

UNIVERSIDADE DO PORTO

FACULDADE DE DESPORTO

**Impacto de 9 meses de treino combinado aeróbio e de força em adultos
idosos na aptidão física e funcional e no equilíbrio dinâmico como
importantes preditores
de risco de queda**

Paulo Jorge Quintela Cardoso do Carmo

Porto, 2021

Universidade do Porto

Faculdade de Desporto

Centro de Investigação em Atividade Física e Saúde

**Impacto de 9 meses de treino combinado aeróbio e de força em adultos
idosos na aptidão física e funcional e no equilíbrio dinâmico como
importantes preditores
de risco de queda**

A presente dissertação foi escrita para a obtenção do título de Doutor no âmbito do curso de Doutoramento em Atividade Física e Saúde, organizado pelo Centro de Investigação em Atividade Física, Saúde e Lazer (CIAFEL) da Faculdade de Desporto da Universidade do Porto, nos termos do Decreto-Lei n.º 74/2006, de 24 de março, orientada pela Prof. Doutora Joana Carvalho e coorientada pelo Prof. Doutor Rubim Santos

The present dissertation was written to achieve the PhD degree included in the doctoral course in Physical Activity and Health designed by the Research Centre in Physical Activity Health and Leisure (CIAFEL), Faculty of Sport – Porto University, according to Decree-Law n.º 74/2006 from mars 24th, supervised by Prof. Doutora Joana Carvalho and co-supervised by Prof. Doutor Rubim Santos

Paulo Jorge Quintela Cardoso do Carmo

Porto, 2021

Cardoso-Carmo P. (2020). *Impacto de 9 meses de treino combinado aeróbio e de força em adultos idosos na aptidão física e funcional e no equilíbrio dinâmico como importantes preditores de risco de queda*. Dissertação apresentada às provas de Doutoramento em Atividade Física e Saúde. Faculdade de Desporto da Universidade do Porto, Porto.

PALAVRAS-CHAVE: EXERCÍCIO FÍSICO, ENVELHECIMENTO ATIVO, APTIDÃO MUSCULAR, EQUILÍBRIO, RISCO DE QUEDA

The authors would like to thank Research Center in Physical Activity, Health and Leisure (CIAFEL) Faculty of Sports – University of Porto (FADEUP), Portugal (FCT/ UIDB/00617/2020); Laboratory for Integrative and Translational Research in Population Health (ITR), Porto, Portugal, FCT (POCI-01-0145-FEDER-031808); IPDJ (Mais Ativos, Mais Vividos), and Center for Rehabilitation Research (CIR) Health Superior School – Polytechnic of Porto, for assisting with technical support and personal availability during data collection related to this study.



ITR LABORATORY FOR INTEGRATIVE
AND TRANSLATIONAL RESEARCH
IN POPULATION HEALTH

FCT
Fundação para a Ciência e a Tecnologia
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR

MA
MAIS
ATIVOS
MAIS
VIVIDOS



ipdj
INSTITUTO PORTUGUÊS DO
DESPORTO E JUVENTUDE, I.P.



**Centro de Investigação
em Reabilitação**
Center for Rehabilitation Research

Dedicatória

Ao meu Filho Paulo Miguel Oliveira Cardoso do Carmo
Pelo convívio, camaradagem e aprendizagem, de partilha de conhecimentos
Nesta simbiose Académica

À minha Mulher Ana Paula Magalhães Oliveira
Pela inspiração, apoio e ajuda

In memoriam aos meus Pais, Belmira Quintela & Manuel Cardoso do Carmo
Por não poderem estar hoje comigo, pelo exemplo de perseverança

*“On doit beaucoup exiger de celui qui se fait auteur
par un sujet de gain et d'intérêt, mais celui qui va
remplir un devoir dont il ne peut pas s'exempter est digne
d'excuse dans les fautes qu'il pourra commettre”
(La Bruyère)*

Agradecimentos

Nesta página o autor faz um reconhecimento público às pessoas sem cujo apoio não poderia levar a cabo esta investigação.

Em primeiro lugar aos Orientadores da tese, sem cujas colaborações não seria possível a presente realização; Não é a praxe que me obriga a colocar nesta página os nomes daqueles que a quem escolhi para esta tarefa, é a mais elevada consideração, sincera amizade e indelével reconhecimento:

À Exma. Prof. Doutora Joana Carvalho, pelo apoio incondicional, pelas importantes contribuições no campo da Ciência do Desporto, o vasto conjunto de saberes da Atividade Física e da sua aplicação aos seus maiores beneficiários, o grupo etário mais avançado. Ao Exmo. Prof. Doutor Rubim Santos, pela disponibilidade e assertividade para acompanhar o autor neste processo.

Aos Participantes dos estudos de campo transversal e longitudinal, pela generosidade em dispor do seu tempo para esta investigação, disponibilizando os seus dados e colaborando ativamente na sua recolha.

A todos os Professores do Programa Doutoral de Atividade Física e Saúde da FADEUP, do Mestrado de Gestão das Organizações (Gestão de Unidades de Saúde), da Licenciatura e Bacharelato em Audiologia da ESS, e dos restantes graus de ensino secundário e básico, pelo incessante e interminável trabalho na transmissão de conhecimentos e exemplo de espírito académico.

Aos Colegas do Programa Doutoral, pelo apoio e amizade, colaborando a converter o projeto em realidade. Dedicatória especial na pessoa da Prof. Doutora Adjane César em representação de toda a equipa FADEUP, pela ajuda endossada na recolha de dados e desenho do programa de atividade física, assim como ao Mestre Tiago Montanha.

Aos Docentes, Prof. Doutor André Seabra, da FADEUP, e Prof.^a Doutora Alexandra Oliveira e Mestre Ilídio Pereira, da ESS.PP, pelo apoio no trabalho estatístico.

Aos Alunos da ESS.PP, pela motivação extrínseca para a atualização de conhecimentos e melhoria contínua.

À Família Cardoso do Carmo, pela compreensão e apoio, durante todo este percurso, permitindo a disponibilidade do autor para a realização do presente trabalho.

Ao Douto Júri que me há-de julgar, as seguintes palavras de Montesquieu: *“Je désire que mes juges voient en moi non l’homme qui écrit, mais celui qui est forcé d’écrire”*.

A Todos, o

Muito Obrigada do autor.

“You cannot hope to build a better world without improving the individuals. To that end, each of us must work for his own improvement and, at the same time, share a general responsibility for all humanity, our particular duty being to aid those to whom we think we can be most useful”

(Marie Curie)

Índice geral

DEDICATÓRIA	VII
AGRADECIMENTOS	IX
ÍNDICE GERAL	XI
RESUMO	XIII
ABSTRACT	XV
ÍNDICE DE TABELAS	XVII
ÍNDICE DE ANEXOS	XVIII
LISTA DE ABREVIATURAS E ACRÓNIMOS	XIX
1. INTRODUÇÃO	1
2. REVISÃO DA LITERATURA	5
ENVELHECIMENTO	5
ALTERAÇÕES DA APTIDÃO FÍSICA ASSOCIADAS AO ENVELHECIMENTO	8
CAPACIDADE AERÓBIA	8
FORÇA E RESISTÊNCIA MUSCULAR	10
FLEXIBILIDADE	13
EQUILÍBRIO	13
COMPOSIÇÃO CORPORAL	19
RISCO DE QUEDA EM IDOSOS	22
3. ESTUDO EMPÍRICO	29
3.1 ARTIGO 1	31
3.2 ARTIGO 2	53
3.3. ARTIGO 3	77
4. DISCUSSÃO GERAL	99
5. CONCLUSÃO	107
ANEXOS	109

Resumo

O objetivo da presente tese foi estudar o efeito de um programa de treino combinado aeróbio e de força (TCAF) no risco de queda (RQ) em idosos. Adicionalmente procuramos estudar as correlações entre a atividade física, a aptidão funcional, e o RQ.

Um grupo de 62 idosos (idade média = 69.02 ± 4.27 anos) foi subdividido em grupo experimental (GE, $n = 37$) e grupo de controlo (GC, $n = 25$) e avaliado antes, 4.5 e 9 meses após intervenção nos seguintes testes: composição corporal (DEXA, GE Medical System, USA, Lunar 8743); aptidão aeróbia (Oxycon Pro, Jaeger, Germany); aptidão muscular (Biodex System 2, USA); aptidão funcional (Fullerton Fitness Test); e RQ (Biodex Balance System, USA); A ANOVA de medidas repetidas mostrou que o programa de TCAF melhorou significativamente o RQ (GE vs. GC) ($F(2,120) = 4.519$; $p = 0.013$; $\eta_p^2 = 0.070$), sendo esta melhoria notória logo aos 4.5 meses.

Para o estudo de correlações, um grupo de 170 idosos (idade média = 72.34 ± 6.70 anos; 124 mulheres) efetuou as seguintes avaliações: antropometria; aptidão funcional (Fullerton Fitness Test); RQ (Performance Orientated Mobility Assessment) e atividade física (acelerómetro GT1M, Actigraph, USA). O modelo de regressão linear múltipla revelou que os idosos com uma maior agilidade motora ($\beta = -0.869$; $p < 0.001$) e força dos membros inferiores ($\beta = -0.223$; $p = 0.041$) tinham um menor RQ. Pelo contrário, os idosos mais sedentários ($\beta = -0.869$; $t(81) = -7.725$; $p < 0.001$) e com mais idade ($\beta = -0.223$; $t(81) = -2.079$; $p = 0.041$) tinham maior RQ. Após ajustar para o sexo, os homens com maior comportamento sedentário apresentaram maior RQ enquanto as mulheres com maior atividade física leve, apresentaram menor RQ.

Podemos concluir que a participação no programa de TCAF promoveu benefícios no RQ. A idade, a agilidade motora, e a força dos membros inferiores parecem ser bons preditores de RQ no idoso, bem como a atividade física leve ou o comportamento sedentário, nas mulheres e homens idosos, respetivamente.

PALAVRAS-CHAVE: EXERCÍCIO FÍSICO, ENVELHECIMENTO ATIVO, APTIDÃO MUSCULAR, EQUILÍBRIO, RISCO DE QUEDA

Abstract

The aim of the present thesis was to study the effects of a combined aerobic and strength training in fall risk (FR) in elderly. Additionally, we sought to study the correlations between physical activity, functional fitness, and FR. A group of 62 older adults (mean age = 69.02 ± 4.27 years) subdivided into experimental group (EG, $n = 37$) and control group (CG, $n = 25$) were evaluated before, 4.5 and 9 months after intervention in the following tests: body composition (DEXA, GE Medical System, USA, Lunar 8743); aerobic capacity (Oxycon Pro, Jaeger, Germany); muscular strength (Biodex System 2, USA); functional fitness (Fullerton Fitness Test); FR (Biodex Balance System, USA); The repeated measures ANOVA showed improvements in FR (EG vs. CG) ($F(2,120) = 4.519$; $p = 0.013$; $\eta_p^2 = 0.070$), being this improvement noticeable after 4.5 months.

Regarding the correlation study, a group of 170 older adults (mean age = 72.34 ± 6.70 years, 124 women) were evaluated in the following tests: anthropometry; functional fitness (Fullerton Fitness Test); FR (Performance Orientated Mobility Assessment); and physical activity (accelerometer GT1M, Actigraph, USA). The *multiple linear regression* model showed that older adults with greater motor agility ($\beta = -0.869$; $p < 0.001$) or strength of the lower limbs ($\beta = -0.223$; $p = 0.041$) had a lower FR. On the contrary, the more sedentary elderly ($\beta = -0.869$; $p < 0.001$) and the older ones ($\beta = -0.223$; $p = 0.041$) had a higher FR. After adjusting for sex, men with greater sedentary behaviour had a higher FR, while women with greater light physical activity had lower FR.

We can conclude that participation in the combined aerobic and strength training program promoted benefits in FR. Age, motor agility and strength of the lower limbs seems to be good predictors of FR in elderly as well as sedentary behaviour and light physical activity levels in elderly men and women, respectively.

KEY-WORDS: PHYSICAL EXERCISE, ACTIVE AGING, MUSCLE FITNESS, BALANCE, FALL RISK

Índice de tabelas

Tabela 1 - Modelo Geral do Envelhecimento	6
Tabela 2 - Desenho da Tese.....	30
Tabela 3 - Test Items of the Performance Oriented Mobility Assessment	146
Tabela 4 - Test Items of the Berg Balance Scale	148
Tabela 5 - Ten Test Items of the Fullerton Advance Balance	150

Índice de anexos

Anexo A – Declaração da Comissão de Ética da Faculdade de Desporto da Universidade do Porto (CEFADE.02.2015).

Anexo B – Publicação aceite: Carmo, P., Carvalho, J., Santos, R., César, A. (2020). Imbalance and fall risk improvements in elderly: Effects of combined strength-aerobic training. *J Hear Sci*, 2020; 10(1): 41-47. DOI: 10.17430/JHS.2020.10.1.5 CC BY-NC-ND 4.0 © the authors

Anexo C – Publicação em revisão: Carmo, P., César, A., Santos, R., Carvalho, J. (2020). Fall risk prediction model for older men and women based on ambulatory physical activity intensity – A cross-sectional population-based study from the Oporto region. November, 2020.

Anexo D – Publicação aceite: Carmo, P., César, A., Santos, R., Carvalho, J. (2020). Association between physical activity, functional fitness and fall risk in the elderly – A cross- sectional population-based study from the Oporto Region. *Med Sport (Roma)*, 2021 June;74(29):313-26.

Anexo E – Table 3 - Test Items of the Performance Oriented Mobility Assessment (POMA) That Measure Multiple Dimensions of Balance (Tinetti, 1986).

Anexo F – Table 4 - Test Items of the Berg Balance Scale (BBS) That Measure Multiple Dimensions of Balance (Berg et al., 1992).

Anexo G – Table 5 – Ten Test Items of the Fullerton Advance Balance (FAB) Scale (Rose, 2003).

Lista de abreviaturas e acrónimos

1-RM – Uma Repetição Máxima
ACSM – American College of Sports Medicine
ACM - Acelerometria
ANOVA - Análise de variância
CA – Comportamento Ativo
CC – Composição Corporal
CEMAH – Centro de Estudos do Movimento e Atividade Humana
CIAFEL – Centro de Investigação em Atividade Física, Saúde e Lazer
CIR – Centro de Investigação e Reabilitação
CIOMS – Council for International Organizations of Medical Sciences
Cm – centímetro
CP – Controlo Postural
CPM – Counts per minute
DEXA – Dual-energy X-ray Absorptiometry
DP – Desvio-Padrão.
ESS-PP – Escola Superior de Saúde – Politécnico do Porto
EF – Exercício Físico
EP – Estabilidade Postural
FADEUP – Faculdade de Desporto da Universidade do Porto
FM – Força Muscular
ISE – Interações Sensoriais no Equilíbrio
M- Média
M – Metro
MVPA – Moderate to Vigorous Physical Activity
ONAFD – Observatório Nacional da Atividade Física e Desporto
p – Prova, valor de
POMA – Performance Orientated Mobility Asssessment
RC – Ritmo Cardíaco
RPE – Rated Perceived Exertion
RPM – Rotações por minuto

RQ – Risco de Queda

Seg – Segundo

TA – Treino aeróbio

TC – Treino combinado

TCAF – Treino combinado aeróbio e de força

TF – Treino de força

1. Introdução

A população mundial está a envelhecer a um ritmo acelerado, dada a redução das taxas de natalidade e de mortalidade (World Health Organization, 2015). Este envelhecimento populacional, entre outros, acarreta problemas individuais ao nível da funcionalidade e de saúde dos idosos, que desafiam os sistemas social, económico e de saúde pública (World Health Organization, 2015).

O envelhecimento tem sido associado a várias alterações físicas, fisiológicas, psicológicas e sociais que provocam alterações na autonomia, saúde e qualidade de vida do idoso (Spirduso et al., 2005).

Várias linhas de investigação sugerem que os indivíduos que se envolvem em comportamentos ativos e saudáveis podem adiar ou reduzir as consequências negativas do envelhecimento e, assim, evitar os padrões esperados de senescência linear (Bjerk et al., 2017; Dondzila et al., 2015; Orwoll et al., 2019; World Health Organization, 2015).

A queda, definida como uma falta de capacidade para corrigir o deslocamento do corpo, durante o seu movimento no espaço, constitui um dos principais problemas clínicos e de saúde pública devido à sua alta incidência, e significativas taxas de mortalidade e morbilidade associadas (Brodie et al., 2014; Tinetti, 2008). A queda, para além de estar associada a um elevado custo financeiro e social, é uma das principais causas para a perda de funcionalidade, independência e aumento de morbilidade e mortalidade em idosos (Saito et al., 2014; Smee et al., 2012). A sua prevenção é então fundamental, requerendo uma abordagem multifacetada e multidisciplinar que permita não apenas identificar alterações do controlo postural (CP), das interações sensoriais no equilíbrio (ISE) mas também avaliar pessoas idosas que estão em risco de queda (RQ) (Matarese et al., 2014; Rispens et al., 2015; Rivolta et al., 2015; Rivolta et al., 2018) na tentativa de desenhar intervenções realistas focadas na redução dos fatores de RQ (Nguyen et al., 2018; Sparrow et al., 2016; Tideiksaar, 2001).

Intervenções com programas de exercício físico (EF) têm-se mostrado potencialmente eficazes no atenuar de, pelo menos, alguns fatores de risco de queda (Davis et al., 2013; Ferrari et al., 2016). No entanto, apesar de toda a informação disponível na literatura sobre esta problemática, ainda não há consenso sobre qual a melhor prescrição, nomeadamente no que concerne a programas isolados ou combinados de treino. Por outro lado, independentemente da modalidade de treino, a adesão a esta terapêutica não-farmacológica parece depender da sua prática sistemática e consequentemente na maior ou menor motivação para as sessões de exercício físico (Stewart, 2004).

Evidências recentes têm sugerido que o treino combinado não apenas é capaz de promover um aumento da aptidão cardiorrespiratória e muscular (Ferrara et al., 2004; Harris, 2005; Kim et al., 2008), mas também apresenta-se, dada a diversidade de exercícios, como uma modalidade de treino apelativa com elevada adesão por parte da população idosa (Klika & Jordan, 2013).

Assim o objetivo principal da presente tese foi estudar o efeito de um programa de treino combinado aeróbio e de força (TCAF) no Risco de Quedas (RQ) de idosos. Como objetivo secundário procuramos ainda estudar as correlações entre a atividade física, a aptidão funcional e o RQ.

Para dar resposta a este objetivo, no desenvolvimento da presente tese, após um enquadramento teórico inicial da problemática do envelhecimento, atividade/exercício físico, introduz-se o estudo empírico com três artigos diferenciados, apresentando-se posteriormente a discussão e conclusões gerais da tese, terminando com as referências bibliográficas indispensáveis à sua construção assim como os anexos.

Decorrente da investigação associada a esta tese realçamos as seguintes publicações:

1. Carmo, P., César, A., Santos, R., Carvalho, J. (2020). Association between physical activity, functional fitness and fall risk in the elderly – A cross-sectional population-based study from the Oporto Region. (publicado *Med Sport (Roma)*; Anexo D)
2. Carmo, P., César, A., Santos, R., Carvalho, J. (2020). Fall risk

prediction model for older men and women based on ambulatory physical activity intensity – A cross-sectional population-based study from Oporto Region. (em revisão; Anexo C).

3. Carmo, P., Carvalho, J., Santos, R., César, A. (2020). Imbalance and fall risk improvements in the elderly: Effects of combined strength and aerobic training (publicado *J Hear Sci*; Anexo B).

2. Revisão da literatura

Envelhecimento

O processo de envelhecimento é um processo multifatorial que pode ser descrito como um somatório de alterações bio fisiológicas, psicossociais e morfológicas que levam a uma redução do estado de saúde, da funcionalidade e da capacidade de execução das tarefas quotidianas com autonomia (Spirduso et al., 2005).

Assim sendo, a conceção de “idade” pode ser dividida em vários tipos: cronológica, biológica, psicológica e social (Chodzko-Zajko, 2001). A idade cronológica refere-se à extensão de tempo que uma pessoa viveu. É geralmente expressa pelo número de anos ou meses desde o nascimento, e a sua medida é independente de fatores fisiológicos, psicológicos e socioculturais (Chodzko-Zajko, 2001). A idade biológica, considera que o envelhecimento se encontra associado a um conjunto de alterações estruturais e funcionais, designado declínio funcional, que pode ser influenciado, por fatores intrínsecos (como a hereditariedade), ou por fatores extrínsecos (estilo de vida, aspetos nutricionais, exercício físico, entre outros) (American College of Sports Medicine, 1998; Chodzko-Zajko, 2001). A idade psicológica faz referência às capacidades de um indivíduo num certo número de dimensões de funcionamento mental e cognitivo, incluindo a autoestima e autossuficiência, assim como a aprendizagem, a memória, e as perceções (Chodzko-Zajko, 2001). A idade social refere-se à noção desenvolvida pela sociedade das expectativas relativamente rígidas naquilo que é considerado como um comportamento apropriado para uma pessoa de uma dada idade (Rose, 1972).

Assim e com base nos conceitos anteriores podemos verificar não apenas que nem todos envelhecem ao mesmo ritmo, mas também que as definições de idade que se focam exclusivamente no tempo do calendário são incompletas, sendo necessárias definições mais complexas tanto de “idade” como de “envelhecimento” para entender as complexidades associadas ao

envelhecimento humano (Chodzko-Zajko, 1996, 2001; Chodzko-Zajko & Ringel, 1987).

Tendo por base que não apenas a quantidade de anos é importante mas fundamentalmente a forma como se vivem esses anos, a Organização Mundial de Saúde tem sugerido a promoção de um modelo mais vigoroso e saudável de envelhecimento no qual as pessoas idosas são incitadas a terem um papel mais ativo na sua própria senescência (World Health Organization, 1997, 2010). Assim, e segundo esta entidade, o Envelhecimento Ativo encontra-se definido como o processo de otimizar as oportunidades para a saúde, participação social e segurança de modo a aumentar a qualidade de vida à medida que as pessoas envelhecem. Este conceito pretende que os idosos tenham consciência do seu potencial bem-estar físico, social e mental ao longo da vida, com participação na sociedade, sendo facultados proteção, segurança e cuidados adequados quando necessário. De realçar que o termo “Ativo”, faz referência à manutenção das atividades sociais, económicas, culturais, espirituais e cívicas, e não apenas à força física ou atividade laboral (Stegeman et al., 2012; World Health Organization, 2002, 2010, 2015).

Já o Envelhecimento Bem-sucedido implica, segundo a mesma entidade (World Health Organization, 2015), que as pessoas apresentem um baixo risco de doença e incapacidades, que possuam um estilo de vida saudável e uma vida social ativa. Este conceito baseia-se em três componentes principais: i) reduzida probabilidade de doença e incapacidade relacionada; ii) elevada capacidade cognitiva e funcional; iii) envolvimento ativo com a vida, com relações interpessoais e desenvolvimento de atividades produtivas (Moreira, 2013; Stegeman et al., 2012; World Health Organization, 2015).

Embora o envelhecimento possa, tal como anteriormente evidenciado, ocorrer como resultado de uma ampla variedade de mecanismos diferentes, as consequências estruturais e funcionais do envelhecimento são surpreendentemente consistentes numa ampla variedade de diferentes sistemas fisiológicos. Tendo por base esta premissa, Ringel & Chodzko-Zajko propuseram um Modelo Geral do Envelhecimento, que sugere que um número relativamente pequeno de consequências estruturais e funcionais pode ser identificado

(Chodzko-Zajko, 2001). Este modelo de envelhecimento propõe que, com o avanço da idade, todos os sistemas fisiológicos eventualmente exibam atrofia, distrofia e edema ao nível celular. Estas ruturas na integridade da célula são, por sua vez, precursoras de mudanças fisiológicas mais vulgares, como elasticidade e *compliance* diminuídas, aumento da desmielinização e aumento do crescimento neoplásico, conforme listado na Tabela 1 (Chodzko-Zajko, 2001).

Tabela 1 - Modelo Geral do Envelhecimento (adaptado de (Chodzko-Zajko, 2001)) .

Mudanças Estruturais*	Consequências Funcionais*
Atrofia ↑	Precisão ↓
Distrofia ↑	Velocidade ↓
Edema ↑	Variação ↓
Elasticidade ↑	Resistência ↓
Desmielinização ↑	Coordenação ↓
Neoplasia ↑	Estabilidade ↓
Mutação ↑	Força ↓

Legenda: *↑ - aumento; ↓ - diminui.

Como seria de esperar, estas mudanças estruturais estão quase sempre associadas a profundas consequências funcionais. De acordo com o modelo, da mesma forma que as mudanças estruturais exibem semelhanças entre os sistemas fisiológicos, as consequências funcionais também são bastante consistentes nos diferentes sistemas do corpo, tornando-se estes, geralmente, mais lentos e menos precisos. Em resumo, embora a degenerescência relacionada com a idade possa ocorrer como resultado de uma ampla variedade de mecanismos biológicos diferentes, as consequências estruturais e funcionais do envelhecimento são mais ou menos previsíveis e consistentes entre os sistemas fisiológicos que se traduzem numa redução da adaptabilidade e da funcionalidade do indivíduo (Chodzko-Zajko, 2001).

Neste sentido, torna-se importante estudar e caracterizar a funcionalidade dos idosos traduzida essencialmente pela sua aptidão física, refletindo esta uma

variável composta por diferentes parâmetros físicos: força e resistência muscular, resistência aeróbia, flexibilidade, coordenação motora (velocidade/agilidade e equilíbrio) e composição corporal (Jones & Rikli, 2002).

Alterações da aptidão física associadas ao envelhecimento

Capacidade aeróbia

A capacidade aeróbia, também designada por aptidão cardiorrespiratória, refere-se à capacidade do sistema circulatório e respiratório fornecer oxigénio aos músculos esqueléticos durante a atividade física prolongada (Powers & Howley, 2012). A medida básica da capacidade aeróbia é o consumo máximo de oxigénio (VO_{2max}) (Strath et al., 2013) estando a sua definição relacionada com a quantidade máxima de oxigénio que o corpo pode utilizar durante um período específico de esforço físico intenso (Hawkins et al., 2007). Este indicador é expresso em valores absolutos (L/min) ou relativizado ao peso do indivíduo (L/kg/min), sendo o VO_2 relativo uma indicação da quantidade de oxigénio consumido por cada quilograma de massa corporal o que permite a comparação objetiva do consumo de oxigénio entre indivíduos com diferentes massas corporais (Grimmer et al., 2019).

Como consequência do envelhecimento e do progressivo desuso, estima-se uma perda média de VO_{2max} de 0,46 ml/kg/min por ano para os homens e de 0,54 ml/kg/min para as mulheres após os 65 anos de idade (Kenney et al., 2012; Koeppen & Stanton, 2008).

As alterações na estrutura e função cardíaca e vascular associadas ao envelhecimento e/ou desuso mais frequentes são a rigidez vascular e o espessamento e fibrose da parede ventricular esquerda, levando à disfunção diastólica, à redução do volume sistólico, ao aumento das resistências vasculares periféricas e da pós-carga (Strait & Lakatta, 2012). Estas mudanças têm um impacto sobre a capacidade aeróbia dos idosos, diminuindo a sua capacidade de reserva. Por outro lado, mudanças na frequência máxima cardíaca, no débito cardíaco máximo, contração sistólica prolongada, relaxamento diastólico prolongado, e sinalização simpática, são alterações

importantes que irão limitar a funcionalidade cardíaca e a capacidade aeróbia no idoso (Strait & Lakatta, 2012).

Para além destas alterações mais centrais, são observadas alterações periféricas com implicações na redução da diferença arteriovenosa, das quais se destacam as alterações registadas ao nível muscular, nomeadamente da limitada potência do metabolismo energético oxidativo (que se encontra dependente da atividade máxima das enzimas das vias metabólicas), a atrofia muscular, menor capilarização muscular e a menor redistribuição sanguínea para a musculatura ativa (Kenney et al., 2012; Powers & Howley, 2012).

Esta redução da capacidade aeróbia tem implicações no dia-a-dia do idoso, com reflexos sobre a maior dificuldade em realizar tarefas, como por exemplo, caminhar em distâncias longas, subir e descer escadas, deslocar-se às compras, apresentando os idosos um aumento da fadiga para o mesmo esforço comparativamente com os jovens (Jones & Rikli, 2002).

Para além disso, a redução da capacidade aeróbia, nomeadamente a redução do VO_{2max} tem sido associada a um risco aumentado de resultados adversos de saúde, sendo mesmo um preditor mais forte que os fatores de risco tradicionais tais como, a hipertensão, o consumo de tabaco, a obesidade, a hiperlipidémia, e a diabetes mellitus tipo II (Kaminsky et al., 2013).

Neste sentido, importa reverter esta situação, apresentando-se o exercício físico, particularmente o de natureza aeróbia, como um excelente meio de atenuar o declínio da aptidão cardiorrespiratória (Lemmens et al., 2019; Marques et al., 2016; Nevill et al., 2008).

O treino aeróbio (TA) regular promove uma utilização mais eficiente do oxigénio, com aumento da energia disponível para o exercício físico, o que significa poder trabalhar durante mais tempo sem a sensação de fadiga (Themudo-Barata, 2003). Este exercício parece induzir aumentos no débito cardíaco máximo, aumentos da contractilidade cardíaca, e diminuição das resistências vasculares periféricas (Graves et al., 2006; Key et al., 2017).

Além disso, o TA tem ainda como efeitos o ajudar a reduzir o risco de desenvolver doença cardiovascular e diabetes tipo II, reduzir a gordura corporal, ajudando a manter um peso corporal saudável (Themudo-Barata, 2003). O TA a

níveis de intensidade moderada a elevada pode melhorar o fluxo sanguíneo cerebral, tornando-se um potencial mediador de efeitos positivos na função cognitiva (Currie et al., 2009). Ainda, o TA e de força podem afetar positivamente os níveis de insulina como o fator-1 de crescimento e o fator neurotrófico derivado do cérebro que medeiam o crescimento de células neuronais (proliferação, sobrevivência e diferenciação) bem como melhorar o fluxo sanguíneo cerebral, sendo assim um potencial mediador de efeitos positivos na função física e cognitiva, mesmo em pacientes com demência (Bossers et al., 2014; Jiménez-Maldonado et al., 2018).

Força e resistência muscular

A força muscular por unidade de área transversal (Graves et al., 2006; Kenney et al., 2012) é dependente de três fatores principais: (i) número e tipo de unidades motoras recrutadas, (ii) o comprimento inicial do músculo, e (iii) a natureza da estimulação neuronal das unidades motoras (Powers & Howley, 2012).

Vinte e cinco por cento da função muscular, determinada em grande medida pela capacidade de gerar força, perde-se por volta dos 65 anos de idade e até quarenta por cento durante toda a vida (Sousa et al., 2012).

A sarcopenia, entendida como a perda de quantidade e qualidade muscular associada ao processo de envelhecimento, é consequência de mudanças miopáticas e neuropáticas tais como: diminuição do número de fibras, da área (em particular das fibras tipo II), do tamanho das unidades motoras e do seu menor recrutamento, da menor capilarização, menor síntese de proteínas, e das alterações do fator-1 de crescimento e do fator neurotrófico derivado do cérebro, além da diminuição do número de unidades motoras, com a atrofia neurogênica disseminada ou de deservação agrupada (Kenney et al., 2012; Mitchell et al., 2012). Para além dos fatores anteriormente descritos, a sarcopenia é igualmente o resultado da diminuição de estímulos associado aos estilos de vida sedentários (Graves et al., 2006; Sardinha et al., 2014).

A sarcopenia resulta em alterações na potência, força e resistência muscular, estando diretamente associadas a limitações funcionais na

capacidade de realizar autonomamente as atividades da vida diária, na marcha, no equilíbrio e no aumento do RQ e consequentemente no aumento da probabilidade de fraturas ósseas facilitadas pela desmineralização óssea típica do idoso (Beaudart et al., 2014; Espinosa et al., 2016; Marques, Carvalho, et al., 2011).

Acresce que a sarcopenia é considerada um fator preponderante no ciclo da fragilidade (Fried et al., 2001), condição altamente prevalente nos idosos, particularmente nas mulheres, e responsável por um elevado RQ, com consequente incapacidade, hospitalização e mortalidade (Fried et al., 2001). A sarcopenia provoca perda de independência e necessidades elevadas de pessoal cuidador de saúde resultando num grande ónus económico para a saúde (Drey, 2011).

Apesar de não existir consenso quanto à definição de sarcopenia, existe o desafio para estabelecer a sua atual prevalência e de estudar o seu impacto direto e indireto na saúde pública. Assim, e porque esta síndrome geriátrica representa um enorme problema de saúde devido às suas múltiplas consequências clínicas, funcionais e sociais (Beaudart et al., 2014), é de extrema importância que se encontrem estratégias para a sua prevenção e recuperação.

De todos os sistemas corporais, o sistema neuromuscular é aquele cujo estado melhor traduz a diferença entre uma pessoa sedentária e inativa de outra pessoa que pratica exercício físico regular (Chodzko-Zajko, 2001). O sistema muscular é mantido em grande parte pela quantidade de atividade física diária que um indivíduo experimenta, seja no trabalho ou em atividades de lazer, como o desporto (Chodzko-Zajko et al., 2009) sendo que o tipo de movimentos que as pessoas fazem durante as suas atividades diárias ao longo da vida determinam a capacidade funcional do seu sistema músculo-esquelético. Músculos que não são usados, vão deteriorar com o desuso e a passagem do tempo; pelo contrário, indivíduos que são fisicamente ativos e que potenciam o treino de força em todos os seus grupos musculares, irão manter uma adequada quantidade de força até aos seus últimos anos (Chodzko-Zajko, 2001; Spirduso et al., 2005).

Várias pesquisas sobre a plasticidade do sistema neuromuscular após o Treino de Força (TF) têm sido desenvolvidas. Já na década de 90, Frontera e

colegas (1998) relataram melhorias significativas na força muscular nos membros inferiores (227%) após apenas 12 semanas de treino de força em homens idosos com idade média de 65 anos (Frontera et al., 1998). Também, Fiatarone e colaboradores (1994) relataram que nonagenários poderiam melhorar a sua força e a massa muscular após apenas 10 semanas de TF. No entanto, as mudanças de força são bastante variáveis entre os estudos, dependendo de fatores como intensidade de treino, acompanhamento por profissional especializado, níveis de força basais, idade e condições de comorbidade dos sujeitos (Fiatarone et al., 1994; Frontera et al., 1998).

Os dois principais fatores que têm sido implicados no ganho de força induzido pelo treino em adultos idosos são as alterações na morfologia e as adaptações no sistema neuromuscular (Lexell, 2000). Os componentes neurais geralmente incluem fatores tais como mudanças na estratégia de ativação da unidade motora, e modificações da função de estruturas nervosas, tais como a junção neuromuscular, enquanto as adaptações ocorridas no músculo incluem hipertrofia das fibras musculares, modificações do tipo de fibra, e mudanças arquiteturais (Kenney et al., 2012). Em conjunto, as adaptações neurais e musculares permitem o aumento em força, potência e resistência muscular com melhorias do desempenho e maior nível de aptidão funcional (Kennis et al., 2013; Lexell, 2000).

Para além da funcionalidade muscular, o TF em adultos idosos parece ser um importante componente para a manutenção de diferentes condições de saúde, nomeadamente na densidade mineral óssea, metabolismo e controlo de peso, e resistência à insulina (Weir & Cramer, 2006).

Assim e face ao anteriormente exposto, parece existir um potencial razoavelmente forte de que uma combinação de TA e de TF poderá melhorar a função física, a independência para a realização das tarefas diárias, reduzir o risco de quedas e de outras condições de saúde debilitantes no idoso.

Flexibilidade

A flexibilidade pode ser definida como a amplitude do movimento articular disponível em uma articulação ou grupo de articulações (Corbin & Noble, 1980).

Uma perda progressiva de flexibilidade é observada com o passar dos anos após a idade adulta jovem, sendo resultante de um número de fatores, que incluem a doença, a deterioração das estruturas das articulações, e progressiva degenerescência das fibras de colagénio (Corbin & Noble, 1980).

Em termos funcionais a perda de flexibilidade das articulações dos membros superiores é importante em tarefas como por exemplo, pentear o cabelo, colocar vestuário por cima da cabeça, ou alcançar o cinto de segurança no automóvel (Rose et al., 2002). A flexibilidade das articulações dos membros inferiores é importante para uma boa postura, para normais padrões de marcha e para várias tarefas de mobilidade, tais como entrar e sair da banheira ou do automóvel (Jones & Rikli, 2002). Para além disso, baixos valores de flexibilidade têm sido associados a problemas na coluna vertebral (lombalgias) e joelhos (gonartrose) (Graves et al., 2006).

No sentido de atenuar e mesmo reverter o declínio da flexibilidade nos idosos, diferentes estudos utilizando variadas tipologias de treino têm sido desenvolvidos. Por exemplo, algumas pesquisas têm demonstrado que o treino de força associado ao treino de flexibilidade pode promover ganhos de flexibilidade ao lentificar a deterioração de certos fatores neuromusculares (Hwangbo et al., 2015; Oliveira et al., 2017), ajudando o indivíduo a recuperar a capacidade de efetuar as atividades quotidianas de um modo confortável e seguro (Leite et al., 2015; Powers & Howley, 2012). Acresce ainda o estudo de Escrivães (2015) que refere melhorias significativas da flexibilidade em idosos submetidos a treino combinado aeróbio e de força (Escrivães, 2015).

Equilíbrio

Equilíbrio postural pode ser definido como o processo pelo qual o centro de massa corporal do indivíduo, é controlado com respeito à base de sustentação, esteja imóvel ou a mover-se. A pessoa ao assumir a posição ereta

ou fisiológica tem como principal objetivo manter o centro de massa dentro dos limites da base de sustentação, e quando a pessoa começa a andar em frente o centro de massa movimenta-se para a frente e para além da base de sustentação, devendo uma nova base de sustentação deve ser estabelecida em cada passada (Rose, 2005).

Atendendo à natureza multidimensional do equilíbrio, devem ser consideradas várias dimensões importantes, tais como controlo postural voluntário em ambientes estáticos e dinâmicos; controlo postural antecipatório; controlo postural reativo; interação sensorial e o risco de queda. Estas dimensões são avaliadas por testes que exigem equipamentos sofisticados e geralmente conduzidos em laboratório. No entanto, em alguns casos, há testes equivalentes disponíveis que exigem pouco equipamento sendo razoavelmente válidos e adequados para configurações clínicas ou de campo (Maffei et al., 2017; Palm et al., 2009; Rose, 2005).

Tal como as demais capacidades físicas, o equilíbrio encontra-se também sujeito ao processo biológico de envelhecimento, por uma multiplicidade de fatores como a degenerescência das informações aferentes do sistema visual, vestibular e propriocetivo (Spirduso et al., 2005). Com efeito, mudanças em cada um dos sistemas intrínsecos que contribuem para um equilíbrio e mobilidade eficazes são inevitáveis no envelhecimento. Mesmo aqueles adultos idosos que perseguem estilos de vida fisicamente ativos, experimentam algum declínio no funcionamento de um ou mais sistemas que contribuem para o equilíbrio (Chodzko-Zajko, 2001; Rose, 2005).

Mudanças comuns associadas com a idade no componente periférico da visão incluem acuidade reduzida, sensibilidade ao contraste e percepção de profundidade, e um estreitamento do campo visual, particularmente na região periférica (Assländer et al., 2015; Mahoney et al., 2015). Pode-se esperar que essas mudanças alterem a qualidade das informações recebidas no componente central do sistema e resultem num processamento mais lento das informações sensoriais, integração menos eficiente das entradas visuais com aquelas recebidas de outros sistemas sensoriais e, possivelmente, uma percepção

alterada de orientação vertical do corpo (Kilby et al., 2017; Palm et al., 2009; Wiesmeier et al., 2015). Doenças do sistema visual relacionadas com a idade tais como catarata, glaucoma e degenerescência macular são igualmente comuns e influenciadoras do equilíbrio (Rose, 2005).

Com o avançar da idade, a sensibilidade dos recetores cutâneos a diferentes níveis de toque e pressão também diminui, assim como o número de vias sensoriais que inervam esses recetores (Kenney et al., 2012). De facto, os idosos experimentam um aumento de duas a dez vezes no limiar de vibração necessário para detetar sensações de toque, resultando numa capacidade reduzida de perceber a qualidade do contacto entre os pés e a superfície do chão (Araneda & Solorza, 2013).

Acresce que os declínios associados à idade tanto no número como na sensibilidade dos recetores musculares e articulares também contribuem para um conhecimento menos preciso da posição do membro, particularmente quando o corpo está em movimento (Fujimoto et al., 2009; Mahoney et al., 2015). Esta redução de sensibilidade é particularmente problemática em situações que exigem ajustes posturais rápidos como resultado de uma ameaça inesperada ao equilíbrio (Maffei et al., 2017). Os recetores cutâneos na superfície plantar dos pés fornecem informações sobre a qualidade da superfície de suporte e sobre a carga dos membros (Araneda & Solorza, 2013). Estes podem ainda ajudar o Sistema Nervoso Central a determinar o quão próximo o centro de massa está dos limites de estabilidade do indivíduo. Os adultos idosos com deficits somatossensoriais severos também exibem respostas musculares com latências aumentadas e uma incapacidade de ajustar adequadamente a resposta motora à perturbação de equilíbrio (Lou et al., 2018). Em termos conceptuais, o controlo postural consiste na capacidade de manter a posição ortostática nas tarefas quotidianas (Bertora et al., 2006; Dascal et al., 2012; Rath & Wade, 2017; Remaud et al., 2016). Num nível funcional, as deficiências do sistema propriocetivo exigem que o idoso confie mais nos outros sistemas sensoriais para o controlo postural (Rose, 2005).

Também as alterações no sistema vestibular começam após os 30 anos, com um declínio gradual na densidade das células ciliadas que servem como sensores biológicos do movimento da cabeça. Esse declínio continua progressivamente até à idade adulta e resulta numa sensibilidade reduzida aos movimentos da cabeça. Estima-se que, aos 70 anos, o número de células ciliadas e nervosas vestibulares diminua até cerca de quarenta por cento (Walther & Westhofen, 2007). Foi reportada uma redução moderada no ganho do reflexo vestibulo-ocular (RVO), responsável pela estabilização do olhar quando o indivíduo move a cabeça rapidamente, em indivíduos com a idade avançada com repercussões negativas na capacidade dos adultos idosos determinarem com precisão se é o ambiente ou se são eles que se estão a movimentar numa dada situação (Ishiyama, 2009).

Adicionalmente, em estudos que investigaram mudanças associadas com a idade no controlo postural antecipatório, os adultos mais velhos, em média, exibem ajustes posturais antecipatórios mais lentos e menos eficientes quando comparados com adultos jovens (Maffei et al., 2017).

O controlo postural (CP) tem sido utilizado para documentar a capacidade de manutenção de equilíbrio estático em indivíduos com várias doenças músculo-esqueléticas ou neuromusculares, sendo retidas como variáveis os índices de estabilidade geral, medial-lateral e ântero-posterior (Karimi et al., 2008) sendo que uma maior quantidade de movimento corporal associado a uma postura instável produz um índice de estabilidade elevado (Hinman, 2000). A avaliação do equilíbrio dinâmico, em complemento ao equilíbrio estático, torna-se necessária para compreender melhor os défices de instabilidade da anca e propriocetivos sob condições de stress dinâmico (Cachupe et al., 2009).

O controlo postural antecipatório, necessário para evitar obstáculos e para adaptar o padrão da marcha a diferentes tipos de superfície, deteriora-se no idoso (Maffei et al., 2017; Rose, 2005) sendo um dos principais contribuintes para o aumento do RQ (Shumway-Cook & Woollacott, 2001). O controlo postural reativo é crucial para responder rapidamente a um evento inesperado, tal como tropeçar num obstáculo ou degrau, ou ser empurrado por outrem (Rose, 2005).

Os testes de controlo postural reativo revelaram que os adultos mais velhos respondem mais lentamente às alterações e movimentos da superfície, adotando por consequência diferentes estratégias de movimento (por exemplo, estratégia da anca vs. tornozelo) (Rath & Wade, 2017; Remaud et al., 2016). Os idosos, exibem ainda diferentes padrões de ativação muscular em resposta a perturbações de magnitudes progressivamente maiores, sendo mais pronunciadas naqueles posturalmente instáveis (Di Nardo et al., 2015).

Relativamente ao papel das interações sensoriais no equilíbrio (ISE), estas traduzem-se na capacidade de o indivíduo manter o equilíbrio postural, enquanto processa as informações nervosas aferentes originadas nos sistemas vestibular, visual e propriocetivo (Sienko et al., 2018). Esta capacidade geralmente diminui com o envelhecimento devido ao processamento central mais lento, juntamente com a disfunção periférica (Rath & Wade, 2017). Nos testes em que ambas as entradas somatossensoriais e visuais são manipuladas, os adultos idosos exibem uma oscilação postural significativamente maior comparativamente com os jovens (Sienko et al., 2018). Níveis significativamente mais altos de instabilidade postural são observados em adultos idosos quando dois dos três sistemas sensoriais são manipulados (Rose, 2005).

As interações sensoriais no equilíbrio (ISE) dizem respeito ao processamento central contínuo das informações aferentes dos recetores vestibulares, propriocetivos e visuais para o controlo postural. As respostas motoras são geradas para manter o centro de gravidade corporal dentro dos limites da base de suporte e estabilizar a posição ortostática (Palm et al., 2009). Com recurso ao Biodex balance system static dynamic é possível avaliar o índice de oscilação geral em quatro condições sensoriais (Biodex Medical Systems, 2014): i) olhos abertos e superfície firme - informação disponível das três entradas sensoriais (somatossensorial, visual e vestibular); ii) olhos fechados e superfície firme – informação visual não disponível, somatossensorial e vestibular disponíveis e precisas; iii) olhos abertos e superfície instável (esponja) – somatossensorial disponível mas imprecisa, visual e vestibular disponíveis e precisas; iv) olhos fechados e superfície instável (esponja) – visual não

disponível, somatossensorial disponível mas imprecisa, e vestibular disponível e precisa (Cug & Wikstrom, 2014; Guskiewicz et al., 2001; Parraca et al., 2011).

O modelo de equilíbrio dinâmico desenvolvido por Nashner (Nashner, 1990) ilustra precisamente os processos que ocorrem em ambos os componentes periférico e central dos sistemas sensoriais e motor que caracterizam o ciclo de percepção-ação. Os recetores visuais, vestibulares e proprioceptivos compõem a componente periférica do sistema sensorial, enquanto as vias de transmissão e áreas especializadas dentro do Sistema Nervoso Central compõem o componente central do sistema sensorial. No componente central, a informação recebida do ambiente via recetores visuais, vestibular e, ou proprioceptivos, é comparada, selecionada e então combinada de modo a determinar a posição do nosso corpo no espaço. Recursos adicionais de tempo e atenção precisam ser alocados para a tarefa postural quando houver uma redução na informação sensorial disponível, como ao realizar o teste clínico modificado da interação sensorial no equilíbrio (Blaszczyk & Michalski, 2006). A formulação de diferentes estratégias sensoriais é específica do contexto, dependendo das informações sensoriais aferentes disponíveis (Rose, 2005).

Mudanças associadas com a idade no sistema cognitivo também afetam adversamente o equilíbrio e a mobilidade do idoso (Schoene et al., 2014). Por exemplo, as modificações adversas que ocorrem nos processos de atenção e que podem afetar a capacidade do idoso de antecipar e de se adaptar às mudanças que ocorrem no ambiente (Yaffe et al., 2001), foram identificados como um importante fator de risco intrínseco associado ao aumento do RQ nos idosos (Barbosa et al., 2015; K. Chang et al., 2012). Estas alterações são particularmente importantes quando observamos a prevalência dos déficits cognitivos à medida que a idade avança. Isto torna-se relevante quando está descrito que pelo menos dez por cento dos adultos com idade superior a 65 anos e cinquenta por cento dos idosos com mais de 80 anos têm algum tipo de défice cognitivo, variando de défice ligeiro a demência severa (Lawa et al., 2014).

Múltiplas dimensões do equilíbrio e da aptidão física geral devem assim ser avaliadas para melhor compreensão do RQ em adultos idosos (Rose, 2005),

devendo o mau funcionamento das suas múltiplas dimensões e sistemas ser alvo de preocupação.

Composição corporal

O conhecimento da quantidade relativa de gordura corporal é útil em vários aspetos. Vários estudos têm mostrado as associações entre obesidade (gordura corporal excessiva), especialmente gordura intra-abdominal (visceral) com o risco aumentado de muitas doenças crónicas (diabetes tipo II, hipertensão, hiperlipemia, síndrome metabólica, doença das artérias coronárias, e certos tipos de cancro) (Kaminsky & Dwyer, 2006; Kerksick et al., 2010; Stavropoulos-Kalinoglou, Metsios, Panoulas, Douglas, et al., 2009; Stavropoulos-Kalinoglou, Metsios, Panoulas, Nevill, et al., 2009). A taxa metabólica basal diminui aproximadamente cinco por cento por década ao longo da vida adulta sendo este um fator contribuinte, assim como os fatores genéticos, para o ganho de gordura corporal (Aparicio et al., 2016; Ramírez-Vélez et al., 2016; Wouters-Adriaens & Westerterp, 2006).

Com o envelhecimento, os indivíduos apresentam um aumento da massa corporal gorda, distribuída principalmente na região abdominal. Este aumento na gordura visceral, combinado com a diminuição da gordura subcutânea pode ocorrer independentemente de mudanças do peso corporal, adiposidade total ou circunferência abdominal (Kuk et al., 2009). Os fatores de estilo de vida que podem contribuir para estas mudanças associadas com a idade na distribuição da gordura corporal incluem mudanças de ingestão alimentar com elevada ingestão de gorduras saturadas e açúcares simples, e com a redução da atividade física (S. Chang et al., 2012).

Por outro lado, importa igualmente referir as alterações da massa muscular, óssea e quantidade de água (Baumgartner, 2000; Fosbøl & Zerahn, 2015; Kaminsky & Dwyer, 2006; Kerksick et al., 2010; Rothney et al., 2009). Tal como anteriormente referido, as alterações musculares estão associadas à substituição das fibras musculares por tecido conjuntivo e adiposo, apesar da

manutenção do mesmo peso corporal (Sousa et al., 2012), com reflexo sobre a independência e maior RQ em idosos. Por outro lado, o declínio relacionado com a idade no tecido ósseo favorece a osteoporose e a consequente fratura óssea (Tarantino et al., 2016). Por fim, a percentagem de água no peso corporal decresce de setenta por cento na infância, para cinquenta por cento no idoso, dificultando o papel da água na manutenção das funções corporais, como a excreção de produtos, o transporte de nutrientes, hormonas e gases, e a termorregulação (Begg, 2017; Morley, 2015).

Neste sentido, torna-se fundamental conhecer as alterações da composição corporal em adultos idosos, tendo sido desenvolvidos inúmeros testes para determinar os pesos ou proporções relativas entre os diferentes constituintes do corpo humano: o tecido ósseo, o tecido muscular, o tecido adiposo e água. Segundo vários autores como Powers & Howley (2012) e Insel, Ross, McMahon & Bernstein (2014), diferentes métodos de avaliação têm sido utilizados, tais como: a diluição de isótopos por água duplamente marcada, a absorciometria de fótons por isótopo radioativo de potássio, a balança hidrostática (de mergulho), a absorciometria de raios-X de dupla energia (DEXA), a radiografia, os ultrassons, a ressonância magnética nuclear, a condutividade elétrica total do corpo, a análise de impedância bioelétrica, a pletismografia de deslocamento de ar, a espessura das pregas cutâneas e medição de perímetros (Insel et al., 2014; Powers & Howley, 2012).

As medidas mais frequentemente utilizadas, dada a maior acessibilidade, para avaliar a composição corporal em programas de rastreio são o peso e a altura para cálculo do índice de massa corporal (IMC) e a circunferência abdominal. No entanto, este indicador habitualmente utilizado para classificar o peso corporal de um indivíduo e determinar o risco de desenvolver diabetes tipo II, hipertensão e doença arterial coronária, tem sido sujeito a críticas na população idosa dado serem pobres preditores da percentagem de gordura corporal e de massa magra, resultando em classificações mais imprecisas (Kaminsky & Dwyer, 2006).

A avaliação por impedância bioelétrica tem sido estabelecida em estudos de campo, como uma ferramenta portátil, não-invasiva para avaliação da

composição corporal, e tem potencial uso na avaliação do estado nutricional e clínico dos indivíduos (Fosbøl & Zerahn, 2015; Jung et al., 2014; Slee et al., 2015), sendo válida utilizando equações específicas desenvolvidas e validadas para os vários grupos etários (Martin et al., 2015).

Já em estudos de laboratório a “Dual-energy X-ray absorptiometry” (DEXA) permite a quantificação da massa óssea e de tecido mole, permite ainda uma estimativa parcial ou total do corpo humano, com precisão e estimativas fiáveis da CC (Rothney et al., 2009). Tem ainda a vantagem de ser uma técnica passiva em que o avaliado repousa confortavelmente numa mesa, tendo como desvantagens, o custo do equipamento e do suporte técnico (Kenney et al., 2012).

Entre outros, fatores comportamentais relacionados com mudanças de estilos de vida que incluem o aumento da inatividade física estão, cada vez mais, na base destas alterações na CC (Chang et al., 2011; Nana et al., 2012; Soares-Miranda et al., 2012; World Health Organization, 2002). A inatividade associada ao envelhecimento tem sido apontada como um importante fator de aumento da massa gorda, redução da massa muscular e óssea ao restringir o estímulo e afetar negativamente o metabolismo do cálcio e o processo de formação óssea (Graves et al., 2006). No sentido oposto, o exercício físico tem sido descrito como um importante estímulo para manutenção e/ou aumento da massa muscular, de massa óssea e diminuição de gordura corporal, em particular gordura visceral (Andersen et al., 2016; Aparicio et al., 2016; Nana et al., 2012; Rall et al., 1996; Seabra et al., 2016).

Entre outros, o treino combinado parece ser uma escolha equilibrada capaz de contrariar os declínios na massa muscular e óssea e o aumento da massa gorda, para além de favorecer simultaneamente a força, equilíbrio e coordenação motora, ajudando a prevenção de quedas e consequentes fraturas ósseas (Dalz et al., 2016).

Assim, e na sequência do anteriormente exposto, parece natural que a população idosa, no decurso do seu processo de envelhecimento, sofra de algum tipo de diminuição funcional, fruto das alterações na composição corporal, na aptidão aeróbia, força muscular, flexibilidade e equilíbrio (Lobo et al., 2010;

Marques, Mota, et al., 2011). O impacto dessas alterações pode ter efeitos devastadores para a autonomia e saúde do idoso e assim na sua qualidade de vida (Ferreira & Santana, 2003; Pin & Spini, 2016; Rossi-Izquierdo et al., 2016).

No entanto, a adoção pelo idoso, de um estilo de vida mais ativo, e em particular a prática regular de exercício, poderá garantir a sua funcionalidade, autonomia e o menor risco de queda por um período de tempo mais prolongado (Stegeman et al., 2012; World Health Organization, 2002).

Risco de queda em idosos

A Organização Mundial de Saúde (World Health Organization, 2007) define queda como o evento que leva a pessoa inadvertidamente ao solo ou a um nível inferior, sendo um dos eventos adversos mais frequentes em idosos que pode ter consequências físicas, psicológicas e sociais.

O risco de queda (RQ), entre outros métodos, tem sido avaliado em diferentes populações, com recurso à Biodex balance system, colocando o indivíduo em situações dinâmicas de grau de dificuldade progressivamente maior (Schoene et al., 2014) obtendo-se o índice de estabilidade geral. Este, mede a quantidade de movimento corporal associado a uma postura mais instável ou incapacidade de produzir movimentos de correção dos desequilíbrios. Esta dificuldade é induzida pela menor estabilidade da plataforma produzindo um índice de estabilidade mais elevado. Um resultado elevado traduz pobre equilíbrio e risco de queda aumentado (Cakar et al., 2010).

Mais de trinta por cento dos adultos com mais de 65 anos terão pelo menos uma queda por ano (Mahoney et al., 2005), aumentando esta percentagem para cinquenta por cento em adultos com mais de 75 anos. Embora as quedas ocorram em todas as idades, é mais provável que resultem em lesões graves na velhice (American Geriatrics Society British Geriatrics Society American Academy of Orthopaedic Surgeons Panel on Falls Prevention, 2001). Mesmo quando as quedas não resultam em ferimentos graves ou morte, elas são frequentemente associadas a um medo de cair (Ayoubi et al., 2014; Svantesson et al., 2014), que, muitas vezes, pode levar a restrições na atividade

física e social, aumento da dependência e maior necessidade de cuidados de longo prazo (Grimmer et al., 2019).

Reconhecendo o comprometimento de muitas das suas capacidades físicas, os adultos idosos deixam de executar certas tarefas diárias, ou cessam a participação em atividades sociais ou começam a limitar os tipos de ambiente nos quais não se sentem preparados para se envolverem, percebendo-os como fatores acrescidos de RQ (Castro et al., 2019). Se, por um lado, a curto prazo, este cessar de atividades/ambientes que possam colocar o idoso em RQ, poderá representar, pela redução de exposição à ameaça, uma diminuição do número de quedas, por outro lado, a longo prazo, vai levar à diminuição da autoconfiança, aumentar o medo de cair, promover o destreino físico severo, e iniciar um ciclo vicioso de fragilidade física com aumento consequente do RQ (Tinetti et al., 1988).

As quedas são, como já anteriormente mencionado, fruto de uma multiplicidade de fatores que atuam tanto de forma isolada como em diferentes tipos de associação. Para além da idade, os principais fatores de risco são a história anterior de, pelo menos, uma queda no último ano, as polipatologias (em particular dos sistemas neurológico, muscular-esquelético ou cardiovascular), a polimedicação (em particular psicotrópicos) (Agostini et al., 2004; Agostini & Tinetti, 2002; Murphy et al., 2008; Tinetti et al., 2004), o uso de calçado inadequado (Mahoney et al., 2005), o consumo elevado de álcool (Verlinden et al., 2016; Williams et al., 2005), o défice cognitivo, as alterações ou problemas na marcha, na força muscular e no equilíbrio, e a inadequação do ambiente envolvente (Pynoos et al., 2003; Riebe, 2014). Também, a incidência aumentada de déficits sensoriais, particularmente de audição e visão, e limiares elevados de percepção sensorial para muitos estímulos podem ser relacionados com o aumento de 35% a 40% em quedas em pessoas com mais do que 60 anos de idade (Graves et al., 2006).

Os fatores de risco podem ser divididos em dois grandes grupos: os *fatores intrínsecos* – diretamente relacionados com o indivíduo; englobando as alterações fisiopatológicas (ex.: diminuição da visão e audição, distúrbios

vestibulares, proprioceptivos e músculo-esqueléticos, disfunções da marcha, sedentarismo); doenças (ex.: cardiovasculares, neurológicas, osteoarticulares, génito-urinárias); e consequências do uso de fármacos (como a diminuição das funções motoras, fraqueza, tonturas, hipotensão, confusão e sonolência) e os *fatores extrínsecos* – relacionados com características ambientais e sociais tais como características inadequadas dos espaços, mobiliário e iluminação, existência de obstáculos no meio envolvente, vestuário/calçado inadequado, entre outros (Ambrose et al., 2013; Bird et al., 2013; Mahoney et al., 2005; Stevens, 2005; Tinetti et al., 2006).

Embora mudanças isoladas nos sistemas não resultem necessariamente em efeitos observáveis ou adversos na função, quando múltiplos sistemas estão abaixo de um limiar mínimo de função, os efeitos cumulativos quase certamente produzirão mudanças significativas e observáveis no controlo postural (Cho et al., 2004). Por exemplo, ao nível comportamental, as mudanças cumulativas que ocorrem nos sistemas sensorial, motor e cognitivo, manifestam-se numa reduzida capacidade de compreender com rapidez e precisão onde o corpo está no espaço, o que, por sua vez, compromete o desempenho do idoso numa ampla variedade de movimentos complexos que exigem velocidade, precisão, equilíbrio, força e coordenação. Estas mudanças também parecem afetar negativamente a capacidade dos adultos idosos em adaptar os seus padrões de movimento rapidamente para acomodar a mudança de tarefas e exigências ambientais (Rose, 2005).

As quedas estão entre os problemas de saúde mais sérios enfrentados pelos idosos uma vez que podem causar limitações na atividade física e na independência do indivíduo, comprometendo o seu bem-estar físico e mental e afetar a sua qualidade de vida (Santos et al., 2011).

Adicionalmente, as quedas representam uma das principais causas de morte prematura, lesão física, imobilidade, disfunção psicossocial e institucionalização em lares, sendo que a população em mais rápido crescimento, os idosos com 75 anos ou mais, é aquela que apresenta um maior RQ com efeitos económicos volumosos (Davis et al., 2013).

Para reduzir a taxa alarmante de quedas e a mortalidade e morbidade excessivas relacionadas, esforços devem ser feitos para detetar e intervir sobre pessoas em RQ (Ge & Xu, 2014; Özdemir & Barshan, 2014).

Apesar da influência dos fatores genéticos ser considerável, o papel dos fatores ambientais e comportamentais, em particular os relacionados com estilo de vida, são de fundamental importância (Nguyen et al., 2018; Turner et al., 2014).

A intervenção deve ser multifatorial podendo incluir, programas de modificação da medicação; tratamento da hipotensão postural; modificação dos obstáculos ambientais (tais como tapetes soltos, iluminação fraca, falta de corrimões próximo de banheiras, cabos elétricos nas passagens e acessos) entre outros (Cumming et al., 1999; Day et al., 2002). De igual modo, o potencial papel da atividade física diária, englobando a atividade formal e não formal, no menor risco de quedas tem sido demonstrado em diferentes estudos (Mertz et al., 2010; Shimada et al., 2004; Voukelatos et al., 2011; Yoo et al., 2010). Buchner e colaboradores (2017), reportaram uma diminuição do risco de queda em mulheres idosas do quartil máximo de atividade física moderada a vigorosa, quando comparadas com as do quartil mínimo, após ajuste para idade, raça, etnia e fatores de risco de queda (Buchner et al., 2017). Pelo contrário, baixos níveis de aptidão física e a inatividade física parecem aumentar o risco de queda (Mertz et al., 2010).

Embora os efeitos do exercício específico e isolado na redução do RQ entre idosos não sejam consensuais, a literatura sugere que as estratégias de intervenção que incluem exercício têm o potencial de reduzir significativamente muitos dos fatores de risco que contribuem para as quedas nos idosos (Bird et al., 2013; Hill et al., 2014).

Na realidade, diferentes intervenções de exercício têm sido descritas, variando desde exercícios isolados (por exemplo, exercícios de força, de equilíbrio, caminhada, *Tai Chi Chuan*) (Barnett et al., 2016; Carrapatoso, 2015; Carrapatoso et al., 2018; Carrapatoso et al., 2017; Huijben et al., 2018), a

programas de exercícios de múltiplos componentes (Cakar et al., 2010; McMahon et al., 2016; Sousa et al., 2017; Zhuang et al., 2014).

O efeito de diferentes tipos de treino (Cho et al., 2004; Faber et al., 2006; Rose, 2003; Rubenstein et al., 2000) pode traduzir-se num melhor e mais seguro desempenho nas tarefas de mobilidade, numa maior capacidade de força, equilíbrio e da marcha e num menor RQ em idosos (Huijben et al., 2018; Voukelatos et al., 2011).

No entanto, para ser eficaz, a adesão aos programas de exercício por parte da população idosa deve ser elevada para que estes possam ser executados de forma sistemática, o que requer acompanhamento e motivação contínuos pelos profissionais prestadores de serviços (Tideiksaar, 2001). Neste sentido, Shimada e colaboradores (2004) utilizando uma atividade mais “natural” para os idosos, i.e., treino de marcha durante seis meses em idosos frágeis, mostraram melhorias significativas no equilíbrio e no tempo de reação com um número de quedas inferior no grupo experimental vs. grupo de controlo (sujeito a atividade normal), (Shimada et al., 2004). Ainda, segundo Yoo e colaboradores (2010) a administração em senhoras idosas de um programa de marcha durante três meses, pode ter efeitos positivos na aptidão física, promovendo melhoria nas avaliações da força muscular, equilíbrio, agilidade, resistência aeróbia, massa muscular e massa gorda, bem como no metabolismo ósseo e no risco e no medo de queda (Yoo et al., 2010).

No estudo de Rosário e colaboradores (2017), um programa de treino, bissemanal, funcional e de flexibilidade (estiramento) do tornozelo durante doze semanas, promoveu melhorias significativas no ângulo de flexão dorsal do tornozelo, no entanto não foi suficiente para induzir alterações significativas na aptidão física e no risco de queda em 20 idosas (Rosario et al., 2017).

Por outro lado, no ensaio com uma intervenção inovadora envolvendo treino de força, de equilíbrio e “8-form Tai Chi Chuan”, Zhuang e colaboradores (2014) observaram melhorias na aptidão física e na redução do risco de queda após doze semanas de treino num grupo de idosos (Zhuang et al., 2014).

Acresce o trabalho de Buchner e colaboradores (1997), que num ensaio clínico randomizado e controlado, para estudar o efeito do treino combinado de força e resistência na marcha, no equilíbrio, e risco de queda em 50 idosos, relataram que o exercício obteve um efeito significativo e protetor no risco de queda, sendo este avaliado com provas funcionais (Buchner et al., 1997). Também Sousa e colaboradores (2017) relatam no seu ensaio controlado randomizado, em 66 homens idosos que o exercício combinado até 32 semanas foi mais eficaz que o exercício aeróbio na melhoria dos fatores de risco de queda, medidos através do *Functional Fitness Test* (Sousa et al., 2017). Salienta-se ainda a revisão sistemática de Cadore e colaboradores (2013) sobre os efeitos de diferentes intervenções de exercício no RQ, capacidade da marcha, e equilíbrio em idosos fisicamente frágeis, como os mais eficazes no RQ, os programas de exercício de treino de resistência assim como os programas combinados de força, resistência e equilíbrio (Cadore et al., 2013).

3. Estudo Empírico

Tendo como base de partida todo o trabalho de investigação e de pesquisa bibliográfica que a precedeu, a presente tese propôs-se atingir os seguintes objetivos.

1. Avaliar o efeito de um programa de treino combinado aeróbio e de força no risco de queda (*RQ*), em idosos de ambos os sexos.
2. Estudar as correlações entre a Atividade Física, a Aptidão Funcional e o *RQ* em idosos.

Para tal foram elaborados duas tipologias de estudos distintos: i) 2 estudos transversais, observacionais de correlação entre variáveis em estudo: a) "Association between physical activity, functional fitness and fall risk in the elderly – A cross-sectional population-based study from the Oporto Region" e b) "Fall risk prediction model for older men and women based on ambulatory physical activity intensity – A cross-sectional population-based study from the Oporto Region" e ii) um estudo longitudinal quási-experimental envolvendo uma intervenção de treino combinado aeróbio e de reforço muscular: "Imbalance and fall risk improvements in elderly: Effects of combined strength-aerobic training".

Ambos os estudos tiveram como população, indivíduos de ambos os sexos, residentes na área do Grande Porto, com idades superiores aos 65 anos, autónomos.

O estudo foi aprovado pela Comissão de Ética da FADEUP (CEFADE.02.2015; Anexo A) e todos os participantes foram informados acerca dos objetivos e procedimentos do estudo, após o que cederam o consentimento informado, respeitando as Recomendações Éticas Globais (C.I.O.M.S., 2002), a Declaração de Helsínquia da Associação Médica Mundial (World Health Organization, 2011, 2013).

A Tabela 2 apresenta o desenho da presente tese.

Tabela 2 - Desenho da tese

Artigo 1 Association between physical activity, functional fitness and fall risk in the elderly – A cross-sectional population-based study from the Oporto Region	Artigo 2 Fall risk prediction model for older men and women based on ambulatory physical activity intensity – A cross-sectional population-based study from the Oporto region	Artigo 3 Imbalance and fall risk improvements in elderly: Effects of combined strength-aerobic training
Tamanho da amostra		
n = 206; 124 mulheres	n = 206; 124 mulheres	n = 62; 36 mulheres
Idade média (anos)		
72.34 ± 6.70	72.34 ± 6.70	69.02 ± 4.27
Variáveis recolhidas		
Aptidão Funcional Risco Queda Atividade Física Antropometria Idade	Risco Queda Atividade Física Antropometria Idade	Risco Queda Atividade Física Antropometria Idade
Técnica de recolha de dados		
Aptidão Funcional Fullerton (Rikli & Jones, 1999) POMA (Tinetti, 1986) Actigrafia Estadiometro Balança peso Questionário Demográfico	POMA (Tinetti, 1986) Actigrafia Estadiometro Balança peso Questionário Demográfico	Protocolo Risco de Queda Biodex (Finn, 1999) Actigrafia Estadiometro Balança peso Questionário Demográfico
Tratamento e análise de dados		
Correlação de Pearson Regressão Linear Múltipla SPSS G*Power	Correlação de Pearson Regressão Linear Múltipla SPSS G*Power	Anova de medidas repetidas mista SPSS G*Power

3.1 Artigo 1

Association between physical activity, functional fitness and fall risk in the elderly – A cross-sectional population-based study from the Oporto Region

This paper was published as:

Carmo, P., Cesar A., Santos, R., Carvalho, J. Association between physical activity, functional fitness and fall risk in the elderly – A cross-sectional population-based study from the Oporto Region. *Med Sport (Roma)* 2021 June; 74(2):313-26. DOI: 10.23736/S0025-7826.21.03838-2

COPYRIGHT[©] 2021 EDIZIONI MINERVA MEDICA

Medicina dello Sport 2021 June;74(2):313-26
DOI: 10.23736/S0025-7826.21.03838-2

EXERCISE PRESCRIPTION AREA

Association between physical activity, functional fitness and fall risk in the elderly: a cross-sectional population-based study from the Oporto region

Relazione tra attività fisica, fitness funzionale e rischio di caduta negli anziani: uno studio trasversale cross-section sulla popolazione della regione di Oporto

Paulo C. CARMO ^{1, 2, 3 *}, Adjane P. CESAR ³, Rubim S. SANTOS ¹, Joana M. CARVALHO ³

Association between physical activity, functional fitness and fall risk in the elderly – A cross-sectional population-based study from the Oporto Region

Cardoso-Carmo, P., César, A., Santos, R., Carvalho, J.

Abstract

Background: Falls among the elderly are important clinical and health problems being one of the major causes of morbidity and mortality worldwide. Its high incidence and functional and social repercussions cause a significant financial burden on older adults, health systems and communities. According to different methodologies, the relationship between fall risk, physical activity and physical fitness found some inconsistent results. This study aims to examine the association between objective physical activity (PA) levels, fall risk (FR) and different components of functional fitness (FF) creating an appropriate model to explain variability in fall risk.

Methods: One hundred and seventy elderly adults (72.34 ± 6.70 years old, 124 female), completed a Functional-Fitness-Test (FFT) and a Performance-Orientated-Mobility-Assessment (POMA). Ambulatory-PA was assessed by 7-days accelerometry. *Pearson's* correlation was used to verify association between FR, PA and FF. Analyses were adjusted either for gender, age, or both. Inferential stepwise *Multiple Linear Regression* (MLR) was used to investigate the impact of PA and components of FF on FR.

Results: MLR Showed that FR variability was mainly explained by motor agility (46.0%) and also by lower-body strength (14.1%) independently, and 49% when associated. Physical activity and also age were excluded from the models. MLR analysis by gender, only motor agility explains fall risk variability, more in female (45.0%) than in male (23.6%).

Conclusions: The authors concluded that low motor agility and lower-body strength may increase fall risk. However, further evidence from a prospective study is required to establish directions of causality between physical activity behaviour and risk of falls.

Key-words: active ageing, motor activity, physical fitness, balance, accelerometer

INTRODUCTION

Falls are one of the most common and serious public health problems in the elderly due to its high incidence levels and impact on mortality and morbidity (Stevens, 2005). Approximately one-third of community-dwelling older individuals have balance problems, falling at least once per year and about one half suffer from multiple falls (Beegan & Messinger-Rapport, 2015).

Falls are the main cause of fractures, hospital admissions for trauma, loss of independence, and injury-related deaths (Hsieha et al., 2019). Even though the majority of falls do not cause injuries, about 20% of them lead to a serious injury (such as a bone fracture or a head injury) that can greatly restrict a person in their everyday activities (Sterling et al., 2001). Moreover, falls injuries not only cause distress, pain and restrictions on daily living but also can have a serious financial impact on associated health care costs (Pin & Spini, 2016).

On the other hand, due to ageing, a progressive decline in functional function (FF) has also been associated with lower physical independence, resulting in a shift from an independent to a more dependent lifestyle (Spirduso et al., 2005).

Therefore, since avoiding falls and being physically able to complete tasks necessary for everyday living are essential components of independent living with ageing (Illario et al., 2015), identifying modifiable behavioural factors associated with functional function and imbalance, and fall risk (FR), among older adults, is of major importance.

Moreover, while risk factors associated with falls are well established (Lord & Sturnieks, 2005), as are the age-related declines in functional fitness (Sallis, 2000), the relationship between FR and FF with physical activity (PA) has not been so extensively characterised and conflicting results have been demonstrated (Boyle et al., 2007; Chan et al., 2007; Heesch et al., 2008; O'Sullivan et al., 2009). Higher levels of PA have been shown to not relate with FR or even be associated with increased risk for falling in some studies (Chan et al., 2007), but mostly with decreased risk for falling and fractures in others (Buchner et al., 2017; Caban-Martinez et al., 2015). Furthermore, evidence has

verified the negative relationships of self-reported measured physical activity, with aspects of physical performance such as muscle strength, mobility, and balance in older adults (Anderton et al., 2014; Simpson et al., 2015), but more rarely with objectively measures, which is a major limitation because older adults may have difficulty to accurately record their total physical activity levels (Liao et al., 2018).

For the public health prevention practices, it is of value to further explore these relationships and identify the best predictors for FR, determining the contribution of PA and each component of the functional fitness. Therefore, the present study examined the associations of objectively measured PA with different components of physical fitness and FR among older men and women.

MATERIALS AND METHODS

Two-hundred and six elderlies, aged 65 years and older, both genders, drawn from the Oporto area, Portugal were invited to participate in this cross-sectional study. The exclusion criteria were those unable to walk without a cane, or those with known medical, cognitive conditions and muscular-skeletal problems that would limit their ability to safely perform evaluations. Following the screening, 36 candidates did not perform all tests to the required selection criteria standards (due to unwillingness to use the accelerometer or complete functional assessments), resulting in a final suitable sample size of 170 participants (mean age = 72.3 ± 6.7 years; 124 women and 46 men).

Subjects were informed about the study aims and procedures and then signed written informed consent before being enrolled onto the study, respecting The World Medical Association Declaration of Helsinki (World Health Organization, 2013). The study was approved by the ethics committee of the Faculty of Sport, University of Porto (CEFADE.02.2015).

Physical Activity

Habitual ambulatory physical activity (PA) was assessed using uniaxial accelerometry (GT1M, Actigraph, Florida, USA). Participants were instructed to wear the accelerometer on an adjustable nylon belt over the right hip, for seven

consecutive days, apart from sleeping and during water-based activities, and also, to record the schedule of use and the main physical activities in a written self-filled diary, for cross-validation purposes, following guidelines (Egerton et al., 2017).

Wear time validation was used, whereby continuous periods of 60+ consecutive minutes of continuous zero counts, with a tolerance of up to two minutes of activity between zero-100 counts.min⁻¹ (CPM) were defined as “no-wear” and excluded from the analysis. Data were considered valid if there was a minimum of 10 hours of wear time per day, on a minimum of four days (Egerton et al., 2017). Data from all participants meet these validity criteria and none were excluded.

ActiGraph data were processed using Actilife™ software (v.6.11.3 ActiGraph, Pensacola, FL.) that converts acceleration data into counts that are summed over a user-specified interval of time called an “epoch”. For the present study, the epoch was set to a 10-second interval, which allows the highest resolution. The outcome variable was reported in minutes, that is, the number of vertical axis counts.min⁻¹(CPM) and were generated based on magnitude, intensity and frequency of bodily movement; Thus, the higher number of counts measured, the more active a person is. CPM is often used as an outcome variable due to its robustness, as it is not influenced by any external criteria (i.e., intensity threshold) other than wear time validation (Marques et al., 2011).

Physical fitness

The Functional (or Fullerton) Fitness Test was used, consisting of 6 items, designed and validated to assess the functional parameters that support physical mobility in elderly (Rikli & Jones, 1999). It is a simple, easily administered set of tests: i) number of full stands in 30 seconds with arms folded across the chest to assess lower-body strength (30-second chair stand [30-s CS]); ii) number of biceps curls in 30 seconds while holding a hand weight (3 kg for men and 2 kg for women (30-second arm curl [30-s AC]),) to assess upper-body strength; iii) chair sit and reach to assess the lower-body flexibility from sitting position with leg extended at front of chair and hands reaching toward toes, number of centimetres (+ or -) from extended fingers to tip of the toe (chair seat-and-reach

[CSR]); iv) back scratch to assess upper-body flexibility (with one hand reaching over the shoulder and the other one up middle of back, distance (centimetres) between extended middle fingers (+ or -)(back scratch [BS]); v) number of meters walked in 6 minutes to measure aerobic endurance (6-minute walk [6-m W]); and vi) standing up from a chair, walking 8-foot distance, turning, stopping, and sitting down to assess dynamic balance and motor agility (8-foot up-and-go [8FUG])(Wanderley et al., 2011). This battery of tests also assessed body mass index as an estimate of body composition (data not shown). All measurements were performed by a team of trained researchers.

Fuller and more detailed information on test administration and protocols can be found in the work of Rikli and Jones (Rikli & Jones, 2014). The result of each test can be expressed as age (for each 5-year group) and sex standardized percentile scores and normative values have been obtained for the Portuguese elderly population (Marques et al., 2014).

Fall risk

Performance Orientated Mobility Assessment (POMA) developed by Tinetti (Tinetti, 1986) was used. This assessment tool shows proven sensitivity and specificity for fall prediction (Raïche et al., 2000), resulting in the widespread use of POMA in both research and clinical settings (Jahantabi-Nejad & Azad, 2019). POMA consists of 2 parts for assessment of balance and gait and is frequently used to evaluate elderly populations. The score ranges from zero to 28, and a score of 0-19 corresponds to high fall risk, while scores between 19 and 24 reveal the presence of a problem, classified as moderated fall risk, whereas a score of 24–28 is normal and correspond to low fall risk (Cherian et al., 2016; Sterke et al., 2010).

The higher the POMA score, the lower fall risk. So, when POMA score tends to zero, meaning an increase in fall risk, this may be misleading. Thus, so that the increase in the variable fall risk be expressed as an increasing natural number, in the present study POMA was inverted into a new variable, called fall risk (FR) (Finn et al., 1999; Rivolta & Sassi, 2017). FR was created based on POMA score results by applying the formula ($FR = 29 - POMA$), and the new score ranges were categorized as low FR (1-5); moderated FR (5-10); and high

FR (10-28).

Statistical Procedures

SPSS 25 for Mac (SPSS Inc., Chicago, IL, USA) was used for statistical analysis. All continuous variables were expressed as mean $\pm$ standard deviation and were initially evaluated for normality using the *Kolmogorov–Smirnov* test.

Differences between men and women for age, BMI, functional fitness components, FR, and PA were compared via independent sample *t*-test. Afterwards, *Pearson* correlation coefficients test was used to assess the correlation between PA, functional fitness components, FR and age, and inferential stepwise *Multiple Linear Regression (MLR)* test was used to investigate multivariate relationships among predictors of FR. The assumptions of the models, namely, normal distribution, homogeneity and independence of errors were analysed and used the criteria: probability-of-F-to-enter ≤ 0.05 , probability-of-F-to-remove ≥ 0.10 . G*Power was used to obtain the effect size F^2 and power of the tests. Level of significance was set at $p < 0.05$.

Results

Table 1 shows scores for age, FF, POMA, FR and PA.

Table 1 – Age, FF, POMA, FR and PA of the study participants.

Variable	Mean (SD)			<i>p</i>
	Total (n = 170)	Female (n = 124)	Male (n = 46)	
Age (years)	72.34(6.70)	71.97(6.57)	73.35(7.01)	0.281
Aerobic endurance (m)	516.82(137.19)	497.45(139.28)	556.08(125.71)	0.035*
Lower-body strength (n)	16.47(5.61)	15.92(4.86)	17.85(7.05)	0.049*
Upper-body strength (n)	18.49(6.61)	18.43(5.44)	18.64(9.07)	0.861
Lower-body flexibility (cm)	-8.65(13.70)	-8.55(12.75)	-8.89(16.01)	0.887
Upper-body flexibility (cm)	-16.16(14.24)	-15.46(13.67)	-17.92(15.61)	0.322
Motor agility (s)	6.33(3.39)	6.60(3.56)	5.62(2.79)	0.101
POMA (score)	26.26(2.99)	26.10(3.30)	26.67(1.92)	0.318
Static balance (score)	14.80(1.85)	14.71(2.01)	15.05(1.31)	0.324
Dynamic balance (score)	11.45(1.41)	11.39(1.57)	11.62(.84)	0.391
Fall Risk (score)	2.74(2.99)	2.90(3.30)	2.33(1.92)	0.318
PA (CPM)	4.63(2.17)	4.70(2.28)	4.42(1.80)	0.529

Key: POMA – Performance Orientated Mobility Assessment; FR – fall risk; PA – Physical Activity; SD – Standard deviation; *p* - *p* value; * - denotes statistical significance, $p < 0.05$; cm – centimetre; m – meter; n – number; s – second; CPM – counts per minute

Men presented as having higher aerobic endurance ($p = 0.035$) and greater lower-body strength ($p = 0.049$) compared to women. No other differences were observed in all other components or variables evaluated.

Associations among age, components of physical fitness, physical activity and fall risk are shown in Table 2.

Table 2 - Correlation analysis (Pearson's test) between sample participants age, FF, PA, and FR.

Variables	FR			PA		
	<i>r</i>	<i>P</i>	Class	<i>r</i>	<i>p</i>	Class
Age	0.385	<0.001*	M	-0.471	<0.001*	M
Lower-body strength	-0.375	<0.001*	M	0.406	<0.001*	M
Upper-body strength	-0.337	<0.001*	M	0.434	<0.001*	M
Lower-body flexibility	-0.188	0.026*	L	0.324	<0.001*	M
Upper-body flexibility	-0.280	<0.001*	L	0.262	0.003*	L
Motor agility	0.598	<0.001*	H	-0.495	<0.001*	M
Aerobic endurance	-0.591	<0.001*	H	0.530	<0.001*	H
PA	-0.320	<0.001*	L	----	----	----

Key: FR- Fall risk; PA –Physical activity; *r* – *r*-value (Pearson's test); *p* – *p*-value; * - denotes statistical significance, *p* < 0.05; Class – *r* classification (Hopkins, 1997): H – High; M – Moderate; L – Low.

All correlations presented in Table 2 showed statistically significant values (*p* < 0.05).

In this way, significant and positive correlations (strong and moderate) (Hopkins, 1997) were seen between FR and i) 8-f UG test time, i.e., the greater the test time (the lower motor agility) the greater FR; and ii) age, the greater was age, the greater was FR. Moreover, FR correlated significantly and strongly negatively with: iii) aerobic endurance (6-m W), iv) moderately with upper and lower-body strength (30-s AC; 30-s CS), and weakly with v) with upper and lower-

body flexibility (BS, CSR) and vi) physical activity.

Also, Table 2 shows, that PA correlated significantly, strongly and positively with aerobic endurance (6-m W); moderately with upper and lower-body muscle strength (30-s CS, 30-S AC) and lower-body flexibility (CSR), and weakly with upper-body flexibility (BS). Moreover, PA correlated significantly and strongly negatively with 8-f UG test time, i.e., the more active the person is, the smallest test time with higher motor agility, and moderately with age.

An inferential stepwise *multiple linear regression* (Table 3) was undertaken to estimate the contribution of (i) age, (ii) PA (iii) and functional fitness components to explain the variability of FR.

MLR analysis showed that FR variability was mainly explained by the predictors motor agility (8-f UG)(46.0%) and also, with minor expression, by lower-body strength (30-s CS)(14.1%) independently, and even more when associated (49%) ($R_a^2 = 0.49$, $F(2,81) = 38$; $p < 0.001$). It was found that motor agility significantly predicted FR ($\beta = 0.869$; $t(81) = -7.725$; $p < 0.001$), as did lower-body strength ($\beta = -0.223$; $t(81) = -2.079$; $p = 0.041$). Lower-body strength is only marginally significant, but given the limitations of sampling and the relative size of the sample, the authors chose to include this variable in the model. The present study total adjusted model is then $\widehat{FR} = 5.026 + 0.869 \text{ 8-f UG} - 0.147 \text{ 30-s CS}$. Meaning that in elderly, for every second of increase to perform 8-f UG test, the $\widehat{FR}$ score will increase by 0.869 points, tending to a more dangerous score according to FR scale cut-points, mentioned above. Likewise, with the 30-s CS test, the greater the number of stands from the chair, the constant (5.026) value will be decreased by a factor of 0.147 points, i.e., the lower the number of stands from the chair in 30 seconds, the constant (5.026) value will be increased by a factor of 0.147 points, with similar $\widehat{FR}$ score repercussion.

Table 3 – Multiple linear regression models predicting FR in the total, female and male samples.

Model		R^2	R_a^2	SEE	Predictive formula
1_{Total}	8-f UG	0.678	0.460	2.585	
2_{Total}	30-s CS	0.375	0.141	2.801	
FR_{Total}	Predictive variables	0.698	0.487	2.534	$\widehat{FR}_{Total} = 5.026 + 0.869 \text{ 8-f UG} - 0.147 \text{ 30-s CS}^*$
1_{Female}	8-f UG	0.459	0.450	2.856	
FR_{Female}	Predictive variable	0.459	0.450	2.856	$\widehat{FR}_{Female} = 1.818 + 0.732 \text{ 8-f UG}^*$
1_{Male}	8-f UG	0.263	0.236	1.490	
FR_{Male}	Predictive variable	0.263	0.236	1.490	$\widehat{FR}_{Male} = 0.677 + 0.499 \text{ 8-f UG}^*$

Key: * - denotes statistical significance, $p < 0.05$; Variables entered: Fall Risk; age; counts.min-1; 30-s CS; 30-s AC; CSR; BS; 8-f UG; 6-m W. Dependent variable: FR_{total} . Predictive variables: Model 1_{total} - 8-f UG, Model 2_{total} - 30-s CS. Model FR_{Total} - 8-f UG +30-s CS; Dependent variable: FR_{Female} . Predictive variables: Model 1_{Female} - 8-f UG; Dependent variable: FR_{Male} . Predictive variables: Model 1_{Male} - 8-f UG; R^2 - determination coefficient; R_a^2 – adjusted determination coefficient; SEE: standard error of estimative.

Functional fitness components like upper-body strength, lower-body and upper-body flexibility, aerobic endurance, as also PA and age were excluded from the model ($p > 0.100$)(data not shown), since according to statistical procedures, the probability-of-F-to-remove ≥ 0.10 .

Because there were significant gender differences in FF components values in Table 1, *MLR* by gender was carried out.

In the female sample (Table 3), *MLR* indicated that the predictor 8-f UG explained 45.9% of the variance ($R^2 = 0.459$, $F(1,63) = 53.388$; $p < 0.001$). It was found that motor agility significantly predicted FR ($\beta = 0.732$; $t(63) = 38.842$ $p < 0.001$). The present study female adjusted model is then $\widehat{FR} = 1.818 + 0.732 \text{ 8-f UG}$. Meaning that in female elderly, for every second of increase to perform 8-f

UG test, the $\widehat{FR}$ score will increase by 0.732 points, tending to a more menacing score.

In the male sample (Table 3), *MLR* indicated that the predictor 8-f UG explained 26.3% of the variance $R^2 = 0.263$, $F(1,28) = 9.983$; $p = 0.004$). It was found that motor agility significantly predicted FR ($\beta = 0.499$; $t(28) = 30.257$; $p < 0.001$). The present study male adjusted model is then $\widehat{FR} = 0.677 + 0.499$ 8-f UG. Meaning that in male elderly, for every second of increase to perform 8-f UG test, the $\widehat{FR}$ score will increase by 0.499 points, tending to a more menacing score.

In the total sample model, using G*Power with 8-f UG and 30-s CS, the effect size ($f^2 = 0.558701$) was found to exceed convention for a large effect ($f^2 = 0.50$)(Cohen, 1988), and observed statistical power ($\pi = 1.000$), as well in the female model, using G*Power with 8-f UG, the effect size ($f^2 = 0.5339776$) was found to exceed expectation for a large effect ($f^2 = 0.50$)(Cohen, 1988) and observed statistical power ($\pi = 1.000$), and moreover, in the male model using G*Power with 8-f UG, the effect size ($f^2 = 0.5339776$) was found to exceed expectation for a large effect ($f^2 = 0.50$) (Cohen, 1988), and observed statistical power ($\pi = 0.9980457$), all three suitable for detecting a large-sized effect when employing 0.05 criterion of statistical significance.

Discussion

The main findings of this study show that depending mainly on motor agility and with a minor expression on lower-body strength older physically independent community-dwelling individuals may put themselves in a position of greater fall risk, as demonstrated by fall risk prediction models here presented. Moreover, the observed positive associations between aerobic endurance and PA seem to be dependent on age. Also, are presented positive associations between PA and lower and upper-body strength, and flexibility.

Although there were no significant differences between women's and men's in most of the analyzed variables, as expected (Ikezoe et al., 2003), men presented significantly greater lower-body muscle strength and aerobic

endurance. Also, Smee et al. (2012) reported that male participants had higher lower body strength than female (Smee et al., 2012). In the same way, Zoeller (2008) reported that aerobic endurance in older men was greater than for women (Zoeller, 2008).

Even though various risk factors are leading to falls, most of the literature shows, as the present study, that people with higher PA have a lower risk and incidence of falls (Yokoya et al., 2007). Several reported that PA ranging from leisure-time physical activity to the daily moderate to vigorous-intensity physical activity in older adults will prevent and reduce the incidence of falls (Caban-Martinez et al., 2015; Heesch et al., 2008; Sherrington et al., 2011). It is of notice that the present study used objective measures of physical activity.

Moreover, the observed association of PA with functional fitness components in both genders observed in the present study was also confirmed by others (Brach & VanSwearingen, 2002; Brach et al., 2002; Langley & Mackintosh, 2007). Probably, PA reduces fall risk, because it counteracts the age-related decline in physical fitness (Chodzko-Zajko et al., 2009) and improves the individual's capacity to perform every-days tasks without fatigue (Bjerk et al., 2017; Wijnhuizen et al., 2007).

Besides, the present study found that age was positively related to lower PA as in another study (Wanderley et al., 2011). Accordingly, different studies have demonstrated a decline in daily physical activity as people age (Barnett et al., 2016; Buchner et al., 2017). Additionally, the present study results also showed that higher PA correlated significantly and positively with longer 6-m W. This result is in line with Alves et al. (2013) who reported in a sample with similar characteristics to the present study sample, strong correlations of PA and 6-m W in 33 asymptomatic elderly ($r = 0.515$, $p < 0.0001$) (Alves et al., 2013).

Proceeding with the statistical analysis and to investigate multivariate relationships among predictors of FR, an inferential stepwise *Multiple Linear Regression* test was used in the present study. In line with the study of Cho et al. (2004), the present study data showed that lower FR correlated significantly and positively with longer 6-m W and negatively with faster 8-f UG, probably related with muscular-skeletal factors, particularly in lower-body strength (Cho et al.,

2004). In the same line of investigation, other studies observed a high correlation between FR and mobility/balance tests. Despite using another evaluation method, Timed Up-and-Go test (TUG), Faber et al. (2006) and Cherian et al. (2016) found a high correlation between POMA and TUG in elderly adults (Cherian et al., 2016; Faber et al., 2006).

Regarding the relative weight of physical fitness variables contributing to the variation in FR for the *MLR* model, R_a^2 explained about 48.7% of the relationship between 8-f UG (46.0%) and 30-s CS (14.1%) as predictor variables independently, and $\approx 49\%$ when associated. This finding is highly significant ($p < .001$) and accounts for a large proportion ($\approx 50\%$) of *FR* variability, as described by Rikli & Jones (1999), and that it is of major importance to act on motor agility/dynamic balance and lower body strength to reduce FR (Rikli & Jones, 1999). The association of FF components and FR have been also previously studied by Amaro (2012) in other populations with similar age and characteristics. The present study has achieved a better model summary result (49%) in predicting FR variability compared to Amaro's study that only explained 37% of FR variability, based only on functional mobility (Amaro, 2012).

Other investigators have also presented models of prediction of FR, based on objective instruments like Get-up-and-go test, and rising from chair ability, gender, depression, confusion/disorientation states (Mini-Mental Examination), and drug prescriptions like antiepileptics, benzodiazepines, in hospitalized patients (Hendrich et al., 2003).

The present study presents also a substantial model summary results in predicting FR variability when gender stratification was performed. The models achieved 45.0 % in the female sample but only 23.6 % in the male sample. The authors didn't find any other study with similar model gender stratification, for FR based on the same variables.

Analogous implications were achieved with the gender stratification models, as seen in the total sample model. Once 8-f UG was the only predictor explaining FR variability in both female and male participants, for every second of increase to perform 8-f UG test, the FR score will increase by 0.732 points in female and 0.499 points in male, tending to a more menacing FR score. The

present study reinforces the relevance of active lifestyles for a better FF and consequently, in the predictors for a lower FR.

Strengths

The strengths of this study include the use of objective and reliable instruments to monitor PA by accelerometry that provides objective measures of physical activity behaviours that are free of the random and systematic errors associated with self-report. As such, they are believed to provide better assessments for many activities, particularly activities that have proved difficult to measure by self-report (Matthews et al., 2012).

Limitations

Nonetheless, this study is not without limitations. Firstly, the sample size was relatively small and was comprised of volunteer subjects that make generalization of the results difficult. Segmenting the sample by gender could also have weakened the robustness of the statistical analysis. Secondly, the cross-sectional design does not permit causality conclusions. Future large-scale trials are required to investigate which factors are more effective on fall risk parameters. Thirdly, data on other potential confounders, such as visual impairment, foot problems, among others, were not objectively assessed. Fourthly, using total time of physical activity, instead of intensity partial times might have prejudiced the results.

Conclusions

This cross-sectional study suggests that lower FR is achieved in younger, fitter and more active participants. Among all the FF components, a better performance in 8-f UG and 30-s SC tests, meaning better motor agility and lower-body strength, both predictors of FR, may decrease FR. However, this prediction is dependent on the gender analysis, being motor agility/dynamic balance more important for women FR than for men FR.

This knowledge is of utmost importance and reinforces the strategy for improving physical activity exercise programs for a population in general, and specifically in the elderly, promoting active ageing with physical activity, in

walking and running activities.

Practice implication

These findings will be useful for clinicians that could consider using 8-f UG and 30-s SC scores to categorize high-risk fallers amongst the elderly. Like both risk factors are potentially modifiable, rehabilitation programs designed to reduce FR in the elderly should include exercises to improve mobility, motor agility and dynamic balance as well as muscle strength training.

These findings may aware community of the role of PA, namely balance/coordination and lower muscle strength exercises in fall risk reduction, being useful for clinicians, health practitioners in the primary health care service dealing with patients with balance disorders and for policymakers to reduce the burden of falls.

Notes

Declaration of conflicting interests

The Authors declares that there is no conflict of interest.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: César, A. was supported by CAPES (Nº 10143-13-0).

Acknowledgements

The authors would like to thank IPDJ (“Mais Ativos, Mais Vividos”) and CIAFEL (FCT/ UIDB/00617/2020), for assisting with technical support and personal availability during the data collection related to this study.

References

- Alves, M., Bueno, F., Haraguchi, L., Corrêa, F., & Dourado, V. (2013). Correlation between average number of steps per day and the six-minute walk test in asymptomatic adults and elderly. *Fisioter Pesq.*, 20(2), 123-129.
- Amaro, A. (2012). *Mobilidade funcional, risco de queda, nível de actividade física e percepção de saúde em indivíduos com 65 ou mais anos*. Lisboa: Universidade Nova de Lisboa. Dissertação de Mestrado apresentada a Faculdade de Ciências Médicas - Universidade Nova de Lisboa.
- Anderton, N., Newhouse, M., Ainsworth, B., Nygaard, I., Egger, M., & Shaw, J. (2014). "How Hard Could it Be?" A Descriptive Analysis of Errors Made on a Validated Lifetime Physical Activity Questionnaire. *J Phys Act Health*, 2015(Mar;12(3)), 388-394.
- Barnett, A., van den Hoek, D., Barnett, D., & Cerin, E. (2016). Measuring moderate-intensity walking in older adults using the ActiGraph accelerometer. *BMC Geriatrics*, 2016(16), 211.
- Beegan, L., & Messinger-Rapport, B. (2015). Stand by me! Reducing the risk of injurious falls in older adults. *Cleve Clin J Med*, 82(5).
- Bjerk, M., Brovold, T., Skelton, D., & Bergland, A. (2017). A falls prevention programme to improve quality of life, physical function and falls efficacy in older people receiving home help services: study protocol for a randomised controlled trial. *Health Serv Res*, 2017(17), 1-9.
- Boyle, P., Buchman, A., Wilson, R., Bienias, J., & Bennett, D. (2007). Physical Activity Is Associated with Incident Disability in Community-Based Older Persons. *J Amer Geriatr Soc*, 2007(55(2)), 195-201.
- Brach, J., & VanSwearingen, J. (2002). Physical impairment and disability: relationship to performance of activities of daily living in community-dwelling older men. *Phys Ther*, 82(8), 752-761.
- Brach, J., VanSwearingen, J., Newman, A., & Kriska, A. (2002). Identifying early decline of physical function in community-dwelling older women: performance-based and self-report measures. *Phys Ther*, 82(4), 320-328.

- Buchner, D., Rillamas-Sun, E., Di, C., LaMonte, M., Marshall, S., Hunt, J., Zhang, Y., Rosenberg, D., Lee, I., Evenson, K., Herring, A., Lewis, C., Stefanick, M., & LaCroix, A. (2017). Accelerometer-Measured Moderate to Vigorous Physical Activity And Incidence Rates of Falls in Older Women. *J Am Geriatr Soc*, 2017(65(11)), 2480-2487.
- Caban-Martinez, A., Courtney, T., Chang, W., Lombardi, D., Huang, Y., Brennan, M., Perry, M., Katz, J., Christiani, D., & Verma, S. (2015). Leisure-Time Physical Activity, Falls, and Fall Injuries in Middle-Aged Adults. *Am J Prev Med*, 2015(49(6)), 888-901.
- Chan, B., Marshall, L., Winters, K., Faulkner, K., Schwartz, A., & Orwoll, E. (2007). Incident fall risk and physical activity and physical performance among older men: the Osteoporotic Fractures in Men Study. *Am J Epidemiol*, 2007(Mar 15;165(6)), 696-703.
- Cherian, A., Kanagaraj, R., Jidesh, V., & Swaminathan, N. (2016). A Study to Evaluate the Correlation between Tinetti Performance Oriented Mobility Assessment (Tinetti Poma) with Functional Reach Test (FRT) and Timed UP and Go Test (TUG) in Assessing Balance among Elderly. *Indian J Physiother Occup Ther*, 10(July-Sept. No. 3), 169-173.
- Cho, B., Scarpace, D., & Alexander, N. (2004). Tests of Stepping as Indicators of Mobility, Balance, and Fall Risk in Balance-Impaired Older Adults. *J Am Geriatr Soc*, 52(7), 1168-1173.
- Chodzko-Zajko, W., Proctor, D., Singh, M., Minson, C., Nigg, C., Salem, G., & Skinner, J. (2009). American College of Sports Medicine Position Stand Exercise and Physical Activity for Older Adults. *Med Sci Sport Exerc*, 2009(41(7)), 1510-1530.
- Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum Associates.
- Egerton, T., Paterson, K., & Helbostad, J. (2017). The Association Between Gait Characteristics and Ambulatory Physical Activity in Older People: A Cross-Sectional and Longitudinal Observational Study Using Generation 100 Data. *J Aging Phys Act*, 2017(25), 10-19.

- Faber, M., Bosscher, R., & van Wieringen, P. (2006). Clinimetric Properties of the Performance-Oriented Mobility Assessment. *Phys Ther*, 86(7), 944-954.
- Finn, J., Alvarez, M., Jett, R., Axtell, R., & Kemler, D. (1999). Stability Performance Assessment Among Subjects of Disparate Balancing Abilities. *Med Sci Sports Exerc*, 31(5), S252.
- Heesch, K., Byles, J., & Brown, W. (2008). Prospective association between physical activity and falls in community-dwelling older women. *J Epidemiol Community Health*, 2008(62), 421-426.
- Hendrich, A., Bender, P., & Nyhuis, A. (2003). Validation of the Hendrich II Fall Risk Model: A Large Concurrent Case/Control Study of Hospitalized Patients. *Appl Nurs Res*, 16(1), 9-21.
- Hopkins, W. G. (1997). *A new view of statistics. A Scale of Magnitudes for Effect Statistics* (Vol. 1). Melbourne, Australia: Victoria University.
- Hsieha, K., Roacha, K., Wajdab, D., & Sosnoff, J. (2019). Smartphone technology can measure postural stability and discriminate fall risk in older adults. *Gait & Posture*, 2019(67), 160-165.
- Ikezoe, T., Asakawa, Y., & Tsutou, A. (2003). The Relationship between Quadriceps Strenght and Balance to Fall of Elderly Admitted to a Nursing Home. *J. Phys. Ther. Sci.*, 2003(15), 75-79.
- Illario, M., Vollenbroek-Hutten, M., Molloy, D., Menditto, E., Iaccarino, G., & Eklund, P. (2015). Active and Healthy Ageing and Independent Living. *J Aging Res*, 2015(2015: 542183), 1-3.
- Jahantabi-Nejad, S., & Azad, A. (2019). Predictive accuracy of performance oriented mobility assessment for falls in older adults: A systematic review. *Med J Islam Repub Iran*, 2019(1 May), 33-38.
- Langley, F., & Mackintosh, S. (2007). Functional Balance Assessment of Older Community Dwelling Adults: A Systematic Review of the Literature. *J Allied Health*, 5(4), 1-11.
- Liao, Y., Hsu, H., Shibata, A., Ishii, K., Koohsari, M., & Oka, K. (2018). Associations of total amount and patterns of objectively measured sedentary behavior with performance-based physical function. *Prev Med Rep*, 2018(12), 128-134.

- Lord, S., & Sturnieks, D. (2005). The physiology of falling: assessment and prevention strategies for older people. *J Sci Med Sport*, 8(1), 35-42.
- Marques, E., Baptista, F., Santos, R., Vale, S., Santos, D., Silva, A., Mota, J., & Sardinha, L. (2014). Normative functional fitness standards and trends of Portuguese older adults: cross-cultural comparisons. *J Aging Phys Act*, 22(1), 126-137.
- Marques, E., Mota, J., Machado, L., Sousa, F., Coelho, M., Moreira, P., & Carvalho, J. (2011). Multicomponent Training Program with Weight-Bearing Exercises Elicits Favorable Bone Density, Muscle Strength, and Balance Adaptations in Older Women. *Calcif Tissue Int*, 2011(88), 117-129.
- Matthews, C., Hagströmer, M., Pober, D., & Bowles, H. (2012). Best practices for using physical activity monitors in population-based research. *Med Sci Sports Exerc*, 2012(44(Suppl 1)), S68-76.
- O'Sullivan, M., Blake, C., Cunningham, C., Boyle, G., & Finucane, C. (2009). Correlation of accelerometry with clinical balance tests in older fallers and non-fallers. *Age and Ageing*, 2009(38), 308–313.
- Pin, S., & Spini, D. (2016). Impact of falling on social participation and social support trajectories in a middle-aged and elderly European sample. *SSM - Popul Health*, 2016(2), 382-289.
- Raïche, M., Hébert, R., Prince, F., & Coriveau, H. (2000). Screening older adults at risk of falling with the Tinetti Balance scale. *Lancet*, 356(September), 1001-1002.
- Rikli, R., & Jones, C. (1999). Development and validation of a functional fitness test for community-residing older adults. *J. Aging Phys Activ*, 7(2), 129-161.
- Rikli, R., & Jones, C. (2014). *Senior Fitness Test Manual Create guidelines for senior group testing* (2 ed. Vol. 1). Champaign, IL: Human Kinetics.
- Rivolta, M., & Sassi, R. (2017). Linear-Sigmoidal Modelling of Accelerometer Features and Tinetti Score for Automatic Fall Risk Assessment. *IEEE J Biomed Health Inform*, 2017(978-1-5090-2809-2/17), 3810-3813.

- Sallis, J. F. (2000). Age-related decline in physical activity: a synthesis of human and animal studies. *Med Sci Sports Exerc*, 32(9), 1598-1600.
- Sherrington, C., Tiedemann, A., Fairhall, N., Close, J., & Lord, S. (2011). Exercise to prevent falls in older adults: an updated meta-analysis and best practice recommendations. *N S W Public Health Bull*, 22((3-4)), 78-83.
- Simpson, K., Parker, B., Capizzi, J., Thompson, P., Clarkson, P., Freedson, P., & Pescatello, L. S. (2015). Validity and Reliability Question Eight of the Paffenbarger Physical Activity Questionnaire Among Healthy Adults. *J Phys Act Health*, 12(1), 116-123.
- Smee, D., Anson, J., Waddington, G., & Berry, H. (2012). Association between Physical Functionality and Falls Risk in Community-Living Older Adults. *Curr Geront Geriat Res*, 2012, 1-6.
- Spirduso, W., Francis, K., & Mcrae, P. (2005). *Physical Dimensions of Aging* (2 ed.). Champaign, Il.: Human Kinetics.
- Sterke, C., Huisman, S., van Beeck, E., Looman, C., & van der Cammen, T. (2010). Is the Tinetti Performance Oriented Mobility Assessment (POMA) a feasible and valid predictor of short-term fall risk in nursing home residents with dementia? *Int Psychogeriatr*, 2010(Mar;22(2)), 254-263
- Sterling, D., O'Connor, J., & Bonadies, J. (2001). Geriatric falls: Injury severity is high and disproportionate to mechanism. *J Trauma Acute Care Surg*, 2001(50), 116-119.
- Stevens, J. (2005). Falls among older adults-risk factors and prevention strategies. *J Safety Res*, 2005(36), 409 – 411.
- Tinetti, M. (1986). Performance-oriented assessment of mobility problems in elderly patients. *J Am Geriatr Soc*, 34(2), 119-126.
- Wanderley, F., Silva, G., Marques, E., Oliveira, J., Mota, J., & Carvalho, J. (2011). Associations between objectively assessed physical activity levels and fitness and self-reported quality of life in community-dwelling older adults. *Qual Life Res*, 2011(20), 1371-1378.
- Wijlhuizen, G., de Jong, R., & Hopman-Rock, M. (2007). Older persons afraid of falling reduce physical activity to prevent outdoor falls. *Prev Med*, 2007(44), 260-264.

- World Health Organization. (2013). *Ethical issues in Patient Safety Research - Interpreting existing guidance* (Vol. 1). Geneva, Switzerland: World Health Organization.
- Yokoya, T., Demura, S., & Sato, S. (2007). Relationships between Physical Activity, ADL Capability and Fall Risk in Community-Dwelling Japanese Elderly Population. *Environ Health Prev Med*, 12(January 2007), 25–32.
- Zoeller, R. (2008). Gender Differences in Cardiorespiratory Fitness With Advancing Age: Is the Age-Associated Decline in VO₂max More Rapid in Men and Do Older Men and Women Respond Differently to Exercise? *Am J Lifestyle Med*, 2008(2(6)), 492-499.

3.2 Artigo 2

Fall risk prediction model for older men and women based on ambulatory physical activity intensity – A cross-sectional population-based study from the Oporto region

Fall risk prediction model for older men and women based on ambulatory physical activity intensity – A cross-sectional population-based study from the Oporto region

Cardoso-Carmo, P., César, A., Santos, R., Carvalho, J.

ABSTRACT

Objectives: Falls among the elderly are an important community health problem due to its high incidence, functional and social repercussion. Dissimilar results arose in recent studies concerning the relationships between fall risk and objectively measured physical activity levels. This study aims to study the association between physical activity (PA) levels, and fall risk (FR), specifically to investigate which levels of PA is most influential in FR. Furthermore, we aim to develop a robust multifactorial model toward a falls risk prediction for the community-dwelling older adults.

Methods: One hundred and seventy elderly adults (72.34 ± 6.70 years old, 124 female), completed *Performance-Orientated-Mobility-Assessment* (POMA); Ambulatory-PA was assessed by accelerometry. *Pearson's* correlation was used to verify the association between FR, age, and PA. Analyses were adjusted for gender, age, or both. Inferential stepwise *multiple linear regression* (MLR) was used to investigate the influence of the variables collected on FR.

Results: Results showed that PA (moderate and negative) and age (moderate and positive) are significant predictors of FR. Additionally, MLR analysis showed that FR variability was mainly explained by PA (42.0%) and also, with minor expression, by age (37.0%) independently, and even more when associated (47.3%). In the MLR analysis by gender, female FR variability was explained by light physical activity (47.0%), while in male, FR variability was mainly explained by sedentary behaviour (44.1%) and also, with minor expression, by age (22.7%) independently, and even more when associated (45.8%).

Conclusion: Overall, our data suggest that individuals with higher physical activity have lower fall risk and on the other hand, older individuals are more prone to greater fall risk. Also, older women with higher light physical activity, are

less likely to fall or have a lower fall risk. Regarding men, older individuals and with more sedentary behaviour are prone to greater fall risk. However, further evidence from a prospective study are required to establish directions of causality between physical activity levels and fall risk.

Keywords: active aging, accelerometer, sedentary behaviour, balance, risk assessment

INTRODUCTION

Increased age-related falling incidence is an important public health concern that affects 30% of individuals beyond 65 years of age (O'Sullivan et al., 2009; Rubenstein & Josephson, 2002) and up to 50% of individuals older than 75 years (Beegan & Messinger-Rapport, 2015; King & Tinetti, 1995; Shumway-Cook et al., 1997; Tinetti et al., 1988).

The high incidence, long-term effects, loss of autonomy and costs for support, recovery and rehabilitation of falls will impact on health care system increasingly as time goes on (Pin & Spini, 2016). In this sense, the diagnosis of clinical, behaviour and functional parameters associated with falls in the elderly has become a major challenge for the scientific community (Karuka et al., 2011).

Most falls are caused by the interaction of multiple intrinsic and extrinsic risk factors (Ambrose et al., 2013; Bird et al., 2013; Saito et al., 2014), presenting lifestyle, namely physical activity (PA), an important role in the occurrence of falls (Nguyen et al., 2018). However, while the majority of studies showed that PA is associated with decreased risk for falling and fractures (Chan et al., 2007; Sievänen & Kannus, 2007; Wijnhuizen et al., 2007; Yokoya et al., 2007), others state that there is no relationship or even that PA is associated with an increased risk for falling (Klenk et al., 2015). This inconsistency is probably justified within the different methodologies used in studies, especially in the determination of PA: subjective - self-reported vs objective methods – accelerometers (Hsieh et al., 2019; Immonen & Similä, 2018; Kikkert et al., 2016; Rivolta et al., 2018).

Furthermore, the relationship between fall risk (FR) and different levels of PA and, particularly, with sedentary behaviour (SB), as a behavioural risk factor

for many non-communicable diseases (Tremblay, 2012), has not been so extensively researched. The majority of studies on SB have investigated its effects on cardiovascular outcomes and physical function; however, literature is scarce regarding the impact of SB on the occurrence of falls. So, SB as well as different levels of PA, defined as any bodily movement that increases energy expenditure above a basal level, may contribute differently to FR (Heesch et al., 2008).

Thus, the main aim of the study was to examine which PA levels and/or SB better predict fall risk (FR). Besides, taking into account that prediction models for FR have been developed mainly for residents of nursing homes being more scarce studies for the general community-dwelling elderly adults, we sought to develop a predictive model, based on SB and PA levels, that could run for those aged 65 years living in community.

METHODS

Two-hundred and six individuals, aged 65 years and older, drawn from the Oporto area, Portugal, were invited to participate in this cross-sectional study. The exclusion criteria were: those unable to walk without a cane, or those with known medical, cognitive conditions and muscular-skeletal problems that would limit their ability to safely perform evaluations. Following the screening, 36 candidates did not perform all tests to the required selection criteria standards, resulting in a final suitable sample size of 170 participants (mean age = 72.3 ± 6.7 years; 124 women and 46 men).

Subjects were informed about the study aims and procedures and then signed written informed consent before being enrolled in study, respecting Ethical Guidelines (C.I.O.M.S., 2002) and the World Medical Association Declaration of Helsinki (World Health Organization, 2011, 2013). The study was approved by the Ethics Committee, Faculty of Sport, University of Porto (CEFADE.02.2015).

Measurements

Physical Activity

Habitual ambulatory physical activity (PA) was assessed using uniaxial accelerometry (GT1M, Actigraph, Florida, USA). Participants were instructed to wear the accelerometer on an adjustable nylon belt over the right hip, for seven consecutive days, apart from sleeping and during water-based activities, and, also to record activities in a written diary (Sardinha et al., 2008).

Wear time validation was used, whereby continuous periods of 60+ consecutive minutes of continuous zero counts, with a tolerance of up to two minutes of activity between zero-100 counts.min⁻¹ (CPM) were defined as “no-wear” and excluded from the analysis. Data were considered valid if there was a minimum of 10 hours of wear time per day, on a minimum of four days (Egerton et al., 2017; Hagstromer et al., 2007). Data from all participants meet these validity criteria and none were excluded.

ActiGraph data was processed using Actilife™ software (v.6.11.3 ActiGraph, Pensacola, FL.) that converts acceleration data into counts that are summed over a user-specified interval of time called an “epoch”. For the present study, the epoch was set to a 10-second interval, which allows the highest resolution. The outcome variable was reported in minutes, that is, the number of vertical axis counts.min⁻¹(CPM) and were generated based on magnitude, intensity and frequency of bodily movement; Thus, the higher number of counts measured, the more active a person is. CPM is often used as an outcome variable due to its robustness, as it is not influenced by any external criteria (i.e., intensity threshold) other than wear time validation (Egerton et al., 2017; Marques et al., 2011).

Inactivity or sedentary behaviour (SB) was classified as activity below an arbitrary level of 100 CPM, and the cut-off points for light PA (LPA; 500-1,999 CPM), moderate PA (MPA; > 2,000 CPM) and vigorous PA (VPA; >3,000 CPM)(Sardinha et al., 2008).

Fall risk

Performance Orientated Mobility Assessment (POMA) developed by Tinetti (Tinetti, 1986) was used. This assessment tool shows proven sensitivity and specificity for fall prediction (Raïche et al., 2000) resulting in widespread use

of POMA in both research and clinical settings (Jahantabi-Nejad & Azad, 2019). POMA consists of 2 parts for assessment of balance and gait, and is frequently used to evaluate elderly populations. The score ranges from zero to 28, and a score of zero-19 corresponds to high fall risk, while scores between 19-24 reveal the presence of a problem, classified as moderated fall risk, whereas a score of 24–28 correspond to low fall risk (Cherian et al., 2016; Mitchell & Newton, 2006; Sterke et al., 2010).

The higher the POMA score, the lower fall risk. So, when POMA score tends to zero, meaning an increase in fall risk, this may be misleading. Thus, in the present study POMA was inverted into a new variable, called fall risk (FR) (Finn et al., 1999; Rivolta & Sassi, 2017; Schoene et al., 2014). FR was created based on POMA score results by applying the formula ($FR = 29 - POMA$), and the new score ranges were categorized as: low FR (1-5); moderated FR (5-10); and high FR (10-28).

Statistical Procedures

SPSS 25 for Mac (SPSS Inc., Chicago, IL, USA) was used for statistical analysis. All continuous variables were expressed as mean $\pm$ standard deviation and were initially evaluated for normality using the *Kolmogorov–Smirnov* test.

Differences between men and women for age, POMA, FR, PA levels and clinical conditions were compared via independent sample *t-test*. Afterwards, *Pearson* correlation coefficients test was used to assess the correlation between PA, FR and age, and inferential stepwise *Multiple Linear Regression* test was used to investigate multivariate relationships among predictors of FR. The assumptions of the models, namely, normal distribution, homogeneity and independence of errors were analysed and used the criteria: probability-of-F-to-enter ≤ 0.05 , probability-of-F-to-remove ≥ 0.10 . G*Power was used to obtain the effect size F^2 and power of the tests. Level of significance was set at $p < 0.05$.

Results

Table 1 shows scores for age, POMA, FR, PA levels and clinical conditions.

Significant differences were evident between males and females regarding PA levels: men presented as having greater sedentary behaviour ($p = 0.027$) and smaller light PA ($p = 0.012$).

Slight differences (not significant) were found between genders in POMA, static, and dynamic balance, with men presenting better results, however, both genders have a normal score with $M = 26.26$ (> 24). Thereby, regarding FR, both genders presented a low FR (< 5).

No other differences were observed in all the other components/aspects of physical activity and clinical diseases between genders.

Table 1 – Variables values of age, POMA, FR, PA levels, and clinical conditions by gender.

Variable	Mean (SD) Total	Female	Male	<i>p</i>
Gender N/(%)	170(100)	124(72.9)	46(27.1)	< 0.000*
Age (years) mean (SD)	72.34(6.70)	71.97(6.57)	73.35(7.01)	0.281
POMA Score	26.26(2.99)	26.10(3.30)	26.67(1.92)	0.318
Static balance	14.80(1.85)	14.71(2.01)	15.05(1.31)	0.324
Dynamic balance	11.45(1.41)	11.39(1.57)	11.62(.84)	0.391
Fall Risk	2.74(2.99)	2.90(3.30)	2.33(1.92)	0.318
PA (CPM)	4.63(2.17)	4.70(2.28)	4.42(1.80)	0.529
SB (mean/hour)	449.87(83.63)	440.61(86.51)	477.10(68.64)	0.027*
LPA (mean/hour)	274.29(88.65)	285.38(92.82)	241.68(65.99)	0.012*
MPA (mean/hour)	20.42(19.10)	19.32(18.72)	23.64(20.12)	0.256
VPA (mean/hour)	0.05(0.19)	0.03(0.18)	0.08(0.23)	0.152
MVPA (mean/hour)	20.46(19.16)	19.35(18.77)	23.73(20.21)	0.251
Cardiovascular system N/(%)	78(45.88)	60(48.38)	18(39.13)	0.132
Musculoskeletal system	26(15.29)	17(13.71)	9(19.57)	0.233
Respiratory system	19(11.17)	13(10.48)	6(13.04)	0.269
Digestive system	5(2.94)	3(2.41)	2(4.35)	0.310
Signs, symptoms and conditions ill-defined	21(12.35)	16(12.90)	5(10.87)	0.421
Other diseases	3(1.76)	2(1.61)	1(2.17)	0.654

Key: POMA – Performance Orientated Mobility Assessment; PA – physical activity; CPM – counts per minute; SB – sedentary behaviour; LPA – light physical activity; MPA – moderate physical activity; VPA – vigorous physical activity; MVPA – moderate to vigorous physical activity; SD – standard deviation; *p* - *p* value; * - denotes statistical significance, *p* < 0.05.

Associations among age, physical activity levels and fall risk are shown in Table 2.

Table 2 shows that FR correlated significantly and positively (moderate) (Hopkins, 1997) with age ($r = 0.385$, $p < 0.001$) and negatively with PA ($r = -0.320$, $p < 0.001$). All other correlations of FR were non-significant and negative with SB, LPA, MPA, VPA and MVPA.

Table 2 - Correlation analysis (Pearson's test) of participants age, PA, and FR.

Variables	FR			PA		
	<i>r</i>	<i>p</i>	Class	<i>r</i>	<i>p</i>	Class
Age	0.385**	< 0.001	M	-	< 0.001	M
				0.471**		
SB	-0.035	0.700	S	-	< 0.001	M
				0.305**		
LPA	-0.099	0.278	VS	0.568**	< 0.001	L
MPA	-0.153	0.093	S	0.809**	< 0.001	L
VPA	-0.082	0.370	VS	0.239**	0.005	S
MVPA	-0.153	0.092	S	0.809**	< 0.001	VL
PA	-0.320**	< 0.001	M	----	----	----

Key: FR – fall risk; PA – physical activity; SB – Sedentary Behaviour; LPA – light physical activity; MPA – moderate physical activity; VPA – vigorous physical activity; MVPA – moderate to vigorous physical activity - SD – standard deviation; *p* - *p* value; * - denotes statistical significance, $p < 0.05$. Correlation is significant at the 0.01 level (2-tailed) **; Correlation is significant at the 0.05 level (2-tailed) *; Class – *r* classification according to (Hopkins, 1997): VL – very large; L – large; M – moderate; S – small; VS – very small.

Moreover, significant and negative correlation (moderate) (Hopkins, 1997) between PA and SB ($r = -0.305$, $p < 0.001$) were seen. Furthermore, PA correlated significantly, negatively and moderately with age ($r = -0.471$, $p < 0.001$).

Finally, no other non-significant correlations were observed between variables.

An inferential stepwise *Multiple Linear Regression (MLR)* was undertaken to estimate the contribution of (i) age, (ii) PA levels, and gender to explain the variability of FR (Table 3).

MLR analysis found that PA significantly predicted FR ($\beta = -0.869$; $t(81) = -7.725$; $p < 0.001$), as did age ($\beta = -0.223$; $t(81) = -2.079$; $p < .041$), explaining PA (45.0%) and age (43.0%) independently, and even more when associated, predicting both, 52.1% of the variance of FR ($R^2 = 0.521$, $F(6,115) = 0.978$; $p < 0.001$).

Table 3 – Multiple linear regression models predicting FR in the total, female and male samples.

Model		R^2	R_a^2	SEE	Predictive formula
1 _{Total}	PA	0.450	0.420	3.082	
2 _{Total}	Age	0.430	0.370	2.942	
FR _{Total}	Predictive variables	0.521	0.473	3.005	$\widehat{FR}_{total} = 8.289 - 0.134 PA + 0.114 age^*$
1 _{Female}	LPA	0.483	0.470	2.756	
FR _{Female}	Predictive variable	0.483	0.470	2.756	$\widehat{FR}_{Female} = 9.882 - 2.113 LPA^*$
1 _{Male}	SB	0.472	0.441	2.232	
2 _{Male}	Age	0.318	0.227	2.735	
FR _{Male}	Predictive variables	0.469	0.458	2.785	$\widehat{FR}_{Male} = 8.229 + 2.324 SB + 0.665 age^*$

Key: FR – fall risk; PA – physical activity; * - denotes statistical significance, $p < 0.05$; Variables entered: Age; SB; LPA; MPA; VPA; MVPA; PA. Dependent variable: FR. Predictive variables: Model 1_{Total} - PA, Model 2_{Total} – Age. Model FR_{Total} – PA +Age; Model 1_{Female} - LPA, Model FR_{Female} – LPA; Model 1_{Male} - SB, Model 2_{Male} – Age, Model FR_{Male} – SB + Age; R^2 - determination coefficient; R_a^2 – adjusted determination coefficient; SEE: standard error of estimative.

Thus, according to Table 3 adding age to the analysis, increases the explanation of FR variability by 7.1% (52.1 minus 45.0). This study total sample adjusted model is then $\widehat{FR}_{Total} = 8.289 - 0.134 PA + 0.114 age$, meaning that the older participants have greater fall risk, but the more active are less likely to fall.

Gender was not a significant predictor (data not shown). Yet, mainly due to PA levels dissimilarities between genders (Table 1), and proceeding the statistical analysis of data, a *MLR* of the sample with gender stratification was carried out, reaching the models $\widehat{FR}_{Female}$ and $\widehat{FR}_{Male}$ also presented in Table 3.

MLR of the female sample (Table 3) found that light PA significantly predicted FR ($\beta = 0.030$; $t(84) = 11.535$ $p = 0.020$) and explained 47.0% of FR variability ($R^2 = 0.470$, $F(6,84) = 0.582$; $p = 0.020$). The female adjusted model is then $\widehat{FR}_{Female} = 9.882 - 2.113 LPA$, meaning that old women with more light physical activity are less likely to fall.

MLR of the male sample (Table 3), found that FR variability was mainly explained by sedentary behaviour (44.1%) and significantly predicted FR ($\beta = -0.046$; $t(24) = -4.144$; $p < .001$), and also, with minor expression, by age (22.7%) ($\beta = -0.298$; $t(24) = -2.653$; $p = 0.041$), independently, and with both predictors associated, explaining 45.8% of the FR variability $R^2 = 0.458$, $F(6,24) = 4.710$; $p = 0.003$). The male adjusted model is then $\widehat{FR}_{Male} = 8.229 + 2.324 SB + 0.665 age$, meaning that old men with more sedentary behaviour are more prone to fall risk, and also, the older they are the higher fall risk present. Likewise, the older and/or more sedentary men are more likely to fall.

In total sample model using G*Power, with age and PA, the effect size ($f^2 = 0.558701$) was found to exceed convention for a large effect ($f^2 = 0.83223$) (Cohen, 1988), and observed statistical power ($\pi = 1.000$). On female sample model using G*Power with LPA, the effect size ($f^2 = 0.7533136$) was found to exceed convention for a large effect ($f^2 = 0.50$) (Cohen, 1988), and observed statistical power ($\pi = 1.000$). Further, on male sample model, using G*Power with SB and age, the effect size ($f^2 = 0.7581294$) was found to exceed convention for a large effect ($f^2 = 0.50$) (Cohen, 1988), and observed statistical power ($\pi = 0.9434250$), all three suitable for detecting a large-sized effect when employing 0.05 criterion of statistical significance.

Discussion

The major finding of this study is that PA (negatively) and age (positively) are major FR predictors in older adults. Our finding highlights the importance of considering age and physical activity levels in FR assessment models.

The *MLR* showed that FR variability was mainly explained by PA (42.0%) and also, with minor expression, by age (37.0%) independently, and even more when associated (47.3%). Our final adjusted model ($\widehat{FR}_{Total} = 8.289 - 0.134 \text{ PA} + 0.114 \text{ Age.}$) suggest that more active older adults will have lower fall risk, and the oldest ones will be prone to greater fall risk. This model is highly significant ($p < 0.05$) and accounts for a large proportion ($\approx 52\%$) of FR variability.

It is important to highlight that our model accuracy was achieved by encoding not only demographic variables but also different PA levels and SB. In this way, gender stratification showed that light PA in women and sedentary behaviour in men are significant FR predictors. By identifying those community-dwelling aged 65 years and older who are more likely to fall, the predictive model can better direct preventative efforts. In this way, and according to literature (Liao et al., 2018; Yasunaga et al., 2017), sedentary behavior should be avoided and in opposition light-to-moderate PA should be encouraged (Santos et al., 2012).

Regarding PA levels, differences were evident between males and females, with men presenting greater SB ($p = 0.027$) and smaller LPA ($p = 0.012$) that might help understand the different models obtained by *MLR*. Similar male activity behaviour was also reported by others (Silva et al., 2018; Yasunaga et al., 2017).

The observed correlations between total physical activity as well as the so-called health-enhancing physical activity (moderate and vigorous PA) with FR are in line with different studies that reported that higher PA older adults have performed better in POMA evaluation (Liao et al., 2018). The relevance of active lifestyles for a lower FR is thus highlighted. The model's predictions are valuable because they identify the older men who are sedentary and are most at risk, while

the older women that present higher light physical activity are not at risk.

This is of importance since falls and fall-related injuries are common, particularly in those aged over 65, with around one-third of older people living in the community falling at least once a year (Grimmer et al., 2019; Mahoney et al., 2005). So, diagnosis behaviour parameters associated with falls in order to better design fall prevention interventions, namely by changing lifestyles and PA behaviors, are of importance. Multiple component interventions, usually including PA (or exercise) habits, may reduce the rate of falls and risk of falling in community-dwelling older adults (Borysiuk et al., 2018; Chase et al., 2017; Mahoney et al., 2015), just as suggested in the present study.

Also known as the Tinetti Balance and Gait Scale, the POMA is one of the earliest and most widely used batteries designed to assess balance, gait, and fall risk in older adults (Canbek et al., 2013; Raïche et al., 2000; Rivolta et al., 2018; Rivolta & Sassi, 2017). The prevalence of balance and gait deficits increases with age and is associated with the increased incidence of falls seen in the elderly population (Ihlen et al., 2018; Orwoll et al., 2019; Sieńko-Awierianów et al., 2018). Balance is influenced by a multiplicity of age-related factors such as muscular strength of the lower limbs and torso, making age one of the predictors of balance disorders, and consequently of fall risk (Di Nardo et al., 2015; Rath & Wade, 2017; Remaud et al., 2016; Spirduso et al., 2005).

On the other hand, physical activity and physical exercise, as suggested by our data, may act as a potential non-pharmacological intervention in reducing fall risk due to its multiple effects on strength, balance, and fear of falling (Ayoubi et al., 2014; Oliveira et al., 2017; Raimundo et al., 2014; Riebe et al., 2018; Svantesson et al., 2014). The systematic review of Thibaud et al. (2011) and meta-analysis indicates that physical activity constitutes a protector factor for falls in persons aged over 60 years (Thibaud et al., 2012).

By contrast, the observed negative correlation between sedentary behaviour and FR, namely in older men, might raise some questions. Sedentary behaviour has been reported to be a strong factor influencing the health of ageing subjects, and it is also likely to have an impact on the risk of falls (Thibaud et al., 2012).

Thus, it seems the presence of an active lifestyle, where mobility and balance/strength stimulation is high, promotes better performance in dynamic balance by reducing the FR.

The statistical analysis got robust results and achieved large effect size values.

Stating that this study final adjusted model is then $\widehat{FR} = 8.289 - 0.134 PA + 0.114 \text{ Age}$, meaning that more active elderly will have lower fall risk, and older elderly will be prone to a greater fall risk, we can suggest that a combination of these risk factors reported in the present study has led to predicting the degree of risk of falls in community-dwelling older people. Among them, potential protective factors such as physical activity and detrimental factors such as sedentary behaviour are of importance. Therefore, prevention and rehabilitation programmes should take these modifiable factors into consideration and thereby help to reduce the prevalence and magnitude of fall risk.

Regarding the relative weight of PA and age as predictor variable of FR, the *MLR* showed that FR variability was mainly explained by PA (42.0%) and also, with minor expression, by age (37.0%) independently, and even more when associated (47.3%). This model is highly significant ($p < 0.05$) and accounts for a large proportion ($\approx 52\%$) of FR variability. According to our knowledge, no other study like the present study was found that presented an association model with the variables that resulted in the *MLR* model here reported.

Strengths

The strengths of this study include the use of objective and reliable instruments to evaluate PA. Accelerometry methodology provides objective measures of physical activity behaviours that are free of the random and systematic errors associated with self-report. As such, they are believed to provide better assessments for many activities, particularly activities that have proved difficult to measure by self-report (e.g., walking) (Liao et al., 2018). Also, to avoid seasonality effects, data collection occurred for over 14 months. Sample size did not limit the statistical power of the analysis and may have contributed to

correlates of PA and age, in both genders.

Limitations

Nonetheless, this study is not without limitations.

First, sample size was relatively small, and yet, didn't limit statistical power, and comprised volunteered subjects that made generalization of the results difficult. The division of the sample by gender was made, what could threaten the strength, or would jeopardize the robust statistical analysis. Secondly, cross-sectional design does not permit causality conclusions. Future large-scale trials are warranted to investigate which factors are more effective on fall parameters using sensitive measures. Third, data on other potential confounders, such as visual impairment, foot problems, among others, were not assessed. Fourth, the history of falls as a factor of exclusion was chosen, based on the relative increase of the risk to which the participants were exposed during data collection.

Even considering these limitations of the studies, the data information of the present study may be important for general practitioners and geriatricians, that are responsible for observing, studying and evaluating and early identify older people with potential fall and balance disorders, in order to suggest active interventions with non-formal or formal physical activities that can mitigate or delay fall risk.

Conclusion

This cross-sectional study suggest that lower fall risk is achieved in younger and more active participants. Among all of the predictors of fall risk, the older and the more sedentary behaviour men, have increased fall risk, while more light physical activity in women may decrease fall risk.

This knowledge it is of utmost importance and reinforces the strategy for improving physical activity/exercise programs for population in general, and specifically in the elderly, promoting an active aging. Working towards fall risk hazards diminution and restraints could be fundamental to promote better

autonomy in community-dwelling elderly and understanding how health care providers and elderly caring personnel, could impact the falls burdens in social economy.

Practice implication

These findings will be useful for clinicians, for caregivers, for health managers in the primary health care service that would use physical activity, sedentary behaviour and light PA scores to categorize high risk fallers among elderly.

Since these predictors or risk factors are potentially modifiable, rehabilitation programs should be designed to reduce the FR in the elderly, and may include physical exercise to improve mobility, strength and dynamic balance as well as reducing sedentary lifestyles.

Funding

The authors supported all costs as part of PhD program in Physical Activity and Health in CIAFEL-FADEUP, while César, A. was supported by Coordination for the Improvement of Higher Education Personnel (CAPES) N° 10143-13-0.

Acknowledgements

The authors would like to thank CIAFEL (FCT/ UID/DTP/00617/2019), FCT (POCI-01-0145-FEDER-031808) and IPDJ (Mais Ativos, Mais Vividos), for assisting with technical support and personal availability during data collection related to this study.

References

- Ambrose, A., Paul, G., & Hausdorff, J. (2013). Risk factors for falls among older adults: A review of the literature. *Maturitas*, 2013(75), 51-61.
- Ayoubi, F., Launay, C., Annweiler, C., & Beauchet, O. (2014). Fear of Falling and Gait Variability in Older Adults: A Systematic Review and Meta-analysis. *J Am Med Dir Assoc*, 2015(16), 14-19.
- Beegan, L., & Messinger-Rapport, B. (2015). Stand by me! Reducing the risk of injurious falls in older adults. *Cleve Clin J Med*, 82(5).
- Bird, M., Pittaway, J., Cuisick, I., Rattray, M., & Ahuja, K. (2013). Age-Related Changes in Physical Fall Risk Factors: Results from a 3 Year Follow-up of Community Dwelling Older Adults in Tasmania, Australia. *Int. J. Environ. Res. Public Health*, 2013(10), 5989-5997.
- Borysiuk, Z., Konieczny, M., Kręcis, K., Pakosz, P., & Królikowska, B. (2018). Effect of six-week intervention program on postural stability measures and muscle coactivation in senior-aged women. *Clinical Interventions in Aging*, 2018(13), 1701–1708.
- C.I.O.M.S. (2002). *International Ethical Guidelines for Biomedical Research Involving Human Subjects* (Vol. 1). Geneva Switzerland: Council for International Organizations of Medical Sciences Publications.
- Canbek, J., Fulk, G., Nof, L., & Echternach, J. (2013). Test-retest reliability and construct validity of the tinetti performance-oriented mobility assessment in people with stroke. *J Neurol Phys Ther.*, 2013(Mar;37(1)), 14-19.
- Chan, B., Marshall, L., Winters, K., Faulkner, K., Schwartz, A., & Orwoll, E. (2007). Incident fall risk and physical activity and physical performance among older men: the Osteoporotic Fractures in Men Study. *Am J Epidemiol*, 2007(Mar 15;165(6)), 696-703.
- Chase, J., Phillips, L., & Brown, M. (2017). Physical Activity Intervention Effects on Physical Function Among Community-Dwelling Older Adults: A Systematic Review and Meta-Analysis. *J Aging Phys Act*, 2017(25), 149-170.

- Cherian, A., Kanagaraj, R., Jidesh, V., & Swaminathan, N. (2016). A Study to Evaluate the Correlation between Tinetti Performance Oriented Mobility Assessment (Tinetti Poma) with Functional Reach Test (FRT) and Timed UP and Go Test (TUG) in Assessing Balance among Elderly. *Indian J Physiother Occup Ther*, 10(July-Sept. No. 3), 169-173.
- Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum Associates.
- Di Nardo, F., Mengarelli, A., Maranesi, E., Burattini, L., & Fioretti, S. (2015). Assessment of the ankle muscle co-contraction during normal gait: A surface electromyography study. *J Electromyogr Kinesiol*, 2015(25), 347-354.
- Egerton, T., Paterson, K., & Helbostad, J. (2017). The Association Between Gait Characteristics and Ambulatory Physical Activity in Older People: A Cross-Sectional and Longitudinal Observational Study Using Generation 100 Data. *J Aging Phys Act*, 2017(25), 10-19.
- Finn, J., Alvarez, M., Jett, R., Axtell, R., & Kemler, D. (1999). Stability Performance Assessment Among Subjects of Disparate Balancing Abilities. *Med Sci Sports Exerc*, 31(5), S252.
- Grimmer, M., Riener, R., Walsh, C., & Seyfarth, A. (2019). Mobility related physical and functional losses due to aging and disease - a motivation for lower limb exoskeletons. *J NeuroEngineering Rehab*, 2019(16(2)), 1-21.
- Hagstromer, M., Oja, P., & Sjostrom, M. (2007). Physical activity and inactivity in an adult population assessed by accelerometry. *Med Sci Sports Exerc*, 39(9), 1502-1508.
- Heesch, K., Byles, J., & Brown, W. (2008). Prospective association between physical activity and falls in community-dwelling older women. *J Epidemiol Community Health*, 2008(62), 421-426.
- Hopkins, W. G. (1997). *A new view of statistics. A Scale of Magnitudes for Effect Statistics* (Vol. 1). Melbourne, Australia: Victoria University.
- Hsieha, K., Roacha, K., Wajdab, D., & Sosnoff, J. (2019). Smartphone technology can measure postural stability and discriminate fall risk in older adults. *Gait & Posture*, 2019(67), 160-165.

- Ihlen, E., van Schooten, K., Bruijn, S., van Dieën, J., Vereijken, B., Helbostad, J., & Pijnappels, M. (2018). Improved Prediction of Falls in Community-Dwelling Older Adults Through Phase-Dependent Entropy of Daily-Life Walking. *Front. Aging Neurosci.*, 2018(10:44), 1-12.
- Immonen, M., & Similä, H. (2018). Comparison of Accelerometry-Based Features for Fall Risk Assessment Measured From Two Sensor Locations. *IEEE J Biomed Health Inform*, 2018(978-1-5386-3646-6/18), 2076-2079.
- Jahantabi-Nejad, S., & Azad, A. (2019). Predictive accuracy of performance oriented mobility assessment for falls in older adults: A systematic review. *Med J Islam Repub Iran*, 2019(1 May), 33-38.
- Karuka, A., Silva, J., & Navega, M. (2011). Analysis of agreement of assessment tools of body balance in the elderly. *Rev Bras Fisioter, São Carlos*, 15(n. 6, Nov./Dec. 2011), 460-466.
- Kikkert, L., de Groot, M., van Campen, J., Beijnen, J., Hortoba'gyi, T., Vuillerme, N., & Lamothe, C. (2016). Gait dynamics to optimize fall risk assessment in geriatric patients admitted to an outpatient diagnostic clinic. *PLoS ONE*, 12(6)(e0178615.), 1-14.
- King, M., & Tinetti, M. (1995). Falls in community-dwelling older persons. *J Am Geriatr Soc*, 43(10), 1146-1154.
- Klenk, J., Kerse, N., Rapp, K., Nikolaus, T., Becker, C., Rothenbacher, D., Peter, R., & Denking, M. (2015). Physical Activity and Different Concepts of Fall Risk Estimation in Older People—Results of the ActiFE-Ulm Study. *PLoS ONE*, 2015(6), 1-11.
- Liao, Y., Hsu, H., Shibata, A., Ishii, K., Koohsari, M., & Oka, K. (2018). Associations of total amount and patterns of objectively measured sedentary behavior with performance-based physical function. *Prev Med Rep*, 2018(12), 128-134.
- Mahoney, J., Dumas, K., & Holtzer, R. (2015). Visual-Somatosensory Integration is Linked to Physical Activity Level in Older Adults. *Multisens Res*, 2015(28), 11-29.

- Mahoney, J., Glysch, R., Guilfoyle, S., Hale, L., & Katcher, M. (2005). Trends, Risk Factors, and Prevention of Falls in Older Adults in Wisconsin. *Wis Med J*, 104(1), 22-28.
- Marques, A., Soares, P., Soares-Miranda, L., Moreira, C., Oliveira-Tavares, A., Clara-Santos, P., Vale, S., Santos, R., & Carvalho, J. (2011). Evaluation of physical activity programmes for the elderly - exploring the lessons from other sectors and examining the general characteristics of the programmes. *BMC Res Notes*, 4, 368.
- Mitchell, K., & Newton, R. (2006). Performance-oriented mobility assessment (POMA) balance score indicates need for assistive device. *Disabil Rehabil Assist Technol*, 2006(June; 1(3)), 183 – 189.
- Nguyen, H., Mirza, F., Naeem, M., & Baig, M. (2018). Falls management framework for supporting an independent lifestyle for older adults: a systematic review. *Aging Clin Exp Res*, 2018(30), 1275–1286.
- O'Sullivan, M., Blake, C., Cunningham, C., Boyle, G., & Finucane, C. (2009). Correlation of accelerometry with clinical balance tests in older fallers and non-fallers. *Age and Ageing*, 2009(38), 308–313.
- Oliveira, L., Mattos, R., Castro, J., Barbosa, J., Chame, F., & Vale, R. (2017). Effect of supervised physical exercise on flexibility of fibromyalgia patients. *Rev Dor. São Paulo*, 2017(18), 2.
- Orwoll, E., Fino, N., Gill, T., Cauley, J., Strotmeyer, E., Ensrud, K., Kado, D., Barrett-Connor, E., Bauer, D., Cawthon, P., & Lapidus, J. (2019). The Relationships Between Physical Performance, Activity Levels, and Falls in Older Men. *J Gerontol A Biol Sci Med Sci*, 2019(74(9)), 1475-1483.
- Pin, S., & Spini, D. (2016). Impact of falling on social participation and social support trajectories in a middle-aged and elderly European sample. *SSM - Popul Health*, 2016(2), 382-289.
- Raîche, M., Hébert, R., Prince, F., & Coriveau, H. (2000). Screening older adults at risk of falling with the Tinetti Balance scale. *Lancet*, 356(September), 1001-1002.
- Raimundo, A., Correia, P., Batalha, N., Tomas-Carus, P., & Pereira, C. (2014). Isokinetics Strenght Relation With Fear of Fall, Falls and Physical Activity

- Level in Elderly Women. *International Congress of Exercise and Sports Performance, 2014*(cidesd 2014), 71.
- Rath, R., & Wade, M. G. (2017). The Two Faces of Postural Control in Older Adults: Stability and Function. *EBioMedicine, 2017*(21), 5-6.
- Remaud, A., Thuong-Cong, C., & Bilodeau, M. (2016). Age-Related Changes in Dynamic Postural Control and Attentional Demands are Minimally Affected by Local Muscle Fatigue. *Front. Aging Neurosci., 7*(257), 1-13.
- Riebe, D., Ehrman, J., Liguori, G., & Magal, M. (2018). *ACSM's Guidelines for Exercise Testing and Prescription*. Philadelphia, PA: Wolters Kluwer.
- Rivolta, M., Aktaruzzamana, M., Rizzo, G., Lafortuna, C., Ferrarin, M., Bovi, G., Bonardi, D., Caspani, A., & Sassi, R. (2018). Evaluation of the Tinetti score and fall risk assessment via accelerometry-based movement analysis. *Artif Intelli Med, 2018*(08), 1-10.
- Rivolta, M., & Sassi, R. (2017). Linear-Sigmoidal Modelling of Accelerometer Features and Tinetti Score for Automatic Fall Risk Assessment. *IEEE J Biomed Health Inform, 2017*(978-1-5090-2809-2/17), 3810-3813.
- Rubenstein, L., & Josephson, K. (2002). The epidemiology of falls and syncope. In R. A. K. D. O'Shea (Ed.), *Falls and syncope in elderly patients. Clinics in geriatric medicine* (pp. 141-158). Philadelphia: Saunders.
- Saito, E., Ueki, S., Yasuda, N., Yamazaki, S., & Yasumura, S. (2014). Risk factors of functional disability among community-dwelling elderly people by household in Japan: a prospective cohort study. *BMC Geriatr, 14*, 9.
- Santos, D., Silva, A., Baptista, F., Santos, R., Vale, S., Mota, J., & Sardinha, L. (2012). Sedentary behavior and physical activity are independently related to functional fitness in older adults. *Exp Gerontol, 47*(12), 908-912.
- Sardinha, L., Andersen, L., Anderssen, S., Quiterio, A., Ornelas, R., Froberg, K., Riddoch, C., & Ekelund, U. (2008). Objectively measured time spent sedentary is associated with insulin resistance independent of overall and central body fat in 9- to 10-year-old Portuguese children. *Diabetes Care, 31*(3), 569-575.

- Schoene, D., Valenzuela, T., Lord, S., & de Bruin, E. (2014). The effect of interactive cognitive-motor training in reducing fall risk in older people: a systematic review. *BMC Geriatrics*, 2014(14), 107.
- Shumway-Cook, A., Baldwin, M., Polissar, N., & Gruber, W. (1997). Predicting the Probability for Falls in Community-Dwelling Older Adults. *Phys Ther*, 1997(77), 812-819.
- Sieńko-Awierianów, E., Lubkowska, A., Kolano, P., & Chudecka, M. (2018). Postural stability and risk of falls per decade of adult life – a pilot study. *Anthropol Rev*, 81(1), 102–109.
- Sievänen, H., & Kannus, P. (2007). Physical activity reduces the risk of fragility fracture. *PLoS Med*, 4(6), e222.
- Silva, S., Jayawardana, M., & Meyer, D. (2018). Statistical methods to model and evaluate physical activity programs, using step counts: A systematic review. *PLOS One*, 2018(November), 1-19.
- Spirduso, W., Francis, K., & Mcrae, P. (2005). *Physical Dimensions of Aging* (2 ed.). Champaign, Il.: Human Kinetics.
- Sterke, C., Huisman, S., van Beeck, E., Looman, C., & van der Cammen, T. (2010). Is the Tinetti Performance Oriented Mobility Assessment (POMA) a feasible and valid predictor of short-term fall risk in nursing home residents with dementia? *Int Psychogeriatr*, 2010(Mar;22(2)), 254-263
- Svantesson, U., Babagbemi, B., Foster, L., & Alricsson, M. (2014). Influences on modern multifactorial falls prevention interventions and fear of falling in non-frail older adults: a literature review. *J Clin Med Res.*, 2014(Oct;6(5)), 314-320.
- Thibaud, M., Bloch, F., Tournoux-Facon, C., Brèque, C., Rigaud, A. S., Dugué, B., & Kemoun, G. (2012). Impact of physical activity and sedentary behaviour on fall risks in older people: a systematic review and meta-analysis of observational studies. *Eur Rev Aging Phys Act*, 2012(9), 5-15.
- Tinetti, M. (1986). Performance-oriented assessment of mobility problems in elderly patients. *J Am Geriatr Soc*, 34(2), 119-126.
- Tinetti, M., Speechley, M., & Ginter, S. (1988). Risk factors for falls among elderly people living in the community. *N Eng J Med*, 1988(319), 1701-1707.

- Tremblay, M. (2012). Letter to the editor: standardized use of the terms “sedentary” and “sedentary behaviours”. *Appl Physiol Nutr Metab*, 2012(37 (3)), 540-542.
- Wijlhuizen, G., de Jong, R., & Hopman-Rock, M. (2007). Older persons afraid of falling reduce physical activity to prevent outdoor falls. *Prev Med*, 2007(44), 260-264.
- World Health Organization. (2011). *Standards and Operational Guidance for Ethics Review of Health-Related Research with Human Participants* (Vol. 1). Geneva, Switzerland: World Health Organization.
- World Health Organization. (2013). *Ethical issues in Patient Safety Research - Interpreting existing guidance* (Vol. 1). Geneva, Switzerland: World Health Organization.
- Yasunaga, A., Shibata, A., Ishii, K., Koohsari, M., Inoue, S., Sugiyama, T., Owen, N., & Oka, K. (2017). Associations of sedentary behavior and physical activity with older adults' physical function: an isothermal substitution approach. *BMC Geriatrics*, 2017(17:280), 1-7.
- Yokoya, T., Demura, S., & Sato, S. (2007). Relationships between Physical Activity, ADL Capability and Fall Risk in Community-Dwelling Japanese Elderly Population. *Environ Health Prev Med*, 2007(12 January), 25–32.

3.3. Artigo 3

Imbalance and fall risk improvements in elderly: Effects of combined strength-aerobic training

This paper was published as:

Carmo, P., Carvalho, J., Santos, R. & Cesar A. Imbalance and fall-risk improvements in the elderly: Effects of combined strength and aerobic training. *J Hear Sci*, 2020; 10(1): 41-47. DOI: 10.17430/JHS.2020.10.1.5 CC BY-NC-ND 4.0

© the authors

J Hear Sci, 2020; 10(1): 41–47
DOI: 10.17430/JHS.2020.10.1.5
CC BY-NC-ND 4.0, © the authors

Contributions:
A Study design/planning
B Data collection/entry
C Data analysis/statistics
D Data interpretation
E Preparation of manuscript
F Literature analysis/search
G Funds collection

IMBALANCE AND FALL-RISK IMPROVEMENTS IN THE ELDERLY: EFFECTS OF COMBINED STRENGTH AND AEROBIC TRAINING

**Paulo Jorge Quintela Cardoso do Carmo^{1,2,A-G}, Joana Carvalho^{3,A,D-G},
Rubim Santos^{1,A,E-F}, Adjane Cesar^{3,A-D,F-G}**

Imbalance and fall risk improvements in elderly: Effects of combined strength-aerobic training

Cardoso-Carmo, P., Carvalho, J., Santos, R., César, A.

Abstract

Falls among the elderly are an important clinical and health problem due to their high incidence and their functional and social repercussions. The aim of this study was to examine the effects of a combined strength-and-aerobic exercise program (EP) on older adults' fall risk (FR), by the use of a measure of postural stability.

Sixty-two elderly people (69.02 ± 4.27 years old), 39 females and 23 males, were assigned to an experimental group (EG) or a control group (CG) and tested using the Biodex™ Balance System in order to obtain fall risk score at baseline, (M_1), after 4.5 (M_2) and 9 months (M_3). Measures of habitual physical activity (use of accelerometers for 7 consecutive days), as well as socio-economic status, clinical problems and medication were also taken; these were identified as potential confounders. The EG underwent a 9-month, three times a week, combined training programme consisting of strength (once a week) and aerobic (twice a week) one-hour sessions.

The combined training programme had a large and significant effect on FR (EG vs. CG) ($F(2,120) = 4.519$; $p = .013$; $\eta_p^2 = .070$; statistical power (π) = .761). This was more pronounced from M_1 to M_2 , than from M_2 to M_3 (final), with a significant ($p < .001$) improvement in FR, from M_1 to M_3 . In the CG, a non-significant ($p = .919$) slight functional decline between M_1 and M_3 (final) was found.

A 9-month combined EP may have beneficial effects on FR of elderly men and women as a result of improved postural stability.

Key-words: community-programs, fall risk, Biodex Balance System

INTRODUCTION

Impairments of postural stability can result in increased rates of unintentional falls. There is a general consensus that altered postural stability in elderly people is affected by degradation of the sensory channels, i.e., vestibular, visual, and proprioceptive cues, and also by deficits in muscle strength, neuromuscular control and declining reaction times. These factors make falls events more likely (Lord & Sturnieks, 2005).

These age-related conditions have numerous consequences for public health, such as falls, fractures, hospitalisations, institutionalizations and mortality (Beaudart et al., 2014). Falls among the elderly have a great impact on the quality of their lives, on their relatives' lives and on the public health system, due to the high costs of care (Brach & VanSwearingen, 2002; Pereira, 2006). The prevention of falls and mobility-related disability among older people is an urgent public health challenge (Sherrington et al., 2011).

There is now strong evidence for the effectiveness of exercise as a component of a multifactorial intervention in the prevention of falls in community-dwelling older people (Gillespie et al., 2002; Sherrington et al., 2008). However, there is little direct evidence about the differential impact of different approaches to exercise as a single intervention in older people. In terms of the effect of combined exercise on postural stability, contrasting findings have been reported.

Combined EP seems to be of highly relevant to this problem, and can slow, halt or even reverse the age-related decline or loss of the functionality that leads to an increase in the number of falls (Cakar et al., 2010; Kim et al., 2008; Zhuang et al., 2014). In addition, aerobic exercise, such as walking, can improve aerobic capacity and physical function (PF) (Ferrari et al., 2016; Marques et al., 2016). Furthermore, strength training improves critical elements of physical function, such as mobility and balance (Bossers et al., 2014).

Studies have reported extensively on the effectiveness of multifactorial fall prevention programmes involving education, environmental modification, exercises, and psychological intervention (Melo et al., 2010; Speechley & Tinetti, 1991; Tinetti et al., 2000; Yoo et al., 2010).

Recommendations and guidelines for the prevention of falls that advocate identifying high-risk persons, screening for modifiable risk factors, and the targeting of appropriate interventions have been developed (Klein et al., 2014; Murphy et al., 2013; Svantesson et al., 2014).

This study is the first to evaluate this specific population with objective tools such as the Biodex™ Balance System (BBS) Static/Dynamic (SD). Its aim is to investigate imbalance as a key factor related with fall risk, and the effects of a 9-month combined EP, in older women and men. The results may help us to understand how combined exercise intervention can change the performance of those physiological systems associated with balance and fall risk in older women and men.

METHODS

Participants

Elderly people from the Oporto area, Portugal of both genders, aged >65 were eligible to participate. A simple random sampling technique was used to distribute participants across the experimental and control groups. To be eligible to participate in the study, participants had to submit medical certification of their state of physical and mental well-being. Participants were excluded if they were not able to walk without a cane or other assistive device, or had had a previous history of peripheral or vestibular abnormalities. A history of two or more falls in the previous 6 months, having previously known medical and cognitive conditions or musculoskeletal problems limiting safe participation in evaluation or unwillingness to complete the study requirements were also grounds for exclusion.

From the cohort of initial participants, three failed to complete the study. This was due to an injury (broken metatarsals), a case of cancer, and one death from heart disease. The data analysed for this study is based on 62 participants: 39 women (W) and 23 men (M), with an age range of 65-79 years.

The participants were informed about the aims of the study and the study procedures and gave written informed consent before being enrolled. The consent given conformed with Ethical Guidelines (C.I.O.M.S., 2002), World

Medical Association Declaration of Helsinki (World Health Organization, 2011, 2013) and according to Harriss, Macsween & Atkinson (Harriss et al., 2017). The study was approved by the Ethics Committee, Faculty of Sport, University of Porto (CEFADE.02.2015).

Participants were interviewed in a private facility and self-completed questionnaires to provide information about their clinical and socio-demographic characteristics. These were used to assess their eligibility for the study.

Fall Risk

Fall Risk (FR) was evaluated by using a BBS SD, a multi-axial device with an unstable balance platform designed to measure postural stability. Under dynamic tests, the device can give up to a 20° surface tilt in a 360° range of motion. The subjects were required to stand with the feet slightly apart, for three 20-seconds periods with their eyes open. By measuring the pressures exerted by the subject on the platform, a score for overall stability, anterior/posterior and medial/lateral stability can be generated, ranging from 0.0 (Optimum balance/lower fall risk equivalent) to 4.0-5.0 (Poor balance/high fall risk equivalent). In healthy people, and according to Biodex Medical Systems, FR normal score ranges by age are: 2.0-4.0 in 72-89 years group; 0.9-3.7 in 54-71 years group; 0.7-3.1 in 36-53 years group and 0.7-2.1 to 17-35 years group (Arnold & Schmitz, 1998; Aydog et al., 2006; Biodex Medical Systems, 2014; Cachupe et al., 2009; Chen et al., 2014; Melzer et al., 2004; Parraca et al., 2011; Pickerill & Harter, 2011; Silva & Boas, 2002).

The BBS SD was used to provide oscillations from the 12th to 8th level of difficulty (level 12th being the most stable and level 8th more unstable). The subject was required to stand up with feet slightly apart in physiological position, for three 20-second periods. Different force plate fixation movements were automatically generated by the equipment and the resulting scores relating to stability were weighted to the age and height of the subjects (Biodex Medical Systems, 2014; Branco, 2013; Burton et al., 2015; Khalaj et al., 2014; Province et al., 1995; Sieri & Beretta, 2004).

Physical Activity

Habitual physical activity was assessed over 7 consecutive days using uniaxial accelerometry (accelerometer GT1M, Actigraph, Florida, USA). Participants were instructed to wear the accelerometer over the right hip for a 7-day period (5 weekdays and 2 weekend days). Exceptions included time spent sleeping, showering, and participating in water-based activities. Participants were asked to maintain their usual activities and keep records in a written diary. A valid day was defined as at least 10 hours of wear time per day. All non-wear time was excluded from further analysis. Data from the monitors was uploaded using the Actilife Monitoring System v.6.11.3 software by the investigating team and was compared with data from a written diary before the average counts per minute were calculated. This outcome variable was reported in counts per minute, that is, the number of vertical axis counts.min⁻¹ (CPM), generated based on the magnitude and frequency of movement (Egerton et al., 2017; Hagstromer et al., 2007; Sardinha et al., 2008).

Exercise intervention

The Experimental Group subjects (EG)(n = 37) were submitted to a 9-month combined training course. This involved one-hour bi-weekly aerobic training sessions (Mondays and Fridays) and a single weekly one-hour strength training session (Wednesdays) conducted by a physical education instructor with academic specialization in physical activity for older adults. This was in accordance with ACSM guidelines for exercise for older adults (American College of Sports Medicine, 2006; Garber et al., 2011; Riebe, 2014):

Aerobic training (AT) – AT consisted of a 10-minute warm-up, that included walking, calisthenics and stretching, 30 minutes of aerobic exercises – mainly walking – at an intensity corresponding to 50-70% HR_{Reserve} or a rating of perceived effort (RPE) of 4 to 6 on a 10-point scale (Borg, 2007). Besides walking, a 10-minute exercise period was devoted to developing muscular endurance, balance, proprioceptive sensitivity, and coordination skills (Garber et al., 2011). The session ended with a 10-minute cool-down. The training load was gradually

increased by five minutes each week during the first four weeks until subjects could walk continuously for thirty minutes.

Strength training (ST) – ST consisted of a 10-minute warm-up that included walking, calisthenics and stretching, a specific resistance training period (30–40 min) consisted of nine exercises (leg press, chest press, leg extension, seated row, seated leg curl, abdominal flexion, biceps curl, low-back extension, and triceps extension) (Nautilus-Sports/Medical-Industries, 1974, 2015). ST concluded with a 10-minute cool-down. The load increased during the first 2 weeks (Rall et al., 1996; Raymond et al., 2013), commencing with familiarization with the machines (for correct breathing and technique), progressing to 60%-70% of one-repetition maximum (1RM). The individual strength tests (1RM) were performed every 15 days for the first month and then every 4 weeks until the final session of the program. Between these tests, the load was increased for those subjects who were able to easily complete 10-12 for both sets (Pescatello et al., 2014).

Attendance of at least 80% of the exercise sessions was required for the training programme to be considered complete.

Control Group (CG) - Subjects allocated into the CG (n = 25) were instructed not to change their daily living PA routines or dietary patterns during the study and not to carry out any supervised PA. They were informed that they would receive intervention when the study had ended. After the data collection period, subjects who had been randomized into the CG were invited to participate in specific EP's designed to seniors undergoing in FADEUP.

Statistical Procedures

Descriptive measures like mean (*M*) and standard deviation (*SD*) were used for data collection and analysis. The Kolmogorov-Smirnov test with Lilliefors correction was used to assess distribution normality whilst independent sample t-tests were carried out to detect gender differences.

A *mixed repeated measures ANOVA* was applied to investigate the efficacy of EP over FR comparing groups (EG/CG) and moments (baseline(*M*₁),

4.5-months(M_2) and 9-months(M_3)). The assumptions of the method, namely the normal distribution of FR at 3 moments and the sphericity of the variance-covariance matrix were evaluated, with the *Kolmogorov-Smirnov* test ($p > 0.1$ for the 3 moments and groups) and with the *Mauchly* test ($W = .993$; $\chi^2(2) = .419$; $p = .811$).

Change (Δ) between moments was calculated for each pair according to the formula ($M_a - M_{a+1}$); Δ_1 - change from baseline (M_1) to 4.5-months (M_2), Δ_2 - change from 4.5-months (M_2) to 9-months (M_3), and Δ_3 - change from baseline (M_1) to final (M_3). Between-group differences in pre-post intervention was evaluated with unpaired two-tailed *Student t-tests* by *one-way ANOVA*.

Analyses were performed with SPSS statistics (v.25; IBM SPSS, Chicago, IL). A significance level of 0.05 was set for all analyses.

Results

The demographic and anthropometric characteristics of the study sample are shown in Table 1. The study population consisted of 62 elderly people, most of whom were female, with an age range of 65-79 yrs., a height range of 137-175 cm and with a weight range from normal to obese Class II (World Health Organization, 2006).

Table 1. Demographic and anthropometric characteristics of the study sample divided by EG and CG

Variable	Total	EG	CG	<i>p</i>
Participants – <i>n</i> (%)	62 (100)	37 (59.7)	25 (40.3)	0.375
Gender – % female	58.06	63.89	52.00	0.102
Age, years – mean (SD)	69.02 (4.27)	68.11 (3.19)	70.36 (5.28)	0.064
Weight, kg – mean (SD)	71.77 (11.47)	70.80 (10.87)	81.45 (17.75)	0.219
Height, cm – mean (SD)	159.04 (10.25)	158.43 (10.50)	165.50 (3.54)	0.550
Body mass index, kg/m ² – mean (SD)	28.77 (4.12)	28.66 (4.21)	30.80 (3.32)	0.627

Key: EG, experimental group; CG, control group; SD, standard deviation; * statistical significance, $p < 0.05$; *n*, number.

With the purpose of reaching the goal of the present study, a *mixed repeated measures ANOVA* evaluated the significance of the efficacy of physical activity training on FR and their evolution in the 3 sampled moments, as can be seen in Table 2.

The mean value of FR in the participants of the experimental group ($M = 1.359$, $SD = 0.082$, $n = 37$) was significantly different from the value of the variable in participants in the control group ($M = 1.618$, $SD = 0.100$, $n = 25$) with high dimension ($F(1,60) = 0.078$, $p = 0.009$; Statistical power = 0.799). The size of the effect is ($\eta^2_p = 0.076$) recommended minimum (Ferguson, 2009), being the confidence interval 95% for the difference of means of the value of FR of the two groups (0.029; 0.356).

Regarding the evolution of FR values evaluated, there were highly significant differences between the 3 moments ($F(2,120) = 4.928$; $p = 0.009$; $\eta^2_p = 0.076$; Statistical power (π) = 0.799).

Table 2. Mean $\pm$ standard deviation of fall risk (FR) in the EG vs. CG at M₁, M₂, and M₃

Group	M ₁	M ₂	M ₃	Δ_1	p	Δ_2	p	Δ_3	p
FR Total (M $\pm$ SD) ($n = 62$)	1.695 ± 0.067	1.499 ± 0.065	1.463 ± 0.065	0.196	0.007*	0.036	0.608	0.232	<0.001*
FR EG (M $\pm$ SD) ($n = 37$)	1.754 ± 0.084	1.509 ± 0.083	1.359 ± 0.068	0.245	0.015*	0.150	0.103	0.395	<0.001*
FR CG (M $\pm$ SD) ($n = 25$)	1.608 ± 0.109	1.485 ± 0.106	1.618 ± 0.120	0.123	0.235	-0.133	0.216	-0.010	0.919
Δ by Group	0.146	0.240	-0.259						
p	0.287	0.856	0.049*						

Key: FR, fall risk; M₁, baseline; M₂, 4.5 months; M₃, 9 months (final); M $\pm$ SD, mean $\pm$ standard deviation; Δ_1 , M₁–M₂; Δ_2 , M₂–M₃; Δ_3 , M₁–M₃; n , number of participants; * denotes statistical significance, $p < 0.05$.

When considering data from the two groups combined, the values of FR were higher in M₁ (baseline: $M = 1.695$, $SD = 0.67$, $n = 62$) decreasing at M₂ ($M = 1.499$, $SD = 0.065$, $n = 62$) and further decreasing in M₃ ($M = 1.463$, $SD = 0.065$, $n = 62$).

Finally, the effect of physical activity training on changing the values of FR depends on the group of participants (EG vs. CG) as demonstrated by the significant interaction ($F(2,120) = 4.519$; $p = 0.013$; $\eta_p^2 = 0.070$; Statistical Power (π) = 0.761).

As shown in Table 2, the effect of physical activity training in FR is more pronounced in the participants of the experimental group, from M₁(baseline) to M₂, than from M₂ to M₃ (post-intervention) evaluation moment, with an evident improvement in FR, from M₁ to M₃, $\Delta_3 = 0.395$ and significant ($p < 0.001$). Table 2 also shows that for participants of the control group, the effect of time on FR occurs in the expected direction, that is, between M₁ (baseline) and M₃ (final)

moment evaluation there is a slight functional decline, with a variation in FR ($\Delta_3 = -0.010$, non-significant $p = 0.919$).

Comparing the difference between groups (EG vs. CG): at M_1 (baseline) $\Delta = 0.146$, it was small and non-significant ($p = 0.287$) whilst at M_3 (final) it was more pronounced $\Delta = -0.259$, and significant ($p = 0.049$).

Showing that *PA* did not biased *FR* results, a *mixed repeated measures ANOVA* evaluated objectively by accelerometry, showed that its evolution over the 3 sampled times returned non-significant p -values. Table 3 shows that all interactions between group (EG/CG) and time (M_1 , M_2 and M_3) gave $p > .05$.

Table 3. Mean $\pm$ standard deviation of physical activity (PA, in CPM) in EG vs. CG at M_1 , M_2 , and M_3

Group	M_1	M_2	M_3	Δ_1	p	Δ_2	p	Δ_3	p
CPM Total ($M \pm SD$) ($n = 62$)	11.015 ± 3.44	10.788 ± 3.49	11.794 ± 3.25	-0.227	0.238	-1.006	0.126	0.779	0.233
CPM EG ($M \pm SD$) ($n = 37$)	11.150 ± 3.83	11.32 ± 3.87	12.308 ± 3.88	0.171	0.356	0.987	0.151	1.158	0.142
CPM CG ($M \pm SD$) ($n = 25$)	10.880 ± 3.02	10.255 ± 3.08	11.281 ± 2.49	-0.625	0.284	1.026	0.192	0.401	0.239
Δ by Group p	0.270 0.231	1.066 0.136	1.027 0.174						

Key: PA, physical activity; CPM, counts per minute; EG, experimental group; CG, control group; M_1 , baseline; M_2 , 4.5 months; M_3 , 9 months (final); $M \pm SD$, mean $\pm$ standard deviation; Δ_1 , M_1-M_2 ; Δ_2 , M_2-M_3 ; Δ_3 , M_1-M_3 ; n , number of participants; * statistical significance, $p < 0.05$.

Discussion

The objective of this study was to evaluate the effectiveness of a combined (strength and aerobic) exercise-based intervention programme on the modification of observed values of FR in elderly people from the Porto region. To the best of our knowledge, this study is the first to use BBS SD to focus on this population and objectively analyse FR and PA. The EP was found to be safe, with no major incidents occurring. The participants found the EP enjoyable, which is made evident by the high compliance rate and the low number of drop-outs.

With regard to accelerometer determined ambulatory PA, our participants' results (4.07 ± 1.69 CPM) are corroborated by others (Duncan et al., 2016); (Brach & VanSwearingen, 2002; Brach et al., 2002; Langley & Mackintosh, 2007) and maintained the same *PA* during the experimental period as demonstrated in Table 3.

The observed values in FR of participants are included within the limits of the normal ranges for this specific age group, and develop favourably with the practice of regular physical exercise of combined strength-aerobic training for 9 months in the EG, while in the CG there is a natural slight functional decline with the passage of the same 9 months.

Participation on the EP decreased FR. The changes observed in the EG could be a consequence of muscular strengthening and improvement of the postural control resulting from taking part in the various strength-aerobic training activities as part of EP. Similar results have been reported by others in a series of studies with exercise-based program interventions (Close et al., 2005; Lord et al., 1995; Reinsch et al., 1992; Schoene et al., 2014; Sherrington et al., 2011; Sherrington et al., 2008).

The changes seen in the CG can be considered natural and explained by aging due to the passage of the 9 months between the beginning and the end of the study, as reported by Rivolta et al. (Rivolta et al., 2015).

The above results show that physical activity in general, and more specifically, combined strength-aerobic training, may have a role in fall risk prevention.

Based on this analysis, we recommend physical activity training to promote a higher quality for daily living activities and a lowering of fall risk for the elderly.

This recommendation is also proposed by others (Branco et al., 2015; Carrapatoso et al., 2012; Carrapatoso et al., 2017; Carvalho et al., 2004a, 2004b; Carvalho et al., 2007; A. Marques et al., 2011; E. Marques et al., 2011; Marques et al., 2016; Wanderley et al., 2011).

Strengths and limitations

The strengths of this study include the use of objective instruments to measure PA and FR. Using innovative technologies can help to add to our body of knowledge. This was the case as BBS-SD was used for the first time for this type of study. Factors that may have played roles in ensuring that the EP was successful included: care was taken to keep the participant's level of interest high in the physical EP; EP was held in venues that were easily accessible; classes were run by graduated personnel trained in running EP; the rationale for the study and the assessment measures were clearly explained to both the EG and the CG. Also, feedback was provided to all subjects regarding their performances in the tests at the completion of the EP.

Consideration should be given the study's limitations when interpreting the findings. Subjects in intervention studies with exercise cannot be blinded to group assignment; this study involved a highly physical task that could have produced low compliance, if it were to be considered unpleasant. Ambulatory PA was assessed using an accelerometer worn for only one week. The measures of ambulatory PA may be, therefore, affected by atypical happenings such as seasons, unfavourable weather conditions, random events or participant's disease. Future studies using randomized controlled experiments should investigate the effect of PA on FR. Future research should examine if greater compliance could be achieved by participants due to PA training and also evaluating participants' satisfaction through questionnaires or interviews.

Conclusion

The aging process causes innumerable changes in the human body, which can lead the individual to suffer changes, such as an increase in FR, causing elderly people to become more dependent on help from caregivers. As seen in this study, this functional decline can be halted, or reversed by PA exercise practice such as a combined (strength-aerobic) exercise-based intervention program.

These findings reinforce a strategy for programs devoted to improving PA in the general population, and especially for elderly people. A PA program can promote physical fitness and lower FR. A decrease in FR is important for enhancing increased autonomy for community-dwelling elderly people. We need to understand that we, as carers for the elderly, can reduce the burden of falls on the broader social economy (Inouye et al., 2009; Klein et al., 2014).

Acknowledgements

The authors would like to thank CIAFEL (Centro de Investigação em Atividade Física e Lazer) and its team investigators, from the Sports Faculty, Porto University, for assisting with technical support and availability during the data collection related to this study.

References

- American College of Sports Medicine, A. (2006). *ACSM's Resource Manual for Guidelines for Exercise Testing and Prescription* (5th ed.). Baltimore - U.S.A.: Lippincott Williams & Wilkins.
- Arnold, B., & Schmitz, R. (1998). Examination of Balance Measures Produced by the Biodex Stability System. *J Athl Tr*, 33(4), 323-327.
- Aydog, E., Aydog, S. T., Cakci, A., & Doral, M. N. (2006). Dynamic postural stability in blind athletes using the biodex stability system. *Int J Sports Med*, 27(5), 415-418.
- Beaudart, C., Rizzoli, R., Bruyère, O., Reginster, J., & Biver, E. (2014). Sarcopenia: burden and challenges for public health. *Arch Public Health*, 2014(72:45), 1-8.
- Biodex Medical Systems, I. (2014). *Balance System SD Operation/Service Manual*. New York: Biodex Medical Systems, Inc.
- Borg, E. (2007). *On Perceived Exertion and its Measurement*. Stockholm: Stockholm University. Dissertação de Doctoral dissertation apresentada a Department of Psychology Stockholm University.
- Bossers, W., Scherder, E., Boersma, F., Hortobágyi, T., van der Woude, L., & van Heuvelen, M. (2014). Feasibility of a Combined Aerobic and Strength Training Program and Its Effects on Cognitive and Physical Function in Institutionalized Dementia Patients. A Pilot Study. *PLoS ONE*, 9(5), e97577.
- Brach, J., & VanSwearingen, J. (2002). Physical impairment and disability: relationship to performance of activities of daily living in community-dwelling older men. *Phys Ther*, 82(8), 752-761.
- Brach, J., VanSwearingen, J., Newman, A., & Kriska, A. (2002). Identifying early decline of physical function in community-dwelling older women: performance-based and self-report measures. *Phys Ther*, 82(4), 320-328.
- Branco, J., Jansen, K., Sobrinho, J., Carrapatoso, S., Spessato, B., Carvalho, J., Mota, J., & Silva, R. (2015). Physical benefits and reduction of depressive

- symptoms among the elderly: Results from the Portuguese “National Walking Program”. *Ciênc Saúde Colet*, 20(3), 789-795.
- Branco, P. P. V. G. S. (2013). *Avaliação E Modificação Do Risco De Queda Em Idosos Com Recurso À Posturografia Dinâmica Computorizada*. Lisboa: Faculdade de Ciências Médicas. Dissertação de Doutoramento apresentada a Universidade Nova de Lisboa.
- Burton, E., Cavalheri, V., Adams, R., Browne, C., Boverly-Spencer, P., Fenton, A., Campbell, B., & Hill, K. (2015). Effectiveness of exercise programs to reduce falls in older people with dementia living in the community: a systematic review and meta-analysis. *Clin Interv Aging*, 10(February), 421–434.
- C.I.O.M.S. (2002). *International Ethical Guidelines for Biomedical Research Involving Human Subjects* (Vol. 1). Geneva Switzerland: Council for International Organizations of Medical Sciences Publications.
- Cachupe, W., Shifflett, B., Kahanov, L., & Wughalter, E. (2009). Reliability of Biodex Balance System Measures. *Meas Phys Educ Exerc Sci*, 5(2), 97-108.
- Cakar, E., Dincer, U., Kiralp, M., Cakar, D., Durmus, O., Kilac, H., Soydan, F. C., Sevinc, S., & Alper, C. (2010). Jumping combined exercise programs reduce fall risk and improve balance and life quality of elderly people who live in a long-term care facility. *Eur J Phys Rehabil Med*, 2010(46), 59-67.
- Carrapatoso, S., Carvalho, J., & Silva, P. (2012). *Efeito de um Programa de Caminhada nas Percepções do Envolvimento em Idosos*. Porto: Universidade do Porto. Dissertação de Mestrado apresentada a Faculdade de Desporto da Universidade do Porto.
- Carrapatoso, S., Silva, P., Purakom, A., Novais, C., Colaço, P., & Carvalho, J. (2017). The Experience of Older Adults in a Walking Program at Individual, Interpersonal, and Environmental Levels. *Act Adapt Aging*, 41(1).
- Carvalho, J., Oliveira, J., Magalhães, J., Ascensão, A., Mota, J., & Soares, J. (2004a). Força muscular em idosos I — Será o treino generalizado suficientemente intenso para promover o aumento da força muscular em idosos de ambos os sexos? *Rev Port Ciênc Desporto*, 4(1), 51-57.

- Carvalho, J., Oliveira, J., Magalhães, J., Ascensão, A., Mota, J., & Soares, J. (2004b). Força muscular em idosos II — Efeito de um programa complementar de treino na força muscular de idosos de ambos os sexos. *Rev Port Ciênc Desporto*, 4(1), 58-65.
- Carvalho, J., Pinto, P., & Mota, J. (2007). Actividade física, equilíbrio e medo de cair. Um estudo em idosos institucionalizados. *Rev Port Ciênc Desporto*, 7(2), 225-231.
- Chen, T., Chou, L., Tsai, M., Io, M., & Kao, M. (2014). Effectiveness of a heel cup with an arch support insole on the standing balance of the elderly. *Clin Interv Aging*, 2014(9), 351–356.
- Close, J., Lord, S., Menz, H., & Sherrington, C. (2005). What is the role of falls? *Best Pract Res Cl Rh*, 19(6), 913–935.
- Duncan, M., Minatto, G., & Wright, S. (2016). Dose–Response Between Pedometer Assessed Physical Activity, Functional Fitness, and Fatness in Healthy Adults Aged 50–80 Years. *Am J Hum Biol*, 2016(28(6)), 890-894.
- Egerton, T., Paterson, K., & Helbostad, J. (2017). The Association Between Gait Characteristics and Ambulatory Physical Activity in Older People: A Cross-Sectional and Longitudinal Observational Study Using Generation 100 Data. *J Aging Phys Act*, 2017(25), 10-19.
- Ferguson, C. (2009). An Effect Size Primer: A Guide for Clinicians and Researchers. *Prof Psychol: Res Pract*, 40(5), 532-538.
- Ferrari, R., Fuchs, S., Kruel, L., Cadore, E., Alberton, C., Pinto, R., Radaelli, R., Schoenell, M., Izquierdo, M., Tanaka, H., & Umpierre, D. (2016). Effects of Different Concurrent Resistance and Aerobic Training Frequencies on Muscle Power and Muscle Quality in Trained Elderly Men: A Randomized Clinical Trial. *Aging and Disease*, Volume 8(Number 1; February 2017), xxx-xx,.
- Garber, C., Blissmer, B., Deschenes, M., Franklin, B., Lamonte, M., Lee, I., Nieman, D., & Swain, D. (2011). American College of Sports Medicine position stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in

- apparently healthy adults: guidance for prescribing exercise. *Med Sci Sports Exerc*, 43(7), 1334-1359.
- Gillespie, L., Gillespie, W., Cumming, R., Lamb, S., & Rowe, B. (2002). Interventions for preventing falls in elderly people (Cochrane Review). In U. Software (Ed.), *The Cochrane Library, Issue 3*. Oxford: Update Software.
- Hagstromer, M., Oja, P., & Sjostrom, M. (2007). Physical activity and inactivity in an adult population assessed by accelerometry. *Med Sci Sports Exerc*, 39(9), 1502-1508.
- Harriss, D., Macsween, A., & Atkinson, G. (2017). Standards for Ethics in Sport and Exercise Science Research: 2018 Update. *Int J Sports Med*, 2017(38), 1126–1131.
- Inouye, S., Brown, C., & Tinetti, M. (2009). Medicare nonpayment, hospital falls, and unintended consequences. *N Engl J Med*, 360(23), 2390-2393.
- Khalaj, N., Osman, N. A. A., Mokhtar, A. H., Mehdikhani, M., & Abas, W. A. B. W. (2014). Balance and Risk of Fall in Individuals with Bilateral Mild and Moderate Knee Osteoarthritis. *PLoS ONE*, 9(3), e92270.
- Kim, E., Park, S., & Kwon, Y. (2008). The Effects of Combined Exercise on Functional Fitness and Risk Factors of Metabolic Syndrome in the Older Women. *Jpn. J. Phys. Fitness Sports Med.*, 2008(57), 207-216.
- Klein, D., Rapp, K., Küpper, M., Becker, C., Fischer, T., Büchele, G., & Benzinger, P. (2014). A Population-Based Intervention for the Prevention of Falls and Fractures in Home Dwelling People 65 Years and Older in South Germany: Protocol. *JMIR Res Protoc*. 3(1): e19, 3(1), 1-49.
- Langley, F., & Mackintosh, S. (2007). Functional Balance Assessment of Older Community Dwelling Adults: A Systematic Review of the Literature. *J Allied Health*, 5(4), 1-11.
- Lord, S., Ward, J., Williams, P., & Strudwick, M. (1995). The effect of a 12-month exercise trial on balance, strength, and falls in older women: A randomized controlled trial. *J Am Geriatr Soc*, 1995(43), 1198-1206.
- Lord, S. R., & Sturnieks, D. L. (2005). The physiology of falling: assessment and prevention strategies for older people. *J Sci Med Sport*, 8(1), 35-42.

- Marques, A., Soares, P., Soares-Miranda, L., Moreira, C., Oliveira-Tavares, A., Clara-Santos, P., Vale, S., Santos, R., & Carvalho, J. (2011). Evaluation of physical activity programmes for the elderly - exploring the lessons from other sectors and examining the general characteristics of the programmes. *BMC Res Notes*, 4, 368.
- Marques, E., Carvalho, J., & Mota, J. (2011). *Exercise training, Bone and Aging. Evidence from different impact loading exercise interventions on age-related bone loss*. Porto: Universidade do Porto. Dissertação de Doutoramento apresentada a Faculdade de Desporto da Universidade do Porto.
- Marques, E., Figueiredo, P., Harris, T., Wanderley, F., & Carvalho, J. (2016). Are resistance and aerobic exercise training equally effective at improving knee muscle strength and balance in older women? *Arch Gerontol Geriatr.*, 2016(Oct 11), 106-112.
- Melo, C., Carvalho, J., & Silva, P. (2010). *Efeito da actividade física na funcionalidade e auto-percepções corporais do idoso*. Porto: Universidade do Porto. Dissertação de Mestrado apresentada a Faculdade de Desporto da Universidade do Porto.
- Melzer, I., Benjuya, N., & Kaplanski, J. (2004). Postural stability in the elderly: a comparison between fallers and non-fallers. *Age and Ageing*, 33(6), 602-607.
- Murphy, T., Baker, D., Leo-Summers, L., Allore, H., & Tinetti, M. (2013). Association between treatment or usual care region and hospitalization for fall-related traumatic brain injury in the Connecticut Collaboration for Fall Prevention. *J Am Geriatr Soc*, 61(10), 1763-1767.
- Nautilus-Sports/Medical-Industries. (1974). Arthur Jones Exercise. *Arthur Jones Exercise* Consult. december, 28, 2018, disponível em http://www.arthurjonesexercise.com/NautilusManual/NAUTILUS_SPORTS-MEDICAL_INDUSTRIES.pdf
- Nautilus-Sports/Medical-Industries. (2015). Arthur Jones Exercise. *Arthur Jones Exercise* Consult. december, 28, 2018, disponível em

http://www.arthurjonesexercise.com/NautilusManual/NAUTILUS_SPORT S-MEDICAL_INDUSTRIES.pdf

- Parraca, J., Olivares, P., Carbonell-Baeza, A., Aparicio, V., Adsuar, J., & Gusi, N. (2011). Test-Retest reliability of Biodex Balance SD on physically active old people. *J Hum Sport Exerc*, 6(2), 444-451.
- Pereira, A. (2006). *A queda e suas consequências para o idoso: aspectos psicológicos e emocionais*. Uberlândia: Universidade Federal de Uberlândia. Dissertação de Mestrado apresentada a Instituto de Psicologia da Universidade Federal de Uberlândia.
- Pescatello, L., Arena, R., Riebe, D., & Thompson, P. (2014). *ACSM's Guidelines for Exercise Testing and Prescription* (Ninth ed.). Baltimore: Wolters Kluwer Health - Lippincott Williams & Wilkins.
- Pickerill, M. L., & Harter, R. A. (2011). Validity and Reliability of Limits-of-Stability Testing: A Comparison of 2 Postural Stability Evaluation Devices. *J Athl Train*, 46(6), 600–606.
- Province, M., Hadley, E., Hornbrook, M., Lipsitz, L., Miller, J., Mulrow, C., Ory, M., Sattin, R., Tinetti, M., & Wolf, S. (1995). The effects of exercise on falls in elderly patients. A preplanned meta-analysis of the FICSIT Trials. Frailty and Injuries: Cooperative Studies of Intervention Techniques. *JAMA*, 273(17), 1341-1347.
- Rall, L., Meydani, S., Kehayias, J., Dawson-Hughes, B., & Roubenoff, R. (1996). The Effect of Progressive Resistance Training in Rheumatoid Arthritis Increased Strength Without Changes in Energy Balance or Body Composition. *Arthritis Rheum*, Vol. 39(No. 3, March), 415-426.
- Raymond, M., Bramley-Tzerefos, R., Jeffs, K., Winter, A., & Holland, A. (2013). Systematic Review of High-Intensity Progressive Resistance Strength Training of the Lower Limb Compared With Other Intensities of Strength Training in Older Adults. *Arch Phys Med Rehab*, 2013(94), 1458-1472.
- Reinsch, S., MacRae, P., Lachenbruch, P., & Tobias, J. (1992). Attempts to prevent falls and injury: A prospective community study. *Gerontologist*, 1992(32), 114-122.

- Riebe, D. (2014). Exercise Prescription for Healthy Populations with Special Considerations and Environmental Considerations. In L. S. Pescatello, R. Arena, D. Riebe & P. D. Thompson (Eds.), *ACSM's Guidelines for Exercise Testing and Prescription* (pp. 194-235). Baltimore: Wolters Kluwer Health - Lippincott Williams & Wilkins.
- Rivolta, M., Aktaruzzaman, M., Rizzo, G., Lafortuna, C., Ferrarin, M., Bovi, G., Bonardi, D., & Sassi, R. (2015). Automatic vs. Clinical assessment of fall risk in older individuals: a proof of concept. *J Biomed Health*, 2015;6935-8.
- Sardinha, L., Andersen, L., Anderssen, S., Quiterio, A., Ornelas, R., Froberg, K., Riddoch, C., & Ekelund, U. (2008). Objectively measured time spent sedentary is associated with insulin resistance independent of overall and central body fat in 9- to 10-year-old Portuguese children. *Diabetes Care*, 31(3), 569-575.
- Schoene, D., Valenzuela, T., Lord, S., & de Bruin, E. (2014). The effect of interactive cognitive-motor training in reducing fall risk in older people: a systematic review. *BMC Geriatrics*, 2014(14), 107.
- Sherrington, C., Tiedemann, A., Fairhall, N., Close, J., & Lord, S. (2011). Exercise to prevent falls in older adults: an updated meta-analysis and best practice recommendations. *NSW Public Health Bulletin*, 22((3-4)), 78-83.
- Sherrington, C., Whitney, J., Lord, S., Herbert, R., Cumming, R., & Close, J. (2008). Effective Exercise for the Prevention of Falls: A Systematic Review and Meta-Analysis. *J Am Geriatr Soc*, 2008(56(12)), 2234-2243.
- Sieri, T., & Beretta, G. (2004). Fall risk assessment in very old males and females living in nursing homes. *Disabil Rehabil*, 26(12), 718-723.
- Silva, M. A. F., & Boas, J. P. V. (2002). *Estabilidade Postural nos Adultos Seniores Estudo da sua Variabilidade*. Porto: Universidade do Porto. Dissertação de Mestrado apresentada a Faculdade de Ciências do Desporto e Educação Física da Universidade do Porto.
- Speechley, M., & Tinetti, M. (1991). Falls and injuries in frail and vigorous community elderly persons. *J Am Geriatr Soc*, 39(1), 46-52.

- Svantesson, U., Babagbemi, B., Foster, L., & Alricsson, M. (2014). Influences on modern multifactorial falls prevention interventions and fear of falling in non-frail older adults: a literature review. *J Clin Med Res.*, 2014(Oct;6(5)), 314-320.
- Tinetti, M., Williams, C., & Gill, T. (2000). Health, functional, and psychological outcomes among older persons with chronic dizziness. *J Am Geriatr Soc*, 48(4), 417-421.
- Wanderley, F., Silva, G., Marques, E., Oliveira, J., Mota, J., & Carvalho, J. (2011). Associations between objectively assessed physical activity levels and fitness and self-reported quality of life in community-dwelling older adults. *Qual Life Res*, 2011(20), 1371-1378.
- World Health Organization. (2006). BMI classification. *Global Database on Body Mass Index*. Consult. 25 novembro 2016, disponível em http://apps.who.int/bmi/index.jsp?introPage=intro_3.html
- World Health Organization. (2011). *Standards and Operational Guidance for Ethics Review of Health-Related Research with Human Participants* (Vol. 1). Geneva, Switzerland: World Health Organization.
- World Health Organization. (2013). *Ethical issues in Patient Safety Research - Interpreting existing guidance* (Vol. 1). Geneva, Switzerland: World Health Organization.
- Yoo, E., Jun, T., & Hawkins, S. (2010). The effects of a walking exercise program on fall-related fitness, bone metabolism, and fall-related psychological factors in elderly women. *Res Sports Med*, 18(4), 236-250.
- Zhuang, J., Huang, L., Wu, Y., & Zhang, Y. (2014). The effectiveness of a combined exercise intervention on physical fitness factors related to falls in community-dwelling older adults. *Clin Interv Aging*, 9, 131-140.

4. Discussão Geral

Este capítulo pretende resumir e revisitar os principais resultados relatados nos capítulos anteriores, tentando abordar e discutir de forma integrada os objetivos do presente trabalho.

A presente tese teve como objetivo principal estudar o efeito de um programa de treino trissemanal com duração de 9 meses no RQ em idosos de ambos os sexos. Secundariamente, e tendo por base alguma inconsistência observada na literatura, a presente tese pretendeu ainda estudar as relações entre os níveis de atividade física, os diferentes componentes da aptidão física, com o RQ com vista a desenvolver um modelo de predição para explicar a variabilidade do mesmo.

O estudo 1 apresentado no capítulo 3.1 da presente tese, de natureza transversal, confirmou que a aptidão física parece ter um efeito central no RQ. Com exceção da flexibilidade, correlações significativas moderadas a fortes foram observadas entre o RQ e a agilidade motora, a resistência aeróbia e a força superior e inferior do corpo. Além disso, de acordo com a literatura, também os dados do estudo 1 mostraram que a idade parece ser um dos principais fatores de risco para quedas (Bird et al., 2013). Por outro lado e em concordância com vários estudos (Caban-Martinez et al., 2015; Heesch et al., 2008; Sherrington et al., 2011; Yokoya et al., 2007), o mesmo estudo 1, embora com uma associação fraca mas significativa, aponta que pessoas com maior AF têm menor risco e menor incidência de quedas. Adicionalmente, a análise multivariada mostrou que entre todos os componentes da aptidão física, um melhor desempenho nos testes 8-f UG e 30-s SC, significando melhor agilidade motora e força da parte inferior do corpo, ambos preditores de RQ, podem diminuir o RQ. No entanto, essa predição é dependente da variável sexo, sendo a agilidade motora/equilíbrio dinâmico mais determinante no sexo feminino comparativamente ao masculino.

Ainda num registo exploratório, no estudo 1 e após aplicação de uma regressão linear múltipla, as variáveis explanatórias foram a agilidade motora e

a força da parte inferior do corpo, enquanto o RQ se trata da variável resultado. A equação linear para a amostra total, $\widehat{RQ}_{\text{Total}} = 5.026 + 0.869 \text{ 8-f UG} - 0.147 \text{ 30-s CS}$, sugere que, por cada segundo de aumento no desempenho do teste 8-f UG, o resultado do $\widehat{RQ}$ irá sofrer um aumento de 0.869 pontos, apontando um resultado mais indesejável de acordo com os pontos de corte reportados por Sardinha e colegas (Sardinha et al., 2008). Já no caso oposto, por cada segundo de diminuição no desempenho do teste 8-f UG, o resultado do $\widehat{RQ}$ irá sofrer uma diminuição de 0.869 pontos. Do mesmo modo, no teste 30-s CS, quanto maior o número de elevações da cadeira, ao valor da constante (5.026) será subtraído por um múltiplo de 0.147 pontos, ou por outro lado, quanto menor o número de elevações da cadeira em trinta segundos, ao valor da constante (5.026) será aumentado por um múltiplo de 0.147 pontos, com repercussão semelhante no resultado do $\widehat{RQ}$, aumentando-o. Quando diferenciadas por sexos, verificamos que a equação linear para o sexo feminino, $\widehat{RQ}_F = 1.818 + 0.732 \text{ 8-f UG}$, sugere, que em mulheres idosas, para cada segundo de aumento no desempenho do teste 8-f UG, o resultado do $\widehat{RQ}$ irá sofrer um aumento de 0.732 pontos, sugerindo assim, um resultado mais alarmante. No sexo masculino a equação linear encontrada, $\widehat{RQ}_m = 0.677 + 0.499 \text{ 8-f UG}$, mostra que, no idoso masculino, por cada segundo de aumento no desempenho do teste 8-f UG, o resultado do $\widehat{RQ}$ irá sofrer um aumento de 0.499 pontos, insinuando também, um resultado mais alarmante.

O estudo 2, também de natureza transversal, em complemento ao estudo 1 que se focou essencialmente nos diferentes componentes da aptidão física, deu especial atenção aos níveis de intensidade da atividade física, e ao comportamento sedentário na análise do RQ. Este estudo 2, permitiu confirmar que a idade e a atividade física parecem ter um efeito central no RQ, em particular o comportamento sedentário nos homens e a atividade física ligeira nas mulheres. Com exceção dos níveis de intensidade da atividade física, correlações significativas moderadas foram observadas entre o RQ e a atividade física e a idade. Além disso, de acordo com a literatura, também os dados do estudo 2 mostraram que a idade parece ser um dos principais fatores de risco para quedas (Bird et al., 2013). Por outro lado e em concordância com vários

estudos (Liao et al., 2018; Ribeiro, 2009), quer o estudo 1 quer o estudo 2, apontam que pessoas com maior AF têm menor risco de queda. A análise multivariada mostrou que das variáveis observadas, uma maior atividade física, assim como a menor idade, ambos preditores de RQ, podem diminuir o RQ. No entanto, essa predição é dependente da variável sexo, sendo os níveis de intensidade de atividade física ligeira mais determinantes no sexo feminino comparativamente ao masculino. Em contrapartida, o comportamento sedentário é mais determinante no sexo masculino comparativamente ao feminino.

A análise efetuada no estudo 2 permitiu a obtenção de modelo de predição de RQ baseado nos valores das variáveis recolhidas pela acelerometria, principalmente de grandeza *Counts Per Minute (CPM)*, e ainda da intensidade de atividade física ligeira, sedentária, além da idade. A equação linear para a amostra total, $\widehat{RQ}_{\text{Total}} = 8.289 - 0.134 \text{ PA} + 0.114 \text{ age}$, mostrou que quanto mais velhos os participantes, maior o RQ. Mas, por outro lado, quanto mais ativos os idosos são, menor é o RQ, ou têm menor tendência à queda. Pelo contrário, quanto mais sedentários, em particular os do sexo masculino, maior o RQ.

De facto, a análise por sexos, mostrou que no sexo masculino, $\widehat{RQ}_M = 8.229 + 2.324 \text{ SB} + 0.665 \text{ age}$, quanto maior o comportamento sedentário, maior é o RQ. Adicionalmente, quanto maior é a idade, maior é também o RQ, ou dito de outro modo, quanto mais velhos ou mais sedentários os homens são, maior é a probabilidade de cair. Também Orwoll e colaboradores (2018) ao avaliarem 2741 idosos homens americanos com média de idade de 78.8 ± 5 anos, relatam que as quedas ocorrem naqueles com menor atividade física ou pior desempenho físico e funcional (Orwoll et al., 2019).

Já para o sexo feminino, a equação linear, $\widehat{RQ}_F = 9.882 - 2.113 \text{ LPA}$, mostra que a mulher idosa com maior atividade física ligeira, tem menor risco de queda, ou menor tendência à queda. Em concordância com este resultado, Buchner e colaboradores (2017), ao avaliarem a incidência da frequência de quedas em 5545 mulheres idosas de 63-99 anos de idade, em função da intensidade da atividade física, verificaram um RQ aumentado nas que realizavam apenas atividade física de menor intensidade (Buchner et al., 2017).

Tal como sustentado por Yokoya e colaboradores (2007) (Yokoya et al., 2007), os resultados obtidos nos estudos 1 e 2 são dignos de destaque uma vez que a associação da agilidade/equilíbrio dinâmico e, embora em menor escala, a força muscular dos membros inferiores e por outro lado da atividade física ligeira nas mulheres e do comportamento sedentário nos homens, são fatores importantes no RQ.

Deste modo, tendo por base a literatura e os resultados dos estudos 1 e 2, podemos inferir que enquanto o tempo gasto em atividade física ligeira pode ter efeito benéfico para o RQ, o tempo ocupado em comportamentos sedentários poderá refletir-se negativamente no RQ, com consequências nefastas à saúde, no medo de cair, facilitando, frequentemente, as fraturas do colo do fémur em idosos (Klenk et al., 2015; Peeters et al., 2009).

Assim, parece ser primordial incentivar o idoso a assumir um comportamento mais ativo e a permanecer o menor tempo possível em inatividade (e/ou em comportamento sedentário). Esta mudança comportamental poderá ter impacto na própria aptidão física, devendo ser incentivadas estratégias para diminuir os riscos do sedentarismo, aumentando a funcionalidade e a qualidade de vida no idoso (World Health Organization, 2007).

Os resultados dos estudos transversais 1 e 2 para além de mostrar a importância de adotar um estilo de vida mais ativo, evitando em paralelo a adoção de comportamentos sedentários, evidencia quais os componentes fundamentais (agilidade/equilíbrio dinâmico, força muscular dos membros inferiores) a estimular no contexto de programas de exercício físico para idosos, no sentido de prevenir o RQ. Também Toraman e Yildirim (2010) relatam o equilíbrio, a força dos membros inferiores como sendo dos parâmetros de aptidão física mais importantes na redução do RQ nos idosos (Toraman & Yildirim, 2010). Adicionalmente, Mitchell e colaboradores (2014) destacam a importância que uma boa aptidão muscular e aeróbia, na melhoria da capacidade de realização das atividades quotidianas e da qualidade de vida no idoso (Mitchell et al., 2014).

Neste sentido, e considerando os resultados anteriores dos estudos 1 e 2, bem como o impacto individual e social marcante do RQ (Karuka et al., 2011), e

entendendo a importância de melhoria da funcionalidade global do idoso, no estudo 3, os autores implementaram um programa de treino trissemanal combinado aeróbio e de força durante 9 meses, privilegiando, sempre que possível, a componente da força dos membros inferiores e de equilíbrio dinâmico como importantes preditores de RQ.

Complementando os resultados da tese de César (2017), onde foi notório o efeito deste programa trissemanal de treino de EF com duração de 9 meses na melhoria da aptidão funcional, nomeadamente do equilíbrio e da agilidade, a presente tese mostrou, utilizando o mesmo protocolo de treino, melhorias significativas no RQ logo aos 4.5 meses ($p = 0.0015$), existindo uma interação significativa tempo * grupo após 9 meses ($p < 0.001$).

Os resultados do estudo 3 demonstram, a existência de uma variação significativa ao longo do tempo na variável RQ. Assim a ANOVA mista de medidas repetidas mostrou que enquanto no Grupo Experimental se verificaram melhorias estatisticamente significativas entre todos os momentos de avaliação (M_1 , M_2 e M_3), no Grupo de Controlo, o RQ permaneceu praticamente inalterado, traduzindo, assim uma interação tempo * grupo positiva.

Schoene e colaboradores (2014) destacaram, na sua revisão sistemática, que a intervenção com treino aeróbio, força e com recurso a exercícios de equilíbrio, parece induzir melhorias significativas no RQ, seja através da avaliação por posturografia, como no presente estudo 3, seja com recurso ao POMA como utilizado nos estudos 1 e 2 (Schoene et al., 2014).

O estudo 3, mostra assim as potencialidades do treino trissemanal combinado aeróbio e de reforço muscular, promovendo a diminuição do RQ. Porque a queda tem efeitos nefastos, com elevada probabilidade de fratura óssea, cirurgias e internamentos (Dalz et al., 2016; Marques, Carvalho, et al., 2011), medidas eficazes para atuar sobre estas ocorrências que debilitam e incapacitam os idosos e induzem acréscimos económicos marcantes nos custos com a saúde, são de fundamental importância para as sociedades progressivamente mais envelhecidas.

Acreditamos, no entanto, que mais estudos serão necessários para compreender os mecanismos envolvidos no RQ na população idosa.

Mais-valias e Limitações

Esta tese, apresenta na opinião dos autores, alguns pontos positivos.

Temos como uma das principais mais-valias da presente tese a presença de um grupo de controlo no desenho do estudo longitudinal, que permite melhor confirmar os resultados obtidos. Consideramos, ainda como mais-valia, terem sido efetuados três momentos de avaliação, o primeiro (no início da intervenção), um segundo (intercalar) e o terceiro (no final da intervenção) que permitiu avaliar a evolução das variáveis e aferir no momento intercalar a necessidade de ajuste da intervenção.

Também como vantagem, foi realizado no estudo longitudinal o controlo de algumas variáveis confundidoras, nomeadamente a avaliação/controlo objetiva por acelerometria dos níveis diários de atividade física.

Também, o recurso aos protocolos da Biodex Balance System Static/Dynamic (Biodex Medical Systems, 2014) para estudar o impacto do treino combinado aeróbio e de força no RQ de idosos de ambos os géneros, enquanto equipamento precursor instrumental do RQ, e considerado medida padrão-ouro, constitui um ponto forte do trabalho podendo dar uma maior credibilidade e consistência à presente tese. A utilização deste equipamento, permitiu obter valores objetivos e quantificáveis, com validade científica comprovada, uma vez que a posturografia pode ser considerada como medida ouro-padrão para o RQ (Arifin et al., 2014; Cachupe et al., 2009; Hinman, 2000; Parraca et al., 2011).

Ainda como mais-valias, podemos referir que nos diferentes estudos todo o trabalho de suporte técnico na recolha de dados foi conduzido por instrutores de exercício físico com especialização académica em atividade física em adultos idosos, assim como, nos estudos transversais, os períodos de recolha foram dispersos ao longo do ano para evitar risco de viés induzido por fatores sazonais.

Apesar destas mais-valias, é importante referir algumas limitações que podem condicionar a generalização dos resultados obtidos na presente amostra para a população geral. Por um lado, o reduzido tamanho da amostra do estudo longitudinal, pode ter condicionado o poder estatístico dos testes de medição do

efeito do treino combinado de exercício físico sobre as variáveis em estudo. Adicionalmente, o número inferior de idosos do sexo masculino poderá ter enviesado alguns dos resultados apresentados. Ainda, o facto de os elementos da amostra serem voluntários, constituindo-se, talvez, uma amostra mais apta e mais saudável do que a população geral. Neste sentido, sugere-se cautela na generalização dos resultados para populações de adultos mais idosos e frágeis.

Adicionalmente, apesar de ter sido efetuado o controlo sobre as patologias e terapêuticas médicas de cada um dos participantes, não existiu um controlo efetivo no potencial efeito da posologia dos medicamentos nas variáveis estudadas. Assim é possível, que os resultados possam estar mascarados pelos efeitos do uso de medicação.

No que respeita ao estudo longitudinal, é de referir também como limitação o facto dos elementos do grupo controlo participarem em atividades recreativas num dia por semana, de modo a promover a colaboração e participação no estudo, mas que poderá, mesmo assim, ter influenciado, ainda que de forma ligeira, os resultados aqui apresentados.

Futuros estudos

Atendendo aos pressupostos acima, caberia agora elencar as seguintes propostas de estudos futuros:

- i. Realização de estudos com um n amostral superior ao do presente estudo, com maior paridade de género, e mais representativos da população idosa.
- ii. Estudos que utilizem a metodologia *QualiQuanti*, acrescentando à avaliação quantitativa e estritamente estatística, presente na atual tese, uma avaliação qualitativa por entrevista estruturada ou aberta, por exemplo, que permitisse obter outro tipo de informações como por exemplo, o medo de cair.
- iii. Outros estudos de intervenção com distintas metodologias no que diz respeito ao exercício físico (tipo de treino, intensidade, carga, volume) para um melhor entendimento do impacto do EF na aptidão funcional, no equilíbrio e no RQ, de modo a permitir o

desenvolvimento de programas de EF mais específicos e eficientes para este problema específico.

- iv. Estudos experimentais associados a sessões de educação, sensibilização, motivação e esclarecimento para um estilo de vida saudável, seriam também potencialmente relevantes.

5. Conclusão

Tendo por base os resultados dos estudos desta tese podemos concluir que:

- i. Existe uma relação positiva entre os níveis de AF e negativa do tempo sedentário com o RQ, sugerindo que o idoso deverá aumentar o tempo gasto em níveis de atividade física promotoras de saúde (ligeira, moderada e vigorosa) assim como deverá diminuir o tempo sedentário para minorar o RQ.
- ii. Existe uma relação positiva entre a aptidão funcional, em particular da agilidade/equilíbrio dinâmico e força muscular dos membros inferiores, e o RQ sugerindo a necessidade de manutenção de um limiar de aptidão física, mesmo nos grupos etários mais idosos, determinantes para o menor RQ.
- iii. A agilidade motora e a força muscular dos membros inferiores parecem predizer o RQ.
- iv. A atividade física medida por acelerometria e a idade parecem predizer o RQ.
- v. O treino combinado trissemanal de EF aeróbio e de reforço muscular parece ser importante para a melhoria do RQ.

Apesar das limitações elencadas, podemos considerar que houve um contributo positivo na produção de conhecimento sobre as mais-valias da atividade física, assim como, da influência negativa e prejudicial do comportamento sedentário nos idosos de ambos os sexos, levando-nos a propor que os idosos devem participar em programas de exercício físico, com particular destaque para aquele utilizado no presente estudo envolvendo sessões trissemanais de treino combinado, envolvendo exercícios aeróbios e de reforço muscular, de modo a reduzir o RQ.

No entanto, mais estudos sobre aquelas estratégias são ainda necessários para validação dos resultados apresentados nesta tese.

Espera-se que a participação no programa combinado de exercício físico aeróbio e de reforço muscular possa, para além dos benefícios no RQ, induzir alterações comportamentais no sentido de os idosos adotarem um estilo de vida mais ativo, diminuindo potencialmente o declínio provocado pelo envelhecimento e/ou desuso.

Anexo A.

ETHICS OPINION

Process **CEFADE 02.2015**

The Ethics Committee of the Faculty of Sport from the University of Porto analyzed the project entitled "Impact of 9 Months of Combined Strength/Aerobic Training on Elderly Adults in Functional Fitness, Body Composition, Muscle Strength, and Balance as important modifiable risk factors for Falls" presented by MSc. Paulo Jorge Cardoso do Carmo. Considering the project's characteristics, as well as the competence of the research team, the Ethics Committee addresses a positive opinion, because the ethical principles that govern this type of scientific work are respected.

Porto and Faculty of Sport, 18th February, 2016

The chairman of the Ethics Committee,



Anexo B.

IMBALANCE AND FALL-RISK IMPROVEMENTS IN THE ELDERLY: EFFECTS OF COMBINED STRENGTH AND AEROBIC TRAINING

Contributions:
A Study design/planning
B Data collection/entry
C Data analysis/statistics
D Data interpretation
E Preparation of manuscript
F Literature analysis/search
G Funds collection

Paulo Jorge Quintela Cardoso do Carmo^{1,2,A-G}, Joana Carvalho^{3,A,D-G},
Rubim Santos^{1,A,E-F}, Adjane Cesar^{3,A-D,F-G}

¹ Escola Superior de Saúde, Politécnico do Porto, Portugal

² Centro Hospitalar de Vila Nova de Gaia - Serviço de Otorrinolaringologia

- Gabinete de Audiologia, Ministério da Saúde, Portugal

³ Faculdade de Desporto, Universidade do Porto, Portugal

Corresponding author: Dr. Paulo Jorge Quintela Cardoso do Carmo, Escola Superior de Saúde, Politécnico do Porto, Portugal, Centro Hospitalar de Vila Nova de Gaia - Serviço de Otorrinolaringologia - Gabinete de Audiologia, Ministério da Saúde, Portugal, email: pjqu@ess.ipp.pt, tel. +35 19 65665465

Abstract

Background: Falls among the elderly are an important clinical and health problem due to their high incidence and their functional and social repercussions. The aim of this study was to examine the effects of a combined strength and aerobic exercise program (EP) on the fall risk (FR) in older adults by use of a measure of postural stability.

Material and methods: Sixty-two elderly people (69.0 ± 4.3 years, 39 females and 23 males) were assigned to an experimental group (EG) or a control group (CG) and tested using the Biodex Balance System in order to obtain a fall-risk score at baseline (M1), after 4.5 months (M2), and 9 months (M3). Measures of physical activity (use of accelerometers for 7 consecutive days) as well as socio-economic status, clinical problems, and medication were also taken; these factors were identified as potential confounders. The EG underwent a 9-month, three times a week, combined training program consisting of 1-hour sessions of strength (once a week) and aerobic exercise (twice a week).

Results: The combined training program had a large and significant effect on FR (EG vs. CG) ($F(2,120) = 4.519$; $p = 0.013$; $\eta_p^2 = 0.07$; statistical power ($n = 0.76$). This was more pronounced from M1 to M2 than from M2 to M3, with a significant improvement ($p < 0.001$) in FR from M1 to M3. In the CG, there was a slight but non-significant functional decline ($p = 0.92$) between M1 and M3.

Conclusions: A 9-month combined EP may have beneficial effects on FR of elderly men and women as a result of improved postural stability.

Key words: Biodex Balance System • fall risk • community programs

POPRAWA RÓWNOWAGI I ZMNIEJSZENIE RYZYKA UPADKU U OSÓB STARSZYCH: EFEKTY ŁĄCZENIA TRENINGU SIŁOWEGO I AEROBOWEGO

Streszczenie

Wprowadzenie: Upadki wśród osób starszych są ważnym problemem klinicznym i zdrowotnym ze względu na ich częstotliwość występowania oraz reperkusje funkcjonalne i społeczne. Celem tego badania było sprawdzenie wpływu połączonego programu ćwiczeń siłowych i aerobowych (EP) na ryzyko upadku (FR) u starszych osób dorosłych za pomocą pomiaru stabilności postawy.

Materiał i metody: Grupa eksperymentalna (EG) i kontrolna (CG) obejmowała sześćdziesiąt dwie osoby w podeszłym wieku (69.0 ± 4.3 lata, 39 kobiet i 23 mężczyzn). Testy prowadzono przy użyciu Biodex Balance System w celu uzyskania oceny ryzyka upadku na początku badania (M1), po 4,5 miesiącach (M2) i po 9 miesiącach (M3). Sprawdzano również aktywność fizyczną (stosowanie akcelerometrów przez 7 kolejnych dni), a także status społeczno-ekonomiczny, problemy zdrowotne i przyjmowane leki; czynniki te zostały zidentyfikowane jako potencjalne czynniki zakłócające. Grupa EG została poddana 9-miesięcznemu, trzy razy w tygodniu, połączonemu programowi treningowemu, który składał się z 1-godzinnych sesji siłowych (raz w tygodniu) i ćwiczeń aerobowych (dwa razy w tygodniu).

Wyniki: Połączony program treningowy miał duży i znaczący wpływ na FR (EG vs. CG) ($F(2,120) = 4.519$; $p = 0.013$; $\eta_p^2 = 0.07$; moc statystyczna ($n = 0.76$). Było to wyraźniejsze w zestawieniu M1 do M2 niż z M2 do M3, ze znaczącą poprawą ($p < 0.001$) w zakresie FR między M1 a M3. W grupie CG nastąpił niewielki, ale nieistotny spadek czynnościowy ($p = 0.92$) między M1 a M3.

Wnioski: Łączony 9-miesięczny program EP może mieć korzystny wpływ na FR starszych mężczyzn i kobiet w wyniku poprawy stabilności postawy.

Słowa kluczowe: Biodex Balance System • ryzyko upadku • programy społeczne

Introduction

Impairments of postural stability can result in increased rates of unintentional falls. There is a general consensus that altered postural stability in elderly people is affected by degradation of the sensory channels, i.e., vestibular, visual, and proprioceptive cues, and also by deficits in muscle strength, neuromuscular control, and declining reaction times. These factors make fall events more likely [1].

These age-related conditions have numerous consequences for public health, such as falls, fractures, hospitalisations, institutionalisations, and mortality [2]. Due to the high costs of care, falls among the elderly have a great impact on the quality of their lives, on their relatives' lives, and on the public health system [3, 4]. The prevention of falls and mobility-related disability among older people is an urgent public health challenge [5].

There is now strong evidence for the effectiveness of exercise as a component of a multifactorial intervention in the prevention of falls in community-dwelling older people [6,7]. However, there is little direct evidence about the differential impact of different approaches to exercise as a single intervention in older people. In terms of the effect of combined exercise on postural stability, contrasting findings have been reported.

A combined exercise program (EP) seems to be highly relevant to this problem, and it can slow, halt, or even reverse age-related decline or loss of functionality that leads to an increase in the number of falls [8–10]. In addition, aerobic exercise, such as walking, can improve aerobic capacity and physical function (PF) [11,12]. Furthermore, strength training improves critical elements of physical function, such as mobility and balance [13].

Studies have reported extensively on the effectiveness of multifactorial fall prevention programs involving education, environmental modification, exercises, and psychological intervention [14–17]. Recommendations and guidelines for the prevention of falls which advocate identifying high-risk persons, screening for modifiable risk factors, and the targeting of appropriate interventions have been developed [18–20].

This study is the first to evaluate this specific population with objective tools such as the Biodex Balance System (BBS) Static/Dynamic (SD). Its aim is to investigate imbalance as a key factor related to fall risk, and to study the effects of a 9-month combined EP in older women and men. The results may help us to understand how combined exercise intervention can change the performance of those physiological systems associated with balance and fall risk in older women and men.

Methods

Participants

Elderly people of both genders from the Oporto area, Portugal, aged >65 years, were eligible to participate. A simple random sampling technique was used to distribute participants across the experimental and control groups. To

be eligible to participate in the study, participants had to submit medical certification of their state of physical and mental well-being. Participants were excluded if they were not able to walk without a cane or other assistive device, or had had a previous history of peripheral or vestibular abnormalities. Other grounds for exclusion were a history of two or more falls in the previous 6 months, having previous medical and cognitive conditions or musculoskeletal problems limiting safe participation and evaluation, or unwillingness to complete the study requirements.

From the cohort of initial participants, three failed to complete the study. This was due to an injury (broken metatarsals), a case of cancer, and one death from heart disease. The data analysed for this study is based on 62 participants: 39 women and 23 men aged from 65 to 79 years.

Participants were informed about the aims of the study and the study procedures and gave written informed consent before being enrolled. The consent conformed with the International Ethical Guidelines for Biomedical Research Involving Human Subjects [21], the World Medical Association Declaration of Helsinki [22,23], and Harris et al. [24]. The study was approved by the Ethics Committee, Faculty of Sport, University of Porto (CEFADE.02.2015).

Participants were interviewed in a private facility and self-completed questionnaires to provide information about their clinical and socio-demographic characteristics. These were used to assess their eligibility for the study.

Fall risk

Fall risk (FR) was evaluated by using the BBS SD, a multi-axial device with an unstable balance platform designed to measure postural stability. Under dynamic tests, the device can provide up to a 20° tilt in a 360° range of motion. Subjects were required to stand with their feet slightly apart for three 20-second periods with their eyes open. By measuring the pressures exerted by the subject on the platform, a score for overall stability, anterior/posterior, and medial/lateral stability can be generated, ranging from 0.0 (optimum balance/low fall risk equivalent) to 4.0–5.0 (poor balance/high fall risk equivalent). In healthy people, and according to Biodex Medical Systems, normal score ranges for FR by age are: 2.0–4.0 in the 72–89 years group; 0.9–3.7 in the 54–71 years group; 0.7–3.1 in the 36–53 years group, and 0.7–2.1 in the 17–35 years group [25–33].

The BBS SD was used to provide oscillations from the 12th to the 8th level of difficulty (level 12 being the most stable and level 8 the most unstable). The subject was required to stand up with feet slightly apart in a physiological position for three 20-second periods. Different force plate movements were automatically generated by the equipment and the resulting scores relating to stability were weighted according to the age and height of the subjects [25, 34–38].

Physical activity

Day-to-day physical activity (PA) was assessed over 7 consecutive days using uniaxial accelerometry (GT1M accelerometer, Actigraph, Florida, USA). Participants were instructed to wear the accelerometer over the right hip

for a 7-day period (5 week-days and 2 weekend days). Exceptions included time spent sleeping, showering, and participating in water-based activities. Participants were asked to maintain their usual activities, as tracked objectively by accelerometry, and keep written records in a diary. A valid day was defined as at least 10 hours of wear time per day. All non-wear time was excluded from further analysis. Data from the monitors was uploaded by the investigating team using the Actilife Monitoring System v.6.11.3 software and was compared with data from the written diary before the average counts per minute were calculated. This outcome variable was reported in the number of vertical axis counts per minute (CPM), generated based on the magnitude and frequency of movement [39–41].

Exercise intervention

Subjects in the experimental group (EG) ($n = 37$) submitted to a 9-month combined training course. This involved 1-hour bi-weekly aerobic training sessions (Mondays and Fridays) and a single weekly 1-hour strength training session (Wednesdays) conducted by a physical education instructor with academic specialisation in physical activity for older adults. This was in accordance with ACSM guidelines for exercise for older adults [42–44].

Aerobic training (AT) consisted of a 10-minute warm-up that included walking, calisthenics, and stretching and 30 minutes of aerobic exercises – mainly walking – at an intensity corresponding to 50–70% HR_{max} or a rating of perceived effort (RPE) of 4 to 6 on a 10-point scale [45]. Besides walking, a 10-minute exercise period was devoted to developing muscular endurance, balance, proprioceptive sensitivity, and coordination skills [43]. The session ended with a 10-minute cool-down. The training load was gradually increased by 5 minutes each week during the first 4 weeks until subjects could walk continuously for 30 minutes.

Strength training (ST) consisted of a 10-minute warm-up that included walking, calisthenics, and stretching and a specific resistance training period (30–40 min) consisting of nine exercises (leg press, chest press, leg extension, seated row, seated leg curl, abdominal flexion, biceps curl, low-back extension, and triceps extension) [46]. ST concluded with a 10-minute cool-down. The load increased during the first 2 weeks [47,48], commencing with familiarisation with the machines (for correct breathing and technique) and progressing to 60–70% of one-repetition maximum (1RM) individual strength tests. The 1RM was performed every 15 days for the first month and then every 4 weeks until the final session of the program. Between these tests, the load was increased for those subjects who were able to easily complete 10 for both sets [49].

Attendance of at least 80% of the exercise sessions was required for the training program to be considered complete.

Subjects allocated into the control group ($n = 25$) were instructed not to change their daily living PA routines or dietary patterns during the study and not to carry out any supervised PA. They were informed that they would receive intervention when the study had ended. After the data collection period, subjects who had been randomised into the

CG were invited to participate in specific EPs designed for seniors undergoing FADEUP.

Statistical procedures

Descriptive measures such as mean (M) and standard deviation (SD) were used for data collection and analysis. A Kolmogorov–Smirnov test with Lilliefors correction was used to assess distribution normality while independent sample *t*-tests were carried out to detect gender differences.

A mixed repeated measures ANOVA was applied to investigate the efficacy of EP over FR by comparing groups (EG/CG) and timeline: baseline (M_1), 4.5 months (M_2), and 9 months (M_3). The assumptions of the method, namely the normal distribution of FR at 3 times and the sphericity of the variance-covariance matrix, were evaluated with a Kolmogorov–Smirnov test ($p > 0.1$ for the 3 times and groups) and with the Mauchly test ($W = 0.993$; $\chi^2(2) = 0.419$; $p = 0.811$).

Change (Δ) between times was calculated for each pair according to the formula ($M_i - M_{i+1}$). So Δ_1 = change from baseline (M_1) to 4.5 months (M_2), Δ_2 = change from 4.5 months (M_2) to 9 months (M_3), and Δ_3 = change from baseline (M_1) to final (M_3). Between-group differences in pre-intervention was evaluated with unpaired two-tailed Student *t*-tests by one-way ANOVA.

Analyses were performed with SPSS statistics (v.25; IBM SPSS, Chicago, IL). A significance level of 0.05 was set for all analyses.

Results

The demographic and anthropometric characteristics of the study sample are shown in Table 1. The study population consisted of 62 elderly people, most of whom were female, of age 65–79 years, height 137–175 cm, and with weight ranging from normal to obese Class II [50].

With the purpose of reaching the goal of the present study, a mixed repeated measures ANOVA was used to evaluate the significance of the efficacy of physical activity training on FR and its evolution over the 3 sampled times, as shown in Table 2.

Table 2 –

The mean value of FR for participants of the experimental group ($M = 1.359$, $SD = 0.082$, $n = 37$) was significantly different from the value of FR for participants in the control group ($M = 1.618$, $SD = 0.100$, $n = 25$), with high dimension ($F(1,60) = 0.078$, $p = 0.009$; statistical power = 0.799). The size of the effect ($\eta^2 = 0.076$) is recommended minimum [51], being the 95% confidence interval for the difference of means of the value of FR of the two groups (0.029; 0.356).

Regarding the time evolution of FR values evaluated, there were highly significant differences between the 3 times ($F(2,120) = 4.928$; $p = 0.009$; $\eta^2 = 0.076$; statistical power (π) = 0.799).

Table 1. Demographic and anthropometric characteristics of the study sample divided by EG and CG

Variable	Total	EG	CG	p
Participants – n (%)	62 (100)	37 (59.7)	25 (40.3)	0.375
Gender – % female	58.1	63.9	52.0	0.102
Age, years – mean (SD)	69.02 (4.27)	68.11 (3.19)	70.36 (5.28)	0.064
Weight, kg – mean (SD)	71.77 (11.47)	70.80 (10.87)	81.45 (17.75)	0.219
Height, cm – mean (SD)	159.04 (10.25)	158.43 (10.50)	165.50 (3.54)	0.550
Body mass index, kg/m ² – mean (SD)	28.77 (4.12)	28.66 (4.21)	30.80 (3.32)	0.627

Key: EG, experimental group; CG, control group; SD, standard deviation; * statistical significance, $p < 0.05$; n, number

Table 2. Mean $\pm$ standard deviation of fall risk (FR) in the EG vs. CG at M₁, M₂, and M₃

Group	M ₁	M ₂	M ₃	Δ_1	p	Δ_2	p	Δ_3	p
FR Total (M $\pm$ SD) (n = 62)	1.695 $\pm$ 0.067	1.499 $\pm$ 0.065	1.463 $\pm$ 0.065	0.196	0.007*	0.036	0.608	0.232	<0.001*
FR EG (M $\pm$ SD) (n = 37)	1.754 $\pm$ 0.084	1.509 $\pm$ 0.083	1.359 $\pm$ 0.068	0.245	0.015*	0.150	0.103	0.395	<0.001*
FR CG (M $\pm$ SD) (n = 25)	1.608 $\pm$ 0.109	1.485 $\pm$ 0.106	1.618 $\pm$ 0.120	0.123	0.235	-0.133	0.216	-0.010	0.919
Δ by Group	0.146	0.240	-0.259						
p	0.287	0.856	0.049*						

Key: FR, fall risk; M₁, baseline; M₂, 4.5 months; M₃, 9 months (final); M $\pm$ SE, mean $\pm$ standard deviation; Δ_1 , M₁–M₂; Δ_2 , M₂–M₃; Δ_3 , M₁–M₃; n, number of participants; * denotes statistical significance, $p < 0.05$

When considering data from the two groups combined, the values of FR were higher at M₁ (baseline: M = 1.695, SD = 0.67, n = 62), decreased at M₂ (M = 1.499, SD = 0.065, n = 62), and further decreased at M₃ (M = 1.463, SD = 0.065, n = 62).

Finally, the effect of physical activity training on changing the values of FR depended on the group (EG vs. CG) as demonstrated by a significant interaction ($F(2,120) = 4.519$; $p = 0.013$; = 0.070; statistical power (π) = 0.761).

As shown in Table 2, the effect of physical activity training on FR is more pronounced in the experimental group from M₁ (baseline) to M₃, than from M₂ to M₃ (post-intervention), with a clear improvement in FR from M₁ to M₃ ($\Delta_3 = 0.395$, $p < 0.001$). Table 2 also shows that for participants in the control group, the effect of time on FR occurs in the expected direction: that is, between M₁ (baseline) and M₃ (final) there was a slight functional decline, with a variation in FR ($\Delta_3 = -0.010$, non-significant $p = 0.919$).

Comparing the difference between groups (EG vs. CG): at M₁ (baseline), $\Delta = 0.146$ (small and non-significant, $p = 0.287$), while at M₃ (final) it was more pronounced ($\Delta = -0.259$) and significant ($p = 0.049$).

Showing that PA did not bias the FR results, a mixed repeated measures ANOVA of PA, evaluated objectively by accelerometry, showed that its evolution over the 3 sampled times returned non-significant p -values. Table 3 shows

that all interactions between group (EG/CG) and time (M₁, M₂, and M₃) gave $p > 0.05$.

Discussion

The objective of this study was to evaluate the effectiveness of a combined (strength and aerobic) exercise-based intervention program on improving observed values of FR in elderly people from the Porto region. To the best of our knowledge, this study is the first to use BBS SD to focus on this population and objectively analyse FR and PA. The EP was found to be safe, with no major incidents occurring. The participants found the EP enjoyable, evident by the high compliance rate and low number of drop-outs.

With regard to accelerometer-determined ambulatory PA, our participants' results (11.015 $\pm$ 3.44 CPM) are corroborated by others [4, 52–54] and maintained the same PA during the experimental period, as demonstrated in Table 3.

The observed values of FR of participants were within the normal range for this specific age group [25]. In the EG, the FR values developed favourably over 9 months with the practice of regular physical exercise of combined strength and aerobic training. In comparison, in the CG there was a natural slight functional decline over the same 9 months.

Participation in the EP decreased FR. The changes observed in the EG could be a consequence of muscular strengthening and improvement of the postural control resulting from taking part in the various strength-aerobic training

Table 3. Mean $\pm$ standard deviation of physical activity (PA, in CPM) in EG vs. CG at M₁, M₂, and M₃

Group	M ₁	M ₂	M ₃	Δ_1	p	Δ_2	p	Δ_3	p
CPM Total (M $\pm$ SD) (n = 62)	11.015 $\pm$ 3.44	10.788 $\pm$ 3.49	11.794 $\pm$ 3.25	-0.227	0.238	-1.006	0.126	0.779	0.233
CPM EG (M $\pm$ SD) (n = 37)	11.150 $\pm$ 3.83	11.32 $\pm$ 3.87	12.308 $\pm$ 3.88	0.171	0.356	0.987	0.151	1.158	0.142
CPM CG (M $\pm$ SD) (n = 25)	10.880 $\pm$ 3.02	10.255 $\pm$ 3.08	11.281 $\pm$ 2.49	-0.625	0.284	1.026	0.192	0.401	0.239
Δ by Group	0.270	1.066	1.027						
p	0.231	0.136	0.174						

Key: PA, physical activity; CPM, counts per minute; EG, experimental group; CG, control group; M₁, baseline; M₂, 4.5 months; M₃, 9 months (final); M $\pm$ SD, mean $\pm$ standard deviation; Δ_1 , M₁-M₂; Δ_2 , M₂-M₃; Δ_3 , M₁-M₃; n, number of participants; * statistical significance, $p < 0.05$

activities as part of EP. Similar results have been reported by others in a series of studies with exercise-based program interventions [5,7, 55-58].

The changes seen in the CG can be considered natural and explained by aging due to the passage of the 9 months between the beginning and end of the study, as reported by Rivolta et al. [59].

The above results show that physical activity in general, and more specifically, combined strength-aerobic training, may have an effect in lowering fall risk. Based on this analysis, we recommend physical activity training to promote a higher quality for daily living activities and a lowering of fall risk in the elderly. This recommendation has also been made by others [11, 60-68].

Strengths and limitations

The strengths of this study include the use of objective instruments to measure PA and FR. This innovative technology can help add to our body of knowledge. Here, BBS-SD was used for the first time for this type of study. Factors that may have played roles in ensuring that the EP was successful included: care was taken to keep the participant's level of interest high in the physical EP; EP was held in venues that were easily accessible; classes were run by graduates trained in running EP; and the rationale for the study and the assessment measures were clearly explained to both the EG and the CG. Also, at the completion of the EP, feedback was provided to all subjects regarding their performances in the tests.

References

1. Lord S, Sturmeis D. The physiology of falling: assessment and prevention strategies for older people. *J Sci Med Sport*, 2005;8:35-42.
2. Beaudart C, Rizzoli R, Bruyère O, Reginster J-Y, Rivier E. Sarcopenia: burden and challenges for public health. *Arch Public Health* 2014;72:45.
3. Pereira A. A queda e suas consequências para o idoso: aspectos psicológicos e emocionais. Uberlândia: Universidade Federal de Uberlândia; 2006.
4. Brach J, VanSwearingen J. Physical impairment and disability: relationship to performance of activities of daily living in community-dwelling older men. *Phys Ther*, 2002;82:752-61.
5. Sherrington C, Tiedemann A, Fairhall N, Close J, Lord S. Exercise to prevent falls in older adults: an updated meta-analysis and best practice recommendations. *NSW Public Health Bull*, 2011;22:78-83.

When interpreting the findings consideration should be given to the study's limitations. Subjects in intervention studies with exercise cannot be blinded to group assignment; this study involved a highly physical task that could have led to low compliance if it were considered unpleasant. Ambulatory PA was assessed using an accelerometer worn for just 1 week. The measures of ambulatory PA may therefore have been affected by atypical happenings such as unfavourable weather conditions, random events, or participant's illness. Future studies using randomised controlled experiments should investigate the effect of PA on FR. Future research might examine if greater compliance by participants can be achieved through PA training and also evaluating participant satisfaction through questionnaires and interviews.

Conclusion

Aging causes many changes in the human body which can lead an individual to suffer changes, such as an increase in FR, causing elderly people to become more dependent on help from caregivers. As seen in this study, this functional decline can be halted, or reversed, by PA exercise practice such as a combined (strength-aerobic) exercise-based intervention program.

These findings reinforce a strategy for programs devoted to improving PA in the general population, and especially for elderly people. A PA program can promote physical fitness and lower FR. A decrease in FR is important for enhancing increased autonomy for community-dwelling elderly people. We need to understand that we, as carers for the elderly, can reduce the burden of falls on the broader social economy [18, 69].

6. Gillespie LD, Gillespie WJ, Robertson MC, Lamb SE, Cumming RG, Rowe JB. Interventions for preventing falls in elderly people (Cochrane review). In: The Cochrane Collaboration. The Cochrane Library, Issue 3. Oxford: John Wiley & Sons, Ltd, 2002.
7. Sherrington C, Whitney JC, Leed SR, Herbert RD, Cumming RG, Close JC. Effective exercise for the prevention of falls: a systematic review and meta-analysis. *J Am Geriatr Soc*, 2008;56:2234–43.
8. Zhuang J, Huang L, Wu Y, Zhang Y. The effectiveness of a combined exercise intervention on physical fitness factors related to falls in community-dwelling older adults. *Clin Interv Aging*, 2014;9:131–40.
9. Kim E, Park S, Kwon Y. The effects of combined exercise on functional fitness and risk factors of metabolic syndrome in the older women. *Jpn J Phys Fitness Sports Med* 2008;57:207–16.
10. Cakar E, Dincer U, Kiralp MZ, et al. Jumping combined exercise programs reduce fall risk and improve balance and life quality of elderly people who live in a long-term care facility. *Eur J Phys Rehabil Med*, 2010;46:59–67.
11. Marques EA, Pigueiredo P, Harris TB, Wanderley FA, Carvalho J. Are resistance and aerobic exercise training equally effective at improving knee muscle strength and balance in older women? *Arch Gerontol Geriatr* 2017;68:106–112.
12. Ferrari R, Fuchs S, Kruel L, et al. Effects of different concurrent resistance and aerobic training frequencies on muscle power and muscle quality in trained elderly men: A randomized clinical trial. *Aging Dis*, 2016;7:697–704.
13. Bossers W, Scherder E, Boersma F, Hortobágyi T, van der Woude L, van Heuvelen M. Feasibility of a combined aerobic and strength training program and its effects on cognitive and physical function in institutionalized dementia patients. A pilot study. *PLOS One*, 2014;9:e97577.
14. Yoo E, Jun T, Hawkins S. The effects of a walking exercise program on fall-related fitness, bone metabolism, and fall-related psychological factors in elderly women. *Res Sports Med* 2010;18:236–50.
15. Tinetti M, Williams C, Gill T. Health, functional, and psychological outcomes among older persons with chronic dizziness. *J Am Geriatr Soc* 2000;48:417–21.
16. Speechley M, Tinetti M. Falls and injuries in frail and vigorous community elderly persons. *J Am Geriatr Soc* 1991;39:46–52.
17. Melo C, Carvalho J, Silva P. Efeito da actividade física na funcionalidade e auto-percepções corporais do idoso. Porto: Universidade do Porto; 2010.
18. Klein D, Rapp K, Kupper M, et al. A population-based intervention for the prevention of falls and fractures in home dwelling people 65 years and older in south Germany: protocol. *JMIR Res Protoc* 2014;3:e19.
19. Svantesson U, Babagbemi B, Foster L, Alricsson M. Influences on modern multifactorial falls prevention interventions and fear of falling in non-frail older adults: a literature review. *J Clin Med Res* 2014;6:314–20.
20. Murphy T, Baker D, Leo-Summers L, Allore H, Tinetti M. Association between treatment or usual care region and hospitalization for fall-related traumatic brain injury in the Connecticut collaboration for fall prevention. *J Am Geriatr Soc* 2013;61:1763–7.
21. C.I.O.M.S. International ethical guidelines for biomedical research involving human subjects. Geneva, Switzerland: Council for International Organizations of Medical Sciences; 2002.
22. World Health Organization. Ethical Issues in Patient Safety Research: Interpreting Existing Guidance. Geneva, Switzerland: World Health Organization; 2013.
23. World Health Organization. Standards and Operational Guidance for Ethics Review of Health-related Research with Human Participants. Geneva, Switzerland: World Health Organization; 2011.
24. Harris D, Macsween A, Atkinson G. Standards for ethics in sport and exercise science research: 2018 Update. *Int J Sports Med*, 2017;38:1126–31.
25. Biodex Medical Systems I. Balance System SD Operation/service Manual. New York: Biodex Medical Systems, Inc.; 2014.
26. Pickerill ML, Harter RA. Validity and reliability of limits-of-stability testing: a comparison of 2 postural stability evaluation devices. *J Athl Train* 2011;46:600–6.
27. Chen TH, Chou LW, Tsai MW, Lo MJ, Kao MJ. Effectiveness of a heel cup with an arch support insole on the standing balance of the elderly. *Clin Interv Aging* 2014;9:351–6.
28. Arnold B, Schmitz R. Examination of balance measures produced by the Biodex stability system. *J Athl Tr*, 1998;33:323–7.
29. Parraca J, Olivares P, Carbonell-Baeza A, Aparicio V, Adsuar J, Guai N. Test-retest reliability of Biodex balance SD on physically active old people. *J Hum Sport Exerc* 2011;6:444–51.
30. Cachupe W, Shifflet B, Kahanov L, Wughalter E. Reliability of Biodex balance system measures. *Meas Phys Educ Exerc Sci*, 2009;5:97–108.
31. Aydog E, Aydog S, Cakci A, Doral M. Dynamic postural stability in blind athletes using the biodex stability system. *Int J Sports Med*, 2006;27:415–8.
32. Silva MAE, Boas JPV. Estabilidade postural nos adultos seniores: estudo da sua variabilidade. Porto: Universidade do Porto; 2002.
33. Melzer I, Benjuya N, Kaplanski J. Postural stability in the elderly: a comparison between fallers and non-fallers. *Age and Ageing*, 2004;33:602–7.
34. Burton E, Cavalheri V, Adams R, et al. Effectiveness of exercise programs to reduce falls in older people with dementia living in the community: a systematic review and meta-analysis. *Clin Interv Aging*, 2015;10:421–34.
35. Khalaj N, Abu Osman NA, Mokhtar AH, Mehdikhani M, Wan Abbas WA. Balance and risk of fall in individuals with bilateral mild and moderate knee osteoarthritis. *PLOS One*, 2014:e92270.
36. Sieri T, Beretta G. Fall risk assessment in very old males and females living in nursing homes. *Disabil Rehabil*, 2004;26:718–23.
37. Province M, Hadley E, Hornbrook M, et al. The effects of exercise on falls in elderly patients. A preplanned meta-analysis of the FICSIT trials. Frailty and injuries: cooperative studies of intervention techniques. *JAMA*, 1995;273:1341–7.
38. Branco PPVGS. Avaliação e modificação do risco de queda em idosos com recurso à posturografia dinâmica computadorizada. Lisboa: Faculdade de Ciências Médicas; 2013.
39. Sardinha L, Andersen L, Andersen S, et al. Objectively measured time spent sedentary is associated with insulin resistance independent of overall and central body fat in 9- to 10-year-old Portuguese children. *Diabetes Care* 2008;31:569–75.
40. Hagstromer M, Oja P, Sjostrom M. Physical activity and inactivity in an adult population assessed by accelerometry. *Med Sci Sports Exerc*, 2007;39:1502–8.
41. Egerton T, Paterson K, Helbostad J. The association between gait characteristics and ambulatory physical activity in older people: a cross-sectional and longitudinal observational study using generation 100 data. *J Aging Phys Act*, 2017;25:10–19.
42. Riebe D. Exercise prescription for healthy populations with special considerations and environmental considerations. In: Pescatello LS, Arena R, Riebe D, Thompson PD, eds. ACSM's Guidelines for Exercise Testing and Prescription. Baltimore: Wolters Kluwer Health; 2014:194–235.
43. Garber C, Blissmer B, Deschenes M, et al. American College of Sports Medicine position stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise. *Med Sci Sports Exerc*, 2011;43:1334–59.

44. American College of Sports Medicine. ACSM's Resource Manual for Exercise Testing and Prescription. 5th ed. Baltimore: Lippincott Williams & Wilkins; 2006.
45. Borg E. On Perceived Exertion and Its Measurement. Stockholm: Stockholm University; 2007.
46. Arthur Jones Exercise, 2015. (Accessed 2018 Dec 28, at http://www.arthurjonesexercise.com/NautilusManual/nautilus_sports-medical_industries.pdf).
47. Raymond MJ, Bramley-Tzerefos RE, Jeffs KJ, Winter A, Holland AE. Systematic review of high-intensity progressive resistance strength training of the lower limb compared with other intensities of strength training in older adults. *Arch Phys Med Rehabil*. 2013;94:1458-72.
48. Rall L, Meydani S, Kehayias J, Dawson-Hughes B, Roubenoff R. The effect of progressive resistance training in rheumatoid arthritis increased strength without changes in energy balance or body composition. *Arthritis Rheum*. 1996; 39:415-26.
49. Pescatello L, Arena R, Riebe D, Thompson P. ACSM's Guidelines for Exercise Testing and Prescription (9th ed). Baltimore: Wolters Kluwer Health; 2014.
50. BMI Classification, 2006. (Accessed 2016 Nov 25 at http://apps.who.int/bmi/index.jsp?introPage=intro_3.html).
51. Ferguson C. An effect size primer: a guide for clinicians and researchers. *Prof Psychol Res Pract*. 2009;40:532-8.
52. Duncan MJ, Minatto G, Wright SL. Dose-response between pedometer assessed physical activity, functional fitness, and fatness in healthy adults aged 50–80 years. *Am J Hum Biol*. 2016;28:890-4.
53. Langley E, Mackintosh S. Functional balance assessment of older community dwelling adults: a systematic review of the literature. *J Allied Health*. 2007;5:1-11.
54. Brach J, VanSwearingen J, Newman A, Kriska A. Identifying early decline of physical function in community-dwelling older women: performance-based and self-report measures. *Phys Ther*. 2002;82:320-8.
55. Reinsch S, MacRae P, Lachenbruch PA, Tobias JS. Attempts to prevent falls and injury: a prospective community study. *Gerontologist*. 1992;32:450-6.
56. Lord SR, Ward JA, Williams P, Stradwick M. The effect of a 12-month exercise trial on balance, strength, and falls in older women: a randomized controlled trial. *J Am Geriatr Soc*. 1995;43:1198-206.
57. Close JC, Lord SL, Menz HB, Sherrington C. What is the role of falls? *Best Pract Res Clin Rheumatol*. 2005;19:913-35.
58. Schoene D, Valenzuela T, Lord SR, de Bruin ED. The effect of interactive cognitive-motor training in reducing fall risk in older people: a systematic review. *BMC Geriatrics*. 2014;14:107.
59. Rivolta MW, Aktaruzzaman M, Rizzo G, et al. Automatic vs. clinical assessment of fall risk in older individuals: a proof of concept. *J Biomed Health*. 2015;2015:6935-8.
60. Marques A, Soares P, Soares-Miranda L, et al. Evaluation of physical activity programmes for the elderly: exploring the lessons from other sectors and examining the general characteristics of the programmes. *BMC Res Notes*. 2011;4:368.
61. Marques E, Carvalho J, Mota J. Exercise training, bone and aging. Evidence from different impact loading exercise interventions on age-related bone loss. *Porto: Universidade do Porto*; 2011:184.
62. Carrapatoso S, Carvalho J, Silva P. Efeito de um programa de caminhada nas percepções do envolvimento em idosos. *Porto: Universidade do Porto*; 2012.
63. Branco J, Jansen K, Sobrinho J, et al. Physical benefits and reduction of depressive symptoms among the elderly: Results from the Portuguese "National Walking Program". *Ciênc Saúde Colet*. 2015;20:789-95.
64. Carrapatoso S, Silva P, Furakom A, Novais C, Colaço P, Carvalho J. The experience of older adults in a walking program at individual, interpersonal, and environmental levels. *Act Adapt Aging*. 2017;41:72-86.
65. Wanderley FA, Silva G, Marques E, Oliveira J, Mota J, Carvalho J. Associations between objectively assessed physical activity levels and fitness and self-reported quality of life in community-dwelling older adults. *Qual Life Res*. 2011;20:1371-8.
66. Carvalho J, Oliveira J, Magalhães J, Ascensão A, Mota J, Soares J. Força muscular em idosos II: Efeito de um programa complementar de treino na força muscular de idosos de ambos os sexos. *Rev Port Ciênc Desporto*. 2004;4:58-65.
67. Carvalho J, Oliveira J, Magalhães J, Ascensão A, Mota J, Soares J. Força muscular em idosos I: Será o treino generalizado suficientemente intenso para promover o aumento da força muscular em idosos de ambos os sexos? *Rev Port Ciênc Desporto*. 2004;4:51-7.
68. Carvalho J, Pinto P, Mota J. Actividade física, equilíbrio e medo de cair. Um estudo em idosos institucionalizados. *Rev Port Ciênc Desporto*. 2007;7:225-31.
69. Inouye S, Brown C, Tinetti M. Medicare nonpayment, hospital falls, and unintended consequences. *N Engl J Med*. 2009;360:2390-3.

Anexo C.

**Fall risk prediction model for older men and women based
on ambulatory physical activity level – A cross-sectional
population-based study from the Oporto Region**

Journal:	<i>Baltic Journal of Health and Physical Activity</i>
Manuscript ID:	Draft
Manuscript Type:	Original Article
Keywords:	active aging, accelerometer, balance, motor activity levels, sedentary behaviour

SCHOLARONE™
Manuscripts

Anexo D.

EXERCISE PRESCRIPTION AREA

Association between physical activity, functional fitness and fall risk in the elderly: a cross-sectional population-based study from the Oporto region**Relazione tra attività fisica, fitness funzionale e rischio di caduta negli anziani: uno studio trasversale cross-section sulla popolazione della regione di Oporto**Paulo C. CARMO^{1,2,3}*, Adjane P. CESAR³, Rubim S. SANTOS¹, Joana M. CARVALHO³¹School of Medicine, Polytechnic Institute of Porto, Porto, Portugal; ²Service of Otorhinolaryngology, Hospital of Vila Nova de Gaia, Vila Nova de Gaia, Portugal; ³Faculty of Sports, University of Porto, Porto, Portugal

*Corresponding author: Paulo C. Carmo, Section of Audiology, School of Medicine, Polytechnic Institute of Porto, Rua Dr. António Bernardino de Almeida 400, 4200-072 Porto, Portugal. E-mail: pjq@ess.ipp.pt

SUMMARY**BACKGROUND:** Falls among the elderly are important clinical and health problems being one of the major causes of morbidity and mortality worldwide. Its high incidence and functional and social repercussions cause a significant financial burden on older adults, health systems and communities. According to different methodologies, the relationship between fall risk, physical activity and physical fitness found some inconsistent results. This study aims to examine the association between objective physical activity (PA) levels, fall risk (FR) and different components of functional fitness (FF) creating an appropriate model to explain variability in fall risk.**METHODS:** One hundred and seventy elderly adults (72.34±6.70 years old, 124 female), completed a Functional-Fitness-Test (FFT) and a Performance-Oriented-Mobility-Assessment (POMA). Ambulatory-PA was assessed by 7-day accelerometry. Pearson's correlation was used to verify association between FR, PA and FF. Analyses were adjusted either for gender, age, or both. Inferential stepwise multiple linear regression (MLR) was used to investigate the impact of PA and components of FF on FR.**RESULTS:** MLR showed that FR variability was mainly explained by motor agility (46.0%) and also by lower-body strength (14.1%) independently, and 49% when associated. Physical activity and also age were excluded from the models. MLR analysis by gender, only motor agility explains fall risk variability, more in female (45.0%) than in male (23.6%).**CONCLUSIONS:** The authors concluded that low motor agility and lower-body strength may increase fall risk. However, further evidence from a prospective study is required to establish directions of causality between physical activity behavior and risk of falls.(Cite this article as: Carmo PC, Cesar AP, Santos RS, Carvalho JM. Association between physical activity, functional fitness and fall risk in the elderly: a cross-sectional population-based study from the Oporto region. *Med Sport* 2021;74:313-26. DOI: 10.23736/S0025-7826.21.03838-2)**KEY WORDS:** Aging; Motor activity; Physical fitness; Postural balance; Accidental falls.**RIASSUNTO****OBBIETTIVO:** Le cadute tra gli anziani sono una delle problematiche clinico-sanitarie più importanti e comuni, dal momento che rappresentano una delle principali cause di morbidità e mortalità al mondo. L'elevata incidenza e le ripercussioni funzionali e sociali che ne scaturiscono generano un notevole onere finanziario per le persone anziane, per i sistemi sanitari e per le comunità. Analizzando il fenomeno con diverse metodologie, la relazione individuata tra rischio di caduta, attività fisica e forma fisica ha dato luogo ad una serie di risultati non del tutto coerenti. Questo studio si propone di esaminare la relazione tra i livelli oggettivi di attività fisica (physical activity, PA), il rischio di caduta (fall risk, FR) e diversi parametri di fitness funzionale (FF), allo scopo di creare un modello appropriato per spiegare la variabilità del rischio di caduta.**METODI:** Centosettanta adulti anziani (72,34±6,70 anni, 124 dei quali di sesso femminile), hanno completato un

Functional Fitness Test (FFT) e sono stati sottoposti ad una valutazione attraverso la Scala Tinetti per il rischio di caduta nell'anziano (Performance-Oriented Mobility Assessment, POMA). L'attività fisica legata alla deambulazione è stata valutata tramite accelerometria per 7 giorni. L'indice di correlazione di Pearson è stato impiegato per verificare l'associazione tra FR, PA e FF. Le analisi sono state corrette per sesso, età o entrambi i fattori. La regressione lineare multipla inferenziale (stepwise multiple linear regression, MLR) è stata utilizzata per valutare l'impatto della PA e dei parametri di FF sul FR.

RISULTATI: La MLR ha mostrato che la variabilità di FR poteva essere spiegata principalmente dall'agilità motoria (46,0%) e in parte dalla forza espressa dalla parte inferiore del corpo (14,1%), se prese in considerazione indipendentemente. La loro azione combinata raggiungeva il 49%. L'attività fisica, così come l'età, sono state escluse dai modelli. Quando si conduce una analisi MLR per il genere, solo l'agilità motoria spiega la variabilità del rischio di caduta, con effetti più marcati nelle donne (45,0%) rispetto ai soggetti maschi (23,6%).

CONCLUSIONI: Gli autori hanno concluso che una ridotta agilità motoria e forza nella parte inferiore del corpo possono aumentare il rischio di caduta. Tuttavia, è necessario uno studio prospettico per concretizzare ulteriori evidenze necessarie a stabilire le direzioni di causalità tra il comportamento dell'attività fisica ed il rischio di caduta.

PAROLE CHIAVE: Invecchiamento; Forma fisica; Equilibrio; Cadute accidentali.

Falls are one of the most common and serious public health problems in the elderly due to its high incidence levels and impact on mortality and morbidity.¹ Approximately one-third of community-dwelling older individuals have balance problems, falling at least once per year and about one half suffer from multiple falls.²

Falls are the main cause of fractures, hospital admissions for trauma, loss of independence, and injury-related deaths.³ Even though the majority of falls do not cause injuries, about 20% of them lead to a serious injury (such as a bone fracture or a head injury) that can greatly restrict a person in their everyday activities.⁴ Moreover, falls injuries not only cause distress, pain and restrictions on daily living but also can have a serious financial impact on associated health care costs.⁵

On the other hand, due to ageing, a progressive decline in functional function (FF) has also been associated with lower physical independence, resulting in a shift from an independent to a more dependent lifestyle.⁶

Therefore, since avoiding falls and being physically able to complete tasks necessary for everyday living are essential components of independent living with ageing,⁷ identifying modifiable behavioral factors associated with functional function and imbalance, and fall risk (FR), among older adults, is of major importance.

Moreover, while risk factors associated with falls are well established,⁸ as are the age-related declines in functional fitness,⁹ the relationship between FR and FF with physical activity (PA) has not been so extensively characterized and conflicting results have been demonstrated.

Le cadute sono uno dei problemi di salute pubblica più comuni e gravi negli anziani a causa degli alti livelli di incidenza e dell'impatto su mortalità e morbilità.¹ Circa un terzo degli individui anziani che vivono in comunità o struttura ha problemi di equilibrio e fa registrare almeno una caduta all'anno, mentre circa la metà è soggetto a cadute multiple.²

Le cadute sono la causa principale di fratture, ricoveri ospedalieri per traumi, perdita di indipendenza e decessi legati ad incidenti.³ Anche se la maggior parte delle cadute non provoca lesioni, circa il 20% di esse porta ad una lesione grave (come ad esempio una frattura ossea o un trauma cranico) che può limitare notevolmente la persona nelle sue attività quotidiane.⁴ Inoltre, le lesioni scaturite da una caduta non solo causano angoscia, dolore e difficoltà nella vita quotidiana, ma possono anche avere un ragguardevole impatto finanziario sui costi sanitari associati.⁵

D'altra parte, a causa dell'invecchiamento, un declino progressivo nel livello di fitness funzionale (FF) è stato associato ad una ridotta indipendenza fisica, con un conseguente passaggio da uno stile di vita indipendente ad uno maggiormente dipendente.⁶

Pertanto, dal momento che evitare le cadute ed essere fisicamente in grado di completare le attività necessarie per la vita quotidiana rappresentano componenti essenziali di una vita indipendente nell'età dell'invecchiamento,⁷ identificare i fattori comportamentali associati alla FF, allo squilibrio e al rischio di caduta (fall risk, FR) sui quali è possibile agire, tra gli adulti anziani, è di fondamentale importanza.

Inoltre, mentre i fattori di rischio associati alle cadute sono ben consolidati,⁸ così come il declino dell'idoneità funzionale legato all'età,⁹ la relazione tra FR e FF ed il regime di attività fisica (physical activity, PA) non è stata descritta altrettanto esaurientemente e sono altresì emersi risultati contrastanti.¹⁰⁻¹³ È stato dimostrato che livelli ele-

ed.¹⁰⁻¹³ Higher levels of PA have been shown to not relate with FR or even be associated with increased risk for falling in some studies,¹⁰ but mostly with decreased risk for falling and fractures in others.^{14, 15} Furthermore, evidence has verified the negative relationships of self-reported measured physical activity, with aspects of physical performance such as muscle strength, mobility, and balance in older adults,^{16, 17} but more rarely with objectively measures, which is a major limitation because older adults may have difficulty to accurately record their total physical activity levels.¹⁸

For the public health prevention practices, it is of value to further explore these relationships and identify the best predictors for FR, determining the contribution of PA and each component of the functional fitness. Therefore, the present study examined the associations of objectively measured PA with different components of physical fitness and FR among older men and women.

Materials and methods

Two-hundred and six elderly, aged 65 years and older, both genders, drawn from the Oporto area, Portugal were invited to participate in this cross-sectional study. The exclusion criteria were those unable to walk without a cane, or those with known medical, cognitive conditions and muscular-skeletal problems that would limit their ability to safely perform evaluations. Following the screening, 36 candidates did not perform all tests to the required selection criteria standards (due to unwillingness to use the accelerometer or complete functional assessments), resulting in a final suitable sample size of 170 participants (mean age = 72.3±6.7 years; 124 women and 46 men).

Subjects were informed about the study aims and procedures and then signed written informed consent before being enrolled onto the study, respecting The World Medical Association Declaration of Helsinki.¹⁹ The study was approved by the ethics committee of the Faculty of Sport, University of Porto (CEFADE.02.2015).

Physical activity

Habitual ambulatory physical activity (PA) was assessed using uniaxial accelerometry (GT1M, Actigraph, Pensacola, FL, USA). Participants were instructed to wear the accelerometer

vati di PA non sono necessariamente correlati al rischio di caduta o addirittura risultano associati con un rischio aumentato in taluni studi,¹⁰ mentre altri prevalentemente li mettono in relazione a una diminuzione del rischio di caduta e di fratture.^{14, 15} Inoltre, le evidenze scientifiche hanno confermato la relazione negativa esistente tra l'attività fisica misurata attraverso autovalutazione con elementi propri della prestazione fisica quali la forza muscolare, la mobilità e l'equilibrio negli individui adulti nell'età dell'invecchiamento,^{16, 17} il che rappresenta un grosso limite perché gli individui adulti anziani possono avere difficoltà a registrare accuratamente i loro livelli di attività fisica complessiva, attraverso misurazioni oggettive.¹⁸

Per quanto concerne le pratiche di prevenzione di salute pubblica, è utile esplorare ulteriormente queste correlazioni e identificare i migliori predicatori di FR, determinando il contributo della PA e di ogni componente del livello di fitness funzionale. Pertanto, il presente studio ha esaminato la relazione esistente tra la PA misurata oggettivamente, diverse componenti della forma fisica ed il rischio di caduta in uomini e donne anziani.

Materiali e metodi

Duecentosei anziani, di età pari o superiore a 65 anni, di entrambi i sessi, provenienti dalla zona di Oporto, Portogallo, sono stati invitati a partecipare a questo studio trasversale (cross-section). I criteri di esclusione sono stati: coloro che non erano in grado di camminare senza l'ausilio di un bastone o individui affetti da condizioni mediche, cognitive e problemi muscolo-scheletrici noti che avrebbero limitato la capacità di effettuare delle valutazioni in sicurezza. Successivamente allo screening, 36 candidati non hanno eseguito tutti i test secondo gli standard richiesti dai criteri di selezione (a causa dell'impossibilità di utilizzare l'accelerometro o di completare le varie valutazioni funzionali), il che ha comportato una dimensione finale del campione di partecipanti idonei pari a 170 unità (età media 72,3±6,7 anni; 124 donne e 46 uomini).

I soggetti sono stati informati sugli obiettivi e sulle procedure dello studio e hanno firmato un consenso informato scritto prima di essere arruolati nello studio, in ottemperanza ai dettami della Dichiarazione di Helsinki della World Medical Association.¹⁹ Lo studio è stato approvato dal comitato etico della Facoltà di Sport dell'Università di Porto (CEFADE.02.2015).

Attività fisica

L'abituale PA legata alla deambulazione è stata valutata usando un accelerometro monoassiale (GT1M, Actigraph, Pensacola, FL, USA). I partecipanti sono stati istruiti ad indossare l'accelerometro per mezzo di una cintura di nylon regolabile sopra

on an adjustable nylon belt over the right hip, for seven consecutive days, apart from sleeping and during water-based activities, and also, to record the schedule of use and the main physical activities in a written self-filled diary, for cross-validation purposes, following guidelines.²⁰

Wear time validation was used, whereby continuous periods of 60+ consecutive minutes of continuous zero counts, with a tolerance of up to two minutes of activity between 0-100 counts/min (CPM) were defined as "no-wear" and excluded from the analysis. Data were considered valid if there was a minimum of 10 hours of wear time per day, on a minimum of four days.²⁰ Data from all participants meet these validity criteria and none were excluded.

ActiGraph data were processed using Actilife™ software (v.6.11.3 ActiGraph) that converts acceleration data into counts that are summed over a user-specified interval of time called an "epoch." For the present study, the epoch was set to a 10-second interval, which allows the highest resolution. The outcome variable was reported in minutes, that is, the number of vertical axis CPM and were generated based on magnitude, intensity and frequency of bodily movement. Thus, the higher number of counts measured, the more active a person is. CPM is often used as an outcome variable due to its robustness, as it is not influenced by any external criteria (i.e., intensity threshold) other than wear time validation.

Physical fitness

The Functional (or Fullerton) Fitness Test was used, consisting of 6 items, designed and validated to assess the functional parameters that support physical mobility in elderly.²¹ It is a simple, easily administered set of tests: 1) number of full stands in 30 seconds with arms folded across the chest to assess lower-body strength (30-second chair stand [30-s CS]); 2) number of biceps curls in 30 seconds while holding a hand weight (3 kg for men and 2 kg for women (30-second arm curl [30-s AC]), to assess upper-body strength; 3) chair sit and reach to assess the lower-body flexibility from sitting position with leg extended at front of chair and hands reaching toward toes, number of centimeters (+ or -) from extended fingers to tip of the toe (chair sit-and-reach [CSR]); 4) back scratch to assess upper-body flexibility (with one hand reaching over the shoulder and the other one up middle of back, distance

l'anca destra, per un totale di sette giorni consecutivi, a parte durante il sonno e le attività in acqua, e inoltre, a registrare il programma di utilizzo, oltre alle principali attività fisiche svolte in un diario scritto autocompilato, allo scopo di avere a disposizione una convalida incrociata, secondo linee guida.²⁰

Si è provveduto a registrare l'ammontare di tempo durante il quale l'accelerometro è stato indossato, sulla base di questi dati, i periodi durante i quali non si è registrato alcun utilizzo (zero conteggi) per 60+ minuti consecutivamente sono stati definiti come "non utilizzo" ("no-wear"), con una tolleranza fino a due minuti di attività tra 0-100 conteggi/min (CPM) ed esclusi dall'analisi; I dati sono stati considerati validi a partire da un minimo di 10 ore di utilizzo al giorno, per un periodo di almeno quattro giorni.²⁰ I dati di tutti i partecipanti presi in considerazione soddisfanno questi criteri di validità e nessuno è stato escluso dallo studio.

I dati del dispositivo ActiGraph sono stati elaborati mediante l'ausilio del software Actilife™ (v.6.11.3 ActiGraph) che converte i dati di accelerazione in conteggi che vengono sommati su un intervallo di tempo specificato dall'utente chiamato "epoch." Per il presente studio, l'epoch è stato impostato su un intervallo di 10 secondi, di modo da raggiungere la massima risoluzione. La variabile di risultato è stata riportata in minuti sull'asse verticale ed è stata generata in base a grandezza, intensità e frequenza del movimento del corpo; di conseguenza, più alto è il numero di conteggi misurati, più attiva è una persona. CPM è sovente utilizzato come variabile di risultato per la sua robustezza, dato che non è influenzato da nessun criterio esterno (ad esempio, la soglia di intensità) al di là della conferma del tempo di utilizzo.

Livello di fitness dell'organismo

Il FFT (conosciuto anche come Fullerton Fitness Test) utilizzato nel nostro studio è composto da sei componenti ed è stato progettato e approvato specificatamente per valutare i parametri funzionali che promuovono la mobilità negli anziani.²¹ Si tratta di un insieme di test semplice e facilmente somministrabile: 1) numero di piegamenti da seduti al raggiungimento della posizione eretta in 30 secondi, con le braccia piegate sul petto allo scopo di valutare la forza della parte inferiore del corpo (30-second chair stand, 30-s CS); 2) numero di flessioni dei bicipiti in 30 secondi tenendo un manubrio in mano (3 kg per gli uomini e 2 kg per le donne (30-second arm curl, 30-s AC)) per valutare la forza della parte superiore del corpo; 3) test chair sit-and-reach (CSR) per valutare la flessibilità della parte inferiore del corpo dalla posizione seduta con gamba estesa davanti alla sedia e mani che si protendono verso le dita dei piedi, numero di centimetri dalle dita estese alla punta del piede; 4) test back scratch (BS) per valutare la flessibilità della parte superiore del cor-

(cm) between extended middle fingers (+ or -) (back scratch [BS]); 5) number of meters walked in 6 minutes to measure aerobic endurance (6-minute walk [6-mW]); 6) standing up from a chair, walking 8-foot distance, turning, stopping, and sitting down to assess dynamic balance and motor agility (8-foot up-and-go [8-FUG]).²² This battery of tests also assessed body mass index as an estimate of body composition (data not shown). All measurements were performed by a team of trained researchers.

Fuller and more detailed information on test administration and protocols can be found in the work of Rikli and Jones.²³ The result of each test can be expressed as age (for each 5-year group) and sex standardized percentile scores and normative values have been obtained for the Portuguese elderly population.²⁴

Fall risk

Performance Orientated Mobility Assessment (POMA) developed by Tinetti²⁵ was used. This assessment tool shows proven sensitivity and specificity for fall prediction,²⁶ resulting in the widespread use of POMA in both research and clinical settings.²⁷ POMA consists of 2 parts for assessment of balance and gait and is frequently used to evaluate elderly populations. The score ranges from zero to 28, and a score of 0-19 corresponds to high fall risk, while scores between 19 and 24 reveal the presence of a problem, classified as moderated fall risk, whereas a score of 24-28 is normal and correspond to low fall risk.^{28, 29}

The higher the POMA score, the lower fall risk. So, when POMA score tends to zero, meaning an increase in fall risk, this may be misleading. Thus, so that the increase in the variable fall risk be expressed as an increasing natural number, in the present study POMA was inverted into a new variable, called fall risk (FR).^{30, 31} FR was created based on POMA score results by applying the formula ($FR = 29 - POMA$), and the new score ranges were categorized as low FR (1-5); moderated FR (5-10); and high FR (10-28).

Statistical analysis

SPSS v. 25 for Mac (SPSS Inc., Chicago, IL, USA) was used for statistical analysis. All continuous variables were expressed as mean and standard deviation and were initially evaluated for normality using the Kolmogorov-Smirnov test.

po (con una mano che arriva sopra la spalla e poi spinge in giù e l'altra che risale dal basso nel mezzo alla schiena, distanza (cm) tra il dito medio esteso di entrambe le mani; 5) numero di metri camminati in 6 minuti per misurare la resistenza aerobica (6-Minute Walk Test, 6-mW); 6) alzarsi da una sedia, camminare per 8 piedi (circa 2,4 m), girare, fermarsi e sedersi per valutare l'equilibrio dinamico e l'agilità motoria (8-foot up-and-go, 8-FUG)).²² Questa batteria di test ha anche valutato l'indice di massa corporea come stima della composizione corporea (dati non mostrati). Tutte le misurazioni sono state eseguite da un team di ricercatori addestrati.

Informazioni più complete e dettagliate sulla somministrazione dei test e sui protocolli impiegati si possono trovare nel lavoro di Rikli e Jones.²³ Il risultato di ognuno dei test può essere espresso come punteggi percentili standardizzati per età (per ciascun gruppo di 5 anni) e sesso e sono stati ricavati valori normativi per la popolazione anziana portoghese.²⁴

Rischio di caduta

La scala di valutazione sviluppata da Tinetti²⁵ per il rischio di caduta nell'anziano (Performance-Oriented Mobility Assessment, POMA) è stata implementata nello studio. Questo strumento di valutazione mostra sensibilità e specificità comprovate per quanto concerne la predizione delle cadute,²⁶ il che ha favorito la sua diffusione sia nella ricerca che in ambito clinico.²⁷ Il POMA è composto da due parti per la valutazione dell'equilibrio e dell'andatura rispettivamente ed è frequentemente utilizzato per compiere analisi sulle popolazioni anziane. Il punteggio può variare da zero a 28. Un punteggio di 0-19 corrisponde a un rischio elevato di caduta, mentre i punteggi tra 19 e 24 rivelano la presenza di un problema, classificato come rischio di caduta moderato, mentre un punteggio pari a 24-28 è normale e corrisponde ad un basso rischio di caduta.^{28, 29}

Più alto è il punteggio POMA, minore è il rischio di caduta. Il fatto che un punteggio POMA che tende a zero si traduce in un aumento del rischio di caduta può essere fuorviante. Ergo, affinché l'aumento della variabile rischio di caduta sia espresso come un numero naturale crescente, nel presente studio POMA è stato invertito in una nuova variabile, chiamata rischio di caduta (fall risk, FR).^{30, 31} FR è stato creato in base ai risultati del punteggio POMA applicando la formula ($FR = 29 - POMA$), e i nuovi intervalli di punteggio sono stati categorizzati come FR basso (1-5), FR moderato (5-10), e FR alto (10-28).

Analisi statistica

Per l'analisi statistica è stato utilizzato il software SPSS v. 25 per Mac (SPSS Inc., Chicago, IL, USA).

Differences between men and women for age, BMI, functional fitness components, FR, and PA were compared *via* independent sample *t*-test. Afterwards, Pearson correlation coefficients test was used to assess the correlation between PA, functional fitness components, FR and age, and inferential stepwise multiple linear regression test was used to investigate multivariate relationships among predictors of FR. The assumptions of the models, namely, normal distribution, homogeneity and independence of errors were analyzed and used the criteria: probability-of-F-to-enter ≤ 0.05 , probability-of-F-to-remove ≥ 0.10 . G*Power was used to obtain the effect size F^2 and power of the tests. Level of significance was set at $P < 0.05$.

Results

Table I shows scores for age, FF, POMA, FR and PA.

Men presented as having higher aerobic endurance ($P=0.035$) and greater lower-body strength ($P=0.049$) compared to women. No other differences were observed in all other components or variables evaluated.

Associations among age, components of physical fitness, physical activity and fall risk are shown in Table II.³²

All correlations presented in Table II showed statistically significant values ($P < 0.05$).

In this way, significant and positive correlations (strong and moderate)³² were seen between FR and: 1) 8-FUG test time, *i.e.*, the greater the test time (the lower motor agility)

Tutte le variabili continue sono state espresse come media e deviazione standard e sono state inizialmente valutate per la normalità usando il test di Kolmogorov-Smirnov.

Le differenze tra uomini e donne per quanto riguarda età, **Indice di Massa Corporea (IMC)**, parametri di fitness funzionale, FR e PA sono state confrontate tramite il test *t* di Student per campioni indipendenti. In seguito, è stato usato il coefficiente di correlazione *r* di Pearson per valutare la correlazione tra PA, parametri di fitness funzionale, FR ed età, e le relazioni multivariate tra i predittori di FR sono state indagate per mezzo della regressione lineare multipla inferenziale stepwise (multiple linear regression, MLR). I presupposti dei modelli, cioè distribuzione normale, omogeneità e indipendenza degli errori sono stati analizzati e a questo scopo sono stati selezionati i seguenti criteri: probabilità di *F* di inserimento (probability-of-F-to-enter) ≤ 0.05 , probabilità di *F* di rimozione (probability-of-F-to-remove) ≥ 0.10 . G*Power è stato usato per ottenere la dimensione dell'effetto F^2 e la potenza del test. Il livello di significatività è stato fissato a $P < 0.05$.

Risultati

La Tabella I mostra i punteggi per età, FF, POMA, FR e PA.

Gli uomini presentavano una maggiore resistenza aerobica ($P=0.035$) e una maggiore forza della parte inferiore del corpo ($P=0.049$) rispetto alle donne. Non sono state osservate ulteriori differenze in alcuna delle altre componenti o variabili valutate.

Le interazioni tra età, componenti del fitness fisico, attività fisica e rischio di caduta sono mostrate nella Tabella II.³²

Tutte le correlazioni presentate nella Tabella II hanno fatto registrare valori statisticamente significativi ($P < 0.05$).

TABLE I.—Age, FF, POMA, FR and PA of the study participants.

TABELLA I.—Età, FF, POMA, FR e PA dei partecipanti allo studio.

Variable	Total (N=170)	Female (N=124)	Male (N=46)	P value
Age, years	72.34±6.70	71.97±6.57	73.35±7.01	0.281
Aerobic endurance, m	516.82±137.19	497.45±139.28	556.08±125.71	0.035*
Lower-body strength, N	16.47±5.61	15.92±4.86	17.85±7.05	0.049*
Upper-body strength, N	18.49±6.61	18.43±5.44	18.64±9.07	0.861
Lower-body flexibility, cm	-8.65±13.70	-8.55±12.75	-8.89±16.01	0.887
Upper-body flexibility, cm	-16.16±14.24	-15.46±13.67	-17.92±15.61	0.322
Motor agility, s	6.33±3.39	6.60±3.56	5.62±2.79	0.101
POMA score	26.26±2.99	26.10±3.30	26.67±1.92	0.318
Static balance score	14.80±1.85	14.71±2.01	15.05±1.31	0.324
Dynamic balance score	11.45±1.41	11.39±1.57	11.62±0.84	0.391
Fall risk score	2.74±2.99	2.90±3.30	2.33±1.92	0.318
PA, CPM	4.63±2.17	4.70±2.28	4.42±1.80	0.529

POMA: Performance Orientated Mobility Assessment; FR: fall risk; PA: physical activity; CPM: counts per minute.

*Statistically significant difference ($P < 0.05$).

TABLE II.—Correlation analysis (Pearson's test) between sample participants age, FF, PA, and FR.

TABELLA II.—Indice di correlazione (test di Pearson) tra età, FF, PA e FR degli appartenenti al campione.

Variables	FR			PA		
	r	P value	Class	r	P value	Class
Age	0.385	<0.001*	M	-0.471	<0.001*	M
Lower-body strength	-0.375	<0.001*	M	0.406	<0.001*	M
Upper-body strength	-0.337	<0.001*	M	0.434	<0.001*	M
Lower-body flexibility	-0.188	0.026*	L	0.324	<0.001*	M
Upper-body flexibility	-0.280	<0.001*	L	0.262	0.003*	L
Motor agility	0.598	<0.001*	H	-0.495	<0.001*	M
Aerobic endurance	-0.591	<0.001*	H	0.530	<0.001*	H
PA	-0.320	<0.001*	L	—	—	—

FR: fall risk; PA: physical activity; Class: r classification; H: high; M: moderate; L: low.

*Statistically significant difference (P<0.05).

the greater FR; and 2) age, the greater was age, the greater was FR. Moreover, FR correlated significantly and strongly negatively with: 3) aerobic endurance (6-mW), 4) moderately with upper and lower-body strength (30-s AC; 30-s CS), and weakly with 5) with upper and lower-body flexibility (BS, CSR) and 6) physical activity.

Also, Table II shows, that PA correlated significantly, strongly and positively with aerobic endurance (6-mW); moderately with upper and lower-body muscle strength (30-s CS, 30-s AC) and lower-body flexibility (CSR), and weakly with upper-body flexibility (BS). Moreover, PA correlated significantly and strongly negatively with 8-FUG test time, i.e., the more active the person is, the smallest test time with higher motor agility, and moderately with age.

An inferential stepwise multiple linear regression (Table III) was undertaken to estimate the contribution of: 1) age, 2) PA, and 3) and functional fitness components to explain the variability of FR.

Per mezzo di questa analisi si sono riscontrate correlazioni positive e significative (forti e moderate)³² tra FR e: 1) tempi nel test 8-FUG, cioè, maggiore è il tempo fatto registrare nel test (minore sarà l'agilità motoria) maggiore è la FR; e 2) età, maggiore è l'età, più elevata è la FR. Inoltre, FR si correlava in maniera significativa e fortemente negativa con: 3) la resistenza aerobica (6-mW); 4) moderatamente con la forza espressa dalla parte superiore e inferiore del corpo (30-s AC, 30-s CS), e debolmente con 5) con la flessibilità della parte inferiore e superiore del corpo (BS, CSR) e 6) la PA.

Inoltre, la Tabella II mostra che la PA entrava in correlazione in maniera significativa, importante e positiva con la resistenza aerobica (6-mW); moderatamente con la forza muscolare della parte inferiore e superiore del corpo (30-s CS, 30-s AC) e con la flessibilità della parte inferiore del corpo (CSR), e debolmente con la flessibilità della parte superiore del corpo (BS). Inoltre, la PA correlava significativamente e in maniera decisamente negativa con i tempi fatti registrare nel test 8-FUG (ovvero, più la persona è attiva, più i tempi nel test sono bassi, il che si traduce in una maggiore agilità motoria), e moderatamente con l'età.

TABLE III.—Multiple linear regression models predicting FR in the total, female and male samples.

TABELLA III.—Modelli di regressione lineare multipla predittivi di FR in relazione al campione totale, e alla popolazione femminile e maschile.

Model		R ²	R ² _{adj}	SEE	Predictive formula
1 _{total}	8-FUG	0.678	0.460	2.585	
2 _{total}	30-s CS	0.375	0.141	2.801	
FR _{total}	Predictive variables	0.698	0.487	2.534	FR _{total} = 5.026 + 0.869 8-FUG - 30-s CS*0.147
1 _{female}	8-FUG			2.856	
FR _{female}	Predictive variable			2.856	
1 _{male}	8-FUG			1.490	
FR _{male}	Predictive variable			1.490	

Variables entered: fall risk; age; counts/min; 30-s CS; 30-s AC; CSR; BS; 8-FUG; 6-m W. Dependent variable: FR_{total}. Predictive variables: Model 1_{total} - 8-FUG; Model 2_{total} - 30-s CS. Model FR_{total} - 8-FUG + 30-s CS. Dependent variable: FR_{female}. Predictive variables: Model 1_{female} - 8-FUG. Dependent variable: FR_{male}. Predictive variables: Model 1_{male} - 8-FUG; R² - determination coefficient; R²_{adj} - adjusted determination coefficient; SEE: standard error of estimate.

*Statistically significant difference (P<0.05).

MLR analysis showed that FR variability was mainly explained by the predictors motor agility (8-FUG; 46.0%) and also, with minor expression, by lower-body strength (30-s CS; 14.1%) independently, and even more when associated (49%) ($R^2=0.49$, $F(2, 81)=38$; $P<0.001$). It was found that motor agility significantly predicted FR ($b=0.869$; $t(81)=7.725$; $P<0.001$), as did lower-body strength ($b=0.223$; $t(81)=2.079$; $P=0.041$). Lower-body strength is only marginally significant, but given the limitations of sampling and the relative size of the sample, the authors chose to include this variable in the model. The present study total adjusted model is then $FR=5.026 + 0.869 \text{ 8-FUG} - 0.147 \text{ 30-s CS}$. Meaning that in elderly, for every second of increase to perform 8-FUG test, the FR score will increase by 0.869 points, tending to a more dangerous score according to FR scale cut-points, mentioned above. Likewise, with the 30-s CS test, the greater the number of stands from the chair, the constant (5.026) value will be decreased by a factor of 0.147 points, i.e., the lower the number of stands from the chair in 30 seconds, the constant (5.026) value will be increased by a factor of 0.147 points, with similar FR score repercussion.

Functional fitness components like upper-body strength, lower-body and upper-body flexibility, aerobic endurance, as also PA and age were excluded from the model ($P>0.100$) (data not shown), since according to statistical procedures, the probability-of-F-to-remove ≥ 0.10 .

Because there were significant gender differences in FF components values in Table I, probably due to gender asymmetry in the sample, MLR by gender was carried out.

In the female sample (Table III), MLR indicated that the predictor 8-FUG explained 45.9% of the variance ($R^2=0.459$, $F(1, 63)=53.388$; $P<0.001$). It was found that motor agility significantly predicted FR ($b=0.732$; $t(63)=38.842$; $P<0.001$). The present study female adjusted model is then $FR=1.818 + 0.732 \text{ 8-FUG}$. Meaning that in female elderly, for every second of increase to perform 8-FUG test, the FR score will increase by 0.732 points, tending to a more menacing score.

In the male sample (Table III), MLR indicated that the predictor 8-FUG explained 26.3% of the variance ($R^2=0.263$, $F(1, 28)=9.983$; $P=0.004$). It was found that motor agility significantly predicted FR ($b=0.499$; $t(28)=30.257$; $P<0.001$). The present study male adjusted model is then

La MLR è stata utilizzata per stimare il contributo di: 1) età, 2) PA, e 3) e parametri di fitness funzionale per spiegare la variabilità di FR (Tabella III). L'analisi MLR ha mostrato che la variabilità di FR era spiegata principalmente dai predittori dell'agilità motoria (8-FUG; 46,0%) e anche dalla forza espressa dalla parte inferiore del corpo (30-s CS; 14,1%), sebbene in misura minore e indipendentemente. L'effetto appariva statisticamente amplificato in caso di associazione delle due variabili (49%) ($R^2=0,49$, $F(2, 81)=38$; $P<0,001$). Si è scoperto che l'agilità motoria era in grado di predire in maniera statisticamente significativa la FR ($\beta=0,869$; $t(81)=7,725$; $P<0,001$), così come la forza espressa dalla parte inferiore del corpo ($\beta=0,223$; $t(81)=2,079$; $P=0,041$). Quest'ultima appare solo marginalmente significativa da un punto di vista statistico, tuttavia, considerando le limitazioni della campionatura e la dimensione relativa del campione preso in esame, gli autori hanno scelto di includere questa variabile nel modello. Il modello complessivo corretto del presente studio è quindi $FR = 5,026 + 0,869 \text{ 8-FUG} - 0,147 \text{ 30-s CS}$. Ciò significa che negli individui anziani, per ogni secondo in più speso nell'esecuzione del test 8-FUG, il punteggio FR aumenterà di 0,869 punti, tendendo ad un punteggio più preoccupante stando ai valori di soglia della scala FR menzionati sopra. Analogamente, vi è una correlazione tra il numero di alzate dalla sedia nel test 30-s CS ed il valore della costante (5,026), più il primo si accresce, più il secondo diminuisce di un fattore pari a 0,147 punti e viceversa, con ripercussioni similari sul punteggio FR.

Parametri di fitness funzionale quali la forza della parte superiore del corpo, la flessibilità della parte inferiore e superiore del corpo, la resistenza aerobica, così come la PA e l'età, sono state escluse dal modello ($P>0,100$) (dati non presentati), poiché secondo le procedure statistiche, la probabilità di F di rimozione $\geq 0,10$.

Poiché c'erano significative differenze di genere nei valori delle componenti FF nella Tabella I, probabilmente dovute all'asimmetria di genere nel campione, è stata effettuata la MLR per genere.

Nel campione femminile (Tabella III), MLR ha indicato che il predittore 8-FUG spiegava il 45,9% della varianza ($R^2=0,459$, $F(1, 63)=53,388$; $P<0,001$). Si è scoperto che l'agilità motoria ha predetto significativamente FR ($\beta=0,732$; $t(63)=38,842$; $P<0,001$).

Il modello corretto femminile del presente studio è quindi $FR=1,818 + 0,732 \text{ 8-FUG}$. Ciò significa che negli individui anziani di sesso femminile, per ogni secondo in più speso nell'esecuzione del test 8-FUG, il punteggio FR aumenterà di 0,732 punti, tendendo ad un punteggio più minaccioso.

Nel campione maschile (Tabella III), MLR ha indicato che il predittore 8-FUG spiegava il 26,3% della varianza ($R^2=0,263$, $F(1, 28)=9,983$; $P=0,004$). Si è scoperto che l'agilità motoria ha predetto significativamente FR ($\beta=0,499$, $t(28)=30,257$; $P<0,001$).

FR=0.677 + 0.499 8-FUG. Meaning that in male elderly, for every second of increase to perform 8-FUG test, the FR score will increase by 0.499 points, tending to a more menacing score.

In the total sample model, using G*Power with 8-FUG and 30-s CS, the effect size ($f^2=0.558701$) was found to exceed convention for a large effect ($f^2=0.50$),³³ and observed statistical power ($p=1.000$), as well in the female model, using G*Power with 8-FUG, the effect size ($f^2=0.5339776$) was found to exceed expectation for a large effect ($f^2=0.50$)³³ and observed statistical power ($p=1.000$), and moreover, in the male model using G*Power with 8-FUG, the effect size ($f^2=0.5339776$) was found to exceed expectation for a large effect ($f^2=0.50$),³³ and observed statistical power ($p=0.9980457$), all three suitable for detecting a large-sized effect when employing 0.05 criterion of statistical significance.

Discussion

The main findings of this study show that depending mainly on motor agility and with a minor expression on lower-body strength older physically independent community-dwelling individuals may put themselves in a position of greater fall risk, as demonstrated by fall risk prediction models here presented. Moreover, the observed positive associations between aerobic endurance and PA seem to be dependent on age. Also, are presented positive associations between PA and lower and upper-body strength, and flexibility.

Although there were no significant differences between women's and men's in most of the analyzed variables, as expected,³⁴ men presented significantly greater lower-body muscle strength and aerobic endurance. Even gender differences may be explained by the large difference sample size between groups (Table I). Also, Smee *et al.* (2012) reported that male participants had higher lower body strength than female.³⁵ In the same way, Zoeller (2008) reported that aerobic endurance in older men was greater than for women.³⁶

Even though various risk factors are leading to falls, most of the literature shows, as the present study, that people with higher PA have a lower risk and incidence of falls.³⁷ Several reported that PA ranging from leisure-time physical activity to the daily moderate to vigorous-intensity physical activity in older adults will

Il modello rettificato maschile del presente studio è quindi FR=0,677 + 0,499 8-FUG. Ciò significa che negli individui anziani di sesso maschile, per ogni secondo in più speso nell'esecuzione del test 8-FUG, il punteggio FR aumenterà di 0,499 punti, tendendo ad un punteggio più preoccupante.

Nel modello che tiene in considerazione il campione totale, usando G*Power con 8-FUG e 30-s CS, la dimensione dell'effetto ($f^2=0,558701$) è risultata superare i valori convenzionali per un grande effetto ($f^2=0,50$),³³ e per la potenza statistica ($\pi=1,000$); parimenti, nel modello femminile, usando G*Power con 8-FUG, la dimensione dell'effetto ($f^2=0,5339776$) è risultata superare i valori convenzionali per un grande effetto ($f^2=0,50$),³³ e per la potenza statistica ($\pi=1,000$) e inoltre, nel modello maschile usando G*Power con 8-FUG, la dimensione dell'effetto ($f^2=0,5339776$) è risultata superare i valori convenzionali per un grande effetto ($f^2=0,50$),³³ e per la potenza statistica ($\pi=0,9980457$). In tutti e tre i casi sono risultate adeguate rilevare un effetto di grandi dimensioni quando viene usato un criterio di significatività statistica pari a 0,05.

Discussione

I risultati salienti di questo studio mostrano che, dipendendo principalmente dall'agilità motoria e con una minore capacità di esercitare forza con la parte inferiore del corpo, gli individui anziani fisicamente indipendenti che vivono in comunità o strutture potrebbero incorrere in un maggior rischio di caduta, come dimostrato dai modelli di previsione del rischio di caduta qui presentati. Inoltre, le correlazioni positive osservate tra resistenza aerobica e PA sembrano dipendere dall'età. Infine, vengono anche descritte delle correlazioni positive tra PA, flessibilità e forza esercitata dalla parte inferiore e superiore del corpo.

Sebbene non ci fossero differenze significative tra donne e uomini per quanto riguarda la maggior parte delle variabili analizzate, come previsto,³⁴ gli uomini hanno presentato una forza muscolare della parte inferiore del corpo ed una resistenza aerobica significativamente maggiori. Le differenze di genere possono peraltro essere spiegate dalla cospicua differenza nelle dimensioni del campione tra i gruppi (Tabella I). In aggiunta, Smee *et al.* (2012) hanno riferito che i partecipanti di sesso maschile avevano una forza muscolare della parte inferiore del corpo maggiore rispetto alle donne.³⁵ Analogamente, Zoeller (2008) ha riferito che la resistenza aerobica negli uomini anziani era maggiore rispetto a quella esibita dalle donne.³⁶

Nonostante vari fattori di rischio possano portare a cadute, la maggior parte della letteratura esistente mostra, in maniera non dissimile al qui presente studio, che le persone con una PA più elevata sono caratterizzate da un rischio e un'incidenza di cadute più bassi.³⁷ Diversi ricercatori hanno riferito che la

prevent and reduce the incidence of falls.^{11, 15, 38} It is of notice that the present study used objective measures of physical activity.

Moreover, the observed association of PA with functional fitness components in both genders observed in the present study was also confirmed by others.³⁹⁻⁴¹ Probably, PA reduces fall risk, because it counteracts the age-related decline in physical fitness⁴² and improves the individual's capacity to perform every-days tasks without fatigue.^{43, 44}

Besides, the present study found that age was positively related to lower PA as in another study.²² Accordingly, different studies have demonstrated a decline in daily physical activity as people age.^{14, 45} Additionally, the present study results also showed that higher PA correlated significantly and positively with longer 6-m W. This result is in line with Alves *et al.* who reported in a sample with similar characteristics to the present study sample, strong correlations of PA and 6-m W in 33 asymptomatic elderly ($r = 0.515$, $P < 0.0001$).⁴⁶

Proceeding with the statistical analysis and to investigate multivariate relationships among predictors of FR, an inferential stepwise MLR test was used in the present study. In line with the study of Cho *et al.*, the present study data showed that lower FR correlated significantly and positively with longer 6-m W and negatively with faster 8-FUG, probably related with muscular-skeletal factors, particularly in lower-body strength.⁴⁷ In the same line of investigation, other studies observed a high correlation between FR and mobility/balance tests. Despite using another evaluation method, Timed Up-and-Go test (TUG), Chertan *et al.* found a high correlation between POMA and TUG in elderly adult.²⁸

Regarding the relative weight of physical fitness variables contributing to the variation in FR for the MLR model, R^2 explained about 48.7% of the relationship between 8-FUG (46.0%) and 30-s CS (14.1%) as predictor variables independently, and =49% when associated. This finding is highly significant ($P < 0.001$) and accounts for a large proportion (=50%) of FR variability, as described by Rikli and Jones, and that it is of major importance to act on motor agility/dynamic balance and lower body strength to reduce FR.²¹ The association of FF components and FR have been also previously studied by Amaro in other populations with similar age and characteristics. The present study has achieved a better model sum-

PA, a partire dall'attività fisica nel tempo libero fino ad arrivare all'attività fisica quotidiana di intensità moderata o vigorosa, negli adulti anziani, è in grado di prevenire e ridurre significativamente l'incidenza delle cadute.^{11, 15, 38} È da notare che il presente studio ha usato misure oggettive di attività fisica.

Inoltre, la correlazione esistente fra la PA e i parametri di fitness funzionale in entrambi i sessi riscontrata in questo studio è stata confermata anche da altri ricercatori.³⁹⁻⁴¹ Con ogni probabilità, PA riduce il rischio di cadute, perché contrasta il declino della forma fisica legato all'età⁴² e migliora la capacità dell'individuo di svolgere le attività di base quotidiane senza fatica.^{43, 44}

Inoltre, il qui presente studio ha constatato che l'età è risultata positivamente correlata a una PA più bassa come accaduto in un altro studio.²² Di conseguenza, diversi studi hanno dimostrato un declino dell'attività fisica quotidiana con l'aumentare dell'età.^{14, 45}

Inoltre, i risultati del presente studio hanno anche indicato che una PA più alta presentava una correlazione statisticamente significativa e positiva con una 6-m W più lunga. Questo risultato è in linea con Alves *et al.* I quali hanno rilevato in un campione con caratteristiche simili a quello del nostro studio, forti correlazioni tra PA e 6-mW in 33 anziani asintomatici ($r = 0.515$, $P < 0.0001$).⁴⁶

Procedendo con l'analisi statistica e allo scopo di indagare le relazioni multivariate tra i predittori di FR, nel presente studio si è ricorso alla regressione lineare multipla inferenziale stepwise (MLR). In linea con lo studio di Cho *et al.*, i dati da noi ottenuti hanno mostrato che una FR più bassa era correlata in maniera positiva e significativa con tempi di 6-m W più lunghi e negativamente con tempi più veloci nel 8-FUG, probabilmente a causa della relazione con fattori muscolo-scheletrici, in particolare per quanto riguarda la forza esercitata della parte inferiore del corpo.⁴⁷ Lungo la stessa linea di indagine, altri studi hanno osservato una elevata correlazione tra FR e prove di mobilità/equilibrio. Nonostante l'utilizzo di un diverso metodo di valutazione, il Timed Up-and-Go test (TUG), Chertan *et al.* hanno riscontrato un'elevata correlazione tra POMA e TUG in individui adulti anziani.²⁸

Per quanto riguarda il peso relativo delle variabili di fitness fisico che contribuiscono alla variazione di FR per il modello MLR, R^2 spiegava circa il 48,7% della relazione tra 8-FUG (46,0%) e 30-s CS (14,1%) come variabili predittive indipendentemente, e =49% se associate. Questo risultato è altamente significativo ($P < 0.001$) e rappresenta una larga fetta (=50%) della variabilità della FR, come descritto da Rikli e Jones, e corrobora la tesi secondo la quale è di grande importanza agire sull'agilità motoria/equilibrio dinamico e sulla forza della parte inferiore del corpo per ridurre la FR.²¹ Il legame fra i parametri FF e FR è stata precedentemente studiata anche da Amaro in altre popolazioni con

mary result (49%) in predicting FR variability compared to Amaro's study that only explained 37% of FR variability, based only on functional mobility.⁴⁸

Other investigators have also presented models of prediction of FR, based on objective instruments like Get-up-and-go test, and rising from chair ability, gender, depression, confusion/disorientation states (Mini-Mental Examination), and drug prescriptions like antiepileptics, benzodiazepines, in hospitalized patients.⁴⁹

The present study presents also a substantial model summary results in predicting FR variability when gender stratification was performed. The models achieved 45.0% in the female sample but only 23.6% in the male sample. The authors did not find any other study with similar model gender stratification, for FR based on the same variables.

Analogous implications were achieved with the gender stratification models, as seen in the total sample model. Once 8-FUG was the only predictor explaining FR variability in both female and male participants, for every second of increase to perform 8-FUG test, the FR score will increase by 0.732 points in female and 0.499 points in male, tending to a more menacing FR score. The present study reinforces the relevance of active lifestyles for a better FF and consequently, in the predictors for a lower FR.

Strengths and limitations of the study

The strengths of this study include the use of objective and reliable instruments to monitor PA by accelerometry that provides objective measures of physical activity behaviors that are free of the random and systematic errors associated with self-report. As such, they are believed to provide better assessments for many activities, particularly activities that have proved difficult to measure by self-report.⁵⁰

Nonetheless, this study is not without limitations. Firstly, the sample size was relatively small and was comprised of volunteer subjects that make generalization of the results difficult. Segmenting the sample by gender could also have weakened the robustness of the statistical analysis. Secondly, the cross-sectional design does not permit causality conclusions. Future large-scale trials are required to investigate which factors are more effective on fall risk parameters. Thirdly, data on other potential confounders, such as visual impairment, foot

età e caratteristiche assimilabili. Il presente studio ha ottenuto un migliore risultato del modello riassuntivo (49%) nel predire la variabilità di FR rispetto allo studio di Amaro che era in grado di spiegare solamente il 37% della variabilità di FR, basandosi unicamente sulla mobilità funzionale.⁴⁸

Altri studiosi hanno presentato modelli predittivi della FR basati su svariati indicatori oggettivi quali il test get-up-and-go, l'abilità di alzarsi dalla posizione seduta, il sesso, la depressione, gli stati di confusione/disorientamento (Mini-Mental Examination), e le prescrizioni di farmaci come antiepilettici e benzodiazepine in pazienti ospedalizzati.⁴⁹

Il presente studio ha inoltre fornito una sintesi sostanziale dei risultati dei modelli volti a predire la variabilità di FR quando viene eseguita la stratificazione di genere. I modelli hanno raggiunto il 45,0% nel campione femminile ma solo il 23,6% nel campione maschile. Gli autori non hanno trovato nessun altro studio con una stratificazione di genere del modello analoga per FR, basata sulle medesime variabili.

Implicazioni analoghe sono state raggiunte con i modelli di stratificazione di genere, come visto nel modello del campione totale. Una volta che 8-FUG è stato individuato come l'unico predittore che spiega la variabilità di FR sia nelle partecipanti femminili che maschili, per ogni secondo di aumento nell'esecuzione del test 8-FUG, il punteggio FR aumenta di 0,732 punti nelle femmine e di 0,499 punti nei maschi, tendendo ad un punteggio FR più preoccupante. Il presente studio consolida la rilevanza degli stili di vita attivi per una migliore FF e, di conseguenza, nei predittori per una FR inferiore.

Punti di forza e limiti dello studio

Tra i punti di forza di questo studio annoveriamo l'uso di indicatori oggettivi e affidabili per il monitoraggio della PA tramite accelerometria, la quale fornisce misure oggettive dei comportamenti legati all'attività fisica scorse dagli errori casuali e sistematici associati all'autovalutazione. In quanto tali, si ritiene che forniscano valutazioni migliori per molte attività e in particolare per quelle che si sono dimostrate difficili da misurare tramite autovalutazione.⁵⁰

Tuttavia, questo studio non è privo di limitazioni. In primo luogo, la dimensione del campione era relativamente piccola ed era composta da soggetti volontari, il che rende ostica la generalizzazione dei risultati. La segmentazione del campione per sesso inoltre potrebbe aver indebolito la robustezza dell'analisi statistica. In secondo luogo, il disegno trasversale non permette conclusioni di causalità. Si rendono dunque necessari ulteriori studi su larga scala per indagare quali fattori siano più efficaci sui parametri di rischio di caduta. In terzo luogo, non sono stati valutati oggettivamente i dati su altri potenziali confonditori, come ad esempio, tra gli altri, problemi alla vista o problemi ai piedi.

problems, among others, were not objectively assessed. Fourthly, using total time of physical activity, instead of intensity partial times might have prejudiced the results.

Conclusions

This cross-sectional study suggests that lower FR is achieved in younger, fitter and more active participants. Among all the FF components, a better performance in 8-FUG and 30-s SC tests, meaning better motor agility and lower-body strength, both predictors of FR, may decrease FR. However, this prediction is dependent on the gender analysis, being motor agility/dynamic balance more important for women FR than for men FR.

This knowledge is of utmost importance and reinforces the strategy for improving physical activity exercise programs for a population in general, and specifically in the elderly, promoting active ageing with physical activity, in walking and running activities.

Practice implication

These findings will be useful for clinicians that could consider using 8-FUG and 30-s SC scores to categorize high-risk fallers amongst the elderly. Like both risk factors are potentially modifiable, rehabilitation programs designed to reduce FR in the elderly should include exercises to improve mobility, motor agility and dynamic balance as well as muscle strength training.

These findings may aware community of the role of PA, namely balance/coordination and lower muscle strength exercises in fall risk reduction, being useful for clinicians, health practitioners in the primary health care service dealing with patients with balance disorders and for policymakers to reduce the burden of falls.

References/Bibliografia

- 1) Stevens JA. Falls among older adults—risk factors and prevention strategies. *J Safety Res* 2005;36:409–11.
- 2) Beegan L, Messinger-Rapport BJ. Stand by me! Reducing the risk of injurious falls in older adults. *Cleve Clin J Med* 2015;82:301–7.
- 3) Hsieh KL, Roach KL, Wajda DA, Sosnoff JJ. Smartphone technology can measure postural stability and discriminate fall risk in older adults. *Gait Posture* 2019;67:160–5.

- 4) Sterling DA, O'Connor JA, Bonadies J. Geriatric falls: injury severity is high and disproportionate to mechanism. *J Trauma* 2001;50:116–9.
- 5) Pin S, Spini D. Impact of falling on social participation and social support trajectories in a middle-aged and elderly European sample. *SSM Popul Health* 2016;2:382–9.
- 6) Spirduso W, Francis K, McAra P. *Physical Dimensions of Aging*. Second edition. Champaign, IL: Human Kinetics; 2005.
- 7) Ilario M, Vollenbroek-Hutten M, Molloy DW, Menditto E, Iaccarino G, Ekland P.

- Active and Healthy Ageing and Independent Living. *J Aging Res* 2015;2015:542183.
- 8) Lord SR, Stumicks DL. The physiology of falling: assessment and prevention strategies for older people. *J Sci Med Sport* 2005;8:35–42.
- 9) Sallis JE. Age-related decline in physical activity: a synthesis of human and animal studies. *Med Sci Sports Exerc* 2000;32:1598–600.
- 10) Chan BK, Marshall LM, Winters KM, Fulkner KA, Schwartz AV, Orwoll ES. Incident fall risk and physical activity and physical performance among older men.

In quarto luogo, l'utilizzo del tempo totale di attività fisica, invece dei tempi parziali di intensità potrebbe aver pregiudicato i risultati.

Conclusioni

Questo studio cross-section suggerisce che una FR più contenuta è associata a partecipanti più giovani, più in forma e più attivi. Tra tutti i parametri della FF, una migliore performance nelle prove 8-FUG e 30-s SC, ovvero una migliore agilità motoria e forza esercitata dalla parte inferiore del corpo, entrambi predittori della FR, sono in grado di diminuire la FR. Tuttavia, questa previsione dipende dall'analisi di genere, essendo l'agilità motoria/equilibrio dinamico più importante per FR nelle donne che per quella maschile.

Questa informazione è di estrema importanza e può essere utilizzata per consolidare le strategie volte a migliorare i programmi di esercizio dell'attività fisica per la popolazione in generale, e in special modo per gli anziani, promuovendo l'invecchiamento attivo con attività fisica sotto forma di camminata e corsa.

Implicazioni sulla pratica

Questi risultati saranno utili per i medici che lavorano in ambito ospedaliero che potrebbero prendere in considerazione l'ausilio dei punteggi 8-FUG e 30-s SC per individuare e valutare le persone ad alto rischio di caduta tra gli anziani. Poiché entrambi i fattori di rischio sono potenzialmente modificabili, i programmi di riabilitazione progettati per ridurre la FR negli anziani dovrebbero includere esercizi per migliorare la mobilità, l'agilità motoria e l'equilibrio dinamico, nonché l'allenamento della forza muscolare.

Questi risultati possono potenzialmente sensibilizzare la comunità sul ruolo della PA, ossia esercizi di equilibrio/coordination e forza muscolare della parte inferiore del corpo, nella riduzione del rischio di caduta, essendo utili per i medici e gli operatori sanitari operanti all'interno delle strutture di assistenza sanitaria primaria che si occupano di pazienti con disturbi dell'equilibrio e per i policymaker per ridurre le ripercussioni delle cadute.

- the Osteoporotic Fractures in Men Study. *Am J Epidemiol* 2007;165:696-703.
- 11) Heisch KC, Byles JE, Brown WJ. Prospective association between physical activity and falls in community-dwelling older women. *J Epidemiol Community Health* 2008;62:421-6.
 - 12) Boyle PA, Buchman AS, Wilson RS, Bienias JL, Bennett DA. Physical activity is associated with incident disability in community-based older persons. *J Am Geriatr Soc* 2007;55:195-201.
 - 13) O'Sullivan M, Blake C, Cunningham C, Boyle G, Finucane C. Correlation of accelerometer with clinical balance tests in older fallers and non-fallers. *Age Ageing* 2009;38:308-13.
 - 14) Buchner DM, Rillamas-Sun E, Di C, LaMonte MJ, Marshall SW, Hunt J, et al. Accelerometer-Measured Moderate to Vigorous Physical Activity and Incidence Rates of Falls in Older Women. *J Am Geriatr Soc* 2017;65:2480-7.
 - 15) Caban-Martinez AJ, Courtney TK, Chang WR, Lombardi DA, Huang YH, Brennan MJ, et al. Leisure-Time Physical Activity, Falls, and Fall Injuries in Middle-Aged Adults. *Am J Prev Med* 2015;49:888-901.
 - 16) Anderson N, Newhouse ME, Ainsworth BE, Nygaard IE, Egger MJ, Shaw JM. "How Hard Could It Be?" A Descriptive Analysis of Errors Made on a Validated Lifetime Physical Activity Questionnaire. *J Phys Act Health* 2015;12:588-94.
 - 17) Simpson K, Parker B, Capizzi J, Thompson P, Clarkson P, Freedson P, et al. Validity and reliability question 8 of the Paffenbarger Physical Activity Questionnaire among healthy adults. *J Phys Act Health* 2015;12:116-23.
 - 18) Liao Y, Hsu HH, Shibata A, Ishii K, Koohsari MJ, Oka K. Associations of total amount and patterns of objectively measured sedentary behavior with performance-based physical function. *Prev Med* 2018;12:128-34.
 - 19) World Health Organization. Ethical issues in Patient Safety Research - Interpreting existing guidance. WHO Library Cataloguing-in-Publication Data. Geneva, Switzerland: World Health Organization; 2013.
 - 20) Egerton T, Paterson K, Helbostad JL. The Association Between Gait Characteristics and Ambulatory Physical Activity in Older People: A Cross-Sectional and Longitudinal Observational Study Using Generation 100 Data. *J Aging Phys Act* 2017;25:10-9.
 - 21) Rikli R, Jones C. Development and validation of a functional fitness test for community-residing older adults. *J Aging Phys Act* 1999;7:129-61.
 - 22) Wanderley PA, Silva G, Marques E, Oliveira J, Mota J, Carvalho J. Associations between objectively assessed physical activity levels and fitness and self-reported health-related quality of life in community-dwelling older adults. *Qual Life Res* 2011;20:1371-8.
 - 23) Rikli R, Jones C. Senior Fitness Test Manual. Create guidelines for senior group testing. Second edition. Champaign, IL: Human Kinetics; 2014.
 - 24) Marques EA, Baptista F, Santos R, Vale S, Santos DA, Silva AM, et al. Normative functional fitness standards and trends of Portuguese older adults: cross-cultural comparisons. *J Aging Phys Act* 2014;22:126-37.
 - 25) Tinetti ME. Performance-oriented assessment of mobility problems in elderly patients. *J Am Geriatr Soc* 1986;34:119-26.
 - 26) Raiche M, Hébert R, Prince F, Coriveau H. Screening older adults at risk of falling with the Tinetti balance scale. *Lancet* 2000;356:1001-2.
 - 27) Jahantab-Nejad S, Azad A. Predictive accuracy of performance oriented mobility assessment for falls in older adults: A systematic review. *Med J Islam Repub Iran* 2019;33:38.
 - 28) Cherian A. A Study to Evaluate the Correlation between Tinetti Performance Oriented Mobility Assessment (Tinetti POMA) with Functional Reach Test (FRT) and Timed UP and Go Test (TUG) in Assessing Balance among Elderly. *Indian J Physiother Occup Ther* 2016;10:169-73.
 - 29) Sterke CS, Huisman SL, van Bodek EF, Looman CW, van der Cammen TJ. Is the Tinetti Performance Oriented Mobility Assessment (POMA) a feasible and valid predictor of short-term fall risk in nursing home residents with dementia? *Int Psychogeriatr* 2010;22:254-63.
 - 30) Finn J. Stability Performance Assessment Among Subjects of Disparate Balancing Abilities. *Med Sci Sports Exerc* 1999;31:S252.
 - 31) Rivolta MW, Sassi R. Linear-Sigmoidal modelling of accelerometer features and Tinetti score for automatic fall risk assessment. *Annu Int Conf IEEE Eng Med Biol Soc* 2017;2017:3810-3.
 - 32) Hopkins WG. A new view of statistics. A Scale of Magnitudes for Effect Statistics. Melbourne, Australia: Victoria University; 1997.
 - 33) Cohen J. Statistical power analysis for the behavioral sciences. Second edition. Hillsdale, NJ: Lawrence Erlbaum Associates; 1988.
 - 34) Ikezoe T, Asakawa Y, Tsunoda A. The Relationship between Quadriceps Strength and Balance to Fall of Elderly Admitted to a Nursing Home. *J Phys Ther Sci* 2003;15:75-9.
 - 35) Smeed DJ, Anson JM, Waddington GS, Berry HL. Association between Physical Functionality and Falls Risk in Community-Living Older Adults. *Curr Gerontol Geriatr Res* 2012;2012:864516.
 - 36) Zoeller R. Gender Differences in Cardiorespiratory Fitness With Advancing Age: Is the Age-Associated Decline in VO₂max More Rapid in Men and Do Older Men and Women Respond Differently to Exercise? *Am J Lifestyle Med* 2008;2:492-9.
 - 37) Yokoyama T, Demura S, Sato S. Relationships between physical activity, ADL capability and fall risk in community-dwelling Japanese elderly population. *Environ Health Prev Med* 2007;12:25-32.
 - 38) Sherrington C, Tiedemann A, Fairhall N, Close JC, Lord SR. Exercise to prevent falls in older adults: an updated meta-analysis and best practice recommendations. *N S W Public Health Bull* 2011;22:78-83.
 - 39) Langley F, Mackintosh S. Functional Balance Assessment of Older Community Dwelling Adults: A Systematic Review of the Literature. *J Allied Health* 2007;5:1-11.
 - 40) Beach JS, VanSwearingen JM. Physical impairment and disability: relationship to performance of activities of daily living in community-dwelling older men. *Phys Ther* 2002;82:752-61.
 - 41) Beach JS, VanSwearingen JM, Newman AB, Kriska AM. Identifying early decline of physical function in community-dwelling older women: performance-based and self-report measures. *Phys Ther* 2002;82:320-8.
 - 42) Chodsko-Zajko WJ, Proctor DN, Fitzarone Singh MA, Minson CT, Nigg CR, Salem GJ, et al. American College of Sports Medicine. American College of Sports Medicine position stand. Exercise and physical activity for older adults. *Med Sci Sports Exerc* 2009;41:1510-30.
 - 43) Bjerk M, Brøvdal T, Skelton DA, Berglund A. A falls prevention programme to improve quality of life, physical function and falls efficacy in older people receiving home help services: study protocol for a randomised controlled trial. *BMC Health Serv Res* 2017;17:559.
 - 44) Wijnhuizen GJ, de Jong R, Hopman-Rock M. Older persons afraid of falling reduce physical activity to prevent outdoor falls. *Prev Med* 2007;44:260-4.
 - 45) Barnett A, van den Hoek D, Barnett D, Cerin E. Measuring moderate-intensity walking in older adults using the ActiGraph accelerometer. *BMC Geriatr* 2016;16:211.
 - 46) Alves M, et al. Correlation between average number of steps per day and the six-minute walk test in asymptomatic adults and elderly. *Fisioter Pesqui* 2013;20:123-9.
 - 47) Cho BL, Scarpone D, Alexander NB. Tests of stepping as indicators of mobility, balance, and fall risk in balance-impaired older adults. *J Am Geriatr Soc* 2004;52:1168-73.
 - 48) Amaro A. Mobilidade funcional, risco de queda, nível de actividade física e percepção de saúde em indivíduos com 65 ou mais anos. Lisboa: Universidade Nova de Lisboa; 2012.
 - 49) Hendrich AL, Bender PS, Nyhuis A. Validation of the Hendrich II Fall Risk Model: a large concurrent case/control study of hospitalized patients. *Appl Nurs Res* 2003;16:9-21.
 - 50) Matthews CE, Hagströmer M, Pober DM, Bowles HR. Best practices for using physical activity monitors in population-based research. *Med Sci Sports Exerc* 2012;44(Suppl 1):S68-76.

Conflicts of interest.—The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

Funding.—The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: César, A. was supported by CAPES (N° 10143-13-0).

Authors' contributions.—All authors took part in study designing. Paulo C. Carmo and Adjane P. Cesar collected and analyzed the data, and provided data interpretation alongside Joana M. Carvalho. Paulo C. Carmo, Rubim S. Santos, and Joana M. Carvalho prepared the manuscript, and performed the literature search with the help of Adjane P. Cesar. Paulo C. Carmo, Adjane P. Cesar, and Joana M. Carvalho also collected the funds for this study. All authors read and approved the final version of this manuscript.

Acknowledgements.—The authors would like to thank IPDJ ("Mais Ativos, Mais Vividos") and CIAPEL (PCT grant UID/DTP/00617/2019), for assisting with technical support and personal availability during the data collection related to this study.

History.—Manuscript accepted: April 28, 2021. - Manuscript received: November 29, 2020.

Anexo E.

Tabela 3 - Test Items of the Performance Oriented Mobility Assessment (POMA)
That Measure Multiple Dimensions of Balance (Tinetti, 1986)

Test item	Dimensions of balance measured
1. Sitting Balance	Static Balance
2. Rises from chair	Static Balance
3. Attempts to rise	Static Balance
4. Immediate standing Balance (first 5 seconds)	Static Balance
5. Standing Balance	Static Balance
6. Nudged	Static Balance
7. Eyes closed	Static Balance
8. Turning 360 degrees	Dynamic balance
9. Sitting down	Static Balance
10. Indication of gait	Dynamic balance
11. Step length and height	Dynamic balance
12. Foot clearance	Dynamic balance
13. Step symmetry	Dynamic balance
14. Step continuity	Dynamic balance
15. Path	Dynamic balance
16. Trunk	Dynamic balance
17. Walking time	Dynamic balance

Anexo F.

Tabela 4 - Test Items of the Berg Balance Scale (BBS) That Measure Multiple Dimensions of Balance (Berg et al., 1992)

Test item	Dimensions of balance measured
1. Rise from a chair	Dynamic balance
2. Stand unsupported, eyes open	Static Balance
3. Sit unsupported with feet on floor	Static balance in seated position
4. Stand to sit	Dynamic balance
5. Transfers	Dynamic balance
6. Stand unsupported, eyes closed	Sensory organization (use of somatosensory inputs)
7. Stand unsupported, feet together	Static balance in reduced base of support
8. Reach forward with extended arm	Forward limits of stability
9. Pick up object from floor	Dynamic balance
10. Turn to look behind each shoulder	Dynamic balance
11. Turn in full circle to right and left	Dynamic balance, sensory organization
12. Alternate toe touches up onto bench	Dynamic balance
13. Maintain tandem stance	Static balance in reduced base of support
14. Stand one leg	Static balance in reduced base of support

Anexo G.

Tabela 5 – Ten Test Items of the Fullerton Advance Balance (FAB) Scale (Rose, 2003)

Test item	Dimensions of balance measured
1. Stand with feet together, eyes closed	Sensory organization (use of somatosensory inputs)
2. Reach forward to retrieve object	Forward limits of stability
3. Turn in a full circle to right and left	Sensory organization, dynamic balance
4. Step up and over bench	Anticipatory postural control, dynamic balance
5. Tandem walk	Dynamic balance in reduced base of support
6. Stand on one leg, eyes open	Static balance in reduced base of support
7. Stand on foam, eyes closed	Sensory organization (use of vestibular inputs)
8. Two-footed jump for distance	Dynamic balance, whole body motor coordination
9. Walk with head turns	Sensory organization (visual-vestibular inputs)
10. Unexpected backward release	Reactive postural control

Referências/References

- Agostini, J., Han, L., & Tinetti, M. (2004). The relationship between number of medications and weight loss or impaired balance in older adults. *J Am Geriatr Soc*, 52(10), 1719-1723.
- Agostini, J., & Tinetti, M. (2002). Drugs and falls: rethinking the approach to medication risk in older adults. *J Am Geriatr Soc*, 50(10), 1744-1745.
- Ambrose, A., Paul, G., & Hausdorff, J. (2013). Risk factors for falls among older adults: A review of the literature. *Maturitas*, 2013(75), 51-61.
- American College of Sports Medicine, A. (1998). Position stand on exercise and physical activity for older adults. *Med Sci Sports Exerc*, 30(6), 992-1008.
- American Geriatrics Society British Geriatrics Society American Academy of Orthopaedic Surgeons Panel on Falls Prevention, A. (2001). Guideline for the prevention of falls in older persons. *J Am Geriatr Soc*, 2001(49), 664-672.
- Andersen, T., Schmidt, J., Pedersen, M., Krstrup, P., & Bangsbo, J. (2016). The Effects of 52 Weeks of Soccer or Resistance Training on Body Composition and Muscle Function in +65-Year-Old Healthy Males – A Randomized Controlled Trial. *PLoS ONE*, 2016(11(2)), 18.
- Aparicio, V., Ruiz-Cabello, P., Borges-Cosic, M., Andrade, A., Coll-Risco, I., Acosta-Manzano, P., & Soriano-Maldonado, A. (2016). Association of physical fitness, body composition, cardiometabolic markers and adherence to the Mediterranean diet with bone mineral density in perimenopausal women. The Flamenco project. *J Sports Sci*, 2016(34), 1-8.
- Araneda, J., & Solorza, E. (2013). Plantar cutaneous sensibility and dynamic balance in healthy elderly of the community: relational study. *Fisioter Pesq.*, 2013(20(4)), 310-315.
- Arifin, N., Osman, N., & Abas, W. (2014). Intrarater test-retest reliability of static and dynamic stability indexes measurement using the biodex stability system during unilateral stance. *J Appl Biomech*, 30(2), 300-304.

- Assländer, L., Hettich, G., & Mergner, T. (2015). Visual contribution to human standing balance during support surface tilts. *Hum Mov Sci*, 2015(41), 147-164.
- Ayoubi, F., Launay, C., Annweiler, C., & Beauchet, O. (2014). Fear of Falling and Gait Variability in Older Adults: A Systematic Review and Meta-analysis. *J Am Med Dir Assoc*, 2015(16), 14-19.
- Barbosa, A., Souza, C., Chen, J., Francato, D., Caromano, F., Chien, H., Barbosa, E., Greve, J., & Voos, M. (2015). The competition with a concurrent cognitive task affects posturographic measures in patients with Parkinson disease. *Arq Neuropsiquiatr*, 2015(October), 906-912.
- Barnett, A., van den Hoek, D., Barnett, D., & Cerin, E. (2016). Measuring moderate-intensity walking in older adults using the ActiGraph accelerometer. *BMC Geriatrics*, 2016(16), 211.
- Baumgartner, R. (2000). Body Composition in Healthy Aging. *Ann N Y Acad Sci*, 2000 May(904), 437-448.
- Beaudart, C., Rizzoli, R., Bruyère, O., Reginster, J., & Biver, E. (2014). Sarcopenia: burden and challenges for public health. *Arch Public Health*, 2014(72:45), 1-8.
- Begg, D. (2017). Disturbances of thirst and fluid balance associated with aging. *Physiol Behav*, 2017(178), 28-34.
- Bertora, G., Bergmann, J., & Contarino, D. (2006). Bipedestation Studied by Posturography. *Arch Sensol Neurotol Sci Pract - ASN*, 2006(March), 2.
- Biodex Medical Systems, I. (2014). *Balance System SD Operation/Service Manual*. New York: Biodex Medical Systems, Inc.
- Bird, M., Pittaway, J., Cuisick, I., Rattray, M., & Ahuja, K. (2013). Age-Related Changes in Physical Fall Risk Factors: Results from a 3 Year Follow-up of Community Dwelling Older Adults in Tasmania, Australia. *Int. J. Environ. Res. Public Health*, 2013(10), 5989-5997.
- Bjerk, M., Brovold, T., Skelton, D., & Bergland, A. (2017). A falls prevention programme to improve quality of life, physical function and falls efficacy in older people receiving home help services: study protocol for a randomised controlled trial. *Health Serv Res*, 2017(17), 1-9.

- Blaszczyk, J., & Michalski, A. (2006). Ageing and Postural Stability. *Stud Phys Cult Tour*, 13(Supplement), 11-14.
- Bossers, W., Scherder, E., Boersma, F., Hortobágyi, T., van der Woude, L., & van Heuvelen, M. (2014). Feasibility of a Combined Aerobic and Strength Training Program and Its Effects on Cognitive and Physical Function in Institutionalized Dementia Patients. A Pilot Study. *PLoS ONE*, 9(5), e97577.
- Brodie, M., Lovell, N., Canning, C., Menz, H., Delbaere, K., Redmond, S., Latt, M., Sturnieks, D., Menant, J., Smith, S., & Lord, S. (2014). Gait as a Biomarker? Accelerometers Reveal that Reduced Movement Quality while Walking is Associated with Parkinson's Disease, Ageing and Fall Risk. *IEEE J Biomed Health Inform*, 2014(978-1-4244-7929-0/14), 5968-5971.
- Buchner, D., Cress, M., de Lateur, B., Esselman, P., Margherita, A., Price, R., & Wagner, E. (1997). The effect of strength and endurance training on gait, balance, fall risk, and health services use in community-living older adults. *J Gerontol Med Sci*, 52A(4), M218-M224.
- Buchner, D., Rillamas-Sun, E., Di, C., LaMonte, M., Marshall, S., Hunt, J., Zhang, Y., Rosenberg, D., Lee, I., Evenson, K., Herring, A., Lewis, C., Stefanick, M., & LaCroix, A. (2017). Accelerometer-Measured Moderate to Vigorous Physical Activity And Incidence Rates of Falls in Older Women. *J Am Geriatr Soc*, 2017(65(11)), 2480-2487.
- Caban-Martinez, A., Courtney, T., Chang, W., Lombardi, D., Huang, Y., Brennan, M., Perry, M., Katz, J., Christiani, D., & Verma, S. (2015). Leisure-Time Physical Activity, Falls, and Fall Injuries in Middle-Aged Adults. *Am J Prev Med*, 2015(49(6)), 888-901.
- Cachupe, W., Shifflett, B., Kahanov, L., & Wughalter, E. (2009). Reliability of Biodex Balance System Measures. *Meas Phys Educ Exerc Sci*, 5(2), 97-108.
- Cadore, E., Rodríguez-Manás, L., Sinclair, A., & Izquierdo, M. (2013). Effects of Different Exercise Interventions on Risk of Falls, Gait Ability, and Balance in Physically Frail Older Adults: A Systematic Review. *Rejuven Res*, 16(2), 105-114.

- Cakar, E., Dincer, U., Kiralp, M., Cakar, D., Durmus, O., Kilac, H., Soydan, F. C., Sevinc, S., & Alper, C. (2010). Jumping combined exercise programs reduce fall risk and improve balance and life quality of elderly people who live in a long-term care facility. *Eur J Phys Rehabil Med*, 2010(46), 59-67.
- Carrapatoso, S. (2015). *Relationships of walking at individual, interpersonal and environmental levels among seniors*. Porto: Universidade do Porto. Dissertação de Doutoramento apresentada a Faculdade de Desporto da Universidade do Porto.
- Carrapatoso, S., Cardon, G., Van Dyck, D., Carvalho, J., & Gheysen, F. (2018). Walking as a Mediator of the Relationship of Social Support With Vitality and Psychological Distress in Older Adults. *J Aging Phys Act* 2018(26(3)), 430-437.
- Carrapatoso, S., Silva, P., Purakom, A., Novais, C., Colaço, P., & Carvalho, J. (2017). The Experience of Older Adults in a Walking Program at Individual, Interpersonal, and Environmental Levels. *Act Adapt Aging*, 41(1).
- Castro, P., Kaski, D., Schieppati, M., Furman, M., Arshad, Q., & Bronstein, A. (2019). Subjective stability perception is related to postural anxiety in older subjects. *Gait Posture*, 2019(68), 538-544.
- Chang, K., Chen, S., Lee, H., Ching, C., & Huang, C. (2012). A wireless accelerometer-based body posture stability detection system and its application for meditation practitioners. *Sensors (Basel)*, 12(12), 17620-17632.
- Chang, S., Beason, T., Hunleth, J., & Colditz, G. (2012). A Systematic Review of Body Fat Distribution and Mortality in Older People. *Maturitas*, 2012(July ; 72(3)), 175–191.
- Chang, S., Vaz Fragoso, C., Van Ness, P., Fried, L., & Tinetti, M. (2011). Association between combined interleukin-6 and C-reactive protein levels and pulmonary function in older women: results from the Women's Health and Aging Studies I and II. *J Am Geriatr Soc*, 59(1), 113-119.
- Cho, B., Scarpace, D., & Alexander, N. (2004). Tests of Stepping as Indicators of Mobility, Balance, and Fall Risk in Balance-Impaired Older Adults. *J Am Geriatr Soc*, 52(7), 1168-1173.

- Chodzko-Zajko, W. (1996). The Physiology of Aging: Structural changes and functional consequences. *Quest*, 1996(48), 311-329.
- Chodzko-Zajko, W. (2001). Biological Theories of Aging: Implications for Functional Performance. In B. R. Bonder & B. M. Wagner (Eds.), *Functional Performance in Older Adults* (pp. 28-41). Philadelphia, PA.: F. A. Davis Company.
- Chodzko-Zajko, W., Proctor, D., Singh, M., Minson, C., Nigg, C., Salem, G., & Skinner, J. (2009). American College of Sports Medicine Position Stand Exercise and Physical Activity for Older Adults. *Med Sci Sport Exerc*, 2009(41(7)), 1510-1530.
- Chodzko-Zajko, W., & Ringel, R. (1987). Physiological fitness measures and sensory and motor performance in aging. *Exp Gerontol*, 22(5), 317-328.
- Corbin, C., & Noble, L. (1980). Flexibility. *J Phys Educ Recreat*, 51(6), 23-60.
- Cug, M., & Wikstrom, E. (2014). Learning effects associated with the least stable level of the biodex(R) stability system during dual and single limb stance. *J Sports Sci Med*, 13(2), 387-392.
- Cumming, R., Thomas, M., Szonyi, G., Salkeld, G., O'Neill, E., Westbury, C., & Frampton, G. (1999). Home visits by an occupational therapist for assessment and modification of environmental hazards: A randomised controlled trial. *J Am Geriatr Soc*, 1999(47), 1397-1402.
- Currie, J., Ramsbottom, R., Ludlow, H., Nevill, A., & Gilder, M. (2009). Cardio-respiratory fitness, habitual physical activity and serum brain derived neurotrophic factor (BDNF) in men and women. *Neurosci Lett*, 451(2), 152-155.
- Dalz, M., Śliwicka, E., Huta-Osiecka, A., & Nowak, A. (2016). The role of physical activity in bone metabolism and osteoporosis prevention. *Trends Sport Sci*, 2(23), 63-71.
- Dascal, J., Okazaki, V., & Mauerberg-deCastro, E. (2012). Effects of the anchor system on postural control in older adults. *Rev Bras Cineantropom Desempenho Hum*, 2012(14 (2)), 144-153.
- Davis, J., Bryan, S., Marra, C., Sharma, D., Chan, A., Beattie, B., Graf, P., & Liu-Ambrose, T. (2013). An Economic Evaluation of Resistance Training and

- Aerobic Training versus Balance and Toning Exercises in Older Adults with Mild Cognitive Impairment. . *PLoS ONE*, 8(5), e63031.
- Day, L., Fildes, B., Gordon, L., Fitzharris, M., Flamer, H., & Lord, S. (2002). Randomised factorial trial of falls prevention among older people living in their own homes. *Br Med J*, 2002(325), 128-133.
- Di Nardo, F., Mengarelli, A., Maranesi, E., Burattini, L., & Fioretti, S. (2015). Assessment of the ankle muscle co-contraction during normal gait: A surface electromyography study. *J Electromyogr Kinesiol*, 2015(25), 347-354.
- Dondzila, C., Gennuso, K., Swartz, A., Tarima, S., Lenz, E., Stein, S., Kohl, R., & Strath, S. (2015). Dose-response walking activity and physical function in older adults. *J Aging Phys Act.*, 2015(23), 194-199.
- Drey, M. (2011). Sarcopenia – pathophysiology and clinical relevance. *Wien Med Wochenschr* (2011) 161/17–18: 402–408, 161(17-18), 402-408.
- Escrivães, J. (2015). *Treino multicomponente e treino de força na Terceira Idade*. Porto: Faculdade de Desporto. Dissertação de Mestrado apresentada a Faculdade de Desporto da Universidade do Porto.
- Espinosa, J., Esteve, T., Monzó, A., Abella, C., & Deval, V. (2016). Relationship between training volume and bone mineral density changes in elderly women. *Rev Bras Med Esporte*, 22(3).
- Faber, M., Bosscher, R., Paw, M., & van Wieringen, P. (2006). Effects of Exercise Programs on Falls and Mobility in Frail and Pre-Frail Older Adults: A Multicenter Randomized Controlled Trial. *Arch Phys Med Rehabil*, 87(July), 885-896.
- Ferrara, C., McCrone, S., Brendle, D., Ryan, A., & Goldberg, A. (2004). Metabolic effects of the addition of resistive to aerobic exercise in older men. *Int J Sport Nutr Exerc Metab*, 2004(14), 73-80.
- Ferrari, R., Fuchs, S., Kruehl, L., Cadore, E., Alberton, C., Pinto, R., Radaelli, R., Schoenell, M., Izquierdo, M., Tanaka, H., & Umpierre, D. (2016). Effects of Different Concurrent Resistance and Aerobic Training Frequencies on Muscle Power and Muscle Quality in Trained Elderly Men: A Randomized Clinical Trial. *Aging Dis*, 7(6), 697-704.

- Ferreira, P., & Santana, P. (2003). Percepção de estado de saúde e de qualidade de vida da população activa: contributo para a definição de normas portuguesas. *Qual Vida*, 21(2), 15-30.
- Fiatarone, M., O'Neill, E., Doyle-Ryan, N., Clements, K., Solares, G., Nelson, M., Roberts, S., Kehayias, J., Lipstiz, L., & Evans, W. (1994). Exercise training and nutritional supplementation for physical frailty in the oldest old. *N Engl J Med*, 1994(330), 1769-1775.
- Fosbøl, M., & Zerahn, B. (2015). Contemporary methods of body composition measurement. *Clin Physiol Funct Imaging*, 35(2), 81-97.
- Fried, L., Tangen, C., Walston, J., Newman, A., Hirsch, C., Gottdiener, J., Seeman, T., Tracy, R., Kop, W., Burke, G., McBurnie, M., & for the Cardiovascular Health Study Collaborative Research Group. (2001). Frailty in Older Adults: Evidence for a Phenotype. *Journal of Gerontology: Medical Sciences*, 56A(3), M146-M156.
- Frontera, W., Meredith, C., O'Reilly, K., Knuttgen, H., & Evans, W. (1998). Strength conditioning in older men: Skeletal muscle hypertrophy and improved function. *J App Phys*, 1998(64), 1038-1044.
- Fujimoto, C., Murofushi, T., Chihara, Y., Ushio, M., Sugasawa, K., Yamaguchi, T., Yamasoba, T., & Iwasaki, S. (2009). Assessment of diagnostic accuracy of foam posturography for peripheral vestibular disorders: Analysis of parameters related to visual and somatosensory dependence. *Clin Neurophysiol*, 2009(120), 1408–1414.
- Ge, Y., & Xu, B. (2014). Detecting Falls Using Accelerometers by Adaptive Thresholds in Mobile Devices. *J Comput*, 9(7), 1553-1559.
- Graves, B., Whitehurst, M., & Findley, B. (2006). Physiologic Effects of Aging and Deconditioning. In L. A. Kaminsky, K. A. Bonzheim, C. E. Garber, S. C. Glass, L. F. Hamm, H. W. K. III & A. Mikesky (Eds.), *ACSM's Resource Manual for Guidelines for Exercise Testing and Prescription* (pp. 79-92). Baltimore - USA: Lippincott Williams & Wilkins.
- Grimmer, M., Riener, R., Walsh, C., & Seyfarth, A. (2019). Mobility related physical and functional losses due to aging and disease - a motivation for lower limb exoskeletons. *J NeuroEngineering Rehab*, 2019(16(2)), 1-21.

- Guskiewicz, K., Ross, S., & Marshall, S. (2001). Why the Clinical Test for Sensory Integration of Balance (CTSIB) for concussion baseline balance testing? *J Athl Train*, 2001(1), 4.
- Harris, B. A. (2005). The influence of endurance and resistance exercise on muscle capillarization in the elderly: a review. *Acta Physiol Scand*, 2005(185), 89-97.
- Hawkins, M., Raven, P., Snell, P., Stray-Gundersen, J., & Levine, B. (2007). Maximal Oxygen Uptake as a Parametric Measure of Cardiorespiratory Capacity. *Medicine & Science in Sports & Exercise*, 2007(39(1)), 103-107.
- Heesch, K., Byles, J., & Brown, W. (2008). Prospective association between physical activity and falls in community-dwelling older women. *J Epidemiol Community Health*, 2008(62), 421-426.
- Hill, K., Day, L., & Haines, T. (2014). What factors influence community-dwelling older people's intent to undertake multifactorial fall prevention programs? *Clin Interv Aging*, 2014(9), 2045–2053.
- Hinman, M. (2000). Factors Affecting Reliability of the Biodex Balance System: A Summary of Four Studies. *J Sport Rehab*, 9(3), 240-252.
- Huijben, B., van Schooten, K., van Dieën, J., & Pijnappels, M. (2018). The effect of walking speed on quality of gait in older adults. *Gait Posture*, 2018, 1-20.
- Hwangbo, G., Lee, C., Kim, S., & Kim, H. (2015). The effects of trunk stability exercise and a combined exercise program on pain, flexibility, and static balance in chronic low back pain patients. *J. Phys. Ther. Sci.*, 2015(27), 1153-1155.
- Insel, P., Ross, D., McMahon, K., & Bernstein, M. (2014). *Nutrition* (5 ed.). Burlington, MA: Jones & Bartlett Learning.
- Ishiyama, G. (2009). Imbalance and Vertigo: The Aging Human Vestibular Periphery. *Semin Neurol*, 29(05), 491-499.
- Jiménez-Maldonado, A., Rentería, I., García-Suárez, P., Moncada-Jiménez, J., & Fernando Freire-Royes, L. (2018). The Impact of High-Intensity Interval Training on Brain Derived Neurotrophic Factor in Brain: A Mini-Review. *Front Neurosci*, 2018(14), 1-9.

- Jones, C., & Rikli, R. (2002). Measuring functional fitness of older adults. *J Active Aging*, 2002(March April), 1-7.
- Jung, H.-W., Kim, S.-W., Lim, J.-Y., Kim, K.-W., Jang, H. C., Kim, C.-H., & Kim, K.-i. (2014). Frailty Status Can Predict Further Lean Body Mass Decline in Older Adults. *J Am Geriatr Soc*, 2014(62), 2110–2117.
- Kaminsky, L., Arena, R., Beckie, T., Brubaker, P., Church, T., Forman, D., Franklin, B., Gulati, M., Lavie, C., Myers, J., Patel, M., Piña, I., Weintraub, W., Williams, M., & on behalf of the American Heart Association Advocacy Coordinating Committee, C. O. C. C., And Council On Nutrition, Physical Activity And Metabolism. (2013). A National Registry for Cardiorespiratory Fitness. *Circulation*, 2013(127), 652-662.
- Kaminsky, L., & Dwyer, G. (2006). Body Composition. In L. A. Kaminsky, K. A. Bonzheim, C. E. Garber, S. C. Glass, L. F. Hamm, H. W. K. III & A. Mikesky (Eds.), *ACSM's Resource Manual for Guidelines for Exercise Testing and Prescription* (pp. 195-205). Baltimore - USA: Lippincott Williams & Wilkins.
- Karimi, N., Ebrahimi, I., Kahrizi, S., & Torkaman, G. (2008). Evaluation of postural balance using the biodex balance system in subjects with and without low back pain. *Pak J Med Sci*, 2008(24(3)), 372-377.
- Karuka, A., Silva, J., & Navega, M. (2011). Analysis of agreement of assessment tools of body balance in the elderly. *Rev Bras Fisioter*, São Carlos, 15(n. 6, Nov./Dec. 2011), 460-466.
- Kenney, W., Wilmore, J., & Costill, D. (2012). *Physiology of sport and exercise* (5 ed.). Champaign, IL.: Human Kinetics.
- Kennis, E., Verschueren, S., Bogaerts, A., Van Roie, E., Boonen, S., & Delecluse, C. (2013). Long-Term Impact of Strength Training on Muscle Strength Characteristics in Older Adults. *Arch Phys Med Rehab*, 2013(94), 2054-2060.
- Kerksick, C., Wismann-Bunn, J., Fogt, D., Thomas, A., Taylor, L., Campbell, B., Wilborn, C., Harvey, T., Roberts, M., La Bounty, P., Galbreath, M., Marcello, B., Rasmussen, C., & Kreider, R. (2010). Changes in weight loss, body composition and cardiovascular disease risk after altering

- macronutrient distributions during a regular exercise program in obese women. *Nutr J*, 9(59), 19.
- Key, A., Parry, M., West, M., Asher, R., Jack, S., Duffy, N., Torella, F., & Walker, P. (2017). Effect of β -blockade on lung function, exercise performance and dynamic hyperinflation in people with arterial vascular disease with and without COPD. *BMJ Open Resp Res*, 2017(4:e000164), 1-7.
- Kilby, M., Molenaar, P., Slobounov, S., & Newell, K. (2017). Real-time visual feedback of COM and COP motion properties differentially modifies postural control structures. *Exp Brain Res*, 2017(235), 109–120.
- Kim, E., Park, S., & Kwon, Y. (2008). The Effects of Combined Exercise on Functional Fitness and Risk Factors of Metabolic Syndrome in the Older Women. *Jpn. J. Phys. Fitness Sports Med.*, 2008(57), 207-216.
- Klenk, J., Kerse, N., Rapp, K., Nikolaus, T., Becker, C., Rothenbacher, D., Peter, R., & Denking, M. (2015). Physical Activity and Different Concepts of Fall Risk Estimation in Older People—Results of the ActiFE-Ulm Study. *PLoS ONE*, 2015(6), 1-11.
- Klika, B., & Jordan, C. (2013). High-intensity circuit training using body weight: Maximum Results With Minimal Investment. *ACSM's Health Fitness J*, 2013(17(3)), 8-13.
- Koeppen, B., & Stanton, B. (2008). *Berne and Levy Physiology* (6 ed.). Philadelphia, PA.: Mosby Elsevier
- Kuk, J., Saunders, T., Davidson, L., & Ross, R. (2009). Age-related changes in total and regional fat distribution. *Ageing Res Rev*, 2009(8), 339-348.
- Lawa, L., Barnett, F., Yaua, M., & Gray, M. (2014). Effects of combined cognitive and exercise interventions on cognition in older adults with and without cognitive impairment: A systematic review. *Ageing Res Rev*, 2014(15), 61-75.
- Leite, T., Teixeira, A. S., Saavedra, F., Leite, R., Rhea, M., & Simão, R. (2015). Influence of Strength and Flexibility Training, Combined or Isolated, on Strength and Flexibility Gains. *J Strength Cond Res*, 29(4), 1083-1088.
- Lemmens, J., De Pauw, J., Van Soom, T., Michiels, S., Versijpt, J., van Breda, E., Castien, R., & De Hertogh, W. (2019). The effect of aerobic exercise

- on the number of migraine days, duration and pain intensity in migraine: a systematic literature review and meta-analysis. *J Headache Pain*, 2019(20:16), 1-9.
- Lexell, J. (2000). Strength training and muscle hypertrophy in older men and women. *Top Geriatr Rehabil*, 2000(15), 41-46.
- Liao, Y., Hsu, H., Shibata, A., Ishii, K., Koohsari, M., & Oka, K. (2018). Associations of total amount and patterns of objectively measured sedentary behavior with performance-based physical function. *Prev Med Rep*, 2018(12), 128-134.
- Lobo, A., Carvalho, J., & Santos, P. (2010). Effects of Training and Detraining on Physical Fitness, Physical Activity Patterns, Cardiovascular Variables, and HRQoL after 3 Health-Promotion Interventions in Institutionalized Elders. *Int J Fam Med*, 2010(Article ID 486097), 10.
- Lou, C., Pang, C., Jing, C., Wang, S., He, X., Liu, X., Huang, L., Lin, F., Liu, X., & Wang, H. (2018). Dynamic Balance Measurement and Quantitative Assessment Using Wearable Plantar-Pressure Insoles in a Pose-Sensed Virtual Environment. *Sensors*, 2018(18), 4193.
- Maffei, G., Herreros, I., Sanchez-Fibla, M., Friston, K., & Verschure, P. (2017). The perceptual shaping of anticipatory actions. *P Roy Soc B: Biol Sci*, 284(1869), 1-9.
- Mahoney, J., Dumas, K., & Holtzer, R. (2015). Visual-Somatosensory Integration is Linked to Physical Activity Level in Older Adults. *Multisens Res*, 2015(28), 11-29.
- Mahoney, J., Glysch, R., Guilfoyle, S., Hale, L., & Katcher, M. (2005). Trends, Risk Factors, and Prevention of Falls in Older Adults in Wisconsin. *Wis Med J*, 104(1), 22-28.
- Marques, E., Carvalho, J., & Mota, J. (2011). *Exercise training, Bone and Aging. Evidence from different impact loading exercise interventions on age-related bone loss*. Porto: Universidade do Porto. Dissertação de Doutoramento apresentada a Faculdade de Desporto da Universidade do Porto.

- Marques, E., Figueiredo, P., Harris, T., Wanderley, F., & Carvalho, J. (2016). Are resistance and aerobic exercise training equally effective at improving knee muscle strength and balance in older women? *Arch Gerontol Geriatr.*, 2016(Oct 11), 106-112.
- Marques, E., Mota, J., Machado, L., Sousa, F., Coelho, M., Moreira, P., & Carvalho, J. (2011). Multicomponent Training Program with Weight-Bearing Exercises Elicits Favorable Bone Density, Muscle Strength, and Balance Adaptations in Older Women. *Calcif Tissue Int*, 2011(88), 117-129.
- Martin, M., Silleras, B., Selva, L., Ortega, S., Rodriguez, L., & Río, M. (2015). Bioimpedance vector analysis and conventional bioimpedance to assess body composition in older adults with dementia. *Nutrition*, 2015(31), 155–159.
- Matarese, M., Ivziku, D., Bartolozzi, F., Piredda, M., & de Marinis, M. (2014). Systematic review of fall risk screening tools for older patients in acute hospitals. *J Adv Nurs*, 2015(71(6)), 1198-1209.
- McMahon, S., Wyman, J., Belyea, M., Shearer, N., Hekler, E., & Fleury, J. (2016). Combining Motivational and Physical Intervention Components to Promote Fall-Reducing Physical Activity Among Community-Dwelling Older Adults: A Feasibility Study. *Am J Health Promot*, 30(8)(2168-6602 (Electronic)), 638-644.
- Mertz, K., Lee, D. S., Sui, X., Powell, K., & Blair, S. (2010). Falls Among Adults The Association of Cardiorespiratory Fitness and Physical Activity with Walking-Related Falls. *Am J Prev Med*, 2010(39(1)), 15-24.
- Mitchell, R., Lord, S., Harvey, L., & Close, J. (2014). Associations between obesity and overweight and fall risk, health status and quality of life in older people. *Aust NZ J Public Health*, 2014(38), 13-18.
- Mitchell, W., Williams, J., Atherton, P., Larvin, M., Lund, J., & Narici, M. (2012). Sarcopenia, dynapenia, and the impact of advancing age on human skeletal muscle size and strength; a quantitative review. *Front Physiol*, 3(260), 1-18.

- Moreira, I. (2013). *Envelhecimento Activo e Bem-sucedido*. Porto: Dissertação de Mestrado apresentada a Instituto Superior de Serviço Social do Porto.
- Morley, J. (2015). Dehydration, Hypernatremia, and Hyponatremia. *Clin Geriatr Med*, 2015(31), 389–399.
- Murphy, T., Agostini, J., Van Ness, P., Peduzzi, P., Tinetti, M., & Allore, H. (2008). Assessing multiple medication use with probabilities of benefits and harms. *J Aging Health*, 20(6), 694-709.
- Nana, A., Slater, G., Hopkins, W., & Burke, L. (2012). Effects of daily activities on dual-energy X-ray absorptiometry measurements of body composition in active people. *Med Sci Sports Exerc*, 44(1), 180-189.
- Nashner, L. (1990). Dynamic posturography in the diagnosis and management of dizziness and balance disorders. *Neurol Clin*, 1990(2), 331-349.
- Nevill, A., Ramsbottom, R., Nevill, M., Newport, S., & Williams, C. (2008). The relative contributions of anaerobic and aerobic energy supply during track 100-, 400- and 800-m performance. *J Sports Med Phys Fitness*, 48(2), 138-142.
- Nguyen, H., Mirza, F., Naeem, M., & Baig, M. (2018). Falls management framework for supporting an independent lifestyle for older adults: a systematic review. *Aging Clin Exp Res*, 2018(30), 1275–1286.
- Oliveira, L., Mattos, R., Castro, J., Barbosa, J., Chame, F., & Vale, R. (2017). Effect of supervised physical exercise on flexibility of fibromyalgia patients. *Rev Dor. São Paulo*, 2017(18), 2.
- Orwoll, E., Fino, N., Gill, T., Cauley, J., Strotmeyer, E., Ensrud, K., Kado, D., Barrett-Connor, E., Bauer, D., Cawthon, P., & Lapidus, J. (2019). The Relationships Between Physical Performance, Activity Levels, and Falls in Older Men. *J Gerontol A Biol Sci Med Sci*, 2019(74(9)), 1475-1483.
- Özdemir, A., & Barshan, B. (2014). Detecting Falls with Wearable Sensors Using Machine Learning Techniques. *Sensors*, 2014(14), 10691-10708.
- Palm, H., Strobel, J., Achatz, G., von Luebken, F., & Friemert, B. (2009). The role and interaction of visual and auditory afferents in postural stability. *Gait Posture*, 2009(30), 328–333.

- Parraca, J., Olivares, P., Carbonell-Baeza, A., Aparicio, V., Adsuar, J., & Gusi, N. (2011). Test-Retest reliability of Biodex Balance SD on physically active old people. *J Hum Sport Exerc*, 6(2), 444-451.
- Peeters, G., Van Schoor, N., & Lips, P. (2009). Fall risk: the clinical relevance of falls and how to integrate fall risk with fracture risk. . *Best Pract Res Clin Rheumatol*, 23(6), 797-804.
- Pin, S., & Spini, D. (2016). Impact of falling on social participation and social support trajectories in a middle-aged and elderly European sample. *SSM - Popul Health*, 2016(2), 382-289.
- Powers, S., & Howley, E. (2012). *Exercise Physiology: Theory and Application to Fitness and Performance* (8 ed.). New York: McGraw-Hill.
- Pynoos, J., Sabata, D., Abernethy, G., Alley, D., Nishita, C., & Overton, J. (2003). Prevention of falls at home: Home and environmental modifications. In C. California Blueprint Fall Prevention (Ed.), *Prevention of falls in older Californians*. Sacramento, CA.: California Blueprint Fall Prevention Conference.
- Rall, L., Meydani, S., Kehayias, J., Dawson-Hughes, B., & Roubenoff, R. (1996). The Effect of Progressive Resistance Training in Rheumatoid Arthritis Increased Strength Without Changes in Energy Balance or Body Composition. *Arthritis Rheum*, Vol. 39(No. 3, March), 415-426.
- Ramírez-Vélez, R., Hernandez, A., Castro, K., Tordecilla-Sanders, A., González-Ruíz, K., Correa-Bautista, J. E., Izquierdo, M., & García-Hermoso, A. (2016). High Intensity Interval- vs Resistance or Combined- Training for Improving Cardiometabolic Health in Overweight Adults (Cardiometabolic HIIT-RT Study): study protocol for a randomised controlled trial. *Trials*, 2016(17:298), 1-14.
- Rath, R., & Wade, M. G. (2017). The Two Faces of Postural Control in Older Adults: Stability and Function. *EBioMedicine*, 2017(21), 5-6.
- Remaud, A., Thuong-Cong, C., & Bilodeau, M. (2016). Age-Related Changes in Dynamic Postural Control and Attentional Demands are Minimally Affected by Local Muscle Fatigue. *Front. Aging Neurosci.*, 7(257), 1-13.

- Ribeiro, T. V. (2009). *Estudo Do Equilíbrio Estático E Dinâmico Em Indivíduos Idosos*. Porto: Universidade do Porto. Dissertação de Mestrado apresentada a Faculdade de Desporto
- Riebe, D. (2014). Behavioral Theories and Strategies for Promoting Exercise. In L. S. Pescatello, R. Arena, D. Riebe & P. D. Thompson (Eds.), *ACSM's Guidelines for Exercise Testing and Prescription* (pp. 355-382). Baltimore: Wolters Kluwer Health - Lippincott Williams & Wilkins.
- Rispens, S., van Schooten, K., Pijnappels, M., Daffertshofer, A., Beek, P., & van Dieën, J. (2015). Identification of Fall Risk Predictors in Daily Life Measurements: Gait Characteristics' Reliability and Association With Self-reported Fall History. *Neurorehabil Neural Repair*, 29(1), 54-61.
- Rivolta, M., Aktaruzzaman, M., Rizzo, G., Lafortuna, C., Ferrarin, M., Bovi, G., Bonardi, D., & Sassi, R. (2015). Automatic vs. Clinical Assessment of Fall Risk in Older Individuals: a Proof of Concept. *J Biomed Health*, 2015(978-1-4244-9270-1/15), 6935-6938.
- Rivolta, M., Aktaruzzamana, M., Rizzo, G., Lafortuna, C., Ferrarin, M., Bovi, G., Bonardi, D., Caspani, A., & Sassi, R. (2018). Evaluation of the Tinetti score and fall risk assessment via accelerometry-based movement analysis. *Artif Intelli Med*, 2018(08), 1-10.
- Rosario, J., Martins, N., Peixinho, C., & Oliveira, L. (2017). Effects of Functional Training and Calf Stretching on Risk of Falls in Older People: A Pilot Study. *J Aging Phys Act*, 2017(25), 228-233.
- Rose, C. (1972). The measurement of social age. *J Aging Hum Dev*, 1972(3), 153-168.
- Rose, D. (2003). *Fallproof. A comprehensive balance and mobility program*. Champaign, IL: Human Kinetics.
- Rose, D. (2005). Balance, Posture, and Locomotion. In W.W. Spirduso, K.L. Francis & P. G. MacRae (Eds.), *Physical dimensions of aging* (2 ed., pp. 374). Champaign, IL: Human Kinetics.
- Rose, D., Jones, C., & Lucchese, N. (2002). Predicting the Probability of Falls in Community- Residing Older Adults Using the 8-Foot Up-and-Go: A New

- Measure of Functional Mobility. *Journal of Aging and Physical Activity*, 2002(10), 466-475.
- Rossi-Izquierdo, M., Santos-Pérez, S., Faraldo-García, A., Vaamonde-Sánchez-Andrade, I., Gayoso-Diz, P., Del-Río-Valeiras, M., Lirola-Delgado, A., & Soto-Varela, A. (2016). Impact of obesity in elderly patients with postural instability. *Aging Clin Exp Res*, 2016(28), 423-428.
- Rothney, M., Brychta, R., Schaefer, E., Chen, K., & Skarulis, M. (2009). Body Composition Measured by Dual-energy X-ray Absorptiometry Half-body Scans in Obese Adults. *Obesity*, 17(6), 1281-1286.
- Rubenstein, L., Josephson, K., Trueblood, P., Loy, S., Harker, J., Pietruska, F., & Robbins, A. (2000). Effects of A Group Exercise Program Strenght, Mobility and Falls Among Fall-Prone Elderly Men. *J Gerontol*, 55A(6), 317-321.
- Saito, E., Ueki, S., Yasuda, N., Yamazaki, S., & Yasumura, S. (2014). Risk factors of functional disability among community-dwelling elderly people by household in Japan: a prospective cohort study. *BMC Geriatr*, 14, 9.
- Santos, C., Dantas, E., & Moreira, M. (2011). Correlation of physical aptitude; functional capacity, corporal balance and quality of life (QoL) among elderly women submitted to a post-menopausal physical activities program. *Arch Gerontol Geriatr*, 2011(53), 344-349.
- Sardinha, L., Andersen, L., Anderssen, S., Quiterio, A., Ornelas, R., Froberg, K., Riddoch, C., & Ekelund, U. (2008). Objectively measured time spent sedentary is associated with insulin resistance independent of overall and central body fat in 9- to 10-year-old Portuguese children. *Diabetes Care*, 31(3), 569-575.
- Sardinha, L., Santos, D., Silva, A., Baptista, F., & Owen, N. (2014). Breaking-up Sedentary Time Is Associated With Physical Function in Older Adults. *J Gerontol Med Sci*, 2014, 1-6.
- Schoene, D., Valenzuela, T., Lord, S., & de Bruin, E. (2014). The effect of interactive cognitive-motor training in reducing fall risk in older people: a systematic review. *BMC Geriatrics*, 2014(14), 107.

- Seabra, A., Katzmarzyk, P., Carvalho, M., Seabra, A., Coelho-E-Silva, M., Abreu, S., Vale, S., Póvoas, S., Nascimento, H., Belo, L., Torres, S., Oliveira, J., Mota, J., Santos-Silva, A., Rêgo, C., & Malina, R. (2016). Effects of 6-month soccer and traditional physical activity programmes on body composition, cardiometabolic risk factors, inflammatory, oxidative stress markers and cardiorespiratory fitness in obese boys. *J Sports Sci*, 2016(2), 10.
- Sherrington, C., Tiedemann, A., Fairhall, N., Close, J., & Lord, S. (2011). Exercise to prevent falls in older adults: an updated meta-analysis and best practice recommendations. *N S W Public Health Bull*, 22((3–4)), 78-83.
- Shimada, H., Obuchi, S., Furuna, T., & Suzuki, T. (2004). New intervention program for preventing falls among frail elderly people: the effects of perturbed walking exercise using a bilateral separated treadmill. *Am J Phys Med Rehabil*, 83(7), 493-499.
- Shumway-Cook, A., & Woollacott, M. (2001). *Motor Control. Theory and practical applications*. Philadelphia: Lippincott Williams & Wilkins.
- Sienko, K., Seidler, R., Carender, W., Goodworth, A., Whitney, S., & Peterka, R. (2018). Potential Mechanisms of Sensory Augmentation Systems on Human Balance Control. *Front Neurol*, 2018(9), 944.
- Slee, A., Birch, D., & Stokoe, D. (2015). Bioelectrical impedance vector analysis, phase-angle assessment and relationship with malnutrition risk in a cohort of frail older hospital patients in the United Kingdom. *Nutrition*, 2015(31), 132–137.
- Smee, D., Anson, J., Waddington, G., & Berry, H. (2012). Association between Physical Functionality and Falls Risk in Community-Living Older Adults. *Curr Geront Geriat Res*, 2012, 1-6.
- Soares-Miranda, L., Sandercock, G., Vale, S., Santos, R., Abreu, S., Moreira, C., & Mota, J. (2012). Metabolic syndrome, physical activity and cardiac autonomic function. *Diabetes Metab Res Rev*, 28(4), 363-369.
- Sousa, M., Carvalho, P., Teixeira, V., & Soares, J. (2012). Sarcopénia, músculo e nutrição. *Rev Port Ciênc Desporto*, 2012(2), 101-112.

- Sousa, N., Mendes, R., Silva, A., & Oliveira, J. (2017). Combined exercise is more effective than aerobic exercise in the improvement of fall risk factors: a randomized controlled trial in community-dwelling older men. *Clin Rehabil*, 31(4), 478–486.
- Sparrow, D., DeAngelis, T., Hendron, K., Thomas, C., Saint-Hilaire, M., & Ellis, T. (2016). Highly Challenging Balance Program Reduces Fall Rate in Parkinson Disease. *J Neurol Phys Ther*, 40(January 2016), 24-30.
- Spiriduso, W., Francis, K., & Mcrae, P. (2005). *Physical Dimensions of Aging* (2 ed.). Champaign, IL: Human Kinetics.
- Stavropoulos-Kalinoglou, A., Metsios, G., Panoulas, V., Douglas, K., Nevill, A., Jamurtas, A., Kita, M., Koutedakis, Y., & Kitas, G. (2009). Associations of obesity with modifiable risk factors for the development of cardiovascular disease in patients with rheumatoid arthritis. *Ann Rheum Dis*, 68(2), 242-245.
- Stavropoulos-Kalinoglou, A., Metsios, G., Panoulas, V., Nevill, A., Jamurtas, A., Koutedakis, Y., & Kitas, G. (2009). Underweight and obese states both associate with worse disease activity and physical function in patients with established rheumatoid arthritis. *Clin Rheumatol*, 28(4), 439-444.
- Stegeman, I., Otte-Trojel, T., Costongs, C., & Considine, J. (2012). Healthy and active ageing. EuroHealthNet. . *EuroHealthNet Healthy Ageing* Consult. 12/12/2018, disponível em <http://www.healthyageing.eu/sites/www.healthyageing.eu/files/featured/Healthy%20and%20Active%20Ageing.pdf>
- Stevens, J. (2005). Falls among older adults-risk factors and prevention strategies. *J Safety Res*, 2005(36), 409 – 411.
- Stewart, K. J. (2004). Role of exercise training on cardiovascular disease in persons who have type 2 diabetes and hypertension. *Cardiol Clin*, 22(4), 569-586.
- Strait, J., & Lakatta, E. (2012). Aging-associated cardiovascular changes and their relationship to heart failure. *Heart Fail Clin*, 2012(January ; 8(1)), 143–164.

- Strath, S., Kaminsky, L., Ainsworth, B., Ekelund, U., Freedson, P., Gary, R., Richardson, C., Smith, D., Swartz, A., & on behalf of the American Heart Association Physical Activity Committee of the Council on Lifestyle and Cardiometabolic Health, E., Cardiac Rehabilitation and Prevention Committee of the Council on Clinical Cardiology, and Council on Cardiovascular and Stroke Nursing. . (2013). Guide to the Assessment of Physical Activity: Clinical and Research Applications A Scientific Statement From the American Heart Association. *Circulation*, 2013(128), 2259–2279.
- Svantesson, U., Babagbemi, B., Foster, L., & Alricsson, M. (2014). Influences on modern multifactorial falls prevention interventions and fear of falling in non-frail older adults: a literature review. *J Clin Med Res.*, 2014(Oct;6(5)), 314-320.
- Tarantino, U., Baldi, J., Scimeca, M., Piccirilli, E., Piccioli, A., Bonanno, E., & Gasbarra, E. (2016). The role of sarcopenia with and without fracture. *Injury*, 2016(August), 8.
- Themudo-Barata, J. (2003). *Mexa-se...Pela Sua Saúde Guia prático de actividade física e emagrecimento para todos* (6.^a ed.). Lisboa: Publicações Dom Quixote.
- Tideiksaar, R. (2001). Falls. In B. W. Bonder, M.B. (Ed.), *Functional performance in older adults* (2nd ed., pp. 267-286). Philadelphia, PA. : F.A.Davis Company.
- Tinetti, M., Gordon, C., Sogolow, E., Lapin, P., & Bradley, E. (2006). Fall-risk evaluation and management: challenges in adopting geriatric care practices. *Gerontologist*, 46(6), 717-725.
- Tinetti, M., Speechley, M., & Ginter, S. (1988). Risk factors for falls among elderly people living in the community. *N Eng J Med*, 1988(319), 1701-1707.
- Tinetti, M. E. (2008). Multifactorial fall-prevention strategies: time to retreat or advance. *J Am Geriatr Soc*, 56(8), 1563-1565.
- Tinetti, M. E., Bogardus, S. T., Jr., & Agostini, J. V. (2004). Potential pitfalls of disease-specific guidelines for patients with multiple conditions. *N Engl J Med*, 351(27), 2870-2874.

- Toraman, A., & Yildirim, N. (2010). The falling risk and physical fitness in older people. *Arch Gerontol Geriatr*, 2010(51), 222-226.
- Turner, B., Navuluri, N., Winkler, P., Vale, S., & Finley, E. (2014). A qualitative study of family healthy lifestyle behaviors of Mexican-American and Mexican immigrant fathers and mothers. *J Acad Nutr Diet*, 114(4), 562-569.
- Verlinden, V., Maksimovic, A., Mirza, S., Ikram, M., Kiefte-de Jong, J., Hofman, A., Franco, O., Tiemeier, H., & van der Geest, J. (2016). The associations of alcohol, coffee and tobacco consumption with gait in a community-dwelling population. *Eur J Clin Nutr*, 2016(70), 116-122.
- Voukelatos, A., Merom, D., Rissel, C., Sherrington, C., Watson, W., & Waller, K. (2011). The effect of walking on falls in older people: the 'Easy Steps to Health' randomized controlled trial study protocol. *BMC Public Health*, 2011(11:888), 1-9.
- Walther, L., & Westhofen, M. (2007). Presbyvertigo-aging of otoconia and vestibular sensory cells. *J Vestib Res*, 2007(17(2-3)), 89-92.
- Weir, J., & Cramer, J. (2006). Principles of Musculoskeletal Exercise Programming. In L. A. Kaminsky, K. A. Bonzheim, C. E. Garber, S. C. Glass, L. F. Hamm, H. W. K. III & A. Mikesky (Eds.), *ACSM's Resource Manual for Guidelines for Exercise Testing and Prescription* (pp. 350-365). Baltimore - USA: Lippincott Williams & Wilkins.
- Wiesmeier, I., Dalin, D., & Maurer, C. (2015). Elderly Use Proprioception Rather than Visual and Vestibular Cues for Postural Motor Control. *Front Aging Neurosci.*, 2015(7: 97.), 97.
- Williams, J., Ballard, M., & Alessi, H. (2005). Aging and Alcohol Abuse: Increasing Counselor Awareness. *Adultspan J*, 4(1), 7-18.
- World Health Organization. (1997). The Heidelberg Guidelines for Promoting Physical Activity Among Older Persons. *J Aging Phys Act* 5(1), 2-8.
- World Health Organization. (2002). *Active Ageing - A Policy Framework* (Vol. 2002). Geneva, Switzerland: World Health Organization.
- World Health Organization. (2007). *WHO global report on falls prevention in older age* (Vol. 1). Geneva: World Health Organization.

- World Health Organization. (2010). *Global recommendations on physical activity for health*. Geneva, Switzerland: World Health Organization.
- World Health Organization. (2011). *Standards and Operational Guidance for Ethics Review of Health-Related Research with Human Participants* (Vol. 1). Geneva, Switzerland: World Health Organization.
- World Health Organization. (2013). *Ethical issues in Patient Safety Research - Interpreting existing guidance* (Vol. 1). Geneva, Switzerland: World Health Organization.
- World Health Organization. (2015). *World Report on ageing and health*. Geneva, Switzerland: World Health Organization.
- Wouters-Adriaens, M., & Westerterp, K. (2006). Basal metabolic rate as a proxy for overnight energy expenditure: the effect of age. *Br J Nutr*, 2006(95), 1166-1170.
- Yaffe, K., Barnes, D., Nevitt, M., Lui, L., & Covinski, K. (2001). A prospective study of physical activity and cognitive decline in elderly women: Women who walk. *Arch Intern Med*, 2001(161), 1703-1708.
- Yokoya, T., Demura, S., & Sato, S. (2007). Relationships between Physical Activity, ADL Capability and Fall Risk in Community-Dwelling Japanese Elderly Population. *Environ Health Prev Med*, 12(January 2007), 25–32.
- Yoo, E., Jun, T., & Hawkins, S. (2010). The effects of a walking exercise program on fall-related fitness, bone metabolism, and fall-related psychological factors in elderly women. *Res Sports Med*, 18(4), 236-250.
- Zhuang, J., Huang, L., Wu, Y., & Zhang, Y. (2014). The effectiveness of a combined exercise intervention on physical fitness factors related to falls in community-dwelling older adults. *Clin Interv Aging*, 9, 131-140.