain the older adults' physical and cognitive health, which can reduce the risk of falls, and efforts should be made in order to promote and encourage all older population to exercise in a regular way as it can help to reduce age-related risks and improve their general health status in a relatively short period of time (16-weeks), and also have longer term protective effects.

4.3. Overall strengths and limitations

The studies included within this thesis are some of few that follow and evaluate in a longitudinal way a very older population and try to understand the influence of exercise (training), its withdrawn (detraining), and the return (retraining) to exercise.

The intervention studies contributed and accounted for more relevant outcomes in an active ageing cohort. Also, since the necessity for a simple and fast way to evaluate fall risk in older population was one of the gaps identified, the validation of FRAT for Portuguese population was an important contribution to the field. Another important contribution for knowledge transfer was the development of a multimedia package for community use in a very didactic and simple way, to be accessed by everyone and not being limited to scientific use.

An overall limitation of the thesis presented includes the limited sample, and disparity of sex, as we have 3 times more female participants than male. This disparity could have influenced some outcomes, as Boit (86) showed in his study, where community-dwelling men over 65 years old, increased their FFM in about 34% while women only increased 9% after 18-weeks of resistance training. However, Churchward-Venne et al. (87) did not observed any changes in FFM after 24-weeks of training, when comparing female and male participants. When we corrected and adjusted by sex in our study, no differences in body composition changes were found between sexes after the exercise program (Paper 3), and do not support the idea related to women being less able to improve body composition when compared to men.

Another potential limitation is linked to the participants physical activity history and the concept of muscle memory that were not analyzed in this thesis. This concept refers to some easy that could exist by individuals who have been prior involved in physical activity in their early live, and it could contribute to the ability to gain more FFM, strength, muscle power than the participants who had a sedentary lifestyle and are novice to the practice (86).

Based on this, the regular practice of physical exercise, mainly resistance training during a long-term period, increases the number of myonuclei inside the muscle cells, which influence and increase the muscle fibers (89). In detraining conditions, muscle atrophy may occur, but not the decline in myonuclei's number (90). Therefore, their training background may have some influence in the individual variation, which was somewhat observed in study 4, mostly related to body composition indicators (FFM(kg), FFM(%), FM(%)), and in the octogenarians study. Even though, the elastic band resistance training still presented and resulted in significant gains.

Future studies should consider objectively measuring physical activity 2 weeks before the clinical trial's begining to establish a more accurate baseline, as previously reported (91), and consider recruiting active older adults from similar training modalities to reduce this potential cofounding bias.

4.4. Suggestions for future research

The studies developed in this thesis extend our current understanding of the baseline characteristics related to the ageing process and fall risk status and help further understand potential successful exercise interventions, in order to promote health and physical improvements and maintenance, as well as a positive increase related to skeletal muscle power outcomes and cognitive status in older adults.

Although we have made some progress by identifying the interaction and influence of elastic band resistance training on fall risk, many gaps in our knowledge remain. The important questions for future research within this study topic include:

1) Would there be any significant differences if older adults from different sporting backgrounds or with physical activity history were studied in relation to their fall risk status? Would they benefit in a similar way from this intervention?

2) How do differences in baseline muscle fiber distribution (e.g., type I and II muscle fibers) affect an individual's response to exercise interventions? And during detraining and retraining phases?

3) Would the general diet or protein intake influence the development of muscle power or fall risk? How would the fall risk status differ in a cohort that habitually consumed lower or higher protein intakes?

4) Would a dual-task (cognitive + physical exercise) activity improve cognition, muscle power, body composition and/or fall risk in a better way?

5) Would some technology-based training improve the results achieved by our elastic band resistance training? What would be the influence on balance (Dynamic and static)? Which is the best predictor Dynamic and static)?

6) What are the biological links between exercise, cognitive function and fall risk?

4.5. Overall Conclusion

This current thesis provides novel insights using previous non-active older adults, who are considered the 'ideal' cohort for studying age-related influences of exercise making it possible to see the specific exercise-influence on some age-related effects, mainly related to fall risk.

Studying the inclusion of elastic band resistance training in daily-live routine has reported some interesting outcomes related to fall risk, and as we could see in Chapter One, physical exercise should be included in all programs that intend to reduce or control the fall risk in older adults. The need for a simple and accurate test for fall risk assessment was also identified, hence the validation of FRAT for the Portuguese population.

The intervention study showed mixed results regarding the influence of elastic band resistance training in older populations, with significant improvements in muscle power, body composition, cognitive status, and fall risk assessed by different and complementary methods. However, when exercise was suspended, it was clear that the beneficial influence of it was also reduced, showing the importance of a regular exercise intervention. The contribution of exercise even in later life, in very old (>80 years old) can be safe and very beneficial, as it was capable of significantly reducing the fall risk, demonstrating some protective effects even during the detraining period.

Together, these studies highlight the complex nature of ageing and identify the many cofounding variables (e.g., age, training status, biological sex, lifetime physical activity history) that should be considered in future studies and even at a clinical level. Novel data from this thesis provides insight into important methodological considerations for future research on exercise, ageing and fall risk, which should include information about diet and outcomes related to sarcopenia and frailty. The inclusion of some biomarkers that may assist in further understanding of potential mechanisms involved in fall risk may also be of interest.

In order to promote health gains through a physically active lifestyle in older populations, simple, illustrated, and objective programs were developed and made available to the community, contributing not only for increasing people's health, but also to society, by promoting a reduction in fall risk that would be reflected in hospitalization rates and consequently the social and financial costs related to falls in older populations.

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APPENDIX I – Consent Form

FCDEF FACULDADE DE CIÊNCIAS DO DESPORTO E EDUCAÇÃO FÍSICA
UNIVERSIDADE DE COIMBRA

CONSENTIMENTO INFORMADO, ESCLARECIDO E LIVRE PARA PARTICIPAÇÃO EM ESTUDOS DE INVESTIGAÇÃO (de acordo com a Declaração de Helsínquia e a Convenção de Oviedo)

A Faculdade de Ciências do Desporto e Educação Física da Universidade de Coimbra (FCDEF-UC), no âmbito do doutoramento em Ciências do Desporto da Mestre Adriana Caldo, vai desenvolver um projeto intitulado: **"Efeito de um programa de exercício físico multicomponente com e sem suplementação de aminoácidos de cadeia ramificada em parâmetros de saúde de idosos institucionalizados"**, para o qual gostaríamos de contar com a sua colaboração. Este projeto é orientado pelos Prof. Doutores. Ana Maria Teixeira e Alain Massart que estarão à sua disposição para qualquer esclarecimento.

Este projeto tem como objetivo determinar os efeitos combinados do exercício físico e da suplementação com aminoácidos de cadeia ramificada em idosos institucionalizados. Assim iremos implementar um programa de exercício adaptado à sua idade e capacidade física. O programa de exercício físico será oferecido por dois profissionais de Educação Física experientes, Adriana Caldo e Rafael Rodrigues, devidamente credenciados e habilitados, o programa será dividido da seguinte forma: **Fase 1 -** (16 semanas) - Os exercícios serão realizados em formato com base na cadeira, que consiste na realização do programa de movimentos corporais com base na cadeira, possuindo boa amplitude de movimentos, segurança adequada ao exercício e sustentação que permite descanso entre as execuções com maior exigência muscular. Serão utilizadas bandas elásticas de diversas graduações, cuja disponibilidade será assegurada pelos responsáveis do projeto. **A banda elástica de intensidade leve (amarela; vermelha leve-moderada; verde moderada-intensa).** A alteração da banda elástica será individual e depende de a capacidade do participante executar o exercício proposto corretamente, serão realizados exercício de agachamento 90 graus, flexão da anca, abdução da anca, supino sentado, remada sentada, rosca bíceps, elevação frontal (ombro), elevação lateral, com cadência de 2 segundos fase concêntrica e 4 segundos fase excêntrica, com intervalo entre as séries aproximadamente 15 segundos e intervalo entre exercícios de 30 segundos, será realizada 2 séries de 20 repetições cada exercícios e após período de adaptação dos participantes, ocorrerá a alteração de faixa, repetições e séries de acordo com a equipe de investigadores, com 2 sessões de exercícios semanais e aproximadamente de 45 minutos cada sessão.

Fase 2 - Destreino, *Washout* (8 semanas) - Neste período não serão realizadas nenhuma atividade física com os participantes, pois iremos avaliar o efeito que o destreino (falta de exercício) resulta na capacidade funcional do mesmo.

Fase 3 - Exercício multicomponente (16 semanas) - são exercícios de (força+equilíbrio+aeróbico) na mesma sessão de exercício, é visto como o programa de exercícios mais adequado e completo para população estudada. Serão realizados exercício de agachamento 90 graus, flexão da anca, abdução da anca, supino sentado, remada sentada, rosca bíceps, elevação frontal (ombro), elevação lateral (ombro), com cadência de 2 segundos fase concêntrica e 4 segundos fase excêntrica, com intervalo entre as séries aproximadamente 15 segundos e intervalo entre exercícios de 30 segundos, será realizada 2 séries de 20 repetições cada exercícios e após período de adaptação dos participantes, ocorrerá a alteração de faixa, repetições e séries de acordo com a equipe de investigadores.

A sessão de exercício envolve uma aula aproximada (máxima) de 60 minutos, dividida em:

- 5 minutos de aquecimento;
- 25 minutos de treinamento de força, e movimentação geral de membros inferiores e superiores;
- 10 minutos de exercício de equilíbrio;
- 10 minutos de exercício aeróbio (caminhada);
- 5 minutos exercício de relaxamento e volta à calma;

O programa proposto será aliado à toma de um suplemento nutricional proteico de nome (**AMINOÁCIDOS DE CADEIA RAMIFICADA** da marca **MYPROTEIN** sua comercialização foi aprovada pela União Europeia, o produto possui certificado de pureza). De modo a melhorar entre outras, a sua mobilidade e força muscular, uma dose de 0,21g/Kg de peso será administrado 2 vezes por semana, dissolvido em água imediatamente, após as sessões de exercício. O estudo envolve também o preenchimento de vários questionários sobre a sua capacidade de realizar tarefas do dia-à-dia, bem-estar social e psicológico, stress, cognição, nutrição e qualidade de vida, bem como a execução de alguns testes físicos simples e a recolha de sangue e saliva para perceber se a intervenção efetuada tem benefícios ao nível da sua saúde física e qualidade de vida. O estudo envolve também o preenchimento de vários questionários entre eles (Índice de Comorbilidade de Charlson, (ICC), Mini Avaliação Nutricional (MNA), Questionário de sintomas do Trato Respiratório Superior, Escala de Depressão Geriátrica (GDS), Euro QoL, Mini Exame do Estado Mental (MEEM), Perfil do Estado de Humor (POMS), Inventário de Motivação Intrínseca (IMI), Escala de Autoeficácia física, Avaliação da funcionalidade física e fragilidade em idosos, Escala de Fragilidade de "Edmonton", Avaliação da Fragilidade-traço, Questionário Internacional de Atividade Física (IPAQ), Escala do Risco de Quedas (Morse), Short Physical Performance Battery (SPPB), Teste de equilíbrio de Tinetti. Cerca de 15 ml de sangue da veia do braço serão colhidos por uma enfermeira registrada. A saliva presente na boca ao fim de 3 minutos será recolhida para um tubo de plástico disponibilizado para o efeito. A recolha de saliva e o preenchimento dos questionários serão feitos pelo investigador principal do projeto numa sala reservada. As amostras de sangue e saliva serão utilizadas para o estudo de vários marcadores biológicos (imunitários e hormonais). A contagem de células sanguíneas será feita logo após a colheita de sangue, e o plasma e soro recolhidos serão armazenados no Laboratório Integrado de Biocinética da FCDEF-UC a -80 °C, até à quantificação dos marcadores séricos e plasmáticos propostos para este estudo de modo perceber se a intervenção efetuada tem benefícios ao nível da sua saúde. No final o material biológico sobrante será colocado em recipiente próprio para ser destruído por incineração.

Para que possa dar o seu consentimento com a máxima sinceridade e liberdade queremos garantir que a investigação segue os termos da Resolução 196/96 do Conselho Nacional de Saúde e que foi aprovado pela Comissão de Ética da Faculdade de Ciências do Desporto e Educação Física da Universidade de Coimbra sendo garantido: a) a confidencialidade, o anonimato dos dados e o uso exclusivo dos dados recolhidos para o presente estudo; b) que sempre que tiver dúvidas sobre os procedimentos ou precisar de mais informações sobre o estudo os investigadores do projeto estarão à sua disposição para quaisquer esclarecimentos adicionais; c) o estudo é de caracter voluntário e pode recusar a participação ou retirar o consentimento, a qualquer momento e sem qualquer prejuízo. Para que possamos recolher as informações necessárias para o desenvolvimento da investigação, pedimos a sua colaboração, manifestando a sua aceitação em participar neste estudo. Assim, na expectativa de contar com a sua colaboração, agradecemos a sua atenção e colocamo-nos à sua disposição para esclarecer quaisquer dúvidas. Por favor, leia com atenção a informação disponibilizada.

Se achar que algo está incorreto ou que não está claro, não hesite em solicitar mais informações. Se concorda com a proposta que lhe foi feita, queira assinar este documento.

Adriana Caldo Contacto: 919697915 (aluna Doutoramento, investigadora principal)

Rafael Rodrigues Contacto: 963 601 701 (aluno de Doutoramento)

Ana Maria Teixeira Contacto: 969881867 (docente FCDEF)

Alain Massart Contacto: 917280201 (docente FCDEF)

TERMO DE CONSENTIMENTO LIVRE E ESCLARECIDO

Declaro ter lido e compreendido este documento, bem como as informações verbais que me foram fornecidas pela/s pessoa/s que acima assinaram. Foi-me garantida a possibilidade de, em qualquer altura, recusar participar neste estudo sem qualquer tipo de consequências. Desta forma, aceito participar neste estudo e permito a utilização dos dados que de forma voluntária forneço, confiando em que apenas serão utilizados para esta investigação e nas garantias de confidencialidade e anonimato que me são dadas pela investigadora.

Nome:____

Assinatura:____

____

Impressão digital

FCDEF FACULDADE DE CIÊNCIAS DO DESPORTO E EDUCAÇÃO FÍSICA
UNIVERSIDADE DE COIMBRA

Nome do participante: ________________________ **Data**___/___/____
Instituição (local): ________________________ **Horário de aplicação:** ________
Nome do aplicador: ____________________________________

BATERIA DE TESTES

Caro participante (ler):

Estes questionários destinam-se à realização de um trabalho de investigação para verificar a saúde relacionada à condição física em pessoas da vossa idade. Trata-se de um conjunto de testes que envolve a recolha de *informação confidencial* pelo que nunca no decorrer deste trabalho será divulgada a identificação dos indivíduos neles intervenientes. Ao responder às questões faça-o de uma forma sincera e, por favor, não deixes qualquer questão por responder, pois disso dependerá o rigor científico deste trabalho.

Obrigada pela sua colaboração!

Questionário Biossocial

Nome Completo: ____

Data de Nascimento: ________________________ **Sexo:** ( )Masculino ( )Feminino

Estado Civil: ( )Solteiro ( )Casado/União Estável ( )Separado/Divorciado ( )Viúvo

Escolaridade: ( )Nunca Frequentou a escola ( )Não completou o Primário
( )Primário ( )Preparatório ( )Secundário

Naturalidade (Concelho): ____

Residência (Concelho):____

Onde vive atualmente: ( )Casa Própria ( )Lar/Instituição ( )Casa dos Filhos
( )Outro:________________________

Prática algum exercício físico (i.e., ginásio, ginastica)? ( )SIM ( )NÃO
Se Sim, com qual frequência semanal? ()1 vezes ()2 vezes ()3 vezes ()4 ou mais vezes

Peso: _________________**Altura:**_______________ **IMC:**__________________
TUG:___________________________**5xSTS:**_____________________________

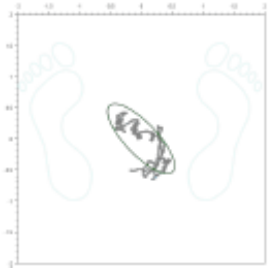
CIDAF – Centro de Investigação em Desporto e Atividade Física

APPENDIX IV – Physiosensing Result Sheet Example

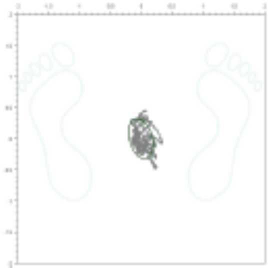
Clinical Report - Fall Risk

Name	Age	Device	PhysioSensing
Gender	Date	Clinic	
Height	ID	Health professional	
Weight			
Diagnosis			
Protocol			

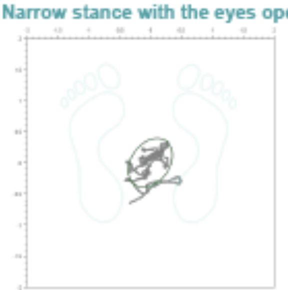
1. Comfortable stance with the eyes open



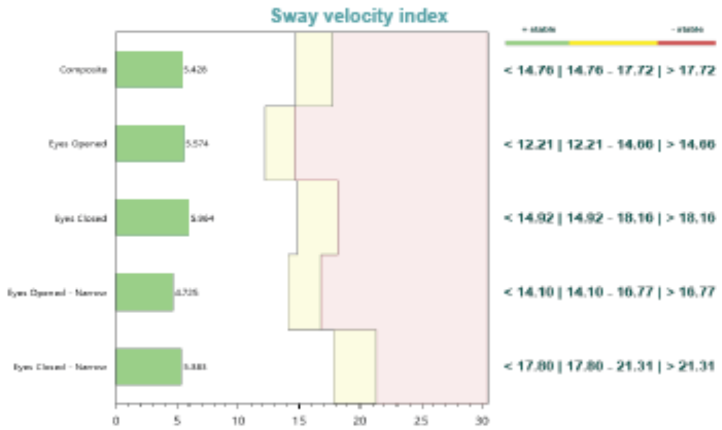
2. Comfortable stance with the eyes closed



3. Narrow stance with the eyes open



4. Narrow stance with the eyes closed



	Velocity (mm/s)	Sway velocity index	Z-Score	Time (s)	Ellipse area (mm²)
Comfortable stance with the eyes open	2.509	5.574	-1.709	45	59.62
Comfortable stance with the eyes closed	2.676	5.964	-1.764	45	19.31
Narrow stance with the eyes open	2.181	4.725	-2.511	44.9	41.86
Narrow stance with the eyes closed	2.431	5.383	-2.538	44.9	36.06
Composite	2.449	5.428	-2.144	-	39.21

frequency acquisition: 62Hz

www.physiosensing.net

physio sensing

APPENDIX V – FRAT

Fall Risk Assessment Tool Portugal (FRAT-P)

Instrumento de Avaliação do Risco de Queda

Fator de Risco	**Nível**	**Pontuação de Risco**
Quedas Recentes (Para pontuar complete o historial de quedas, no verso da folha)	Nenhuma nos últimos 12 meses ………………………… Uma ou mais entre os últimos 3 a 12 meses ……….. Uma ou mais nos últimos 3 meses ……………………… Uma ou mais nos últimos 3 meses enquanto paciente/residente………………………………………………	**2** **4** **6** **8**
Medicação (Sedativos, Antidepressivos Anti-Parkinson, Diuréticos Anti-hipertensivos, hipnóticos)	Não toma nenhum dos medicamentos……………………... Toma um …………………………………………………….. Toma dois …………………………………………………... Toma mais do que dois ………………………………………	**1** **2** **3** **4**
Psicológico (Ansiedade, Depressão Cooperação, Introspeção ou Julgamento **esp re*** mobilidade *especificamente referente à mobilidade	 Não aparenta ter qualquer um destes ……………………… Aparenta ligeiramente afetado por um ou mais ... Aparenta moderadamente afetado por um ou mais ………. Aparenta severamente afetado por um ou mais ….	**1** **2** **3** **4**
Estado Cognitivo (AMTS – Pontuação do Teste Mental Abreviado de Hodkinson)	AMTS 9 ou 10/10 **<u>OU</u>** intacto ……………………… AMTS 7-8 ligeiramente alterado. AMTS 5-6 moderadamente alter. AMTS 4 ou aaaaamenos severamente alter ……	**1** **2** **3** **4**
(Baixo Risco : 5-11 Médio Risco: 12-15 Alto Risco: 16-20)	**Pontuação de Risco**	**/20**

Estado Automático de Alto Risco: (se selecionado então circunde risco **ALTO** em baixo)
☐ Mudança recente no estado funcional e/ou medicação <u>afetando</u> a mobilidade segura (ou antecipada) ☐ Tonturas / Hipotensão postural

<u>**Estado do Risco de Quedas :** *(Circundar):*</u> **Baixo / Médio / Alto**

APPENDIX VI – Portuguese Falls Efficacy Scale

Versão Portuguesa da Falls Efficacy Scale (FES)

ABAIXO ESTÃO INDICADAS VÁRIAS TAREFAS.
À FRENTE DELAS ENCONTRA-SE UMA LINHA QUE MEDE O GRAU DE CONFIANÇA, OU SEJA, O MEDO QUE TEM DE CAIR NA SUA EXECUÇÃO.
MARQUE NA LINHA COM UMA CRUZ O QUE SENTE AO EXECUTAR A TAREFA.

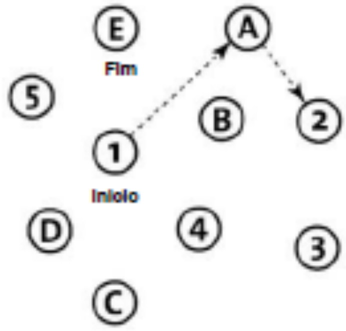
	Sem nenhuma Confiança				Minimamente Confiante					Muito Confiante
1. Vestir e despir-se	1	2	3	4	5	6	7	8	9	10
2. Preparar uma refeição ligeira	1	2	3	4	5	6	7	8	9	10
3. Tomar um banho ou duche	1	2	3	4	5	6	7	8	9	10
4. Sentar / Levantar da cadeira	1	2	3	4	5	6	7	8	9	10
5. Deitar / Levantar da cama	1	2	3	4	5	6	7	8	9	10
6. Atender a porta ou o telefone	1	2	3	4	5	6	7	8	9	10
7. Andar dentro de casa	1	2	3	4	5	6	7	8	9	10
8. Chegar aos armários	1	2	3	4	5	6	7	8	9	10
9. Trabalho doméstico ligeiro (limpar o pó, fazer a cama, lavar a louça)	1	2	3	4	5	6	7	8	9	10
10. Pequenas compras	1	2	3	4	5	6	7	8	9	10

APPENDIX VII – MoCA

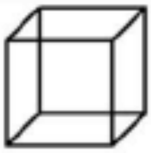
MONTREAL COGNITIVE ASSESSMENT (MOCA)
VERSÃO PORTUGUESA – 7.1 VERSÃO ORIGINAL

Nome: ____________ Idade: ______
Género: ______ Data de Nascimento: ______
Escolaridade: ____ Data de Avaliação: ______

VISUO-ESPACIAL / EXECUTIVA



[ ]



Copiar o cubo [ ]

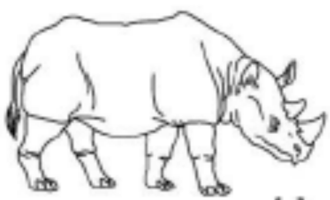
Desenhar um Relógio (onze e dez) (3 pontos)

[ ] Contorno [ ] Números [ ] Ponteiros

Pontos: ___/5

NOMEAÇÃO


[ ]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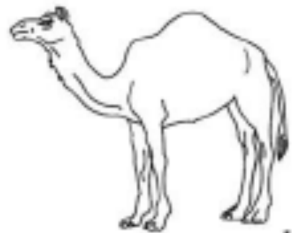

[ ]

___/3

MEMÓRIA

Leia a lista de palavras. O sujeito deve repeti-la. Realize dois ensaios. Solicite a evocação da lista **6 minutos mais tarde.**

	Booa	Linho	Igreja	Cravo	Azul
1º ensaio					
2º ensaio					

Sem Pontuação

ATENÇÃO

Leia a sequência de números. (1 número/segundo)
O sujeito deve repetir a sequência. [ ] 2 1 8 5 4
O sujeito deve repetir a sequência na ordem inversa. [ ] 7 4 2
___/2

Leia a série de letras (1 letra/segundo). O sujeito deve bater com a mão cada vez que for dita a letra A. Não se atribuem pontos se ≥ 2 erros
[ ] F B A C M N A A J K L B A F A K D E A A A J A M O F A A B
___/1

Subtrair de 7 em 7 começando em 100. [ ] 93 [ ] 86 [ ] 79 [ ] 72 [ ] 65
4 ou 5 subtracções correctas: 3 pontos; 2 ou 3 correctas: 2 pontos; 1 correcta: 1 ponto; 0 correctas: 0 pontos
___/3

LINGUAGEM

Repetir: Eu só sei que hoje devemos ajudar o João. [ ] O gato esconde-se sempre que os cães entram na sala. [ ]
___/2

Fluência verbal: Dizer o maior número possível de palavras que comecem pela letra "P" (1 minuto). [ ] ____ (N ≥ 11 Palavras)
___/1

ABSTRACÇÃO

Semelhança p.ex. entre banana e laranja = fruta [ ] combolo - bicicleta [ ] relógio - régua
___/2

EVOCAÇÃO DIFERIDA

		Booa	Linho	Igreja	Cravo	Azul	
	Deve recordar as palavras SEM PISTAS	[ ]	[ ]	[ ]	[ ]	[ ]	Pontuação apenas para evocação SEM PISTAS
Opcional	Pista de categoria						
	Pista de escolha múltipla						

___/5

ORIENTAÇÃO

[ ] Dia do mês [ ] Mês [ ] Ano [ ] Dia da semana [ ] Lugar [ ] Localidade
___/6

Examinador: ______________

TOTAL ___/30

Versão Portuguesa: Freitas, S., Simões, M. R., Santana, I., Martins, C. & Nasreddine, Z. (2013). *Montreal Cognitive Assessment (MoCA): Versão 1.* Coimbra: Faculdade de Psicologia e de Ciências da Educação da Universidade de Coimbra.

ANNEX A – Congress Presentation: 5º Congresso ”Envelhecimento Ativo: Atividade Física e Saúde”

“Efeitos do exercício físico e da suplementação com aminoácidos de cadeia ramificada (BCAA) na composição corporal de mulheres idosas institucionalizadas”

Rodrigues, R.N.; Caldo, A.; Silva, F.; Furtado, G.; Neves, R.; Abreu, C.; Teixeira, A.M. (2021)

Oral Communication

School of Education of Viseu, Portugal; ACES Dão Lafões (Org.). Proceedings of the “5o Congresso de Envelhecimento Ativo: Atividade Física e Saúde”; 2021 Feb 27.

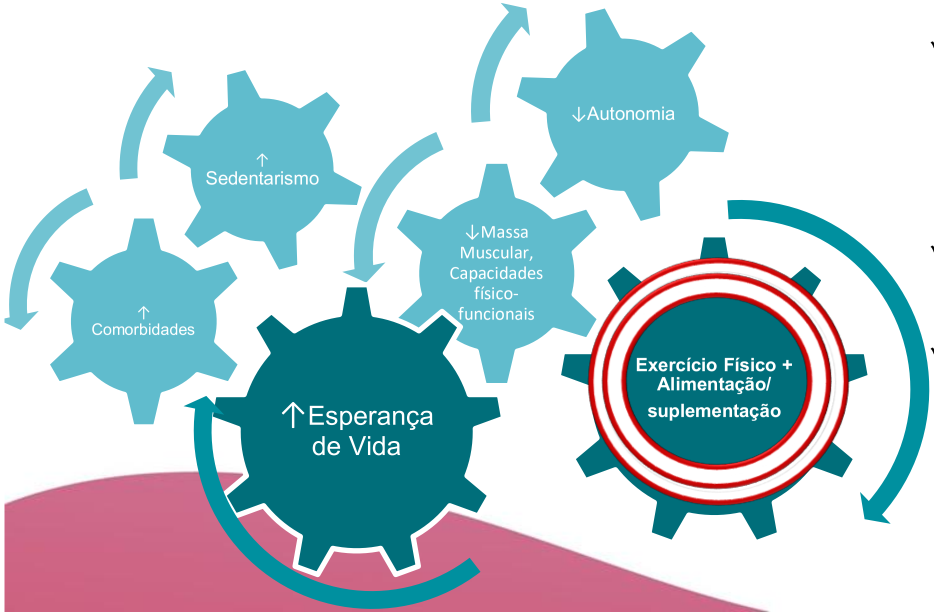
5º CONGRESSO ENVELHECIMENTO ATIVO'21 — ATIVIDADE FÍSICA E SAÚDE

FORMATO ONLINE VIA ZOOM

VISEU | 20 A 27 DE FEVEREIRO

Efeitos do Exercício Físico e da Suplementação com aminoácidos de cadeia ramificada (BCAA) na composição corporal de mulheres idosas instituicionalizadas

Rafael N. Rodrigues, Adriana Caldo, Fernanda M. Silva, Guilherme Furtado, Rafael S. Neves, Cidalina Abreu, Ana Maria Teixeira



- ✓ Portugal está a sentir cada vez mais o peso do envelhecimento e um conjunto de desafios que testam a sustentabilidade do país, pois com o aumento do número de idosos e do tempo de vida, há um aumento de comorbidades associadas, como a diminuição da massa muscular (MM), com consequente instalação de um quadro sarcopenico, afetando diretamente a independência/ autonomia do idoso.
- ✓ O exercício físico pode atenuar esse processo, diminuir a velocidade de evolução e, em alguns casos, reverter processos degenerativos promovendo o aumento da MM e diminuição da % de gordura.
- ✓ O efeito da suplementação com aminoácidos de cadeia ramificada (BCAA) e sua influência na composição corporal de idosos, ainda permanece discutível na literatura, dada a especificidade e alta vulnerabilidade da população-alvo.

Compreender os efeitos de 16 semanas de exercício físico multicomponente e suplementação de BCAA na composição corporal de mulheres idosas institucionalizados.

Organização: MUNICÍPIO DE VISEU, VISEU ATIVO, ATIVIDADE SÉNIOR, Politécnico de Viseu Educação, ACeS Dão Lafões

Efeitos do Exercício Físico e da Suplementação com aminoácidos de cadeia ramificada (BCAA) na composição corporal de mulheres idosas institucionalizadas

GEM

Realizou um programa de exercício físico multicomponente utilizando bandas elásticas

GBCAA

Consumiu BCAA (Leucina, Valina, e Isoleucina, na proporção 2:1:1), com ingestão de 0,21g/kg/dia, 2x na semana

GEM+BCAA

Realizou o mesmo treino do GEM, e consumiu a mesma suplementação que o GBCAA

GC

Não alterou sua rotina e alimentação habitual

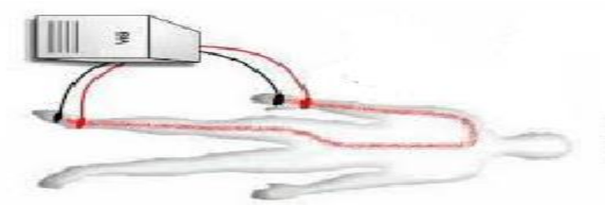


Tabela 1: Características do Programa de Treino Multicomponente

Aquecimento			5 min.
Marcha estática e caminhadas			
Exercícios	**Sets**	**Reps.**	**Cadência**
1. Front squat	2-3	10-20	2:3
2. Chair unilateral hip flexion	2-3	10-20	2:3
3. Chair Bench over row (with flexion)	2-3	10-20	2:3
4. Chest Press (stand and/or chair)	2-3	10-20	2:3
5. Standing (or chair) reverse fly	2-3	10-20	2:3
6. Shoulder Press/twist arm front position	2-3	10-20	2:3
7. Chair (or stand) frontal total raiser	2-3	10-20	2:3
8. Biceps arm curl (stand and/or chair)	2-3	10-20	2:3
9. Chair Overhead triceps extension	2-3	10-20	2:3
Cool-Down			5 min
Alongamentos			

Organização:

VISEU ATIVO

ATIVIDADE SÉNIOR

Efeitos do Exercício Físico e da Suplementação com aminoácidos de cadeia ramificada (BCAA) na composição corporal de mulheres idosas institucionalizadas

Tabela 2: Resultados do estudo.

Variáveis	GBCAA (n= 5)		
Idade	85.75 ±7.84		
Altura	153 ±9.17		
	pré	pós	Δ%
Peso	61.08 ±5.29	63 ±5.54	3.14
IMC	25.35 ±4.01	26.1 ±3.74	2.96
MM (kg)	42.18 ±3.13	42.92 ±3.30	1.75
MM (%)	69.14 ±0.84	67.45 ±2.97	-1.47
MG (%)	33.12 ±6.29	31.58 ±1.27	3.15

Variáveis	GEM+BCAA (n= 7)		
Idade	92 ±7.72		
Altura	153 ±5.16		
	pré	pós	Δ%
Peso	69.55 ±14.42	70.05 ±1.55	0.72
IMC	28.11 ±4.98	28.28 ±4.84	0.63
MM (kg)	42.52 ±2.32	44.48 ±4.01	4.60
MM (%)	62.97 ±10.47	64.95 ±8.62	3.14
MG (%)	34.97 ±9.55	34.11 ±9.14	-2.46

Variáveis	GEM (n= 7)		
Idade	85.71 ±3.19		
Altura	149 ±5.19		
	pré	pós	Δ%
Peso	63.05 ±14.86	62.91 ±14.4	-1.93
IMC	28.22 ±6.42	28.16 ±6.23	-2.25
MM (kg)	40.92 ±5.88	41.6 ±4.76	2.09
MM (%)	66.53 ±8.97	67.97 ±10.21	3.58
MG (%)	31.29 ±10.09	31.67 ±10.13	2.47

Variáveis	GC (n= 7)		
Idade	84.71 ±4.75		
Altura	149 ±7.36		
	pré	pós	Δ%
Peso	66 ±8.04	67.16 ±9.02	1.77
IMC	30.38 ±4.77	30.92 ±5.16	1.78
MM (kg)	40.81 ±2.61	40.53 ±5.59	-0.69
MM (%)	62.33 ±5.98	60.89 ±9.53	-2.32
MG (%)	34.97 ±6.76	34.45 ±7.42	-1.47

Conclusão: A prática de atividade física por si só, durante 16 semanas, não foi suficiente para promover alterações significativas na composição corporal de mulheres idosas institucionalizadas. No entanto, a suplementação com BCAA juntamente com a prática de exercicio multicomponente demonstrou ter algum efeito relacionado, pois promoveu uma diminuição no percentual de gordura concomitante com o aumento no percentual de massa magra, demonstrando a necessidade de novos e mais profundos estudos para a população-alvo.

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ANNEX B – Congress Presentation: “2nd Health & Well-Being Intervention – International Congress”

Influência de 16 semanas de exercício físico na função cognitiva em octogenários.

Rodrigues, R.N.; Silva, F.; Caldo, A.;Teixeira, A.M.; Abreu, C.; Furtado, G.

Oral Communication

In Desouzart G (Coord.), Proceedings of the 2nd International Congress of Health and Well-Being Intervention - ICHWBI2021 and the 1st International Conference on Human Kinesiology – 1st ICOHK; 2021 May 28-29; Viseu, Portugal. ISBN (e-book): 978-989-759-154-9.

2nd Health & Well-Being Intervention INTERNATIONAL CONGRESS
MAY 28 & 29, 2021
INSTITUTO PIAGET UNIVERSITY CAMPUS OF VISEU
ORGANIZATION

Influência de 16 semanas de exercício físico na função cognitiva em octogenários

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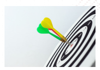
Introdução

Com a crescente expectativa de vida, os problemas de saúde relacionados ao processo de envelhecimento têm chamado a atenção da comunidade científica, com destaque para o declínio cognitivo e o sedentarismo. Alguns estudos têm vindo a demonstrar que o exercício físico pode atenuar esse processo, contudo, o efeito do exercício físico na cognição de idosos octogenários ainda não é bem compreendido dada a especificidade e alta vulnerabilidade desta população.



Objetivos

Verificar os efeitos de um programa de 16 semanas de exercício físico multicomponente na função cognitiva de idosos octogenários institucionalizados.

Material e Métodos

A amostra é constituída por 27 idosos randomizados em dois grupos: Grupo de Exercício Multicomponente (GEM, n= 14) e Grupo Controlo (GC, n= 13). O GEM realizou um programa de exercícios durante 16 semanas e o GC manteve a sua rotina habitual. Para avaliar a cognição foi utilizado o *Montreal Cognitive Assessment*, que é um instrumento que possibilita avaliar diferentes domínios, nomeadamente:

1. capacidades visuo-construtivas/Executivas,
2. Nomeação,
3. Atenção/Concentração
4. Linguagem,
5. Abstração,
6. Evocação Diferida,
7. Orientação.

Gráfico 1. Resultados do Baseline e Follow-up

Variables	MSEG ẋ ± SD	MSEG ẋ ± SD	CG ẋ ± SD	CG ẋ ± SD
	Baseline	Follow-up (16 semanas)	Baseline	Follow-up (16 semanas)
n total Masculino Feminino	14 4 10	14 4 10	13 3 10	13 3 10
Idade (anos)	86 ± 3	86 ± 3	87 ± 4	87 ± 4
Altura (cm)	155 ± 7.4	155 ± 7.4	152 ± 10.2	152 ± 10.2
Massa Corporal (kg)	70.4 ± 15.3	70.46 ± 15.5	69.4 ± 11	70.3 ± 10.29
Indice de Massa Corporal	29.1 ± 5.2	29.1 ± 5.23	30 ± 4	30.46 ± 4.2
MoCA:				
i) Visuo-construtivas /Executivas	1.89 ±1.48	2.10 ±1.52	1.34 ±1.19	1.26 ±1.09
ii) Nomeação	2.31 ±0.67	2.57 ± 0.76	2.65 ±0.57	2.6 ±0.58
iii) atenção/concentração	3.52 ±1.64	3.68 ±1.41	2.82 ±1.33	2.86 ±1.14
iv) linguagem	2.57 ±0.69	2.52 ±0.69	2.52 ±0.73	2.52 ±0.59
v) abstração	0 ± 0	0 ± 0	0 ± 0	0 ± 0
vi) Evocacao Diferida	2.47 ±0.96	2.84 ±1.01	2.39 ±1.03	2.34 ± 1.3
vii) orientação	5.42 ± 0.9	5.57 ±0.83	5.17 ±1.26	5.17 ±1.23
Moca Total	18.35 ±4.63	19.78 ± 3.74	17.31 ± 4.3	16.84 ± 4.1

Resultados

Após a intervenção, o GEM apresentou melhores resultados, com variação percentual de 7,78% no score geral, e melhorias nos domínios *atenção*, *linguagem*, *memória* e *orientação*, com melhoria significativa (p=0.007) no domínio da *nomeação* enquanto o CG teve uma variação de -2,67% no score geral e não alterou, ou houve ligeira diminuição, nos scores dos restantes domínios.

Conclusão

Os nossos resultados sugerem que o exercício físico multicomponente contribui para a redução da velocidade de avanço em relação a alguns domínios cognitivos em octogenários, enquanto hábitos sedentários aumentaram ou não alteraram o status cognitivos.

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ANNEX C – Congress Presentation: 5º Congresso ”Envelhecimento Ativo: Atividade Física e Saúde”

"Influência de 16 semanas de exercício físico no risco de queda em octogenários: uma comparação entre homens e mulheres"

Rodrigues, R.N.; Caldo, A.; Silva, F.; Neves, R.; Abreu, C.; Teixeira, A.M.; Furtado, G.

Oral Communication

School of Education of Viseu, Portugal; ACES ACES Dão Lafões (Org.). Proceedings of the "5 o Congresso de Envelhecimento Ativo: Atividade Física e Saúde"; 2021 Feb 27; Virtual Congress.

5º CONGRESSO ENVELHECIMENTO ATIVO'21 — ATIVIDADE FÍSICA E SAÚDE — FORMATO ONLINE VIA ZOOM

VISEU | 20 A 27 DE FEVEREIRO

Influência de 16 Semanas de Exercício Físico no Risco de Queda em Octogenários:

Uma Comparação Entre Homens e Mulheres

Rafael N. Rodrigues, Adriana Caldo, Fernanda M. Silva, Rafael S. Neves, Cidalina Abreu, Ana Maria Teixeira, Guilherme Furtado

O aumento da esperança média de vida trouxe concomitantemente o aumento de doenças relacionadas ao processo de envelhecimento. A falta de atividade física organizada e planeada contribui para uma rápida pioria dessas situações, incluindo a perda de massa muscular e de determinadas capacidades funcionais. A perda de equilíbrio, por exemplo, pode levar ao aumento do número e risco de quedas na população idosa.

Pelo menos 30% da população idosa reporta algum tipo de queda, no último ano, com pelo menos 10% das quedas necessitando de intervenção médica e atendimento nos serviços de urgência.

Destes, cerca de 5% dos idosos acabam por morrer em consequência da queda.

Evidências têm demonstrado que o exercício físico pode atenuar esse processo, diminuir a velocidade de evolução e, em alguns casos, reverter alguns processos degenerativos e, consequentemente, contribuindo para a diminuição do risco de quedas em idosos, especialmente nos institucionalizados, que são populações de maior risco para sarcopenia e fragilidade. Ainda assim, esse efeito em octogenários idosos ainda não é bem compreendido dada a especificidade e alta vulnerabilidade da população

Objetivo:
- Verificar os efeitos de um programa de 16 semanas de exercício físico multicomponente no risco de queda, de acordo com o sexo, em idosos octogenários.

- Grupo de Exercício Multicomponente (GEM) = Exercício 2x/sem; 45min/sessão.
- Grupo Controlo (GC, n = 13) = não alterou sua rotina.

- PhysioSensing®:
  - i) postura confortável e olhos abertos;
  - ii) postura confortável e olhos fechados;
  - iii) postura estreita e olhos abertos;
  - iv) postura estreita e olhos fechados

- "Velocidade composta" (Velocidade média para todas as condições) fornecendo uma previsão do risco de queda, onde scores mais altos indicam maior risco.

Influência de 16 Semanas de Exercício Físico no Risco de Queda em Octogenários:

Uma Comparação Entre Homens e Mulheres

Tabela 1: Características do Programa de Treino Multicomponente

Aquecimento			5 min.
Marcha estática e caminhadas			
Exercícios	**Sets**	**Reps.**	**Cadência**
1. Front squat	2-3	10-20	2:3
2. Chair unilateral hip flexion	2-3	10-20	2:3
3. Chair Bench over row (with flexion)	2-3	10-20	2:3
4. Chest Press (stand and/or chair)	2-3	10-20	2:3
5. Standing (or chair) reverse fly	2-3	10-20	2:3
6. Shoulder Press/twist arm front position	2-3	10-20	2:3
7. Chair (or stand) frontal total raiser	2-3	10-20	2:3
8. Biceps arm curl (stand and/or chair)	2-3	10-20	2:3
9. Chair Overhead triceps extension	2-3	10-20	2:3
Cool-Down			5 min
Alongamentos			

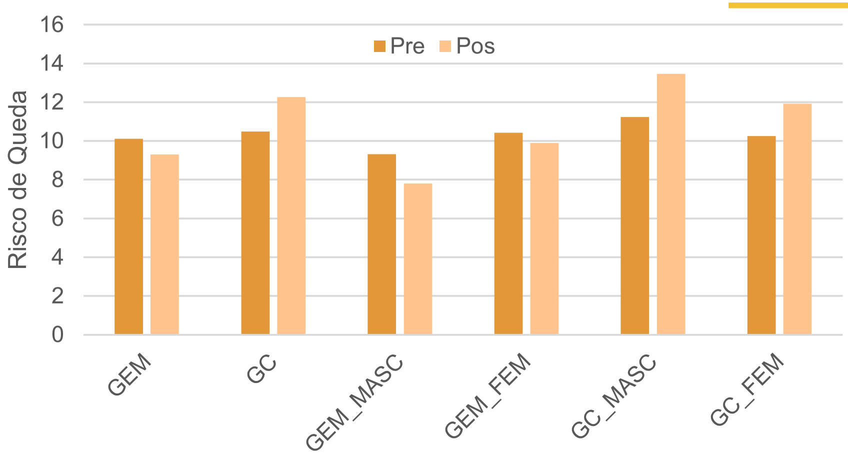
Tabela 2: Características sociodemográficas dos participantes de ambos os grupos e efeitos do exercício físico no risco de queda e indicadores de antropometria, de acordo com o género.

Variáveis	**GEM** ẋ ± SD			**GC** ẋ ± SD		
n total	14			13		
Masculino	4			3		
Feminino	10			10		
Idade (anos)	86 ± 3.258			86.76 ± 4.02		
Altura (cm)	155 ± 7.38			152 ± 10.19		
Peso (kg)	70.43 ± 15.29			69.41 ± 11.04		
IMC	29.08 ± 5.181			30 ± 4.04		
	pré	**pós**	**Δ%**	**pré**	**pós**	**Δ%**
Risco de Queda	10.11 ±2.93	9.30 ±1.89	- 4%,	10.49 ± 2.10	12,27 ± 2,22	19%
Masculino						
Peso (kg)	82.4 ±9.54	81.82 ±10.2	-0.78%	80.16 ±5.75	79.5 ±7.08	-0.91%
IMC	31.17 ±3.26	30.96 ±3.54	-0.80%	30.05 ±4.65	29.84 ±5.16	-0.91%
Risco de Queda	9.31 ±2.46	7.80 ±0.85	-11.38%	11.24 ±2.59	13.46 ±2.33	20.93%
Feminino						
Peso (kg)	65.65 ±14.77	65.92 ±15.22	0.35%	66.19 ±10.22	67.55 ±9.67	2.30%
IMC	28.25 ±5.70	28.38 ±5.76	0.35%	29.98 ±4.12	30.65 ±4.17	2.30%
Risco de Queda	10.43 ±3.17	9.90 ±1.89	-0.98%	10.26 ±2.03	11.92 ±2.19	18.69%

ẋ = Média; SD = Desvio Padrão.

Influência de 16 Semanas de Exercício Físico no Risco de Queda em Octogenários:

Uma Comparação Entre Homens e Mulheres



Conclusão: Os resultados sugerem que o exercício físico multicomponente contribui para a melhoria do equilíbrio e consequentemente, para a redução dos indicadores do risco de queda, avaliados através da plataforma PhysioSensing, em idosos octogenários.

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Organização: