**UNIVERSIDADE FEDERAL DE MINAS GERAIS**

**Escola de Educação Física, Fisioterapia e Terapia Ocupacional**

**Programa de Pós-Graduação em Ciências do Esporte**

Larissa Oliveira Faria

# EFEITOS DA FADIGA MENTAL NA FUNÇÃO FÍSICA DE INDIVÍDUOS IDOSOS

Belo Horizonte

2024

Larissa Oliveira Faria

# EFEITOS DA FADIGA MENTAL NA FUNÇÃO FÍSICA DE INDIVÍDUOS IDOSOS

Tese apresentada ao Programa de Pós-Graduação em Ciências do Esporte da Escola de Educação Física, Fisioterapia e Terapia Ocupacional da Universidade Federal de Minas Gerais como requisito parcial para obtenção do título de Doutora em Ciências do Esporte.

Orientador: Prof. Dr. Maicon Rodrigues Albuquerque

Belo Horizonte

2024

F224e Faria, Larissa Oliveira
2024 Efeitos da fadiga mental na função física de indivíduos idosos. [manuscrito] / Larissa Oliveira Faria – 2024.
112 f.: il.

Orientador: Maicon Rodrigues Albuquerque

Tese (doutorado) – Universidade Federal de Minas Gerais, Escola de Educação Física, Fisioterapia e Terapia Ocupacional.
Bibliografia: f. 89-101

1. Idosos – Saúde e higiene – Teses. 2. Fadiga mental – Teses. 3. Exercícios físicos para idosos – Teses. I. Albuquerque, Maicon Rodrigues. II. Universidade Federal de Minas Gerais. Escola de Educação Física, Fisioterapia e Terapia Ocupacional. III. Título.

CDU: 796-053.9

**Ficha catalográfica elaborada pela bibliotecária Sheila Margareth Teixeira Adão, CRB 6: n° 2106, da Biblioteca da Escola de Educação Física, Fisioterapia e Terapia Ocupacional da UFMG.**

UNIVERSIDADE FEDERAL DE MINAS GERAIS
ESCOLA DE EDUCAÇÃO FÍSICA, FISIOTERAPIA E TERAPIA OCUPACIONAL
PROGRAMA DE PÓS-GRADUAÇÃO EM CIÊNCIAS DO ESPORTE

**ATA DE DEFESA DE TESE**

**LARISSA OLIVEIRA FARIA**

**Às 7:00 horas do dia 29 de janeiro de 2024**, a comissão examinadora, indicada pelo Colegiado do Programa de Pós-Graduação em Ciências do Esporte, reuniu-se por videoconferência, para julgar, em exame final, a tese intitulada **"Efeitos da fadiga mental na função física de indivíduos idosos"** (em inglês: **"Effects of mental fatigue on the physical function of elderly individuals"**). Abrindo a sessão, o presidente da comissão, Prof. Dr. Maicon Rodrigues Albuquerque (EEFFTO/UFMG), orientador, após dar a conhecer aos presentes o teor das Normas Regulamentares de Defesa do Trabalho Final, passou a palavra para a candidata, que realizou a apresentação da sua tese. Seguiu-se a arguição pelos examinadores, com a respectiva defesa da candidata. Logo após, a comissão se reuniu, sem a presença da candidata e do público, para julgamento e expedição do resultado.

Dr. Maicon Rodrigues Albuquerque (UFMG - orientador)

Dr. Aaron James Coutts (UTS - Austrália)

Dr. Leonardo de Sousa Fortes (UFPB)

Dr. Guilherme Menezes Lage (UFMG)

Dr. Samuel Penna Wanner (UFMG)

Após as indicações, a candidata foi considerada **APROVADA**.

Nada mais havendo a tratar, eu, Prof. Dr. Maicon Rodrigues Albuquerque, presidente da comissão examinadora, dei por encerrada a reunião, da qual, para constar, lavrei a presente Ata, que, lida e aprovada, vai por todos assinada eletronicamente.

**Belo Horizonte, 29 de janeiro de 2024.**

Assinatura dos membros da banca examinadora:

Documento assinado eletronicamente por **Samuel Penna Wanner, Professor do Magistério Superior**, em 29/01/2024, às 09:35, conforme horário oficial de Brasília, com fundamento no art. 3º do Decreto nº 10.543, de 13 de novembro de 2020.

Documento assinado eletronicamente por **Guilherme Menezes Lage**, **Professor do Magistério Superior**, em 29/01/2024, às 09:41, conforme horário oficial de Brasília, com fundamento no art. 5º do Decreto nº 10.543, de 13 de novembro de 2020.

Documento assinado eletronicamente por **Maicon Rodrigues Albuquerque**, **Professor do Magistério Superior**, em 29/01/2024, às 09:45, conforme horário oficial de Brasília, com fundamento no art. 5º do Decreto nº 10.543, de 13 de novembro de 2020.

Documento assinado eletronicamente por **Leonardo de Sousa Fortes**, **Usuário Externo**, em 29/01/2024, às 16:54, conforme horário oficial de Brasília, com fundamento no art. 5º do Decreto nº 10.543, de 13 de novembro de 2020.

Documento assinado eletronicamente por **Aaron James Coutts**, **Usuário Externo**, em 18/02/2024, às 20:33, conforme horário oficial de Brasília, com fundamento no art. 5º do Decreto nº 10.543, de 13 de novembro de 2020.

A autenticidade deste documento pode ser conferida no site https://sei.ufmg.br/sei/controlador_externo.php?acao=documento_conferir&id_orgao_acesso_externo=0, informando o código verificador **2988517** e o código CRC **E61BA821**.

Aos meus pais, Mário e Silnara, pelo amor incondicional que oferecem a mim. Por apoiar todas as minhas decisões, vibrar a cada conquista e sempre me receberem com muito carinho quando as coisas não vão como esperado.

Aos meus irmãos, Lorena e Pedro, por estarem sempre presentes mesmo que estejamos longe fisicamente e por me fazerem rir mesmos nos momentos de dificuldade.

À Isa, por trazer mais alegria as nossas vidas e me relembrar que o único lugar em que nós somos insubstituíveis é em nosso lar!

To Nathan, the love of my life, literally a gift from God, who showed me love from the start for who I am and that, in such a short time of marriage, has already proven that he is with me for better and worse, in sickness and in health!

À Jesus Cristo por, mesmo sem eu merecer, ter me sustentado durante todo o processo e me permitido concluir mais esta etapa.

## AGRADECIMENTOS

Ao professor Maicon por ser muito mais que um orientador, por se preocupar conosco como se fôssemos seus filhos e sempre nos ajudar, mesmo em questões que não teria obrigação de fazê-lo! Por me ensinar muito sobre questões técnicas, mas muito mais sobre ser humano e ter fé mesmo quando o mundo está desabando! Obrigada por me fazer atravessar fronteiras! Obrigada por estes mais de 10 anos de convivência!

Obrigada Thais, Márcio e Amanda por dividirem as alegrias e as angústias da vida de pós-graduando! Com certeza foi muito mais leve com vocês ao meu lado!

Obrigada Nathálya Marinho e João Gabriel por serem inspiração e me ensinarem muito. Quando crescer quero ser que nem vocês!

Obrigada Iasmin, Andressa, Gabi, Lígia, Lucas e Ana Luiza pelo convívio diário! A base vem forte!

Obrigada Karine por sua generosidade ao compartilhar suas experiências e conhecimentos comigo.

Obrigada Fran por cuidar com todo carinho da minha saúde mental!

Obrigada Prof. Samuel por todos os ensinamentos e pela ajuda com o pedido de novação!

Thanks to my Wooley Family, for opening the doors of your home for a stranger very soon because I used to live outside the shire. haha Thanks for your kindness, friendship and prayers! Thanks for making me feel home!

Thanks for all HEBC members for the support and prayers for Nathan and I! Special thanks for Ang that gave us the opportunity to spend some time by ourselves in Engadine.

Thank you, Mike Rennie, for your kind heart and the conversations we had at the gym!

Cristina and Clem, thank you for trusting me with teaching and providing the best conditions for me to excel in my work.

Tina, thank you for all the opportunities you gave me, even though you were already surrounded by a team of experts and you were the newest member in the team.

Mark, thanks for all the sightseeing and academic tips.

Franco, thank you for allowing me to attend your lessons. It was the place where I felt more confident and could show a little bit of my knowledge. Thanks for showing me that it's normal to feel like we don't know anything.

Lee, thanks for inviting your parents to my tests.

Libby, thanks for sharing your strengths and weaknesses at the lessons learned. It made me realize that you're all just people like me. Thanks for letting me help in the Cricket Testing!

Kellie and William, thanks for your help with the recruitment process.

Thanks to all the HDR and Honours Students for your warm welcome. A special shout-out to Will, Sam, Emma, and Josh for accepting me in the motor control group without hesitation.

Caitlyn, thanks for sharing your teaching materials. Max and Will, thanks for allowing me to assist in your tests.

Blake, thanks for organizing all the social activities and never forgetting to include me. Thank you for letting me assist in Max's testing.

Geoff and Antony, thanks for the support during the tests and for answering my participants' calls when I needed help.

Katie, thanks for all your teachings and for reviewing my review protocol.

Rob, thanks for the lunchtime conversations and the social club tour.

Hugh, thanks for always taking the time to explain cultural aspects so that I could better understand the conversations.

Donna, thanks for the warm welcome and for introducing me to the Spit Bridge to Manly walk.

Thanks, Louise, for sharing your knowledge regarding VISA stuffs.

A big thanks to Distinguished Prof. Aaron Coutts for being just Aaron, for giving me opportunities and conditions to work, for being not only a worldwide renowned researcher, but also an amazing human being!

Por último, obrigada a Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) por fazer tudo isso possível!

## RESUMO

Na presente tese realizamos dois estudos. O primeiro mapeou os estudos existentes interessados em investigar os efeitos da fadiga mental e da função física de idosos, avaliando sua quantidade, qualidade, métodos, funções físicas avaliadas e os principais resultados. O segundo estudo investigou a influência da fadiga mental no prazer dos idosos durante os testes de caminhada e equilíbrio e o exercício resistido. No estudo 1, realizamos uma revisão sistemática de escopo envolvendo idosos utilizando o PubMed/MEDLINE, Scopus e o Web of Science – Core Collection. A revisão de escopo acompanhou de forma abrangente o estado atual dos estudos sobre fadiga mental e função física de pessoas idosas por meio da categorização dos estudos por características, um resumo tabular das características dos estudos e análise de risco de viés. 15 estudos (1 resumo e 14 textos completos) atenderam aos critérios de inclusão e foram analisados nesta revisão de escopo. Os resultados indicaram que as publicações sobre os efeitos da fadiga mental na população idosa são relativamente novas; portanto, escassos. A combinação mais comum para induzir fadiga mental foi a matemática mental e sentar-se quieto; mas ao analisar as condições experimentais e de controle separadamente, os métodos mais comuns foram tarefas laboratoriais com baixa validade ecológica para indução e o uso de filme, documentário ou leitura como controle. A revisão também sugeriu a falta de estudos experimentais verdadeiros na área. A presente revisão destacou que a maioria dos estudos estava interessada em compreender as diferenças nos efeitos da fadiga mental entre faixas etárias; a maioria dos estudos incluiu apenas participantes saudáveis e; em geral, os idosos apresentam maiores flutuações de força do que os seus pares jovens em contextos de exigência cognitiva. No estudo 2, 35 participantes foram incluídos. Usando um desenho cruzado randomizado, os participantes completaram uma série de testes físicos (isto é, teste de caminhada de 6 minutos e tarefa de equilíbrio) e um breve exercício de resistência padronizado após duas condições experimentais (controle ou fadiga mental). A Análise Não Paramétrica de Dados Longitudinais em Experimentos Fatoriais foi utilizada para comparar a diferença no número de repetições realizadas durante as três séries de exercício resistido entre as condições controle e fadiga mental. O mesmo teste foi utilizado para comparar a PSE e o prazer nos 5 momentos (Pós-6MWT, Pós-TUG, Pós-KE1, Pós-KE2, Pós-KE3) e 2 condições (fadiga mental x controle) e as escalas VAS nos 4 momentos (baseline, Pré-6MWT, Pré-TUG, Pré-KE) e 2 condições (fadiga mental x controle). A fadiga mental não afetou a função física, percepção de esforço e o prazer ao se exercitar dos idosos. Os participantes, no entanto, apresentaram maior afinidade, caracterizada por maior prazer, pela caminhada e pelo equilíbrio dinâmico em comparação ao exercício de força. Porém, devido à relevância dos exercícios resistidos para a saúde, médicos e academias devem alocar recursos para programas de educação sobre a importância dos exercícios resistidos para a saúde no curto e longo prazo, incluir oportunidades de interação social nos programas de exercícios físicos e prescrever atividades adequadas ao nível de habilidade dos participantes. Em conclusão, a presente tese sugere que não está claro se o estado de fadiga mental é realmente um problema para os idosos saudáveis, e que pode ser benéfico dar dois passos atrás e realizar estudos qualitativos e de métodos mistos para compreender se o estado de fadiga mental é uma condição que afeta idosos saudáveis.



**Palavras-Chave***:* fadiga cognitiva; função cardiorrespiratória; equilíbrio; função muscular; idosos.

## ABSTRACT

In the present thesis we conducted two studies. The first one mapped out the existing studies interested to investigate the effects of mental fatigue and physical function of older people, assessing its quantity, quality, methods, physical functions evaluated and the main results. The second study investigated the influence of mental fatigue on older people's enjoyment during the walking and balance tests, and the resistance exercise. In study 1, we conducted a systematic scoping review of literature involving older people using the PubMed/MEDLINE, Scopus, Web of Science – Core Collection. The scoping review comprehensively tracked the current state of studies on mental fatigue and physical function of older people through the categorisation of studies by features, a tabular summary of studies characteristics, and risk of bias analysis. 15 studies (1 abstract and 14 full-texts) met the inclusion criteria and were subject to analysis in this scoping review. Results indicated that publications on the effects of mental fatigue in the elderly population are relatively new; therefore, scarce. The most common combined method to induce mental fatigue was mental maths and quiet sitting; but when analysing experimental and control conditions separately, the most common methods were laboratory-based tasks for induction with low ecological validity and the use of a movie, documentary or reading as control. The review also suggested the lack of true experimental research in the field. The present review highlighted that most studies were interested in understanding the differences in mental fatigue effects between age groups; most studies included only healthy participants and that; overall, elderly people display greater force fluctuations than their young peers in contexts of cognitive demand. 35 participants were included in the study 2. Using a randomised cross-over design, participants completed a series of physical tests (i.e., 6 min walk test, and balance task), and a brief standardised resistance exercise after two experimental conditions (control or mental fatigue). The Nonparametric Analysis of Longitudinal Data in Factorial Experiments was used to compare the difference in the number of repetitions performed during the three sets of resistance exercise between the control and mental fatigue conditions. The same test was used to compare the RPE and Enjoyment in the 5 moments (Post-6MWT, Post-TUG, Post-KE1, Post-KE2, Post-KE3) and 2 conditions (mental fatigue x control) and the VAS scales in the 4 moments (baseline, Pre-6MWT, Pre-TUG, Pre-KE) and 2 conditions (mental fatigue x control). Mental fatigue had no effect on the physical function, perception of effort and enjoyment to exercise of older people. Participants, however, presented a higher affinity, characterized by higher enjoyment, for walking and dynamic balance compared to strength exercise. However, due to the relevance of resistance exercises for health, clinicians and gyms should allocate resources to education programs regarding the importance of resistance exercise for health in the short and long-term, include social interaction opportunities in the physical exercise programs and, prescribe appropriate activities to participants' ability level. In conclusion, the present thesis suggests that is not clear whether the state of mental fatigue is really an issue for healthy older people, and that it might be beneficial to walk two steps back, and conduct qualitative and mixed-methods studies to understand whether mental fatigue as a state is a condition that affects healthy older people.



**Keywords**: cognitive fatigue; cardiorespiratory function; balance; muscular function; elderly.

## LISTA DOS ARTIGOS INCLUÍDOS NA TESE

**ESTUDO 1. Mental Fatigue and Physical Function of Older People: A Scoping Review**
*Artigo submetido para publicação no periódico Perceptual and Motor Skills no dia 16 de Maio de 2024 (CiteScore 2022: 2,3; Qualis B2).

**ESTUDO 2. The influence of mental fatigue on physical performance and factors that affect exercise adherence in older adults**
* Artigo publicado no periódico Research Quarterly for Exercise and Sport no dia 23 de Setembro de 2024 (CiteScore 2020: 2,2: Qualis A3).

## SUMÁRIO

# 1. INTRODUÇÃO GERAL

Mental fatigue can be defined as a psychobiological state of tiredness and lack of energy induced by prolonged and/or intense periods of cognitive demand (Boksem; Tops, 2008b, Marcora; Staiano; Manning, 2009a). Several mechanisms have been proposed to elucidate mental fatigue, and it is possible that these explanations may also apply to the elderly population, as briefly presented below.

*Dopamine and Adenosine*

Although the levels of dopamine and adenosine in conditions of mental fatigue and control have not been measured in vivo, theorists hypothesized that mental fatigue occurs due to the relation between dopamine and adenosine release. Dopamine is a neurotransmitter that plays an important role in cognitive functions of higher order (Nieoullon, 2002), and adenosine release inhibits the release of dopamine (Myers; Pugsley, 1986). According to Pageaux et al. (2014), engaging in demanding cognitive tasks for long periods cause the accumulation of adenosine and the reduction of dopamine levels within active brain regions, such us the Anterior Cingulate Cortex, which leads to subjective feelings of mental fatigue. Therefore, adenosine release seems to cause mental fatigue through the increase in perception of effort during an activity performance and the decrease in motivation due to its interplay with dopamine in the Anterior Cingulate Cortex (Martin *et al.*, 2018).

*Brain activity*

Electroencephalographic activity represents the sum of the inhibitory and excitatory postsynaptic potentials of neurons (Santamaria; Chiappa, 1987). Researchers have extensively investigated and documented alterations in the electroencephalogram frequency ranges corresponding to the emergence of mental fatigue (Tran *et al.*, 2020), and a meta-analysis including adults (+18 years) suggested that elevated theta and reduced alpha wave patterns serve as a reliable and credible neurological indicator of mental fatigue in various regions of the brain, including the frontal, central, and posterior cortical areas (Tran *et al.*, 2020). Similarly, a study comparing the electroencephalogram activity of young and older individuals during the 3h performance of a cognitive test showed larger frontal theta power waves for elderly in comparison to young despite the absence of behavioural differences (Arnau *et al.*, 2017). In addition, data from studies using functional near infrared spectroscopy

indicate that mental fatigue may be linked to a decreased activity in the prefrontal cortex of older adults (Shortz *et al.*, 2015, Terentjeviene *et al.*, 2018b). Therefore, mental fatigue seems to affect brain activity patterns.

*The Dual Regulation System of Mental Fatigue*

The Dual Regulation System of Mental fatigue is composed by the mental facilitation system and the inhibition system (Ishii; Tanaka; Watanabe, 2014). The frontal cortex, the limbic system, the thalamus and the basal ganglia form the mental facilitation system, whereas the insular cortex and the posterior cingulate cortex form the mental inhibition system (Ishii; Tanaka; Watanabe, 2014). Mental workload activates both systems (Ishii; Tanaka; Watanabe, 2014). The activation of the mental facilitation system maintains or improves performance in the task (Ishii; Tanaka; Watanabe, 2014). The activation of the mental inhibition system, instead, impairs performance in the task (Ishii; Tanaka; Watanabe, 2014). The balance between the two systems' activation dictates whether cognitive task performance will impair, maintain or improve (Ishii; Tanaka; Watanabe, 2014). Therefore, according to the model, acute and chronic mental fatigue may occur due to 1) low activation of the mental facilitation system, 2) high activation of the mental inhibition system or, 3) interplay between the two systems' activation (Ishii; Tanaka; Watanabe, 2014).

Mental fatigue can have implications that extend beyond cognitive task performance. Studies with elderly have been showing that mental fatigue may be linked to a decreased activity in the prefrontal cortex (Shortz *et al.*, 2015, Terentjeviene *et al.*, 2018b), which is part of the facilitation system. Changes in brain activation may impair the physical function of elderly, since the ability to perform activities of daily living requires the integration of cognitive functions (De Dieuleveult *et al.*, 2017, Santos Henriques; Tomas-Carus; Filipe Marmeleira, 2023).

The potential mental fatigue effects on elderlies' physical function is concerning since physical function losses are associated with more visits to medical centres, higher medical expenses (Cheng *et al.*, 2020), driving cessation (Edwards *et al.*, 2009), loneliness (De Munter *et al.*, 2022b) and falls (Moreira *et al.*, 2017). In that sense, studies have been investigating the effects of mental fatigue in the physical function of elderly (Behrens *et al.*, 2018, Fletcher; Osler, 2021, Morris; Christie, 2020b). However, a comprehensive review that encompasses various aspects of physical functioning, such as strength and cardiovascular function, remains absent from the current literature.

Physical exercises benefit to counteract aging related physical function losses are well documented (Bouaziz *et al.*, 2017, Sherrington *et al.*, 2017). However, older adults tend to become less active throughout life (Health;  Welfare, 2018). This can be concerning, since exercise benefits are mediated by participants' adherence to the training program (Aartolahti *et al.*, 2015).

Participation in activities that could be advantageous is thought to rely in part on how individuals weigh the perceived advantages against the associated expenses (Hess;  Knight, 2021). In addition, participation in a specific physical task could be driven by the desire to gain a reward, such as money, or by the pure enjoyment we derive from the activity itself, finding it inherently fulfilling (Van Der Kooij *et al.*, 2019). Mental fatigue may be one factor that could influence how someone views the expenses or effort involved in the activity, as well as the enjoyment to perform it.

Hess and Knight (2021), for example, indicated that chronic mental fatigue showed distinct levels of predictability in anticipating both engagement and assessment levels within different groups. As chronic mental fatigue levels rose, older adults tended to perceive greater increases in task difficulty compared to younger adults (Hess;  Knight, 2021). Moreover, the complexity of tasks among older adults was linked to their deliberate decisions to avoid engaging in challenging activities (Hess *et al.*, 2021).

However, as far as we know, no one has investigated the effects of mental fatigue in older people's enjoyment to exercise. Therefore, in the present thesis we conducted two studies. The first one aimed to map out the existing studies interested to investigate the effects of mental fatigue and physical function of older people, assessing its quantity, quality, methods, physical functions evaluated and the main results. The second study sought to investigate the influence of mental fatigue on older people's enjoyment during the walking and balance tests, and the resistance exercise.

## 2. ESTUDO 1

## Mental Fatigue and Physical Function of Older People: A Scoping Review

Larissa Oliveira Faria[1,3], Nathálya Gardênia de Holanda Marinho Nogueira [2], Thais Frois de Sousa [1], Leonardo de Sousa Fortes [4], Maicon Rodrigues Albuquerque [1],

1.Universidade Federal de Minas Gerais, Belo Horizonte – MG, Brazil
2.Universidade do Estado de Minas Gerais, Passos – MG, Brazil
3.University of Technology Sydney, Sydney – NSW, Australia
4. Universidade Federal da Paraíba, João Pessoa – PB, Brazil

**Abstract**

The present review mapped out the existing studies interested to investigate the effects of mental fatigue on the physical function of older people, assessing its quantity, quality, methods, physical functions evaluated and the main results. We conducted a systematic scoping review of literature involving older people using the PubMed/MEDLINE, Scopus, Web of Science – Core Collection. The scoping review comprehensively tracked the current state of studies on the effects of mental fatigue on the physical function of older people through the categorisation of studies by features, a tabular summary of studies characteristics, and risk of bias analysis. 15 studies (1 abstract and 14 full-texts) met the inclusion criteria and were subject to analysis in this scoping review. Results indicated that publications on the effects of mental fatigue in the elderly population are relatively new; therefore, scarce. The most common combined method to induce mental fatigue was mental maths and quiet sitting; but when analysing experimental and control conditions separately, the most common methods were laboratory-based tasks for induction with low ecological validity and the use of a movie, documentary or reading as control. The review also suggested the lack of true experimental research in the field. The present review highlighted that most studies were interested in understanding the differences in mental fatigue effects between age groups; most studies included only healthy participants and that; overall, elderly people display greater force fluctuations than their young peers. This review underscores the recent attention on mental fatigue in older individuals. Studies mainly examined balance and muscle function using low ecological fatigue induction and subjective measures as manipulation check. Complex activities and chronic conditions were underrepresented. The existing evidence, marred by bias and underpowered analysis, calls for more rigorous research to inform healthcare decisions.

**Keywords**: cognitive fatigue; balance; muscular function; ageing; systematic review.

### 1. Introduction

Mental fatigue - a psychobiological state of tiredness and lack of energy induced by prolonged and/or intense periods of cognitive demand (Boksem; Tops, 2008a, Marcora; Staiano; Manning, 2009b) - is a common complaint of older adults (Hardy; Studenski, 2008b). For example, a study by Cohen et al. (2021) found that within a cohort of 2,361 older

adults, 24.8% reported experiencing mental fatigue. This phenomenon was more prevalent among women (Cohen *et al.*, 2021, Meng; Hale; Friedberg, 2010), as well as in older age groups (Cohen *et al.*, 2021), with percentages reported as follows: 14.5% among individuals aged 60-69 (out of 1,004); 18.6% among those aged 70-79 (out of 839); 41.5% among individuals aged 80-89 (out of 253); and 67.2% among those aged 90-108 (out of 265). Also, mental fatigue is a common symptom of people with frailty (Zengarini *et al.*, 2015) and chronic diseases, such as fibromyalgia (Vancampfort *et al.*, 2023b), multiple sclerosis (Linnhoff *et al.*, 2019) and Parkinson disease (Lou, 2009, Lou *et al.*, 2001a).

Several mechanisms have been proposed to explain mental fatigue and these explanations may also apply to the elderly population. According to Pageaux et al. (2014), for example, engaging in demanding cognitive tasks for long periods cause the accumulation of adenosine and the reduction of dopamine levels within active brain regions, which leads to subjective feelings of mental fatigue. Therefore, adenosine release seems to cause mental fatigue through the increase in perception of effort during an activity performance and the decrease in motivation due to its interplay with dopamine in the anterior cingulate cortex (Martin *et al.*, 2018).

The Dual Regulation System of Mental fatigue can be another possible explanation. The system is composed by the mental facilitation system and the inhibition system (Ishii; Tanaka; Watanabe, 2014). The frontal cortex, the limbic system, the thalamus and the basal ganglia form the mental facilitation system, whereas the insular cortex and the posterior cingulate cortex form the mental inhibition system (Ishii; Tanaka; Watanabe, 2014). Mental workload activates both systems (Ishii; Tanaka; Watanabe, 2014). The activation of the mental facilitation system maintains or improves performance in the task (Ishii; Tanaka; Watanabe, 2014). The activation of the mental inhibition system, instead, impairs performance in the task (Ishii; Tanaka; Watanabe, 2014). The balance between the two

systems' activation dictates whether cognitive task performance will impair, maintain or improve (Ishii; Tanaka; Watanabe, 2014). Therefore, according to the model, acute and chronic mental fatigue may occur due to 1) low activation of the mental facilitation system, 2) high activation of the mental inhibition system or, 3) interplay between the two systems' activation (Ishii; Tanaka; Watanabe, 2014).

Mental fatigue can have implications that extend beyond cognitive task performance. Studies with elderly have been showing that mental fatigue may be linked to a decreased activity in the prefrontal cortex (Shortz *et al.*, 2015, Terentjeviene *et al.*, 2018a), which is part of the facilitation system. Changes in brain activation may impair the physical function of elderly, since the ability to perform activities of daily living requires the integration of cognitive functions (De Dieuleveult *et al.*, 2017, Santos Henriques; Tomas-Carus; Filipe Marmeleira, 2023). The possible impact of mental fatigue on the physical function of older people is concerning since physical function losses are associated with more visits to medical centres, higher medical expenses (Cheng *et al.*, 2020), driving cessation (Edwards *et al.*, 2009), loneliness (De Munter *et al.*, 2022a) and falls (Moreira *et al.*, 2017). In addition, physical function state affects many health indicators: people who perform a higher number of steps per day, for example, display better glucose control (Swartz *et al.*, 2007), less risk to suffer a cardiovascular event, and mortality (Kraus *et al.*, 2019). In short, preserving physical function contributes to the independence, mental and physical health of older adults.

Recently, Brahms et al. (2022) conducted a systematic review with a meta-analysis examining the impact of mental fatigue on balance. Their findings revealed that mental fatigue adversely affects the balance of both young and older adults, albeit with a small effect size. Notably, their analysis, when adjusted for age, did not yield significant differences (Brahms *et al.*, 2022). It is worth mentioning that their meta-analysis was based on only four studies involving older adults. According to Jackson and Turner (2017), a random-effects

meta-analysis should ideally include a minimum of five studies to ensure result validity, introducing a level of uncertainty into these findings. Furthermore, it is crucial to underscore that Brahms et al. (2022) study exclusively focused on healthy participants and solely evaluated balance function. As a result, a comprehensive review that encompasses various aspects of physical functioning, such as strength and gait parameters, which are crucial for daily living activities (Naruse; Trappe; Trappe, 2023), remains absent from the current literature. Thus, to address this gap, a systematic scoping review was undertaken.

Although systematic reviews are more often used to brief intervention studies, Munn et al. (Munn *et al.*, 2018)propose that the main difference between systematic and scoping reviews is the research question. While systematic reviews investigate the effectiveness of a specific practice or condition, scoping reviews identify and discuss the characteristics or concepts in studies (Munn *et al.*, 2018). In addition, Munn et al. (Munn *et al.*, 2018) argue that scoping reviews are recommended, amongst other purposes, to identify the types of available evidence in a given field, to identify key characteristics or factors related to a concept, to identify and analyse knowledge gaps. We chose to conduct a scoping review because we anticipate that the physical functions investigated would be very heterogeneous and because we believe there is an overlap between concepts, such as mental fatigue and anxiety or depression.

Therefore, the present scoping review aim to mapped out the existing studies interested to investigate the effects of mental fatigue on the physical function of older people. Thus, the primary objectives were to answer the following research questions: 1) What is the quantity and quality of the research? 2) What are the common methods used to induce and/or assess mental fatigue? 3) What physical functions have been previously investigated? 4) What are the main results?

## 2. Methods

*2.1 Protocol and Registration*

The review protocol was registered online on Open Science Framework (OSF; ID: https://doi.org/10.17605/OSF.IO/CZUBS, 24th January 2023), an open public data repository. We conducted the review using the Preferred Reporting items for Systematic Reviews and Meta-analysis Scoping Review Checklist (PRISMA-ScR) (Tricco *et al.*, 2018) and the Joanna Briggs Institute Reviewer Manual for scoping reviews (Peters *et al.*, 2015, Peters *et al.*, 2020).

*2.2 Inclusion and Exclusion Criteria*

Our inclusion criteria were studies that (1) included people aged 60 years old or over; (2) described methods employed for inducing and/or assessing mental fatigue; (3) assessed any physical function; (4) were original research (i.e., not reviews, book chapters, opinions, editorials). Exclusion criteria included studies that (1) did not delineate results if the sample included young and / or middle-aged people; (2) correlation and association studies; and (3) analysed different constructs of fatigue (i.e., chronic fatigue syndrome, cancer-related fatigue) rather than mental fatigue.

*2.3 Information sources and search strategy*

We conducted a systematic scoping review of literature involving older people using the PubMed/MEDLINE, Scopus, Web of Science – Core Collection. A search strategy was developed to identify all relevant studies using the following lists:

Population ("old* adults" OR elderly OR senior OR aged)
Concept ((fatigue OR depletion OR exertion OR exhaustion OR fatigability) AND (mental OR central OR cognitive))

Context ("physical function" OR walk OR "muscular function" OR "daily activit*" OR balance OR gait OR postural))

All databases were first searched from the earliest record up to and including 1st of February 2023. Potentially relevant literature not found in database searches were identified from other sources (e.g., reference lists; network analysis in connected papers software) and were included for screening. We set up search alerts across all databases and reviewed the results on a weekly basis until 22sd of November of 2023, aiming to identify any potential new publications that align with our inclusion criteria.

*2.4 Selection of Sources of Evidence*

All references were imported to Covidence (app.covidence.org), and all duplicates were automatically removed. LOF, and TFS independently screened the articles by title and abstract. All potentially eligible references proceeded to full-text screening and were independently screened against the eligibility criteria. Conflicts were resolved by a third author (AJC). In both screening stages, Cohen's kappa statistics was used to calculate the inter-rater agreement for study inclusion.

Information regarding the study population (geographic location, demographic descriptors, age distribution, disease-related descriptors), study methodology (study design and setting), the time of mental fatigue induction (if applicable), the tasks adopted to induce or assess mental fatigue, the method used to check mental fatigue induction (if applicable), any physical function assessments (i.e., balance, walking test), and the main results were extracted.

*2.5 Data items*

The studies were categorized based on the design adopted, such as randomised controlled trial, time series, non-randomised clinical trials and crossover studies (Hulley *et al.*, 2013) and on the physical function investigated. The Patient Reported Outcomes Measurement Information System (PROMIS) suggests (Cella *et al.*, 2007) that the physical function domain is theoretically formed by four subdomains that are conceptually related, but distinct (Bruce *et al.*, 2009, Dias, 2014): mobility (lower extremity), dexterity (upper extremity), axial or central (neck and back function), and complex activities that involve more than one subdomain (instrumental activities of daily living) – Figure 1.

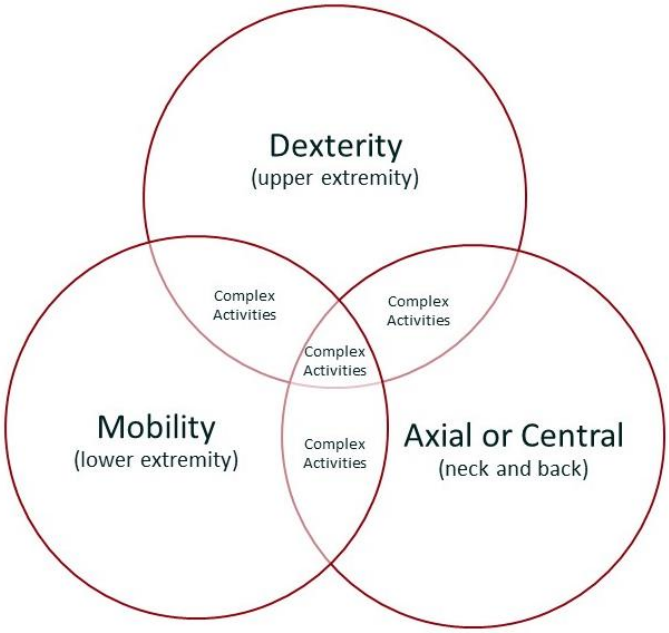



Fig. 1 A visual representation of the physical function domains

All studies were initially categorised by LOF and MRA. Differences in categorisation were discussed and resolved by these two authors plus AJC. Studies were categorised in all applicable domains and components.

*2.6 Data Charting Process*

After categorization, a data-charting form was jointly developed by two reviewers (LOF and NGHMN). To scope the existing mental fatigue effects on older adults' literature,

LOF extracted all data pertaining to study details (e.g., experimental design and country), population (e.g., sample size, age, disease descriptors, anthropometry), specific measures/methods/interventions investigated. Extracted data were entered into a custom-made online spreadsheet allowing for simultaneous data entry and review by multiple authors. After initial data extraction, NGHMN cross-checked the extracted data against the respective full-text article to ensure accuracy.

*2.7 Critical appraisal of individual sources of evidence*

LOF and NGHMN assessed the risk of bias of each study included using the following validated scales: the RoB 2 for crossover trials (Sterne *et al.*, 2019), Cochrane Risk of Bias Tool (RoB 2) for Randomised Controlled Trials (Sterne *et al.*, 2019), and ROBINS-I for non-randomised studies (i.e. time series design; non-randomised between-group trial designs) (Sterne *et al.*, 2016). A judgement of either 'low risk', 'some concerns' or 'high risk' of bias was made for each outcome for randomised controlled trials and randomised crossover trials. Non-randomised trials were classified as low, moderate, serious, and critical risk. Articles with disagreements regarding their bias ratings were resolved through discussion between LOF and NGHMN and when a consensus was not reached, MRA solved the conflicts.

*2.8 Synthesis of results*

The scoping review comprehensively tracked the current state of studies on the effects of mental fatigue on the physical function of older people through the categorisation of studies by features, a tabular summary of studies characteristics, and a qualitative/risk of bias analysis. Also, we assessed whether the studies were underpowered by registering how many of them reported the sample size calculation.

## 3. Results

### *3.1 Selection of sources of evidence*

The initial literature search yielded 7341 studies. An additional 7 studies were identified through other sources (searching reference lists and network analysis on connected papers, search alerts). Once duplicates were removed, the titles and abstracts of 5018 articles were screened for inclusion. Based on the eligibility criteria, 4984 articles were excluded, and 34 articles proceeded to full-text screening. The percentage agreement between the two reviewers on studies that should proceed to full-text screening was 99.8% with kappa = 0.84 (Online Resource 1). Of the 34 full-text articles that were assessed for eligibility, 19 were excluded (Online Resource 2). The reasons for exclusion are noted in Figure 2. Of the full-text articles assessed, 15 (1 abstract and 14 full-texts) met the inclusion criteria and were subject to analysis in this scoping review. The percentage agreement between the two reviewers on studies included in the review was 92% with kappa = 0.82 (Online Resource 2).

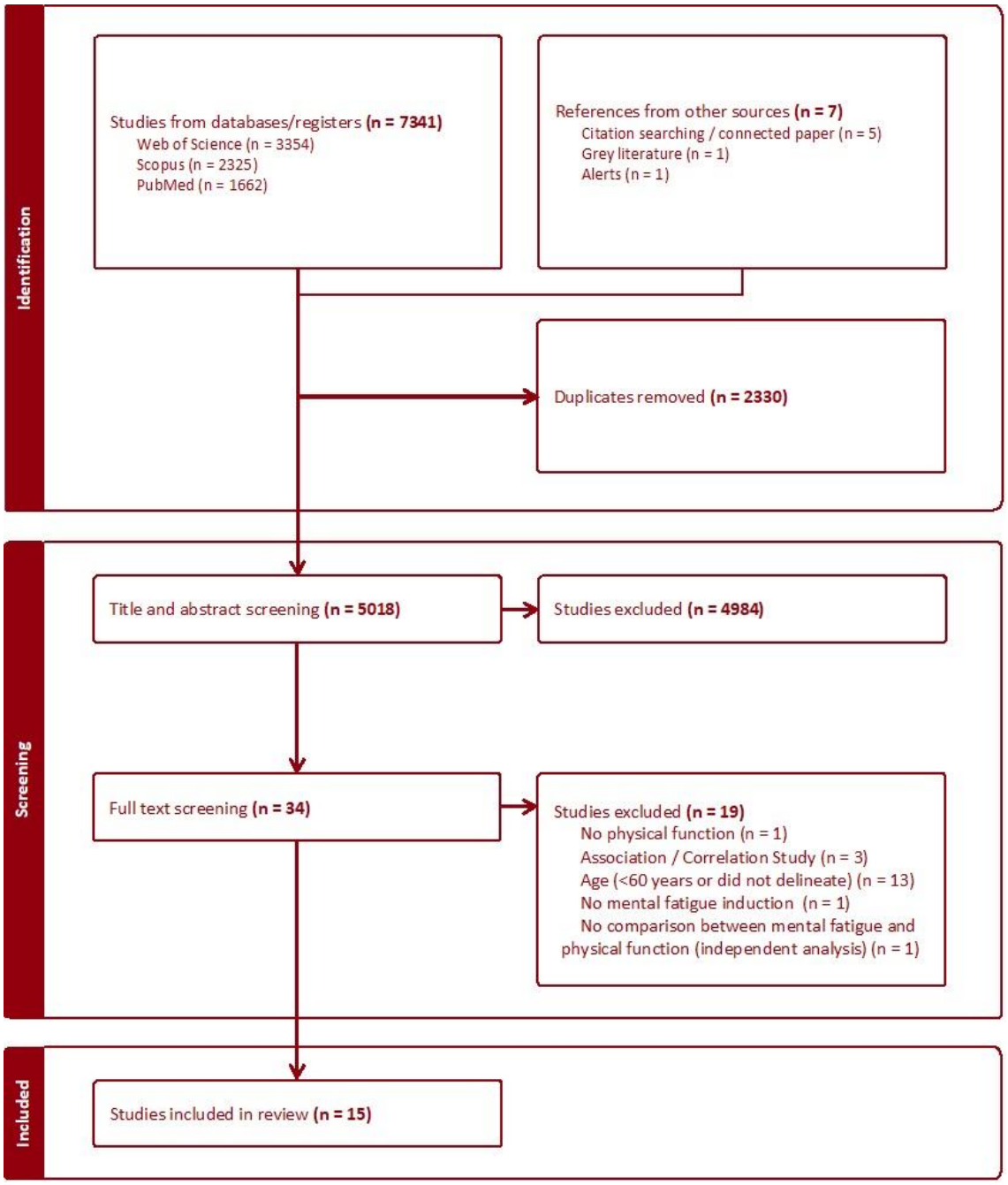



Fig. 2 Study selection flow diagram

### *3.2 Quantity of studies in Mental Fatigue and Older People*

Seven nations, per correspondent author affiliation (8 nations in total), have contributed to track mental fatigue and older people literature (Figure 3a). The United States of America have had the largest contribution with 8 publications, followed by Canada with 2 and the other countries contributing with only one study each (Australia, France, Germany,

Netherlands, and United Kingdom). The number of publications per year in the effects of mental fatigue on the physical function of older people has been scarce and inconsistent (Figure 3b).

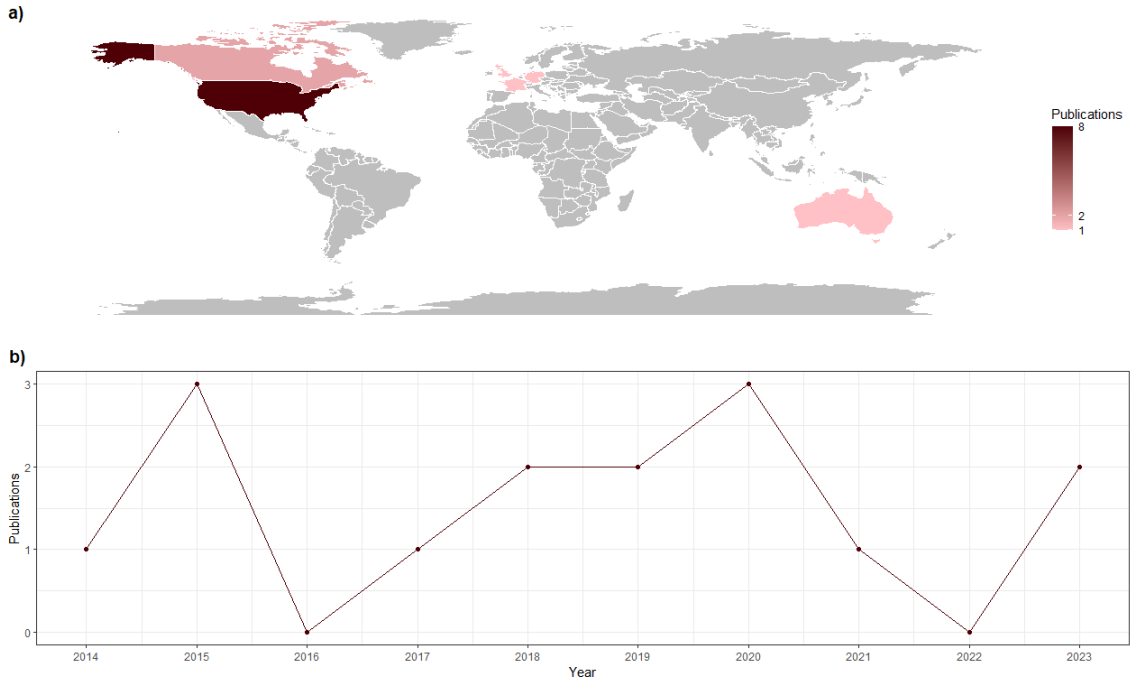



Fig. 3 Quantity of studies in mental fatigue and older people by country (a) and year (b).

*3.3 Risk of Bias*

A summary of the risk of bias assessment results are available in Figures 4, 5 and 6. No study reported a low risk of bias. In respect to the randomisation process, 9 out of 11 randomised designs (randomised controlled trials and cross-over) were of high risk due to a lack of random sequence generation, and lack of allocation concealment. The remaining study presented some concerns. For the cross-over studies, all studies presented a low risk of bias for missing outcome data and measurement of the outcome. All studies presented some concerns for the selection of reported results and deviations from the intended interventions as it was not reported if the data were analysed against a pre-specified plan. One study presented some concerns for bias arising from period and carryover effects as period effects were not accounted for in the analysis (Goodwin; Avolio; Boolani, 2018). For the randomised

controlled trials, all studies showed low risk of bias for missing outcome data and measurement of the outcome. All studies reported some concerns regarding the selection of reported results and deviations from the intended interventions as the authors have not registered the protocol of the studies. For the non-randomised trials, all studies showed low risk of bias for bias in selection of participants, bias in classification of intervention, bias due to deviations from the intended interventions, bias due to missing data, and bias in selection of the reported results. All studies, however, presented moderate risk of bias in measurement of outcomes because assessors were aware of the intervention received by study participants. The studies presented serious to critical risk of bias due to confounding because the authors did not consider important covariates (i.e., anxiety and depression) in the study. Moreover, as an additional evaluation, we recorded the number of studies that reported conducting a sample size calculation, and only two (13%) studies (Salehi; Fard; Jaberzadeh, 2023, Santos *et al.*, 2019) adhered to this rigorous approach.

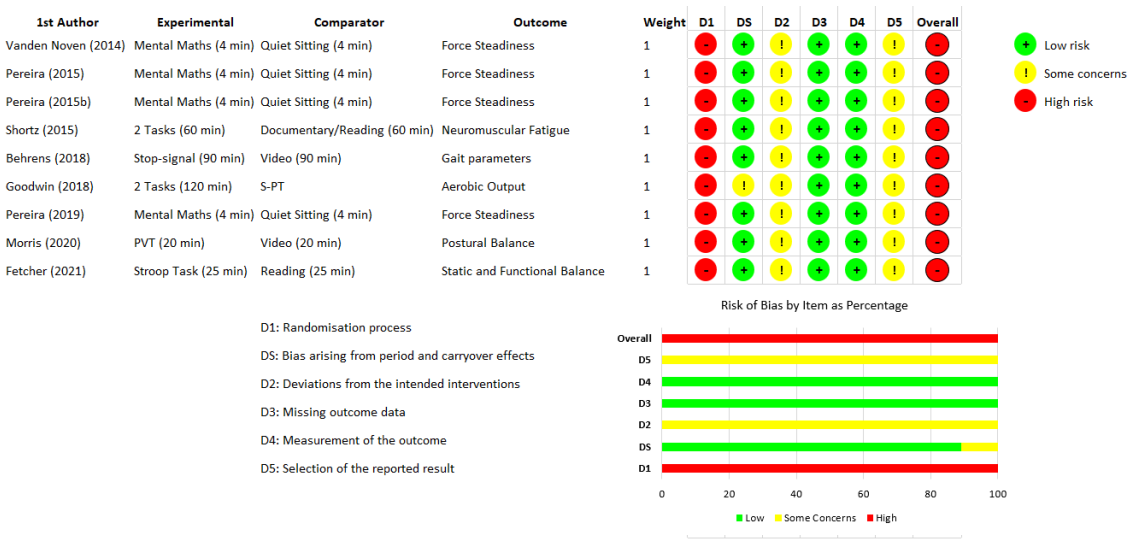



Fig. 4 Risk of Bias of Cross-Over Studies. Legend: S-PT: straight to physical test; PVT: Psychomotor Vigilance Task; min: minutes.

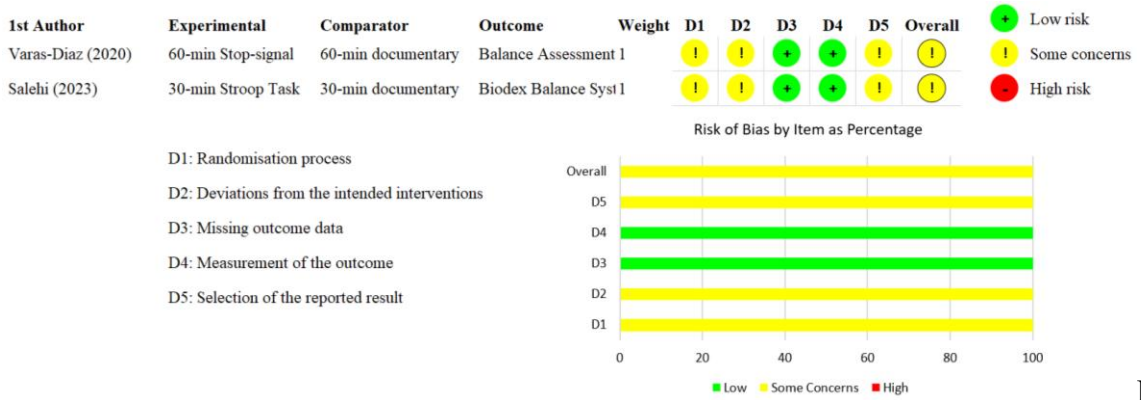



Fig. 5 Risk of Bias of the Randomised Trials. Legend: min: minutes.

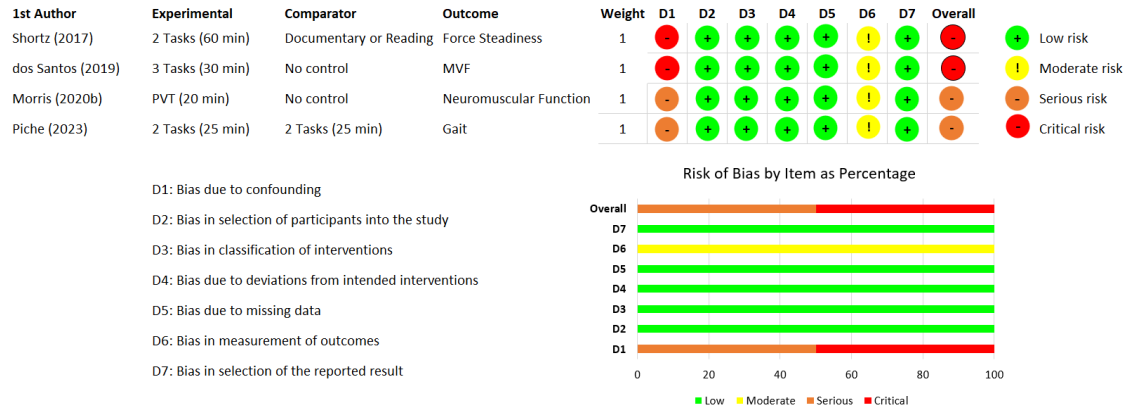



Fig. 6 Risk of Bias of the Non-Randomised Trials. Legend: MVF: maximum voluntary force; PVT: Psychomotor Vigilance Task.

### *3.4 Mental Fatigue and control conditions*

The most common combined approach was to induce mental fatigue through mental maths, with quiet sitting employed as the control condition (n = 4) (Pereira *et al.*, 2019, Pereira *et al.*, 2015a, Pereira *et al.*, 2015b, Vanden Noven *et al.*, 2014). When analysed separately, however, watching a movie, video or reading was the main strategy to control the experiments (n=7) (Behrens *et al.*, 2018, Fletcher; Osler, 2021, Morris; Christie, 2020a, Salehi; Fard; Jaberzadeh, 2023, Shortz; Mehta, 2017, Shortz *et al.*, 2015, Varas-Diaz; Kannan; Bhatt, 2020). Three studies used a time series design, being that: one did not include a control group or condition (Morris; Christie, 2020b), one compared mental and physical

fatigue conditions (Santos *et al.*, 2019) and the other used a documentary (Shortz; Mehta, 2017); one study administered the physical test, in a separate session from the mental fatigue condition, without any prior stimuli - going directly to the physical test (Goodwin; Avolio; Boolani, 2018); and one study used a non-randomised between-groups trial investigating the effects of mental fatigue on walking performance comparing young, frail and non-frail older adults (Piche *et al.*, 2023). Regarding the mental fatigue induction, four studies combined two different cognitive tasks (Stroop task and n-back (Shortz; Mehta, 2017, Shortz *et al.*, 2015); Continuous Performance Task and Rapid Visual Input Processing (Goodwin; Avolio; Boolani, 2018); mental calculation and adapted PVT (Piche *et al.*, 2023)), and one combined three tasks (Psychomotor Vigilance Task, Continuous Performance Test, and Stroop task (Santos *et al.*, 2019)); whereas ten studies used a single task (Behrens *et al.*, 2018, Fletcher; Osler, 2021, Morris; Christie, 2020a, Morris; Christie, 2020b, Pereira *et al.*, 2019, Pereira *et al.*, 2015a, Pereira *et al.*, 2015b, Salehi; Fard; Jaberzadeh, 2023, Vanden Noven *et al.*, 2014, Varas-Diaz; Kannan; Bhatt, 2020) (Figure 7a).

Most studies used a combination of subjective and objective measures to evaluate mental fatigue induction (n = 9) (Behrens *et al.*, 2018, Shortz; Mehta, 2017, Shortz *et al.*, 2015), 4 adopted only objective measures (Morris; Christie, 2020a, Morris; Christie, 2020b, Pereira *et al.*, 2019, Pereira *et al.*, 2015a, Pereira *et al.*, 2015b, Piche *et al.*, 2023, Salehi; Fard; Jaberzadeh, 2023, Santos *et al.*, 2019, Vanden Noven *et al.*, 2014, Varas-Diaz; Kannan; Bhatt, 2020), and 2 relied solely on subjective measures (Fletcher; Osler, 2021, Goodwin; Avolio; Boolani, 2018). The Profile Mood Scale (Behrens *et al.*, 2018, Goodwin; Avolio; Boolani, 2018, Shortz; Mehta, 2017, Shortz *et al.*, 2015) and the Visual Analogue Scale (Fletcher; Osler, 2021, Piche *et al.*, 2023, Salehi; Fard; Jaberzadeh, 2023, Santos *et al.*, 2019) were the most commonly used scales for this purpose, followed by the Multidimensional Fatigue Inventory (Behrens *et al.*, 2018, Morris; Christie, 2020a, Morris; Christie, 2020b) and the

NASA Task Load Index (Varas-Diaz; Kannan; Bhatt, 2020). Among objective measures, cardiovascular responses (heart rate, heart rate variability and blood pressure) were the most frequently employed (Behrens *et al.*, 2018, Morris;  Christie, 2020b, Pereira *et al.*, 2019, Pereira *et al.*, 2015a, Pereira *et al.*, 2015b, Shortz;  Mehta, 2017, Shortz *et al.*, 2015, Vanden Noven *et al.*, 2014, Varas-Diaz; Kannan; Bhatt, 2020). Five studies (Morris;  Christie, 2020a, Morris;  Christie, 2020b, Piche *et al.*, 2023, Salehi; Fard; Jaberzadeh, 2023, Santos Henriques; Tomas-Carus; Filipe Marmeleira, 2023) assessed changes in accuracy and response time during the cognitive tasks used for mental fatigue induction and 1 use neurobiological measure (Shortz *et al.*, 2015) .

The average duration of induction was 37.1 ± 34.4 minutes, with a range spanning from 4 to 120 minutes. The most frequently adopted durations were 4 minutes (n = 4), followed by 60 minutes (n = 3), and 20, 25 and 30 minutes (n = 2 each). Additionally, there was one study each that used durations of 90, and 120 minutes (Figure 7b).

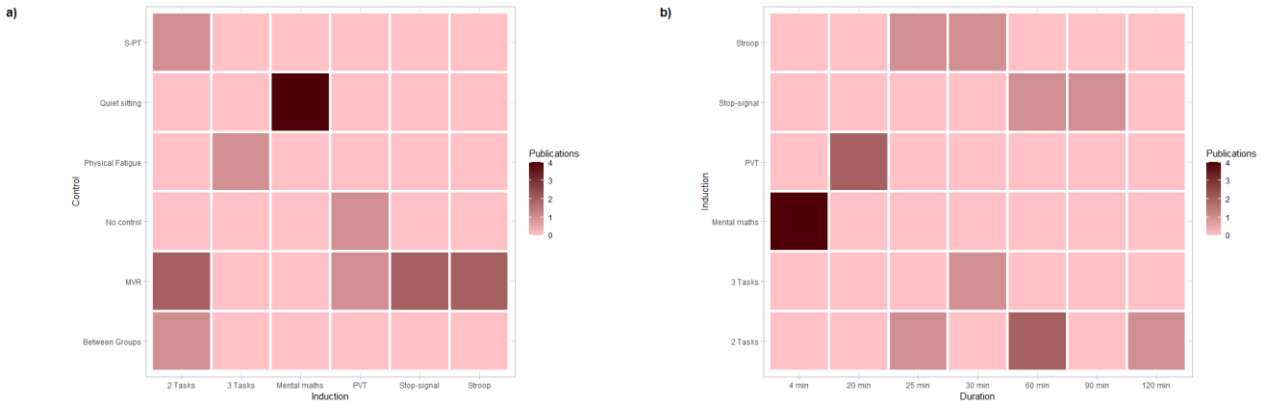



Fig. 7 a) Heat map of the frequency of the methods adopted as mental fatigue and control conditions/groups; b) Heat map of the duration of mental fatigue induction for each task. Legend: MVR: movie, video or reading; S-PT: straight to physical test; PVT: Psychomotor vigilance task.

*3.5 Components of Physical Function and Research Designs*

Each study was assessed for their research design as per the descriptors provided by Hulley et al. (2013). The physical function assessed in each study, organised by research method and type, are shown in Table 1. The results indicate a lack of true experimental research, i.e., randomised control trials [RCTs] published on mental fatigue and older people. Of the 15 publications that met our inclusion criteria, 2 had a true experimental study design. Over 80% of the included studies (n = 13) were quasi-experimental, being that 3 used a time series design, 9 used a randomised crossover design and 1 used a non-randomised between-groups design.

Most of the studies focused on a single domain of physical function (n = 13, 87%). Among them, we observed a similar distribution of studies involving mobility (n = 6) and dexterity (n = 5). Two studies investigated the axial domain. The remaining ones assessed both axial and mobility domains (n = 2) independently, using two different tasks. The search did not yield any study that examined complex activities, and all RCTs investigated the axial domain.

Table 1. Domains of Physical Function by studies research designs.

| | Experimental | Quasi-Experimental | | |
|---|---|---|---|---|
| Physical Function | Randomised Controlled Trial | Randomised Crossover | Time Series | Non-randomised Between-group Trial |
| Mobility | | [37, 40, 45-47] | [39, 49] | [50] |
| Dexterity | | [14, 41-43] | [44] | |
| Axial | [38, 48] | [45, 46] | | |

*3.6 Main results*

Seven studies investigated the effects of mental fatigue on muscular function (Morris; Christie, 2020b, Pereira *et al.*, 2019, Pereira *et al.*, 2015a, Pereira *et al.*, 2015b, Shortz; Mehta, 2017, Shortz *et al.*, 2015, Vanden Noven *et al.*, 2014), 3 focused on gait analysis (Behrens *et al.*, 2018, Piche *et al.*, 2023, Santos *et al.*, 2019), 1 on cardiorespiratory function (Goodwin; Avolio; Boolani, 2018) and 4 in balance or postural function (Table 2). Ten studies (Behrens *et al.*, 2018, Fletcher; Osler, 2021, Morris; Christie, 2020a, Morris; Christie, 2020b, Pereira *et al.*, 2019, Pereira *et al.*, 2015b, Piche *et al.*, 2023, Santos *et al.*, 2019, Shortz; Mehta, 2017, Vanden Noven *et al.*, 2014) were interested to investigate differences in mental fatigue effects between young and older participants. Except for Varas-Diaz *et al.* (2020) and Piche et al. (2023) that recruited participants with stroke and frail elderly, respectively – all the other studies only included healthy subjects.

Regarding muscular function, 4 studies suggested increased force fluctuations and decreased steadiness in older adults compared to young adults. Shortz and Mehta (2017), in contrast, did not find differences in steadiness level for age and time. Two studies indicated decreased force steadiness when the cognitive demand was imposed compared to the control condition (Pereira *et al.*, 2019, Pereira *et al.*, 2015a), and three other studies did not observe differences in steadiness by cognitive challenge (Shortz; Mehta, 2017, Shortz *et al.*, 2015, Vanden Noven *et al.*, 2014).

For gait or walking, only one study reported differences in speed, stride length, stance time, double support time, swing time in mental fatigue pre to post for old participants (Behrens *et al.*, 2018). Two studies compared the effects of mental and muscular fatigue in the physical function analysed: whilst dos Santos et al. (2019) pointed out increased centre of pressure regardless of fatigue type, Piche et al. (2023) reported decreases in swing time and single support time from the pre to the post-test for all groups due to muscular fatigue (not mental fatigue).

Balance and postural studies results are contradictory: two studies reported changes in physical function from the pre to the post-test in mental fatigue condition (Salehi; Fard; Jaberzadeh, 2023, Varas-Diaz; Kannan; Bhatt, 2020), and two did not observe differences (Fletcher; Osler, 2021, Morris; Christie, 2020a). More specifically, Varas-Diaz et al. (2020) indicated increased instability in the centre of mass. Salehi et al. (2023), in contrast, suggested increased stability in the balance task. Lastly, overall, most statically different findings for all physical functions were based on pre and post-test differences.

Table 2. Main results and characteristics of the studies included in the review

| 1st author | Design | Participants | Aim / Results |
|---|---|---|---|
| | | | **Muscular Function** |
| Vanden Noven (2014) | Randomised crossover study | Young (n = 16, 8 ♂, 9 ♀; age: 20.4±2.1); and older adults (n = 17; 9 ♂, 8 ♀, age: 68.8±4.4) | **Aim:** assess motor function with a focus on steadiness and muscle fatigability in young and older adults while they were presented with low and high levels of cognitive demand.<br><br>**Manipulation Check:** MAP and HR were ↑ during high CD compared to low CD and CTRL.<br><br>**Results:** Fatigability ↔ between conditions. Older adults: ↑ force fluctuations than young adults during: (1) the 5% MVC task as CD increased, and (2) the fatiguing contraction for all session. Time to task failure ↔ between sessions or age groups, but the variability between sessions was ↑ for older adults than young. RPE ↔ between conditions. |
| Pereira (2015a) | Randomised crossover study | Older ♀ (n = 17; age: 70 ± 6) and older ♂ (n = 13; age: 71 ± 5) | **Aim:** investigate sex differences in steadiness among older adults when low cognitive demand was imposed.<br><br>**Manipulation Check:** MAP was ↑ during high and low CD compared to CTRL.<br><br>**Results:** Fatigability was ↑ when high and low CD were performed during the fatiguing contraction for the ♀ but not for the ♂. In ♀, time to failure with high CD and low CD were shorter than time to failure in CTRL contractions. In ♂, time to failure was ↔ between conditions. Steadiness ↓ (force fluctuations ↑) more during high CD than CTRL. ↑ anxiety, mean arterial pressure, and salivary cortisol levels in both ♂ and ♀ did not explain the ↑ fatigability. CD ↓ the pain and RPE similarly in ♂ and ♀. |

| | | | |
|---|---|---|---|
| Pereira (2015b) | Randomised crossover study | 36 young adults (18–25 years; 18 ♀) and 30 older adults (60–82 years; 17 ♀). | **Study 1**<br>**Aim:** Compare force fluctuations of young and older men and women while performing isometric contractions in the presence and absence of high cognitive demand across a range of forces.<br><br>**Manipulation Check:** MAP was ↑ during high CD compared to CTRL.<br><br>**Results:** Older individuals: ↑ in force fluctuations with high CD than young adults and CTRL; ↑ agonist EMG activity with high CD and ♀ had greater coactivation than ♂. RPE was not used.<br><br>**Study 2**<br>**Aim:** Determine whether there was a sex difference in force fluctuations among older adults when a low-cognitive demand task was imposed during isometric contractions with the upper limb.<br><br>**Manipulation Check:** MAP was ↑ during high and low CD compared to CTRL. MAP was ↔ between high and low CD.<br><br>**Results:** CV of force ↑ with low CD for the older ♀ but not for the older ♂. RPE was not used. |
| Shortz (2015) | Randomised crossover study | Older ♀ (n = 11; age: 75.82± 7.4; height: 1.59± 0.11; weight: 78.65 ± 15.6; BMI: 29.74± 4.9) | **Aim:** examine the impact cognitive fatigue on neuromuscular fatigue and associated pre frontal cortex activity in older adults.<br><br>**Manipulation Check:** ↑ profile mood states and blunted pre frontal cortex activation patterns were observed in response to cognitive fatigue. |

| | | | |
|---|---|---|---|
| Shortz (2017) | Time Series | Ten younger (age: 24.10±1.79) and ten older (age: 75.90±7.80) ♀ | **Results:** Force fluctuations and muscle activity ↔ between conditions. ↔ neuromuscular outcomes. RPE ↔ between conditions.<br><br>**Aim:** investigate the effects of different cognitive challenges on handgrip fatigue with aging.<br><br>**Manipulation Check:** ↑ profile mood states after the CD test compared to CTRL. HR and HR variability were ↔ across conditions.<br><br>**Results:** Endurance times were ↔ across age and cognitive challenge conditions. Strength loss was ↔ across cognitive challenge. Force steadiness was ↔ by age, cognitive challenge, or time. Muscle activity ↑ over time and ↔ across age and cognitive challenge. RPE was ↔ between age groups, but ↑ during the cognitive fatigue condition when compared to the concurrent CD condition. |
| Pereira (2019) | Randomised crossover study | Young adults (n = 49; 19–30 years; 25 ♀, 24 ♂) and old adults (n = 36; 60–85 years; 19 ♀, 17 ♂) | **Aim:** 1) compare the oscillations in the synaptic input to motor units between young and old adults and ♂ and ♀ during a low-intensity isometric contraction with and without imposition of a CD and 2) determine whether the low-force steadiness with a CD imposed was associated with greater oscillations in the common synaptic input to motor units in young and old ♂ and ♀.<br><br>**Manipulation Check:** MAP ↑ when the cognitive challenge was performed without muscle contraction compared to CTRL.<br><br>**Results:** 1) Old adults and young ♀ showed ↑ oscillations in the common synaptic input to motor units and ↓ force steadiness when the CD was imposed, but young ♂ showed ↔ across conditions. 2) ↓ force steadiness was associated with greater oscillations in the synaptic input to motor units |

| | | | |
|---|---|---|---|
| | | | during both CTRL and cognitive challenge trials. RPE was not used. |
| Morris (2020b) | Time Series | Young (n = 9; age: 22.4±2.9, height: 65.4±3.4; weight: 56.2±12.8) and older ♀ (n = 16; age: 74.1±6.3; height: 64.1±2.1; weight: 60.5±8.8) | **Aim:** examine the effect of a mentally fatiguing task on neuromuscular function in young and older ♀.<br><br>**Manipulation Check:** RT on PVT and MFI were ↑ post-MF compared to baseline.<br><br>**Results:** No effect of age or time on peak twitch force, time to peak twitch force, or half-relaxation time. No significant interaction of time and age for peak twitch force, time to peak, or half-relaxation time. There was a significant main effect of time on force, with ↓ MVC force values post MF, compared with baseline. RPE was not used. |
| | | **Gait or Walking or Cardiopulmonary Function** | |
| Goodwin (2018) | Randomised crossover study | Healthy older adults (n=9, age: 67.39±4.58, height:168.01±55.82 cm, weight: 60.80±12.41) | **Aim:** determine the impact of cognitive fatigue on aerobic output during a 6-minute walk test in older adults.<br><br>**Manipulation Check:** ↑ profile mood states (information provided by the author, it is not in the abstract). |

| | | | |
|---|---|---|---|
| | | | **Results:** $VO_2$ max ↔ between cognitive fatigue and non-cognitive fatigue days. RPE was not used. |
| Behrens (2018) | Randomised crossover study | Young (n = 16, 8 ♀, 8 ♂; age: 24.9 ± 1.4; height: 1.74 ± 0.11; weight: 70.1 ± 13.3); old (n = 16, 10 ♀, 6 ♂; age: 72.2 ± 4.4, height: 1.69 ± 0.11; weight: 73.0 ± 11.4) | **Aim:** assess single- and dual-task walking performance in young and old participants before and after a randomly assigned MF and CTRL intervention.<br><br>**Manipulation Check:** ↑ profile mood states in the MF condition compared to CTRL. ↑ tiredness, negative mood and nervous feelings from post to pre-MF moments, but no difference between conditions. ↔ Stop-signal RT over time and conditions.<br><br>**Results:** Dual task - differences in speed, stride length, stance time, double support time, swing time in MF pre to post for old participants. No difference between MF and CTRL. No differences for single task. RPE was not used |
| dos Santos (2019) | Time Series | Older (n = 12, 7 ♂, 5 ♀; age: 71 ±3.76; height: 173.13 ±7.70; BMI: 73.92 ±10.15); Younger (n = 12, 7 ♂, 5 ♀; age: 22.45 ±1.69; height: 177.45 ±9.17; BMI: 69.81 ±11.38) | **Aim:** determine the effects of age, repetitive sit-to-stand task, and a prolonged mental effort on the spatial and temporal stride outcomes and gait dynamics during treadmill walking.<br><br>**Manipulation Check:** ↑ VAS from post to pre-MF moment. ↑ RT for PVT (˜7%) and Stroop test (15% for congruent and incongruent), and accuracy for incongruent responses in Stroop decreased by 5% from the end to the beginning of the tasks.<br><br>**Results:** In both age groups, repeated sit-to-stand task modestly affected stride length, single support time, cadence, and CV of stride length, while the mental task did not affect gait. After fatigability, COP ↑, independent of fatigue condition (muscular x mental). All observed effects were small. RPE ↔. |

| | | | |
|---|---|---|---|
| | Non-randomised between groups design | | **Aim:** investigate how muscular and mental fatigue affects dual task walking performance comparing young, healthy older adults, and frail older adults. |
| Piche (2023) | | Young (n = 20, age: 24.9 ± 3), non-frail (n = 20, age: 75.8 ± 4.9), Frail (n = 19, age: 81 ± 4.7) | **Manipulation Check:** ↑ accuracy, ↓ errors and ↓ response time between the third and last to the first cognitive task. Each group had a VAS below 5 out of 10 (4.5 ± 1.9) after MF condition. VAS was not measured in the baseline.<br><br>**Results:** The dual task effect walking parameters were ↑ in frail compared to non-frail or young, but no significant effect of MF was highlighted. Muscular fatigue significantly ↓ swing time and single support time from the pre to the post-test for all groups. RPE was not used. |
| | Randomised controlled trial | | **Balance and Postural Function**<br>**Aim:** investigated the impact of MF, induced by sustained cognitive activity, on stance balance performance under different sensory conditions in older adults and in participants with chronic stroke. |
| Varas Diaz (2020) | | Healthy (n = 15; age: 66.1±6.02; height: 173.67±6; weight: 77.4 ±12.06); self-reported hemiparetic chronic stroke (n = 15, 6 ♂, 9 ♀; age: 63.8±8.6, height: 175.1± 4.7; weight: 75.6 ± 5.2); CTRL (n = 15, age: 65.6± 6.2; height: 178.3±8.1; weight: 78.9±4.4) | **Manipulation Check:** ↔ HR variability between groups. ↑ NASA Task Load Index for the stroke group in comparison to the other two groups, and ↑ NASA Task Load Index for the healthy older adults' group compared to CTRL.<br><br>**Results:** ↑ jerk and root mean square of COM were observed after the MF task in both healthy older adults and participants with chronic stroke during sensory organisation task, which was not observed in the CTRL group. No differences were observed between both experimental groups in any of the balance tasks. RPE was not used. |

| | | | |
|---|---|---|---|
| Morris (2020a) | Randomised crossover study | Young ♀ (n = 16; age: 22.4±2.93, height: 164.06±2.29; weight: 59.66±3.49) and older ♀ (n = 16; age: 72.63±6.3; height: 161.37±1.65; weight: 60.50±1.78) | **Aim:** examine the effect of a mentally fatiguing task on postural responses to perturbation in young and older women.<br><br>**Manipulation Check:** MFI and RT were ↑ from post-MF to pre-MF, however MFI and RT were ↔ between conditions.<br><br>**Results:** Postural stability - no significant interactions or main effects of condition or time. Older ♀ had significantly larger anterior-posterior COP displacement than young. Medial gastrocnemius electromyography onset time (muscle activity) was significantly slower in the MF condition than the CTRL condition overall. RPE was not used. |
| Fletcher (2021) | Randomised crossover study | Ten younger adults (6 ♂, age: 21 ± 1, height: 172 ± 10, weight: 74 ± 19) and 10 community-dwelling older adults (4 ♂, age: 74 ± 6, height: 168 ± 8, weight: 72 ± 18). | **Aim:** investigate whether experimentally-induced MF affects static upright stance and functional balance and, if so, whether older adults demonstrate ↑ susceptibility to this effect.<br><br>**Manipulation Check:** ↔ MF and motivation, and ↑ ME in the VAS.<br><br>**Results:** ↔ static and dynamic balance for both single and dual-task. The authors reported differences in static balance when they combined the results of single and dual task. RPE was not used. |
| Salehi (2023) | Randomised controlled trial | Fatigued group (n = 20; 10 ♂ and 10 ♀; age: 66.64 ± 3.38; height: 168.43 ± 6.32; weight: 67.19 ± 7.85) and CTRL group (n = 20; 10 ♂ and 10 ♀; age: 64.11 ± 4.59; height: 170.16 ± 6.46; weight: 69.61 ± 6.99) | **Aim:** investigate the impact of MF on postural stability among healthy older adults.<br><br>**Manipulation Check:** experimental group reported ↑ VAS than the control group. RT ↑ from the beginning to the end of the Stroop task in the experimental group. |

| | |
|---|---|
| | **Results:** EXP group - ↑ stability scores in the posttest compared to pretest. ↔ BBS scores between pre and posttest in CTRL group. There was evidence of an association between visual analogue scale and BBS scores in the EXP group. Follow-up test revealed that BBS scores were higher in experimental group in comparison with control group. RPE was not used. |

Legend: CD, cognitive demand; MF, mental fatigue; MVC, maximal voluntary contraction; BBS, Biodex Balance System; RPE, rating of perception effort; CTRL, control group; EXP, experimental group; COM, centre of mass; COP, centre of pressure, ↑, increased or higher, ↔, similar (no statistical difference)↓, decreased or lower; ♂, male; ♀, female; age in years; height in cm; weight in kg; MAP, mean arterial blood pressure; HR, heart rate; PVT, psychomotor vigilance test; RT, response time; MFI, multidimensional fatigue inventory; ME, mental effort; VAS, visual analogue scale.

## 4. Discussion

*Summary of Evidence*

To the best of our knowledge, this is the first systematic scoping review of the mental fatigue and older adults' literature. The study included all papers published until November 2023. The results provide a snapshot of the published knowledge existing in mental fatigue and older people and provide the reader an understanding of the domains and components that have, to date, received the most and least attention. The review also provides an overview of the research designs that have been employed and the risk of bias of each study, which may provide a proxy of the quality of evidence upon which health and working decisions can be made in practice.

*What is the quantity and quality of the research?*

The difficulties of conducting true experimental research in older people are well known due to restrictive exclusion criteria (e.g., comorbidity, polypharmacy, functional limitations), recruitment (e.g., older people hesitate to participate) and retention issues, such as control participants get disappointed in being allocated to the control group and tend to drop out (Varas-Diaz; Kannan; Bhatt, 2020). This fact is reflected in the lack of true experimental research designs. While several studies included within this review have utilised quasi-experimental research designs to examine mental fatigue effects in various physical functions (e.g., Fletcher;  Osler, 2021, Goodwin; Avolio; Boolani, 2018, Morris;  Christie, 2020a, Morris;  Christie, 2020b), the inevitable risk of bias demands greater caution prior to implementation in practice.

Indeed, the risk of bias assessment indicated that none of the studies included in the review presented low risk. For the randomised trials (randomised controlled and cross-over

trials), the high risk of bias can be explained by the lack of random sequence generation, and lack of allocation concealment. For the non-randomised trials, it may be explained by the unaccountability of confounders in the analysis. We conducted an extra assessment by noting the number of studies that provided information about their sample size calculation. Surprisingly, only 2 studies (13%) followed this meticulous approach, raising the implication that the remaining studies might be underpowered. Low power can stem from either small sample sizes, small effect sizes, or a combination of both factors (Mesquida *et al.*, 2022). Low power brings about some consequences and three of them are related to small sample sizes. First, underpowered designs are less likely to detect a true effect, even if it indeed exists in the population (Fraley;  Vazire, 2014). This is mainly because small sample sizes result in significant sampling variance, reducing the likelihood of accurately capturing the true population parameters within the sample (Mesquida *et al.*, 2022). Second, underpowered designs contribute to a higher proportion of false positives within a body of literature affected by publication bias (Fraley;  Vazire, 2014). Lastly, small samples tend to overestimate the effect sizes (Halsey *et al.*, 2015).

The inexistent number of publications prior to 2014 leads us to believe that researchers became interested in this topic because of the observed trend for later retirement around the world and the increase in the prevalence of chronic diseases. First, retirement only emerged as a distinct stage of life during the 20th century (Coile, 2018). In the past, it was common to work at even the oldest ages; in 1880, over 75 percent of U.S. men aged 65 and above were part of the labour force (Costa, 1998). Over the next century, the rate steadily declined, dropping to less than 20 percent by 1990, due to greater availability of public and private pensions (Costa, 1998). Changes in the age of retirement affect society as a whole: taxes paid and transfers received, as well as the size of the labour force (Coile, 2018). Increases in the age of retirement can serve to counteract the need to share societal resources going to the

elderly (Coile, 2018). Later retirement is a strong trend for both men and women in the United States and around the world over the past several decades due to increased longevity and health improvements (Coile, 2018), which probably made researchers question whether mental fatigue could be a risk for the older labour force.

Second, mental fatigue is a typical symptom in patients with chronic condition, such as, Parkinson's disease and multiple sclerosis (Linnhoff *et al.*, 2019, Lou, 2009, Lou *et al.*, 2001a). According to a monitoring study (Van Oostrom *et al.*, 2016), the prevalence of chronic diseases rose significantly from 2004 to 2011 in general practice registration (34.9% to 41.8%, $p<0.01$) and from 2001 to 2011 in self-reported diseases (41.0% to 46.6%, $p<0.01$) in the Netherlands, which could have made researchers wonder about the impact of mental fatigue in the physical function of elderly.

Research country of origin tends to follow nations that are western, educated, industrialized, rich, and democratic (WEIRD) countries. Whether publication of research directly explains health success and longevity, or vice versa (i.e., reverse causality), cannot be shown with much certainty; the countries with contribution to the mental fatigue and older adults' literature were all WEIRD nations. However, since socioeconomic status negatively impact socioemotional abilities, cognitive and executive functions (Migeot *et al.*, 2022), and cognitive abilities play a mediating role in the relationship between mental fatigue and physical function (Catala *et al.*, 2021), non-WEIRD countries should also investigate mental fatigue.

*What are the common methods used to induce or assess mental fatigue?*

Most studies used laboratory-based tasks (n = 10, 71%) to induce mental fatigue (e.g., Stroop, Stop-signal, Psychomotor Vigilance Test - PVT). Surprisingly, we found 4 studies that used 4 minutes of mental maths and one study that used a combination of mental

calculation and an adapted PVT task for 25 minutes, a more ecological approach, to investigate the effects of low and high cognitive demand on different physical function. Even though the 4 minutes studies met our inclusion criteria, the authors do not address mental fatigue specifically and do not assess whether the cognitive stimuli were successful in cognitively tiring the participants. The authors evaluated, instead, participants' anxiety levels after each experimental condition. Therefore, it seems that there is an overlap between constructs (mental fatigue vs. anxiety), and those concepts need to be better understood.

Most studies used a combination of subjective and objective measures to evaluate mental fatigue induction (n = 9) (Behrens *et al.*, 2018, Shortz; Mehta, 2017, Shortz *et al.*, 2015), 4 adopted only objective measures (Morris; Christie, 2020a, Morris; Christie, 2020b, Pereira *et al.*, 2019, Pereira *et al.*, 2015a, Pereira *et al.*, 2015b, Piche *et al.*, 2023, Salehi; Fard; Jaberzadeh, 2023, Santos *et al.*, 2019, Vanden Noven *et al.*, 2014, Varas-Diaz; Kannan; Bhatt, 2020), and 2 relied solely on subjective measures (Fletcher; Osler, 2021, Goodwin; Avolio; Boolani, 2018). Some authors believe that it is important to combine subjective and objective indicators due to important limitations of subjective measures, such as: 1) the potential of participants to respond what researchers expect them to answer (Hassan; Jones; Buckingham, 2023), and the difficult some participants have to understand what mental fatigue is (Fortes *et al.*, 2019c). The present review indicated that researchers have been using three types of objective measures to check mental fatigue induction, which are: cardiovascular (heart rate, heart rate variability and blood pressure) (Behrens *et al.*, 2018, Morris; Christie, 2020b, Pereira *et al.*, 2019, Pereira *et al.*, 2015a, Pereira *et al.*, 2015b, Shortz; Mehta, 2017, Shortz *et al.*, 2015, Vanden Noven *et al.*, 2014, Varas-Diaz; Kannan; Bhatt, 2020), behavioural (Morris; Christie, 2020a, Morris; Christie, 2020b, Piche *et al.*, 2023, Salehi; Fard; Jaberzadeh, 2023, Santos Henriques; Tomas-Carus; Filipe Marmeleira, 2023), and neurobiological measures (Shortz *et al.*, 2015).

Behavioural measures do not seem to be affected by mental fatigue in the elderly population. Brahms et al. (2022), for instance, reviewed the studies on the effects of mental fatigue on the balance of older people and 3 out of 4 studies did not report changes in objective measures. A possible explanation is that, although the aging process is characterized by many downsides, we tend to become considerably more resilient with age (Feldman, 2020). In the present review, 6 studies analysed changes in response time and/or accuracy during the cognitive task used for mental fatigue induction, 4 of them showed impairment (Morris;  Christie, 2020a, Morris;  Christie, 2020b, Salehi; Fard; Jaberzadeh, 2023, Santos *et al.*, 2019), 1 showed improvement (Piche *et al.*, 2023) and 1 did not find differences in performance from the end to the beginning of the task (Behrens *et al.*, 2018). However, this approach does not allow the comparison of performance to the control condition and might represent a time, not mental fatigue, effect.

Regarding cardiovascular measures, blood pressure seems to be a reliable measure of the effects of cognitive demand on physical function of elderly increasing under cognitive demand condition in comparison to control (Pereira *et al.*, 2019, Pereira *et al.*, 2015a, Pereira *et al.*, 2015b, Vanden Noven *et al.*, 2014). Heart rate and heart rate variability seem to not differ between conditions (Shortz;  Mehta, 2017, Varas-Diaz; Kannan; Bhatt, 2020). More studies are needed with neurobiological measures to reach a conclusion.

Finally, for subjective scales, 3 out of 4 non-randomised clinical trials (Morris; Christie, 2020b, Santos *et al.*, 2019, Shortz;  Mehta, 2017) indicated increased perception of mental fatigue after the induction compared to the baseline. Shortz and Mehta (Shortz; Mehta, 2017) also compared the subjective mental fatigue between groups and found increased mental fatigue in the experimental group compared to control. The non-randomised between groups study (Piche *et al.*, 2023) only measured mental fatigue after the induction. For the randomised trials, 5 out of 7 studies (Behrens *et al.*, 2018, Goodwin; Avolio; Boolani,

2018, Salehi; Fard; Jaberzadeh, 2023, Shortz *et al.*, 2015, Varas-Diaz; Kannan; Bhatt, 2020) that used subjective measures showed increase feelings of mental fatigue in the mental fatigue condition or group in comparison to control and 2 did not find differences (Fletcher; Osler, 2021, Morris; Christie, 2020a). Apparently, subjective measures are sensitive to mental fatigue; however, since it is not possible to bind the participants and researchers are very often aware of the assigned intervention, there is high risk that participants may respond what researchers expect them to answer (Hassan; Jones; Buckingham, 2023).

*What physical functions have been previously investigated?*

We observed a similar distribution of the studies across the three main physical function domains, except for the complex activities domain that has not been investigated yet. The absence of studies investigating complex activities probably relates to the fact that most validated batteries to measure the physical function of elderly are interested in assessing their functionality and not performance, involving basic movements and instrument activities of daily living (Varela; Ayán; Cancela, 2008).

Studies that focused on axial and dexterity domains were considerably homogeneous, investigating the effects of mental fatigue, respectively, on static balance (Fletcher; Osler, 2021, Morris; Christie, 2020a, Salehi; Fard; Jaberzadeh, 2023, Varas-Diaz; Kannan; Bhatt, 2020), handgrip (Shortz; Mehta, 2017, Shortz *et al.*, 2015) and force steadiness of the elbow flexion (Pereira *et al.*, 2019, Pereira *et al.*, 2015a, Pereira *et al.*, 2015b). Studies focusing on the mobility domain, instead, were more heterogeneous assessing functional balance (Fletcher; Osler, 2021), gait (Behrens *et al.*, 2018, Piche *et al.*, 2023, Santos *et al.*, 2019), aerobic capacity (Goodwin; Avolio; Boolani, 2018), muscle activity and force of different structures (e.g., quadriceps (Santos *et al.*, 2019), gastrocnemius (Morris; Christie, 2020a), and ankle dorsiflexors muscles (Morris; Christie, 2020b, Vanden Noven *et al.*, 2014)).

Overall, studies investigated mental fatigue effects on balance and muscle properties (e.g., activation, strength). The interest of researchers on those physical functions do not surprise us. Balance impairment is a prevalent risk factor for falls (Osoba *et al.*, 2019), which are the second leading reason behind unintentional death among older adults (World Health Organization, 2021). The muscular system is essential for activities of daily living, such as: walking, running, cycling, stair ascending and descending, standing up from a chair, getting up from bed, bathing, dressing, carrying groceries, opening jars, eating, toileting, and lifting things from the floor (Naruse; Trappe; Trappe, 2023). In addition, the combined impairment in muscle mass and function or strength is also associated with falls and many other outcomes (e.g., cardiovascular disease, quality of life, mortality) (Damluji *et al.*, 2023). Therefore, if mental fatigue impacts these physical functions, health managers and politicians should consider it in public policies.

*What are the main results?*

The present review highlights 4 main results extracted from the included studies: 1) most studies were interested in understanding the differences in mental fatigue effects between age groups; 2) most studies included only healthy participants; 3) overall, elderly people display greater force fluctuations than their young peers in contexts of cognitive demand; 4) some of the significant results emerged from pre- and post-test comparisons and not from between groups and/or conditions comparison.

Two of the main results raise some concerns about the research regarding the effects of mental fatigue in the physical function of elderly people. First, 13 out of 15 studies included only healthy participants. We considered this result concerning because frail elderly individuals (Zengarini *et al.*, 2015) were found to perceive higher levels of mental fatigability, and mental fatigue is a common symptom of people with chronic diseases, such as

fibromyalgia (Vancampfort *et al.*, 2023b), multiple sclerosis (Linnhoff *et al.*, 2019) and Parkinson disease (Lou, 2009, Lou *et al.*, 2001a). Therefore, the studies are not including participants that suffer from mental fatigue the most.

Second, some of the statistically significant results emerged from pre- and post-test comparisons and not from between groups and/or conditions comparison even in the studies that had a between group design. For instance, studies claimed the existence of mental fatigue effects on physical function; however, the authors based their claim in differences between pre- and post-tests and ignored the insignificancy of the comparison between conditions (Behrens *et al.*, 2018, Fletcher;  Osler, 2021, Varas-Diaz; Kannan; Bhatt, 2020). Nevertheless, differences between pre- and post-tests might be explained by a nocebo or a simple time effect and; therefore, it should be interpreted with caution.

Regarding the reduced steadiness with age during control contractions, it has been consistently observed in different muscle groups [such as, knee extensors (Tracy;  Enoka, 2002), hand muscles (Galganski; Fuglevand; Enoka, 1993), and elbow flexors (Pereira *et al.*, 2015b), and it might be explained by greater motor unit discharge rate variability in older adults at the very low forces (Barry *et al.*, 2007, Laidlaw; Bilodeau; Enoka, 2000, Negro; Holobar; Farina, 2009). Results on the effects of mental fatigue on force steadiness, however, are still unclear once some studies did not show differences between conditions (Shortz; Mehta, 2017, Shortz *et al.*, 2015, Vanden Noven *et al.*, 2014) and others indicated increased fluctuations in high cognitive demand conditions compared to control (Pereira *et al.*, 2019, Pereira *et al.*, 2015a, Pereira *et al.*, 2015b).

*Limitations*

The present review had a potential limitation, which was voluntarily imposed, by excluding studies involving participants below the age of 60. When we first designed the study, we expected to find studies interested to investigate the effects of mental fatigue in

people with chronic diseases (e.g., fibromyalgia, multiple sclerosis). However, due to the difficulties to find participants with these conditions, studies with these populations usually include people in different stages of life (e.g., Dailey; Keffala; Sluka, 2015). Therefore, many studies were possibly excluded based on the age criteria.

The age criteria probably brought about a second limitation. Fatigue can be perceived in two distinct ways: as a trait, which refers to the predisposition to experience fatigue, or as a state, which represents the immediate and momentary experience of fatigue (Wylie *et al.*, 2022). People with chronic diseases can experience both forms of mental fatigue, whereas older people in relatively good health experience mostly the second one. The 15 studies included in the present review all assessed mental fatigue as a state. However, this review aimed to assess the extent and depth of research and pinpoint any potential areas that may demand special attention, particularly concerning older individuals. Therefore, considering the focus of this study, we find the exclusion of broader populations to be justifiable.

*Future research*

The present scoping review shows the necessity to better understand and characterize mental fatigue. There is an overlap and interdependency between mental fatigue and other psychological constructs (e.g., anxiety and depression). Research carried out in any of the three is likely to have positive effects on the others. Contrastingly, although they interact with each other, they can be considered independent. Therefore, they should be studied as distinct entities to enhance our comprehension for application in public policies and elderly health. In particular, researchers must ask what is the cut-off induction time to characterize the cognitive demand as mental fatigue or an anxiety state.

In addition, the limited amount of true experimental research may also restrict the efficacy for implementation of research findings in evidence-based practices. Quasi-

experimental research designs do not allow for understanding the causative effects of various interventions and can result in a greater risk of bias. We acknowledge the difficulties with administering well controlled, randomised research in elderly population, but we do encourage researchers interested in this topic to look for solutions to this issue so that we can improve the quality of our research and understanding of the demands and needs of the population, and the true causative effects of our interventions and practices. The use of multicentre studies should be explored as one method for increasing the sampled populations available to researchers, and closer collaboration with retirement villages or government organisations could be a possible solution to the research-quality limitation.

Finally, we observe the inexistence of studies that investigated the effects of mental fatigue in complex activities probably due to the lack of more complex batteries and the scarcity of studies that used neurobiological measures. Therefore, future studies should develop instruments to assess the effects of mental fatigue in more complex physical functions and measure mental fatigue through neurobiological instruments in order to better understand its mechanisms.

## 5. Conclusions

This review underscores the recent attention on mental fatigue in older individuals. Studies mainly examined balance and muscle function using low ecological fatigue induction and a combination of subjective and objective measures for the manipulation check. Complex activities and chronic conditions were underrepresented. The existing evidence, marred by bias and underpowered analysis, calls for more rigorous research to inform healthcare decisions.

**References**


1. Boksem MA, Tops M. Mental fatigue: costs and benefits. Brain Res Rev. 2008 Nov;59(1):125-39; https://doi.org/10.1016/j.brainresrev.2008.07.001.
2. Marcora SM, Staiano W, Manning V. Mental fatigue impairs physical performance in humans. J Appl Physiol. 2009 Mar;106(3):857-64; https://doi.org/10.1152/japplphysiol.91324.2008.
3. Hardy SE, Studenski SA. Fatigue predicts mortality in older adults. J Am Geriatr Soc. 2008 Oct;56(10):1910-4; https://doi.org/10.1111/j.1532-5415.2008.01957.x.
4. Cohen RW, Meinhardt AJ, Gmelin T, Qiao YS, Moored KD, Katz RD, et al. Prevalence and severity of perceived mental fatigability in older adults: The Long Life Family Study. J Am Geriatr Soc. 2021 May;69(5):1401-3; https://doi.org/10.1111/jgs.17075.
5. Meng H, Hale L, Friedberg F. Prevalence and predictors of fatigue in middle-aged and older adults: evidence from the health and retirement study. J Am Geriatr Soc. 2010 Oct;58(10):2033-4; https://doi.org/10.1111/j.1532-5415.2010.03088.x.
6. Zengarini E, Ruggiero C, Pérez-Zepeda MU, Hoogendijk EO, Vellas B, Mecocci P, et al. Fatigue: Relevance and implications in the aging population. Exp Gerontol. 2015 Oct;70:78-83; https://doi.org/10.1016/j.exger.2015.07.011.
7. Vancampfort D, Brunner E, McGrath RL, Hemmings L, Van Damme T. Correlates of sedentary behavior in people with fibromyalgia: A systematic review. International Journal of Rheumatic Diseases. 2023 2023/05/01;26(5):841-9; https://doi.org/10.1111/1756-185X.14678.
8. Linnhoff S, Fiene M, Heinze HJ, Zaehle T. Cognitive Fatigue in Multiple Sclerosis: An Objective Approach to Diagnosis and Treatment by Transcranial Electrical Stimulation. Brain Sci. 2019 May 2;9(5); https://doi.org/10.3390/brainsci9050100.
9. Lou JS. Physical and mental fatigue in Parkinson's disease: epidemiology, pathophysiology and treatment. Drugs Aging. 2009;26(3):195-208; https://doi.org/10.2165/00002512-200926030-00002.
10. Lou JS, Kearns G, Oken B, Sexton G, Nutt J. Exacerbated physical fatigue and mental fatigue in Parkinson's disease. Movement Disorders. 2001 2001/03/01;16(2):190-6; https://doi.org/10.1002/mds.1042.
11. Pageaux B, Lepers R, Dietz KC, Marcora SM. Response inhibition impairs subsequent self-paced endurance performance. Eur J Appl Physiol. 2014 May;114(5):1095-105; https://doi.org/10.1007/s00421-014-2838-5.
12. Martin K, Meeusen R, Thompson KG, Keegan R, Rattray B. Mental Fatigue Impairs Endurance Performance: A Physiological Explanation. Sports Med. 2018 Sep;48(9):2041-51; https://doi.org/10.1007/s40279-018-0946-9.
13. Ishii A, Tanaka M, Watanabe Y. Neural mechanisms of mental fatigue. Rev Neurosci. 2014;25(4):469-79; https://doi.org/10.1515/revneuro-2014-0028.
14. Shortz AE, Pickens A, Zheng Q, Mehta RK. The effect of cognitive fatigue on prefrontal cortex correlates of neuromuscular fatigue in older women. Journal of NeuroEngineering and Rehabilitation. 2015 2015/12/21;12(1):115; https://doi.org/10.1186/s12984-015-0108-3.
15. Terentjeviene A, Maciuleviciene E, Vadopalas K, Mickeviciene D, Karanauskiene D, Valanciene D, et al. Prefrontal Cortex Activity Predicts Mental Fatigue in Young and Elderly Men During a 2 h "Go/NoGo" Task. Front Neurosci. 2018;12:620; https://doi.org/10.3389/fnins.2018.00620.
16. Santos Henriques RPD, Tomas-Carus P, Filipe Marmeleira JF. Association Between Neuropsychological Functions and Activities of Daily Living in People with Mild Cognitive

Impairment. Exp Aging Res. 2023 Oct-Dec;49(5):457-71; https://doi.org/10.1080/0361073x.2022.2133292.
17. de Dieuleveult AL, Siemonsma PC, van Erp JB, Brouwer AM. Effects of Aging in Multisensory Integration: A Systematic Review. Front Aging Neurosci. 2017;9:80; https://doi.org/10.3389/fnagi.2017.00080.
18. Cheng Y, Goodin AJ, Pahor M, Manini T, Brown JD. Healthcare Utilization and Physical Functioning in Older Adults in the United States. J Am Geriatr Soc. 2020 Feb;68(2):266-71; 10.1111/jgs.16260.
19. Edwards JD, Lunsman M, Perkins M, Rebok GW, Roth DL. Driving cessation and health trajectories in older adults. J Gerontol A Biol Sci Med Sci. 2009 Dec;64(12):1290-5; https://doi.org/10.1093/gerona/glp114.
20. de Munter L, van de Ree CLP, van der Jagt OP, Gosens T, Maas H, de Jongh MAC. Trajectories and prognostic factors for recovery after hip fracture: a longitudinal cohort study. Int Orthop. 2022 Dec;46(12):2913-26; https://doi.org/10.1007/s00264-022-05561-4.
21. Moreira MN, Bilton TL, Dias RC, Ferriolli E, Perracini MR. What are the Main Physical Functioning Factors Associated With Falls Among Older People With Different Perceived Fall Risk? Physiother Res Int. 2017 Jul;22(3); https://doi.org/10.1002/pri.1664.
22. Swartz AM, Strath SJ, Miller NE, Cashin SE, Cieslik LJ. Glucose control and walking in a multiethnic sample of older adults. Gerontology. 2007;53(6):454-61; https://doi.org/10.1159/000118600.
23. Kraus WE, Janz KF, Powell KE, Campbell WW, Jakicic JM, Troiano RP, et al. Daily Step Counts for Measuring Physical Activity Exposure and Its Relation to Health. Med Sci Sports Exerc. 2019 Jun;51(6):1206-12; https://doi.org/10.1249/mss.0000000000001932.
24. Brahms M, Heinzel S, Rapp M, Mückstein M, Hortobágyi T, Stelzel C, et al. The acute effects of mental fatigue on balance performance in healthy young and older adults - A systematic review and meta-analysis. Acta Psychol (Amst). 2022 May;225:103540; https://doi.org/10.1016/j.actpsy.2022.103540.
25. Jackson D, Turner R. Power analysis for random-effects meta-analysis. Res Synth Methods. 2017 Sep;8(3):290-302; https://doi.org/10.1002/jrsm.1240.
26. Naruse M, Trappe S, Trappe TA. Human skeletal muscle-specific atrophy with aging: a comprehensive review. J Appl Physiol (1985). 2023 Apr 1;134(4):900-14; https://doi.org/10.1152/japplphysiol.00768.2022.
27. Munn Z, Peters MDJ, Stern C, Tufanaru C, McArthur A, Aromataris E. Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach. BMC Medical Research Methodology. 2018 2018/11/19;18(1):143; https://doi.org/10.1186/s12874-018-0611-x.
28. Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation. Ann Intern Med. 2018 Oct 2;169(7):467-73; https://doi.org/10.7326/m18-0850.
29. Peters MDJ, Marnie C, Tricco AC, Pollock D, Munn Z, Alexander L, et al. Updated methodological guidance for the conduct of scoping reviews. JBI Evidence Synthesis. 2020;18(10); https://doi.org/10.11124/JBIES-20-00167.
30. Peters MD, Godfrey CM, Khalil H, McInerney P, Parker D, Soares CB. Guidance for conducting systematic scoping reviews. Int J Evid Based Healthc. 2015 Sep;13(3):141-6; https://doi.org/10.1097/XEB.0000000000000050.
31. Hulley SB, Cummings SR, Browner WS, Grady D, Newman TB. Designing clinical research. Fourth edition ed. Philadelphia: Wolters Kluwer Health/Lippincott Williams & Wilkins Philadelphia; 2013.

32. Cella D, Yount SE, Rothrock NE, Gershon RC, Cook KF, Reeve BB, et al. The Patient-Reported Outcomes Measurement Information System (PROMIS): Progress of an NIH Roadmap Cooperative Group During its First Two Years. Medical Care. 2007;45:S3-S11; https://doi.org/10.1016/j.jclinepi.2010.04.011.
33. Bruce B, Fries JF, Ambrosini D, Lingala B, Gandek B, Rose M, et al. Better assessment of physical function: item improvement is neglected but essential. Arthritis Res Ther. 2009;11(6):R191; https://doi.org/10.1186/ar2890.
34. Dias JM. Physical Functioning (PF). In: Michalos AC, editor. Encyclopedia of Quality of Life and Well-Being Research. Dordrecht: Springer Netherlands; 2014. p. 4793-5.
35. Sterne JAC, Savović J, Page MJ, Elbers RG, Blencowe NS, Boutron I, et al. RoB 2: a revised tool for assessing risk of bias in randomised trials. Bmj. 2019 Aug 28;366:l4898; https://doi.org/10.1136/bmj.l4898.
36. Sterne JA, Hernán MA, Reeves BC, Savović J, Berkman ND, Viswanathan M, et al. ROBINS-I: a tool for assessing risk of bias in non-randomised studies of interventions. Bmj. 2016 Oct 12;355:i4919; https://doi.org/10.1136/bmj.i4919.
37. Goodwin A, Avolio A, Boolani A. The impact of cognitive fatigue on aerobic output in a 6-minute walk test among older adults. The FASEB Journal. 2018 04/01;32; https://doi.org/10.1096/fasebj.2018.32.1_supplement.877.13.
38. Salehi NE, Fard JS, Jaberzadeh S. Mental Fatigue Impairs Postural Stability in Older Adults. Res Q Exerc Sport. 2023 Jun;94(2):401-8; https://doi.org/10.1080/02701367.2021.1999892.
39. Santos PCRd, Hortobágyi T, Zijdewind I, Bucken Gobbi LT, Barbieri FA, Lamoth C. Minimal effects of age and prolonged physical and mental exercise on healthy adults' gait. Gait & Posture. 2019 2019/10/01/;74:205-11; https://doi.org/10.1016/j.gaitpost.2019.09.017.
40. Vanden Noven ML, Pereira HM, Yoon T, Stevens AA, Nielson KA, Hunter SK. Motor Variability during Sustained Contractions Increases with Cognitive Demand in Older Adults. Front Aging Neurosci. 2014;6:97; https://doi.org/10.3389/fnagi.2014.00097.
41. Pereira HM, Schlinder-DeLap B, Keenan KG, Negro F, Farina D, Hyngstrom AS, et al. Oscillations in neural drive and age-related reductions in force steadiness with a cognitive challenge. J Appl Physiol (1985). 2019 Apr 1;126(4):1056-65; https://doi.org/10.1152/japplphysiol.00821.2018.
42. Pereira HM, Spears VC, Schlinder-Delap B, Yoon T, Harkins A, Nielson KA, et al. Sex Differences in Arm Muscle Fatigability With Cognitive Demand in Older Adults. Clinical Orthopaedics and Related Research®. 2015;473(8); https://doi.org/10.1007/s11999-015-4205-1.
43. Pereira HM, Spears VC, Schlinder-Delap B, Yoon T, Nielson KA, Hunter SK. Age and sex differences in steadiness of elbow flexor muscles with imposed cognitive demand. Eur J Appl Physiol. 2015 Jun;115(6):1367-79; https://doi.org/10.1007/s00421-015-3113-0.
44. Shortz AE, Mehta RK. Cognitive challenges, aging, and neuromuscular fatigue. Physiol Behav. 2017 Mar 1;170:19-26; https://doi.org/10.1016/j.physbeh.2016.11.034.
45. Fletcher LJ, Osler CJ. Effects of mental fatigue on static upright stance and functional balance in older adults. Aging and Health Research. 2021 2021/12/01/;1(4):100043; https://doi.org/10.1016/j.ahr.2021.100043.
46. Morris AJ, Christie AD. The effect of a mentally fatiguing task on postural balance control in young and older women. Experimental Gerontology. 2020 2020/04/01/;132:110840; https://doi.org/10.1016/j.exger.2020.110840.
47. Behrens M, Mau-Moeller A, Lischke A, Katlun F, Gube M, Zschorlich V, et al. Mental Fatigue Increases Gait Variability During Dual-task Walking in Old Adults. J

Gerontol A Biol Sci Med Sci. 2018 May 9;73(6):792-7; https://doi.org/10.1093/gerona/glx210.
48. Varas-Diaz G, Kannan L, Bhatt T. Effect of Mental Fatigue on Postural Sway in Healthy Older Adults and Stroke Populations. Brain Sciences. 2020;10(6):388; https://doi.org/10.3390/brainsci10060388.
49. Morris AJ, Christie AD. The Effect of Mental Fatigue on Neuromuscular Function is Similar in Young and Older Women. Brain Sci. 2020 Mar 25;10(4); https://doi.org/10.3390/brainsci10040191.
50. Piche E, Gerus P, Zory R, Jaafar A, Guerin O, Chorin F. Effects of muscular and mental fatigue on spatiotemporal gait parameters in dual task walking in young, non-frail and frail older adults. Aging Clin Exp Res. 2023 Aug 3; https://doi.org/10.1007/s40520-023-02506-8.
51. Mesquida C, Murphy J, Lakens D, Warne J. Replication concerns in sports and exercise science: a narrative review of selected methodological issues in the field. Royal Society Open Science. 2022 2022/12/14;9(12):220946; https://doi.org/10.1098/rsos.220946.
52. Fraley RC, Vazire S. The N-Pact Factor: Evaluating the Quality of Empirical Journals with Respect to Sample Size and Statistical Power. PLOS ONE. 2014;9(10):e109019; https://doi.org/10.1371/journal.pone.0109019.
53. Halsey LG, Curran-Everett D, Vowler SL, Drummond GB. The fickle P value generates irreproducible results. Nature Methods. 2015 2015/03/01;12(3):179-85; https://doi.org/10.1038/nmeth.3288.
54. Coile C. The Demography of Retirement. In: Majmundar MK, Hayward MD, editors. Future Directions for the Demography of Aging: proceedings of a workshop. Washington (DC): National Academies Press (US): Division of Behavioral and Social Sciences and Education; 2018.
55. Costa DL. The evolution of retirement: an American economic history, 1880-1990 / Dora L. Costa. Chicago: University of Chicago Press; 1998.
56. van Oostrom SH, Gijsen R, Stirbu I, Korevaar JC, Schellevis FG, Picavet HS, et al. Time Trends in Prevalence of Chronic Diseases and Multimorbidity Not Only due to Aging: Data from General Practices and Health Surveys. PLoS One. 2016;11(8):e0160264; https://doi.org/10.1371/journal.pone.0160264.
57. Migeot J, Calivar M, Granchetti H, Ibáñez A, Fittipaldi S. Socioeconomic status impacts cognitive and socioemotional processes in healthy ageing. Sci Rep. 2022 Apr 11;12(1):6048; https://doi.org/10.1038/s41598-022-09580-4.
58. Catala P, Gutierrez L, Écija C, Serrano Del Moral Á, Peñacoba C. Do Cognitive Abilities Influence Physical and Mental Fatigue in Patients with Chronic Pain after Walking According to a Clinical Guideline for Physical Exercise? Int J Environ Res Public Health. 2021 Dec 13;18(24); https://doi.org/10.3390/ijerph182413148.
59. Hassan EK, Jones AM, Buckingham G. A novel protocol to induce mental fatigue. Behavior Research Methods. 2023 2023/08/03; https://doi.org/10.3758/s13428-023-02191-5.
60. Fortes LS, Lima-Junior D, Nascimento-Júnior JRA, Costa EC, Matta MO, Ferreira MEC. Effect of exposure time to smartphone apps on passing decision-making in male soccer athletes. Psychology of Sport and Exercise. 2019 2019/09/01/;44:35-41; https://doi.org/10.1016/j.psychsport.2019.05.001.
61. Feldman R. What is resilience: an affiliative neuroscience approach. World Psychiatry. 2020 Jun;19(2):132-50; https://doi.org/10.1002/wps.20729.
62. Varela S, Ayán C, Cancela JM. Batteries assessing health related fitness in the elderly: a brief review. European Review of Aging and Physical Activity. 2008 2008/10/01;5(2):97-105; https://doi.org/10.1007/s11556-008-0037-2.

63. Osoba MY, Rao AK, Agrawal SK, Lalwani AK. Balance and gait in the elderly: A contemporary review. Laryngoscope Investig Otolaryngol. 2019 Feb;4(1):143-53; https://doi.org/10.1002/lio2.252.
64. World Health Organization W. Falls. 2021 [cited 02 August 2023]; Available from: https://www.who.int/news-room/fact-sheets/detail/falls
65. Damluji AA, Alfaraidhy M, AlHajri N, Rohant NN, Kumar M, Al Malouf C, et al. Sarcopenia and Cardiovascular Diseases. Circulation. 2023 2023/05/16;147(20):1534-53; https://doi.org/10.1161/CIRCULATIONAHA.123.064071.
66. Tracy BL, Enoka RM. Older adults are less steady during submaximal isometric contractions with the knee extensor muscles. J Appl Physiol (1985). 2002 Mar;92(3):1004-12; https://doi.org/10.1152/japplphysiol.00954.2001.
67. Galganski ME, Fuglevand AJ, Enoka RM. Reduced control of motor output in a human hand muscle of elderly subjects during submaximal contractions. J Neurophysiol. 1993 Jun;69(6):2108-15; https://doi.org/10.1152/jn.1993.69.6.2108.
68. Barry BK, Pascoe MA, Jesunathadas M, Enoka RM. Rate coding is compressed but variability is unaltered for motor units in a hand muscle of old adults. J Neurophysiol. 2007 May;97(5):3206-18; https://doi.org/10.1152/jn.01280.2006.
69. Negro F, Holobar A, Farina D. Fluctuations in isometric muscle force can be described by one linear projection of low-frequency components of motor unit discharge rates. J Physiol. 2009 Dec 15;587(Pt 24):5925-38; https://doi.org/10.1113/jphysiol.2009.178509.
70. Laidlaw DH, Bilodeau M, Enoka RM. Steadiness is reduced and motor unit discharge is more variable in old adults. Muscle Nerve. 2000 Apr;23(4):600-12; https://doi.org/10.1002/(sici)1097-4598(200004)23:4<600::aid-mus20>3.0.co;2-d.
71. Dailey DL, Keffala VJ, Sluka KA. Do cognitive and physical fatigue tasks enhance pain, cognitive fatigue, and physical fatigue in people with fibromyalgia? Arthritis Care Res (Hoboken). 2015 Feb;67(2):288-96; https://doi.org/10.1002/acr.22417.
72. Wylie GR, Pra Sisto AJ, Genova HM, DeLuca J. Fatigue Across the Lifespan in Men and Women: State vs. Trait. Frontiers in Human Neuroscience. 2022 2022-May-09;16; https://doi.org/10.3389/fnhum.2022.790006.

## 3. ESTUDO 2

# The influence of mental fatigue on physical performance and factors that affect exercise adherence in older adults

Larissa Oliveira Faria[1,2], Leonardo de Sousa Fortes [3], Maicon Rodrigues Albuquerque [1]

1.Universidade Federal de Minas Gerais, Belo Horizonte – MG, Brazil
2.University of Technology Sydney, Sydney – NSW, Australia
3.Universidade Federal da Paraíba, João Pessoa – PB, Brazil

ABSTRACT

The present study investigated the influence of mental fatigue on older people's enjoyment during the walking and balance tests, and the resistance exercise. 35 participants were included in the study. Using a randomised cross-over design, participants completed a series of physical tests (i.e., 6 min walk test, and balance task), and a brief standardised resistance exercise after two experimental conditions (control or mental fatigue). The Nonparametric Analysis of Longitudinal Data in Factorial Experiments was used to compare the difference in the number of repetitions performed during the three sets of resistance exercise between the control and mental fatigue conditions. The same test was used to compare the RPE and Enjoyment in the 5 moments (Post-6MWT, Post-TUG, Post-KE1, Post-KE2, Post-KE3) and 2 conditions (mental fatigue x control) and the VAS scales in the 4 moments (baseline, Pre-6MWT, Pre-TUG, Pre-KE) and 2 conditions (mental fatigue x control). Mental fatigue had no effect on the physical function, perception of effort and enjoyment to exercise of older people. Participants, however, presented a higher affinity, characterized by higher enjoyment, for walking and dynamic balance compared to strength exercise. However, due to the relevance of resistance exercises for health, clinicians and gyms should allocate resources to education programs regarding the importance of resistance exercise for health in the short and long-term, include social interaction opportunities in the physical exercise programs and, prescribe appropriate activities to participants' ability level. Mental fatigue had no effect on the physical function, perception of effort and enjoyment to exercise of older people. Participants, however, presented a higher affinity, characterized by higher enjoyment, for walking and dynamic balance compared to strength exercise.

**Keywords**: cognitive fatigue; cardiorespiratory function; balance; muscular function; elderly.

## 1. Introduction

Physical function is theoretically formed by four subdomains that are conceptually related (Cella *et al.*, 2007), but distinct (Bruce *et al.*, 2009, Dias, 2014): mobility (lower extremity), dexterity (upper extremity), axial or central (neck and back function), and complex activities that involve more than one subdomain (instrumental activities of daily living). Physical function tends to decline naturally with advancing age: older people have 25-35% smaller limb muscles and have significantly more fat and connective tissue than limb muscles

compared to younger individuals (Lexell, 1995). Physical function losses may become more severe in the presence of sarcopenia and osteopenia which lead to impaired locomotory function, reduced balance, increased risk of osteoarthritis, falls and fractures (Janssen; Heymsfield; Ross, 2002, Landi *et al.*, 2012).

Physical exercises benefit to counteract aging related losses are well documented (Bouaziz *et al.*, 2017, Sherrington *et al.*, 2017). Sherrington et al. (2017), for example, showed that exercises programmes involving a high dose of complex balance exercises can reduce the rate of falls in 39%. Regarding aerobic and resistance training, results of Marques et al. (2017) indicated that 8 months of aerobic or strength training succeed to improve older women's balance outcomes compared to control group. Strength improvements were observed in the resistance training group, but no conclusions were made about aerobic training. Changes in knee extension and knee flexion were largely associated with performance in the dynamic balance test. Similar results were found in older man, in which both aerobic and combined training improved functional outcomes compared to controls (Sousa *et al.*, 2016). However, older adults enrolled in the combined group displayed higher improvements. Despite that, older adults tend to become less active throughout life (Health; Welfare, 2018). This can be concerning, since exercise benefits are mediated by participants' adherence to the training program with high adherers performing better on instrumental activities of daily living, balance, mobility (Aartolahti *et al.*, 2015) and cognitive tasks (Tiedemann; Sherrington; Lord, 2011) compared to their low adherers' peers.

The reasons why older adults do not regularly engage in exercise programs relate to many psychological constructs, such as self-efficacy (Schutzer; Graves, 2004) -one's belief of their chances to pan out while performing determined task (Bandura, 1977), and affective responses [i.e., pleasure while exercising (Lacharité-Lemieux; Brunelle; Dionne, 2015)]. Whilst self-efficacy has been cited as critical for exercise initiation; authors pointed out enjoyment as crucial for exercise maintenance (Schutzer; Graves, 2004) because it is considered an immediate reward compared to other delayed benefits, such as healthy status and functional performance (Collado-Mateo *et al.*, 2021).

Mental fatigue may be one factor that could influence someone's self-efficacy and enjoyment to exercise. For example, Hess and Knight (2021) indicated that chronic mental fatigue showed distinct levels of predictability in anticipating both engagement and assessment levels within different groups. As chronic mental fatigue levels rose, older adults

tended to perceive greater increases in task difficulty compared to younger adults (Hess; Knight, 2021). Moreover, the complexity of tasks among older adults was linked to their deliberate decisions to avoid engaging in challenging activities (Hess *et al.*, 2021)

Mental fatigue can be defined as a psychobiological state of tiredness and lack of energy induced by prolonged and/or intense periods of high cognitive demand (Boksem; Tops, 2008b, Marcora; Staiano; Manning, 2009a). Mental fatigue is a common complaint of older adults (Hardy; Studenski, 2008a). For example, a study by Cohen et al. (2021) found that within a cohort of 2,361 older adults, 24.8% reported experiencing mental fatigue. This phenomenon was more prevalent among women (Cohen *et al.*, 2021, Meng; Hale; Friedberg, 2010), as well as in older age groups (Cohen *et al.*, 2021), with percentages reported as follows: 14.5% among individuals aged 60-69 (out of 1,004); 18.6% among those aged 70-79 (out of 839); 41.5% among individuals aged 80-89 (out of 253); and 67.2% among those aged 90-108 (out of 265). Additionally, frail elderly individuals (Zengarini *et al.*, 2015) were found to perceive higher levels of mental fatigability.

Studies with elderly have been showing that mental fatigue may be linked to a decreased activity in the prefrontal cortex (Shortz *et al.*, 2015, Terentjeviene *et al.*, 2018b). Changes in brain activation may impair the physical function of elderly, since the ability to perform activities of daily living requires the integration of cognitive functions (De Dieuleveult *et al.*, 2017, Santos Henriques; Tomas-Carus; Filipe Marmeleira, 2023). Indeed, (Noé *et al.*, 2021) indicated that mental fatigue levels significantly relate to balance disturbances when participants stood with open eyes; and (Salehi; Fard; Jaberzadeh, 2023) found deceased postural stability under mental fatigue compared to control condition. In addition, data from a systematic review and meta-analysis (Brahms *et al.*, 2022) show that mental fatigue impairs balance of young and older adults; but differences were not observed when analysis were performed by age. However, it included only four studies with older adults' data, and Jackson and Turner (2017) suggested that at list five studies should be deemed in a random-effects meta-analysis to return valid results. Therefore, Brahms et al. (2022) highlighted what is still unknown and needs further investigation.

Moreover, as far as we know, nobody has investigated the effects of mental fatigue on older adults' physical capacity, and affective responses to perform resistance exercises. The study aimed to investigate the influence of mental fatigue on: 1) physical capacity, balance and strength performance, and 2) enjoyment to perform a walking, balance, and a resistance

exercise. We hypothesize that following mental fatigue participants would walk a shorter distance in the 6-minutes' walk test (6MWT), take longer to do the Time up and Go (TUG) test, as well as would execute less repetitions in knee extension exercise. We also expect that, under mental fatigue, older people would report lower score of enjoyment, and increased mental fatigue and perception of effort during resistance exercise compared to control condition.

## 2. Methods

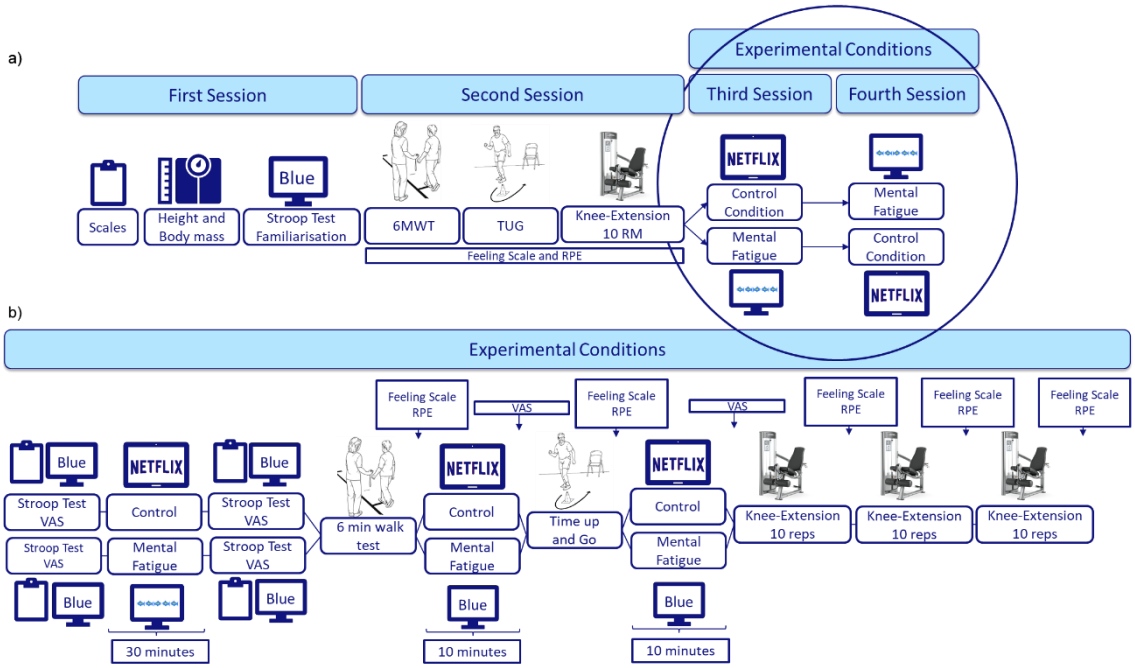
### Experimental Design

Using a randomised cross-over design, participants completed a series of physical tests (i.e., 6 min walk test, and balance task) followed by a brief standardised resistance exercise session in older adults. The protocol of the present study was registered online on Open Science Framework (OSF; ID: osf.io/ejy8b, 12sd April 2023), an open public data repository.

### Experimental conditions

Participants performed four sessions as outlined in Figure 1a. In the first session, the scales Addenbrooke's Cognitive Examination – Revised, Adult Pre-Exercise Screening System, Geriatric Depression Scale, Geriatric Anxiety Inventory were administered. Then, we measured participants' height and body mass, as well as, familiarised them with the Stroop Test used for mental fatigue assessment. In the second session, participants were familiarised with the 6-minutes' walk test and TUG. We conducted the 10-RM on knee extension machine to define exercise intensity during experimental conditions. Lastly, in the third and fourth sessions, they did the following experimental conditions (Figure 1b) in a counterbalanced randomized design: 1) Flanker/Reverse Flanker Test for 30 minutes, followed by the walking test. Then, Stroop Test twice for 10 minutes followed by the balance and the resistance exercise, respectively; and 2) watched a documentary 30 minutes, followed by the walking test. Then, watched a documentary twice for 10 minutes followed by the balance and the resistance exercise. The feeling scale and the RPE were administered after each physical test to measure affective responses. The VAS was administered before and after the Flanker/Reverse Flanker Test and after the 10 minutes Stroop Tests.

Figure 1. Study's outline




## Eligibility criteria for participants

Participants were recruited by personal invitation in the city of Sydney and they were considered eligible for enrolment if: a) were physically active - at least 30 minutes of moderate activity on most (preferably all) days (Sims *et al.*, 2006) - and independent; b) do not present any cardiac and/or orthopaedic dysfunction that could impede the physical exercise practices; c) were not receiving the hormonal replacement; d) showed normal or corrected vision; and e) were fluent English speakers. Participants with cardiovascular conditions were included if they presented medical approval to enrol in the research.

## Participants

44 older adults of both sexes, aged 60 years old and over, enrolled to participate in the study. 9 participants were excluded for different reasons: 1 was colour blind, 5 did not want to do the strength exercise, 1 had several cardiovascular diseases (i.e., diabetes, high blood pressure and high cholesterol and family history of heart-related death), 1 had a score below the cut-off for dementia in the Addenbrooke's Cognitive Examination – Revised (ACE-R), and 1 presented significant symptoms of anxiety. Therefore, 35 participants (9 male and 26 female) were included in the study (Figure 2). The study was submitted to and approved (UTS

HREC REF NO. ETH22-7745) by the Research Ethics Committee of UTS, respecting all the National Health Council's standards for research with human beings. Participants were informed prior that two gift vouchers of $100 would be raffled amongst participants at the completion of the testing.

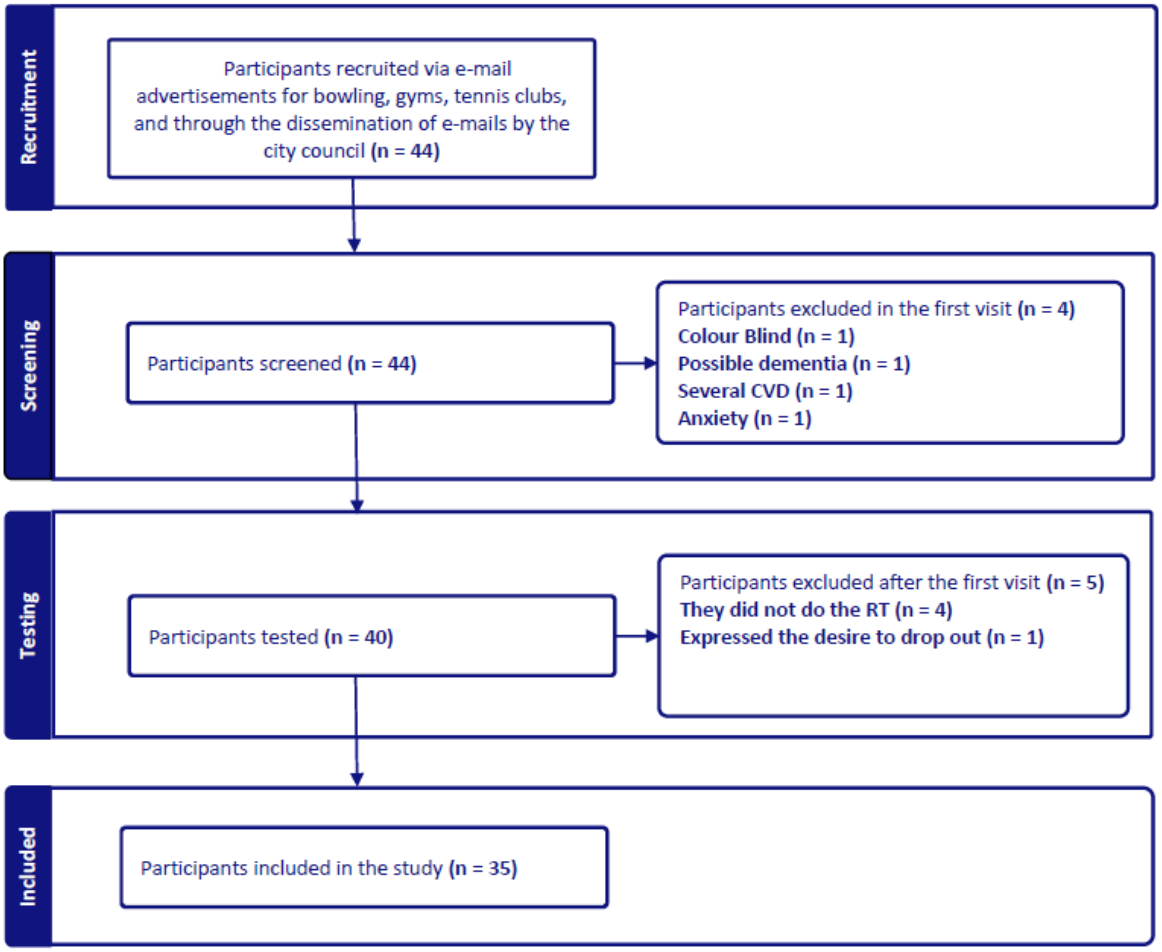



Figure 2. Flow chart of particiants inclusion in the study

**Randomisation**

The randomisation was performed using the function = randbetween(1;2) in excel, being 1: mental fatigue, and 2: control condition. Since we did not know how many participants we would successfully recruit, the randomisation was done in blocks. We randomised the order for the first 16 participants, then a new randomization was done for the next 14 and 10 participants subsequently. After the 40$^{th}$ participant, the randomisation was done every 5 participants until the last one.

**Sample Size:**

According to the calculation considering data from a pilot including 4 participants, the respective sample sizes would be needed to achieve a power of 0.80 for the calculated cohen's F effect size.

Table 1. Sample size needed to achieve 0.80 power considering the calculated cohen's F effect size.

| | 6MWT | TUG | Resistance Exercise |
|---|---|---|---|
| Performance | 63 | 615 | 5 |
| RPE | 15 | 41 | 31 |
| Enjoyment | 89 | 109 | 63 |

Legend: RPE, rating of perceived effort; 6MWT, 6 minutes walking test; TUG, Time Up and Go test.

**Resistance Exercise Sessions:**

*10 RM test*

Participants performed a 10-RM test on the knee extension machine. The 10-RM was chosen to ensure the volunteers' safety (Medicine, 2014). The movement duration was controlled using a metronome allowing 1 second for the concentric phase and 2 seconds for the eccentric phase (Grosicki; Miller; Marsh, 2014). Initially, participants did 10 repetitions with 5kg or 12kg, depending on the participant fitness level, to familiarize with the rhythm. Then, they did two warm-up sets. The initial warm-up load was estimated based on researcher experience. The load for subsequent warm-up set was established using ratings of perceived exertion (Borg 10-point scale). Thereafter, the 10RM load was determined in up to three attempts, with a 3-min rest interval between the attempts (Coelho-Júnior *et al.*, 2022). The resistance was increased according to the participant capacity to perform one more successful RM with the proper technique (Coelho-Júnior *et al.*, 2022). The test was completed when participants were unable to perform >10 repetitions using proper technique.

The resting blood pressure was measured prior to beginning each visit and 3–5 minutes after completing each assessment session. No subject was permitted to begin an

assessment session or leave the testing facility after the session with a blood pressure greater than 160/100 mmHg (Grosicki; Miller; Marsh, 2014). Due to knee problems, one participant did the exercise in a unilateral way.

*Resistance Exercise*

Participants performed 3 sets of the knee extension at the maximum load they lifted in the 10RM test. Participants warmed-up with 1 set of 5 repetitions at 50% of the load chosen to perform the 3 sets. Participants were instructed to seat in the machine and flat their back against the pad. Hips and knees were flexed at approximately 90º. The movement duration was controlled using a metronome allowing 1 second for the concentric phase and 2 seconds for the eccentric phase of the task (67 bpm). Participants were encouraged to do 10 repetitions. Resting blood pressure was measured prior to beginning each visit and 3–5 minutes after completing each assessment session. No subject was permitted to begin an assessment session or leave the testing facility after the session with a blood pressure greater than 160/100 mmHg (Grosicki; Miller; Marsh, 2014). Due to knee problems, one participant did the exercise in a unilateral way.

**Variable Measurements:**

***Primary outcomes***

*6 minutes' walk test*

The 6MWT was used to measure physical endurance capacity of the volunteers. The test was validated for people aged 60 to 89 years old, and showed an excellent (ICC = 0.95) test-retest reliability (Steffen; Hacker; Mollinger, 2002). Testing seems to become more reliable when a practice trial is provided (Janaudis-Ferreira; Sundelin; Wadell, 2010). Participants performed the test in a 30m length hallway, totalling 60 meters for 1 lap (ATS statement: guidelines for the six-minute walk test, 2002). Participants were instructed to walk as fast as possible for 6 minutes, covering the longest distance as possible. In the end, the distance walked, in meters, was registered. We gave standardized information to them about how much time left at the 1$^{st}$, 3$^{rd}$ and 5$^{th}$ minute.

*Time up and go (TUG)*

The TUG was used to measure volunteers' dynamic balance. The test showed good reliability in a sample of 147 older adults with 51 to 90 years old (ICC = 0.80, 95% CI: 0.72–0.86) (Beauchamp *et al.*, 2021). Participants sat in a chair of 46cm of height facing a cone positioned at 3.0 meters. At the sign of the evaluator, the participant walk as fast and safely as possible, turn the cone, and return to the initial position (Rose; Jones; Lucchese, 2002). The participants had two attempts, and the shortest time was registered.

*Perception of Effort*

*The Borg CR-10 Scale* has 12 categories with values ranging from 0 ("nothing at all") to 10 ("maximal") (BORG, 1982). We used the scale to measure participants' perception of exertion after the physical assessments. The scale anchoring was done during the 10-repetition maximum test (10RM).

*Enjoyment*

During physical exercise, people often experience changes in mood (Hardy; Rejeski, 1989). Some individuals feel pleasure, whereas others feel unpleasure (Hardy; Rejeski, 1989). Feeling may also fluctuate throughout time (Hardy; Rejeski, 1989). Scientists have developed the feeling scale (Hardy; Rejeski, 1989); and it has been used to measure affective responses related to exercise (Frazão *et al.*, 2016, Hardy; Rejeski, 1989, Lins-Filho *et al.*, 2019). The feeling scale is presented in an 11-point bipolar format, ranging from +5 to -5. Verbal anchors are provided at the 0 point, and at all odd integers +5 = very good, +3 = good, + 1 = fairly good, 0 = neutral, - 1 = fairly bad, -3 = bad, and -5 = very bad; and the participant must answer how he is feeling. For the statistical analysis the feeling scale was converted in a scale from 0 to 10 (-5 = 0, -4 = 1, -3 = 2, -2 = 3, -1 = 4, 0 = 5, +1 = 6, +2 = 7, +3 = 8, +4 = 9, +5 = 10).

Secondary outcomes:

**Scales**

*Adult Pre-Exercise Screening System (APSS)*

The scale consists in a standardised way of pre-exercise screening, and is composed by three stages. The first stage of the APSS involves seven questions to identify any established cardiovascular, metabolic or respiratory diseases, signs and symptoms of these diseases or other medical issues that represent a substantial risk when beginning or upgrading

physical activity program (Norton *et al.*, 2018). The second stage includes self-reported information on major health risk factors for disease or other conditions that may be exacerbated by exercise including information on family history of coronary vascular disease, smoking status, physical activity patterns, height, body mass, known hypertension, high cholesterol and/or high blood glucose, hospitalisation in the past 12 months, prescribed medications, pregnancy or recent childbirth, and musculoskeletal symptoms (Norton *et al.*, 2018). Stage 3 measurements included resting blood pressure taken after at least five minutes of being seated, anthropometric measures of height, mass and waist girth, total cholesterol and blood glucose recorded (Norton *et al.*, 2018). The first stage is the only one compulsory (Norton, 2012). In the present study, we used only the first and the second stages.

*Addenbrooke's Cognitive Examination – Revised (ACE-R)*

The ACE-R (Mioshi *et al.*, 2006) is a brief and reliable test battery that provides detection of early stages of dementia [cut-off point: 82 (So *et al.*, 2018)] and is also efficient in differentiating its subtypes, such as Alzheimer disease, frontotemporal dementia, progressive supranuclear palsy, and other forms of dementia. The test can be administered in 15 to 20 minutes and provides an evaluation of five cognitive domains, namely: orientation and attention (18 points), memory (26 points), verbal fluency (14 points), language (26 points) and visuospatial ability (16 points). The individual's total score is obtained by the addition of all subtests' scores, ranging from 0 to 100.

*Geriatric Depression Scale (GDS)*

The shortened version of the Geriatric Depression Scale was used to assess depressive symptoms (Yesavage *et al.*, 1982). The Geriatric Depression Scale is a screening inventory designed to assess the presence of depressive symptoms in older people and is extensively used in epidemiological research of geriatric psychiatry. The short form of the GDS includes 15 items with dichotomic 'yes'/'no' responses. Scores of 0–4 are considered normal, 5–9 mildly depressed and scores above 10 moderately to severely depressed. Internal consistency = 0.94 and test-retest reliability = 0.85 in a normative sample are good, and the scale has been validated against Research Diagnostic Criteria (Yesavage; Brink; Rose, 2000).

*Geriatric Anxiety Inventory (GAI)*

The Geriatric Anxiety Inventory (Byrne *et al.*, 2010) is a brief instrument developed to assess anxiety symptoms in older people. The inventory is composed by 20 statements and

participants must select the answer stating that they agree or disagree with the statements made according to the way they have been feeling in the last week. Participants were considered to suffer from significant anxiety symptoms if they answer agree to more than 9 questions (Byrne *et al.*, 2010).

**Anthropometric Measures**

Body mass was determined using a digital balance (Seca, model 813) with 100g of accuracy and height with a stadiometer (Seca, model 123) with 0.1 cm of accuracy.

**Mental Fatigue Assessment (Manipulation check)**

*Stroop Test*

The test (Stroop, 1935) is composed by forty-four incongruent trials, where a visual stimulus is provided by words representing colours painted with different colours (e.g., "red" word painted black), and 18 congruent trials, where a visual stimulus is provided by words representing colours painted with the same colours (e.g., "red" word painted red), was used. The volunteers must correctly point out the options where the words are painted in the colours, they represent by pressing the bottom of the correspondent colour. The test consists of 62 stimuli, which did not fade from the screen until a response was given (Fortes *et al.*, 2019a, Fortes *et al.*, 2019b); besides, a 500ms is given between one stimulus and another (Fortes *et al.*, 2022). The stimuli disappear when the answer is correct, and then a new one was set. An X showed up on the screen in case of incorrect answers, and a new subsequently stimulus appeared. The correct answers and response time is collected at the end of the test. The Stroop Test familiarization was conducted in the first visit to reduce learning effects (Hooper *et al.*, 2020). During familiarization, participants did the Stroop Test four times with a 3-minutes interval between tests. This test has been shown to be reliable for older adults (Faria *et al.*, 2024).

*Visual Analogue Scale (VAS)*

We used a 100mm VAS with two demarcated reference points at either end of the line (at 0mm which represented "none" or no mental fatigue; and at 100mm which represented "extremely" mentally fatigued) to separately measure both mental fatigue, mental effort and motivation to engage in further exercise (Smith *et al.*, 2016). Participants were instructed to draw a vertical line on the continuum at a point that best represented the sensation they were experiencing at that moment.

## Mental Fatigue Induction

*Flanker test*

The Flanker/Reverse Flanker Test (Diamond *et al.*, 2007, Hooper *et al.*, 2020) was administered before the walking test. This task has been shown to effectively induce mental fatigue in elderly (Faria *et al.*, 2024). The task is composed by three blocks: standard, reverse and mixed. In the standard block, the fish are blue, and participants should press the button corresponding to the direction in which the middle fish is pointing. In the reverse block, the fish are pink, and participants were instructed to press the button corresponding to the direction in which the outside fish are pointing, ignoring the middle fish. Finally, in the mixed block, both pink and blue fish are presented. Participants were exposed to the task for 30 minutes.

*Stroop Colour Test*

The Stroop test was conducted using a computerized version of the Stroop colour-word (PsychoPy, v. 2022.1.4). Participants were presented with four words (red, blue, green, black) in random order on the screen. Participants should respond by selecting the appropriate colour using a coloured keyboard. Words appear in alternate coloured text (i.e., the word "red" would be written in green text) where the participant must identify the correct answer as green by clicking on the "green" prompt on the screen. Each stage in the Stroop test can be described as congruent (i.e., the word "red" written in the colour red) and others being incongruent (i.e., the word "red" written in blue). The Stroop Test performed was 100% incongruent. Participants performed the task for 10 minutes previous to the TUG. Participants were instructed to ignore the meaning of the word and only respond to the colour of the text in which the words were written.

*Stroop Meaning Test*

Participants performed the task for 10 minutes previous to the knee extension exercise. The structure of the Stroop Meaning Test was very similar to the Stroop Colour Test; however, participants were instructed to ignore the colour of the letters and respond to the meaning of the words written.

**Control Condition**

The control session consisted of a 30-minute (previous to walk) or 10-minute (previous to balance and knee extension exercise) viewing of an emotionally neutral Netflix show entitled “Atypical”.

**Data analysis**

We used the statistical software *Rstudio* (version 3.5.3) for data analysis. The Shapiro-Wilk test was conducted to verify assumptions of normality. Subsequently, if the data present a normal distribution, the mean and standard deviation were used as descriptive statistics. Otherwise, median and interquartile interval were calculated. The Friedman test was used to compare accuracy and response time between the four sets of the Stroop Test in the familiarisation. The effect size, Kendal’s W Value [(0.1 - < 0.3 (small effect), 0.3 - < 0.5 (moderate effect) and ≥ 0.5 (large effect)] was calculated. The Wilcoxon’s post-hoc with Bonferroni correction was used to identify which comparisons showed significant difference.

The student t-test was used to compare accuracy and response time in the pre- and post-experimental conditions (mental fatigue x control) Stroop Test. The Cohen's d test (classified by trivial: 0-0.2; small: 0.2-0.6; moderate: 0.6-1.2; large: 1.2-2.0; very large: 2.0-4.0; almost perfect: >4.0) was used as a measure of effect size. The same tests were adopted to compare the performance in the 6MWT and TUG between mental fatigue and control conditions.

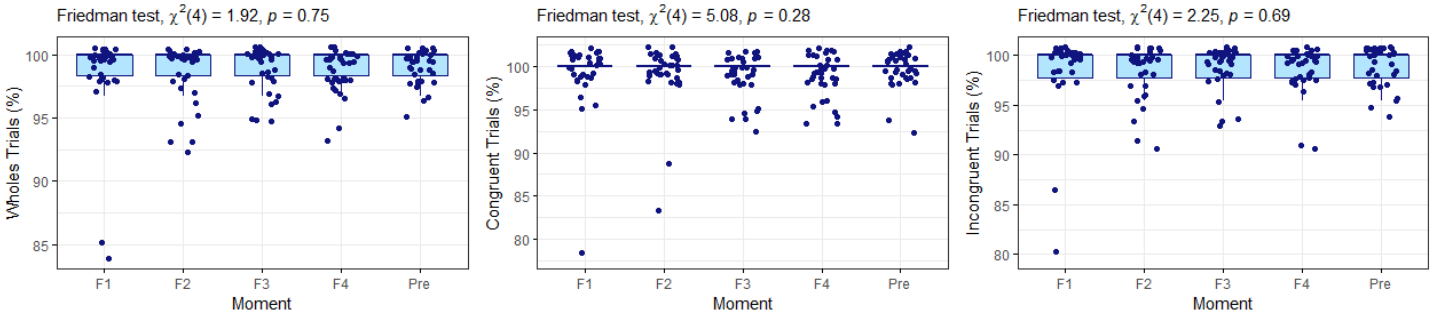
The Nonparametric Analysis of Longitudinal Data in Factorial Experiments (Noguchi *et al.*, 2012) was used to compare the difference in the number of repetitions performed during the three sets of resistance exercise between the control and mental fatigue conditions. The same test was used to compare the RPE and Enjoyment in the 5 moments (Post-6MWT, Post-TUG, Post-KE1, Post-KE2, Post-KE3) and 2 conditions (mental fatigue x control) and the VAS scales in the 4 moments (baseline, Pre-6MWT, Pre-TUG, Pre-KE) and 2 conditions (mental fatigue x control). The partial eta squared (0.01, small; 0.06, medium; 0.14, large) was used as a measure of effect size. We used the post-hoc of Bonferroni to identify where the differences were. A significance level of $\alpha=0.05$ for all analyses was adopted.

**3. Results**

### 3.1 Familiarisation – Stroop Test

The Friedman Test (Figure 3) indicated that there was no significant difference between the Stroop Test sets for all variables [Overall, W = 0.014 (small); Congruent, W = 0.036 (small); Incongruent, W = 0.016 (small)] analysed.

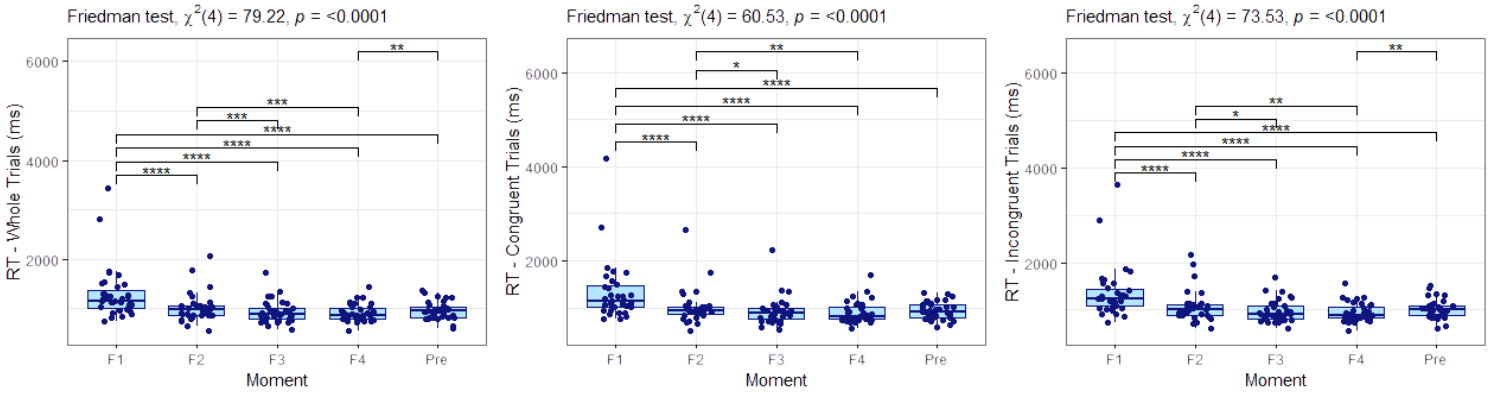
Figure 3. Boxplot of the accuracy – whole trials, accuracy – congruent trials and accuracy incongruent trials in the four sets of the Stroop test familiarisation




Legend: F1, first set; F2, second set; F3, third set; F4, fourth set; Pre, Stroop pre-test in the first experimental session.

Regarding the response time, the Friedman Test (Figure 4) indicated the existence of significant difference for all comparisons [whole trials, W = 0.566 (large); congruent trials, W = 0.432 (moderate); incongruent trials, W = 0.525 (large)] with moderate to large effects. Except for the comparison between F3 and F4 [whole trials, p = 0.154; congruent trials, p = 0.533; incongruent trials, p = 0.810], the Wilcoxon's post-hoc with Bonferroni correction suggested statistical difference for all the other comparisons (p≤0.001).

Figure 4. Boxplot of the response time – whole trials, response time – congruent trials and response time – incongruent trials in the four trials of the stroop test familiarisation.




Legend: F1, first set; F2, second set; F3, third set; F4, fourth set; Pre, Stroop pre-test in the first experimental session; ms, milliseconds; RT, response time.

### 3.3 Experimental Conditions

#### 3.3.1 Manipulation Check

The Wilcoxon Test indicated no significant differences between pre- [accuracy – whole trials, V = 106.5, p = 0.364, r = 0.034 (small); accuracy – congruent trials, V = 7, p-value = 0.484, r = 0.089 (small); accuracy – incongruent trials, V = 91, p-value = 0.238, r = 0.068 (small)] and post-test [accuracy – whole trials, V = 64.5, p-value = 0.566, r = 0.758 (small); accuracy – congruent trials, V = 36, p-value = 0.375, r = 0.111 (small); accuracy – incongruent trials, V = 31, p-value = 0.323, r = 0.078 (small)] for all the comparisons (Table 2).

The student t-test did not show any differences between pre- [RT – whole trials, t(34) = 0.219, p = 0.828, d = 0.021 (negligible); RT – congruent trials, t(34) = -0.009, p = 0.993, d = -0.001 (negligible); RT – incongruent trials, t(34) = 0.531, p = 0.599, d = 0.053 (negligible)] and post-test [RT – whole trials, t(33) = 1.025, p = 0.313, d = 0.107 (negligible); RT – congruent trials, t(33) = 1.565, p = 0.127, d = 0.182 (negligible); RT – incongruent trials, t(33) = 1.118, p = 0.272, d = 0.129 (negligible)] for all response time comparisons (Table 2).

Table 2. Performance comparison between CNTR and MF conditions on the Stroop Test used for manipulation check.

| | Accuracy (%) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Pre | | | | Post | | | |
| | CNTR | MF | p | Effect Size | CNTR | MF | P | Effect Size |
| Whole Trials | 100 (1.6) | 100 (1.6) | 0.364 | 0.034 | 99.20 (1.6) | 100 (1.6) | 0.566 | 0.758 |
| Congruent | 100 (0) | 100 (0) | 0.484 | 0.089 | 100 (0) | 100 (0) | 0.375 | 0.111 |
| Incongruent | 100 (2.3) | 100 (2.3) | 0.238 | 0.068 | 100 (2.3) | 100 (2.3) | 0.323 | 0.078 |
| | Response Time (ms) | | | | | | | |
| Whole Trials | 946.7±185.2 | 942.9±181.4 | 0.828 | 0.021 | 902.85±177.3 | 885.6±142.3 | 0.313 | 0.107 |
| Congruent | 921.2±180.7 | 921.4±201.4 | 0.99 | -0.001 | 893.6±173.8 | 864.4±145.6 | 0.127 | 0.182 |
| Incongruent | 1009±212.2 | 998.2±198.5 | 0.599 | 0.053 | 952.8±204.5 | 928.7±167.5 | 0.272 | 0.129 |

Legend: Mean and standard deviation were used as cental and variability measures for the response time and median and interquartile range were used for accuracy; ms, milliseconds; CNTR, control; MF, mental fatigue.

The analysis of the VAS - MF data (Table 3) suggested significant difference between conditions, moments, and for the interaction between moments and conditions. The post-hoc

of Bonferroni indicated that, except for Pre-6MWT x Pre-TUG (p = 0.600), Pre-6MWT x Pre-KE (p = 1.000) and Pre-TUG x Pre-KE (p = 1.000), all the other comparisons were statistically different (Baseline x Pre-6MWT, p = 0.0001; Baseline x Pre-TUG, p = 0.04; Baseline x Pre-KE, p = 0.006).

Very similar results were found for VAS – ME (Table 3), with significant differences between conditions, moments, and for the interaction between moments and conditions. The post-hoc of Bonferroni indicated that, except for Pre-6MWT x Pre-TUG (p = 0.14), Pre-6MWT x Pre-KE (p = 0.86) and Pre-TUG x Pre-KE (p = 1.000), all the other comparisons were statistically different (Baseline x Pre-6MWT, p < 0.001; Baseline x Pre-TUG, p < 0.001; Baseline x Pre-KE, p < 0.001).

Differently, the analysis of VAS – Mot indicated the absence of significant difference for conditions and for the interaction between moments and conditions. Significant differences were found, however, for the comparison between moments. The post-hoc of Bonferroni indicated significant difference between the Baseline and the Pre-KE (p = 0.008). All the other comparisons were not significant different (p > 0.05).

Table 3. VAS Scales comparison between 2 conditions (mental fatigue x control) and 4 moments (baseline, pre-6MWT, pre-TUG and pre-KE)

| | **VAS-MF** | | **VAS-ME** | | **VAS-MOT** | |
|---|---|---|---|---|---|---|
| | **CNTR** | **MF** | **CNTR** | **MF** | **CNTR** | **MF** |
| Baseline | 12 (19) | 14 (21) | 4 (13) | 4 (8.5) | 80 (24) | 80 (36) |
| Pre-6MWT | 10 (21.5) | 66 (28) | 12 (28.5) | 72 (15.5) | 77 (25.5) | 72 (30) |
| Pre-TUG | 12 (15.5) | 50 (33) | 12 (18.5) | 60 (27) | 74 (26.5) | 74 (22.5) |
| Pre-KE | 10 (16.5) | 57 (37) | 8 (20) | 71 (28) | 67 (53) | 68 (31.5) |
| | **Statistics** | | | | | |
| | **Condition** | | **Moment** | | **Interaction** | |
| VAS-MF | F = 138.20, p < 0.001, $\eta p^2$ = 0.803 (large) | | F = 23.93, p < 0.001, $\eta p^2$ = 0.413 (large) | | F = 38.77, p < 0.001, $\eta p^2$ = 0.533 (large) | |
| VAS-ME | F = 237.321, p < 0.001, $\eta p^2$ = 0.875 (large) | | F = 98.185, p < 0.001, $\eta p^2$ = 0.743 (large) | | F = 67.317, p < 0.001, $\eta p^2$ = 0.664 (large) | |
| VAS-MOT | F = 0.003, p = 0.955, $\eta p^2$ < 0.001 (small) | | F = 4.920, p = 0.011, $\eta p^2$ = 0.126 (large) | | F = 0.579, p = 630, $\eta p^2$ = 0.017 (medium) | |

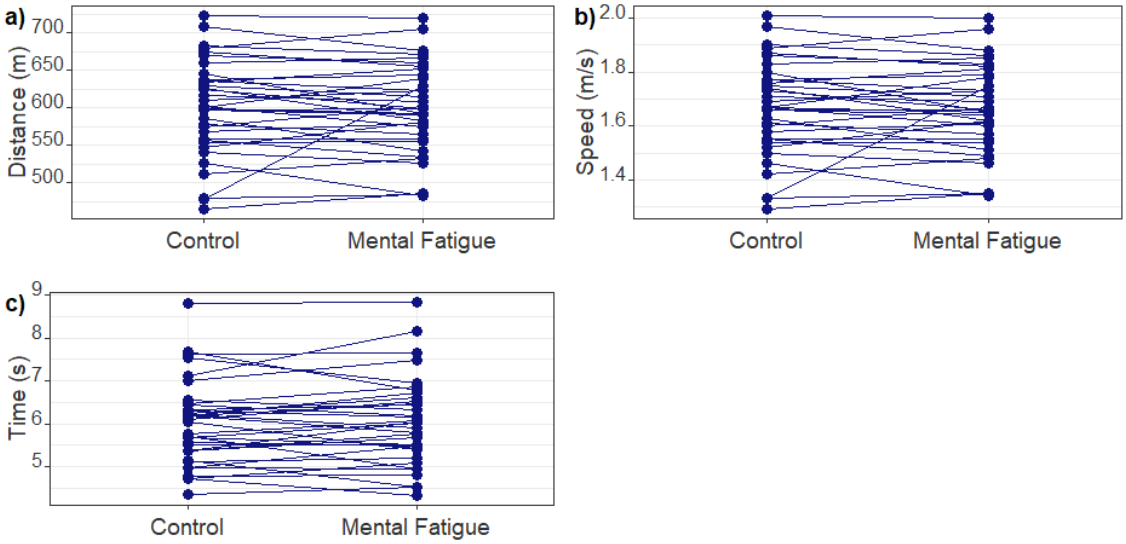
Legend: 6MWT, 6 minutes' walk test; TUG, Time up and Go Test; KE, Knee Extension; a.u., arbitrary units; VAS, Visual Analogue Scale; MF, mental fatigue; ME, mental effort; MOT, motivation; CNTR, control condition; MF, mental fatigue condition

## 3.2 Performance

### 6MWT and TUG

The student t-test did not suggest statistical difference between conditions for distance [t(34) = -0.166, p = 0.870, d = 0.016 (negligible)] and speed [t(34) = -0.139, p = 0.890, d = 0.013 (negligible)] in the 6MWT and time [t(34) = 0.532, p = 0.598, d = -0.04 (negligible)] spent to perform the TUG (Figure 5).

Figure 5. Distance and Speed in the 6MWT and time in the TUG




Legend: 6MWT, 6 minutes' walk test; TUG, Time Up and Go test; m, meters; m/s, meters per seconds; s, seconds.

### Resistance Exercise

The comparison between the number of repetitions in the resistance training exercise did not indicate significant difference between sets, condition and in the interaction between sets and condition (Table 4).

Table 4. Comparison of the number of repetitions in the resistance exercise between control and mental fatigue conditions.

| | Set | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| CNTR | 9.86±0.55 | 9.83±0.51 | 9.89±0.32 |
| MF | 9.80±0.53 | 9.66±0.68 | 9.69±0.72 |
| **Statistics** | | | |
| Condition | $F = 4.322$, $p = 0.05$, $\eta p^2 = 0.113$ (medium) | | |
| Sets | $F = 0.868$, $p = 0.425$, $\eta p^2 = 0.025$ (medium) | | |
| Interaction | $F = 0.531$, $p = 0.590$, $\eta p^2 = 0.015$ (small) | | |

Legend: CNTR, control; MF, mental fatigue

**RPE**

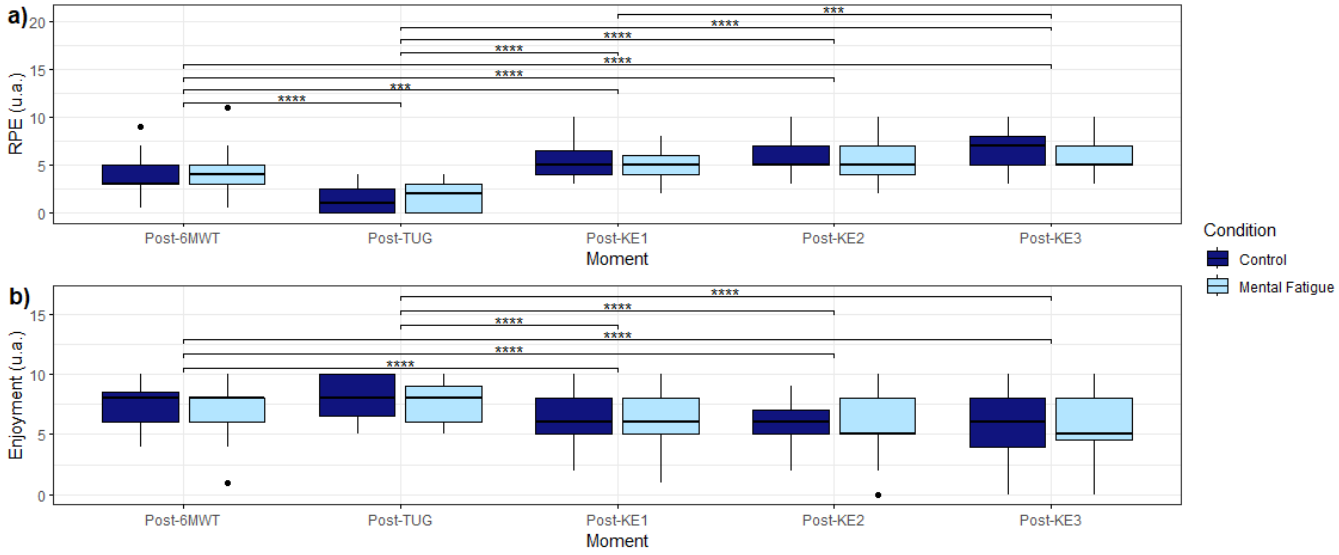
The analysis of the RPE data (Figure 6a) suggested the absence of significant difference between conditions [$F = 0.167$, $p = 0.685$, $\eta p^2 = 0.005$ (small)]. Significant differences were found, however, for moments comparison [$F = 88.160$, $p < 0.0001$, $\eta p^2 = 0.722$ (large)], and for the interaction between moments and conditions [$F = 5.013$, $p < 0.0001$, $\eta p^2 = 0.128$ (medium)]. The post-hoc of Bonferroni indicated that, except for Post-KE1 x Post-KE2 ($p = 0.258$) and Post-KE2 x Post-KE3 ($p = 1.000$), all the other comparisons were statistically different ($p < 0.05$). Overall, there RPE was higher in the 6MWT compared to TUG, and higher in the resistance exercise sets compared to the 6MWT and the TUG [6MWT x TUG, $p < 0.0001$; 6MWT x KE1, $p = 0.003$; 6MWT x KE2, $p < 0.0001$; 6MWT x KE3, $p < 0.0001$; TUG x KE1, $p < 0.0001$, TUG x KE2, $p < 0.0001$; TUG x KE3, $p < 0.0001$; KE1 x KE3, $p = 0.003$].

**Enjoyment**

Concerning the enjoyment data (Figure 6b), the analysis did not show statistical difference between conditions [$F = 3.385$, $p = 0.075$, $\eta p^2 = 0.091$ (medium)] and in the interaction between conditions and moment [$F = 0.559$, $p = 0.587$, $\eta p^2 = 0.016$ (small)]. Significant differences were found, in contrast, between moments [$F = 19.532$, $p < 0.001$, $\eta p^2 = 0.365$ (large)]. The Bonferroni post-hoc pointed significant decreases in enjoyment between the 6MWT and the three sets of the resistance exercise (Set 1, $p = 0.002$; Set 2, $p < 0.001$; Set

3, $p < 0.001$). The same pattern was observed when comparing the enjoyment after the TUG and after the resistance exercise ($p < 0.0001$ for all sets).

Figure 6. Boxplot with the enjoyment comparison in each moment between control and mental fatigue conditions




Legend: KE1, first set of the knee extension exercise; KE2, second set of the knee extension exercise; KE3, third set of the knee extension exercise; 6MWT, 6 min walking test; TUG, Time Up and Go Test; ****, $p < 0.0001$; ***, $p<0.001$.

## 4. Discussion

The present study is the first one, as far as we know, to investigate the effects of mental fatigue on participants pleasure to exercise. The study aimed, also, to investigate the influence of mental fatigue on: 1) physical capacity, balance and strength performance. We hypothesize that following mental fatigue, participants would walk a shorter distance in the 6MWT, take longer to do the TUG test, as well as would execute less repetitions in knee extension exercise. We also expect that, under mental fatigue, older people would report lower score of enjoyment, and increased mental fatigue and perception of effort during resistance exercise compared to control condition.

*Familiarisation*

Results suggested a ceiling effect for accuracy in the Stroop Test, which might occur due to the simplicity of the task requiring the reading of short words and the identification of basic colours. These tasks are considerably easy for cognitive-preserved older adults making it more difficult to distinguish levels of performance (Terwee *et al.*, 2007) in both learning

and pre-post-test sessions. Therefore, our findings support the idea that accuracy can be used as a control variable to assess participants engagement in the task (Hooper *et al.*, 2022).

Regarding the response time, our results showed significant differences with moderate to large effect sizes. The response time significantly decreased from F1 to F3 and stabilized from F3 to F4 for all measurements. Even though participants were potentially familiarised with the Stroop task, the increase in response time from F4 to Pre suggests that the participants did not recall all the specific details of the test. This might be explained by the long interval between the two sessions (i.e., the familiarisation was performed in the first session, the experimental sessions occurred in the third and fourth days, and the interval between sessions varied from a few days to 2 weeks) or because the amount of incongruent practice trials in our Stroop Task was not enough. Once differences were not found for the congruent analyses and considering that: 1) we struggled to make elderly participants dislocate from their homes to the laboratory four times in a shorter time interval and; 2) learning effects are found even when the sessions occur in shorter time-intervals (Hausknecht *et al.*, 2007), we hypothesized that simply increasing the number of incongruent practice trials in our Stroop Test might be sufficient to solve this limitation.

*Manipulation check*

In support of our hypothesis, participants reported greater mental fatigue, and mental exertion in the VAS following all cognitive tasks relative to watching the Netflix show (control). Differences between conditions were not found for motivation levels to perform the upcoming task. As an additional analysis, we divided the Flanker Test accuracy and response time in 20 blocks. Interestingly, accuracy in the first block was significantly lower in relation to blocks 5, 16, 17, 19 and 20 in the whole trials analysis. Similarly, response time significantly decrease from block 1 to 20 suggesting that participants remained engaged in the task throughout the 30 minutes of induction. Performance in the Stroop Test, however, like in previous studies (Brahms *et al.*, 2022, Faria *et al.*, 2024), did not change under mental fatigue conditions in older adults.

Some authors believe that it is important to combine subjective and objective indicators due to important limitations of subjective measures, such as: 1) the potential of participants to respond what researchers expect them to answer (Hassan; Jones; Buckingham, 2023), and the difficulty some participants have to understand what mental fatigue is (FORTES et al., 2019c). However, mental fatigue not always results in behavioural

impairment and the age-related improvement in resilience (FELDMAN, 2020) seems to be a protective factor.

*Induction*

In the present study, we used three different tasks to induce mental fatigue. We adopted this strategy in order to reinforce participants mental fatigue once previous research has shown that mental fatigue effects last only 3-10 minutes (Bray *et al.*, 2008, Tyler; Burns, 2008). Therefore, after the walking test, that takes 6 minutes, participants could probably not be suffering from mental fatigue anymore.

The additional tasks, however, did not result in higher VAS – MF scores compared to the VAS – MF score reported after the Flanker Test. In summary, mental fatigue levels were higher after the Flanker Test in comparison to both Stroop Tests adopted, and the Stroop Colour displayed lower levels of mental fatigue compared to the Stroop Meaning. This result can probably be explained by the fact that participants were already familiarised with the Stroop Colour and that both Stroop Tests, in contrast to the Flanker Test, did not have time constraints and were performed for a shorter time.

Even though, in the VAS, participants are instructed to indicate their current levels of mental fatigue and informed that their responses should not be based in any previous task; our results support the ideas that mental fatigue feelings are task-related (Dallaway; Lucas; Ring, 2022) and dependent on how long the task is performed (Dallaway; Lucas; Ring, 2022, Fortes *et al.*, 2019a).

*Performance, Perception of Effort and Enjoyment*

The results of the present study did not indicate significant differences in performance for all physical tests administered; therefore, denying our hypothesis. This is, as far as we know, the second study to analyse the effects of mental fatigue on the aerobic capacity of elderly. Goodwin et al. (2018) also did not find differences between cognitive fatigue and non-cognitive fatigue days. Despite that, the authors highlighted that 6 out of 9 participants had lower VO2 peak on cognitive days compared to non-cognitive days. However, participants were not submitted to any control condition in the non-cognitive day and the randomisation process was not very clear, which increases the chances of bias.

Regarding the balance task, a recent meta-analysis suggested impaired performance in mental fatigue condition compared to control (Brahms *et al.*, 2022). However, the analysis by

age indicated that there were no differences between conditions for older participants, reinforcing the idea that older people are more resilient to mental fatigue. Another possible explanation for the absence of difference is that, overall, balance tasks involve multiple muscle groups and mental fatigue effects appear to be mediated by the physical task that is performed. Isolated muscle tasks, for instance, may be more sensitive to mental fatigue than global tasks (Giboin; Wolff, 2019), such as dynamic balancing. This effect seems to be linked to differences in automatic control, in which isolated muscle tasks present higher attentional control demands (Giboin; Wolff, 2019).

In that sense and based on the results of Behrens et al. (2018), Brahms et al. (2022) argue that dual tasks might increase the chances of mental fatigue effects. However, Behrens et al. (2018) found impaired performance in a balance dual-task from the pre to the post-mental fatigue moment. Differences between control and mental fatigue conditions were not found for both single and dual-task (Behrens *et al.*, 2018, Fletcher; Osler, 2021); therefore, even though it sounds logic, this conclusion is inappropriate once this may be an effect of time and not of condition.

Someone might speculate that the balance task we adopted is too simple to detect differences; however, previous studies have shown its appropriate reliability (Beauchamp *et al.*, 2021). Therefore, if the difference exists, the test should be able to capture it. In addition, even though some studies with more precise measures claimed the existence of mental fatigue effects on balance, the authors compared moments (pre and post-test) and ignored the insignificancy of the comparison between experimental conditions (Fletcher; Osler, 2021, Varas-Diaz; Kannan; Bhatt, 2020). Once again, the difference might be explained by a nocebo effect.

We also did not find differences in the number of repetitions in the knee extension exercise. Studies with mental fatigue and strength exercise in young adults usually instruct participants to perform the exercise until failure (Gantois *et al.*, 2021, Queiros *et al.*, 2020). We adopted a fixed number of repetitions because the majority of older people do not exercise until failure.

We hypothesized mental fatigue would impair physical capacity and affective responses because it increases adenosine release, an inhibitory neurotransmitter, which raises up the perceived exertion and reduces motivation (Martin *et al.*, 2018, Smith *et al.*, 2018). In the present study, however, RPE and enjoyment were not different between conditions for all the measurements. Results regarding RPE and mental fatigue are controversy, being that two

studies did not find difference (Santos *et al.*, 2019, Vanden Noven *et al.*, 2014), one indicated that cognitive demand decreased RPE (Pereira *et al.*, 2015a), one collected the data but did not report the results (Shortz *et al.*, 2015) and many others did not use the scale (Fletcher; Osler, 2021, Morris; Christie, 2020a, Morris; Christie, 2020b, Shortz; Mehta, 2017).

Concerning enjoyment, as far as we know, this is the first study to investigate the effects of mental fatigue on older people's enjoyment to exercise. We believe there are two possible explanations for our results: 1) older adults' resilience to mental fatigue and; 2) exercise neurotransmitter release counteracted adenosine effects. First, as we mentioned before, older adults seem to present compensatory neural mechanisms to counteract mental fatigue. Shortz et al. (2015), for example, observed blunted pre-frontal cortex activation patterns in elderly. Second, physical exercise is well known for the catecholamines release and the relationship between both variables is modulated by exercise intensity. In a nutshell, during periods of rest and low-intensity exercise, the gradual and steady release of catecholamines hampers alertness and focus, leading to a decline in cognitive abilities (Mcmorris, 2016, 2021, Mcmorris *et al.*, 2016). Contrastingly, during moderate-intensity physical activity, the balanced release of catecholamines activates specific receptors in key brain regions, such as the locus coeruleus, ventral tegmental area, and substantia nigra, resulting in an enhancement of cognitive functions (Mcmorris, 2016, 2021, Mcmorris *et al.*, 2016). Although the high-intensity exercise is not so clearly understood, it seems the heightened levels of central catecholamines prompt an increased steady release, dampening the intermittent bursts and ultimately impairing cognitive performance (Albuquerque *et al.*, 2023, Mcmorris, 2016, 2021, Mcmorris *et al.*, 2016). Therefore, even though our mental fatigue induction might have been able to increase adenosine levels, the moderate intensity exercise might have counteracted mental fatigue effects by the release of catecholamines.

Although this was not an objective of the present study, we found out that participants enjoyed more and reported lower RPE in the 6MWT and TUG in comparison to the resistance exercise. This is in line with previous studies that show that older people prefer other types of physical exercise (Van Roie *et al.*, 2015), such as aerobic exercise (Kekäläinen *et al.*, 2018) or team sport (Pedersen *et al.*, 2017), over resistance exercise. Progressive resistance exercise offers major benefits for elderly physical function and health through the development of muscle mass, strength and power (Damluji *et al.*, 2023, Latham *et al.*, 2004, Liu; Latham, 2009); and its recommended at least two sessions per week for this population (Damluji *et al.*, 2023). However, a minority of older people regularly engage in this activity (Bennie *et al.*,

2017). Strategies to increase resistance exercise participation in this population have been investigated. The manipulation of training variables, such as intensity (Van Roie *et al.*, 2015) and periodization (Conlon *et al.*, 2018), seems to not impact older people's enjoyment and adherence to resistance exercise. Solutions may be related to education programs regarding the importance of resistance exercise for health in the short and long-term, the inclusion of social interaction opportunities and, the prescription of appropriate activities to participants' ability level (Gluchowski *et al.*, 2022).

*Limitations*

No studies are absent of limitations. First, the present study is a quasi-experimental research design; therefore, do not allow for understanding the causative effects of various interventions and can result in a greater risk of bias. Second, the main outcome of the present study was assessed through a subjective scale, which allows the potential of participants to respond what researchers expect them to answer (Hassan; Jones; Buckingham, 2023). Thirdly, researchers and participants were not blinded to the experimental conditions. However, we adopted some strategies to reduce those bias: 1) participants were informed that we were investigating the effects of different cognitive stimuli in their physical function; 2) we reinforced at any moment that there was no correct answer for the subjective scales and that they should be as honest as possible. Despite that, we acknowledge that the lack of true experimental research in this field remains and researchers should seek to work together in order to increase the human resources involved in the projects, produce studies of better quality and provide more reliable results to guide public health decisions.

*Future Studies*

Fatigue can be perceived in two distinct ways: as a trait, which refers to the predisposition to experience fatigue, or as a state, which represents the immediate and momentary experience of fatigue (Wylie *et al.*, 2022). The literature does not let us doubt that elderly people suffer from mental fatigue as a trait since mental fatigue is a symptom of many chronic diseases (Linnhoff *et al.*, 2019, Lou, 2009, Lou *et al.*, 2001b, Vancampfort *et al.*, 2023a). However, it is not clear whether the state of mental fatigue is really an issue for healthy older people. Therefore, it might be beneficial to walk two steps back, and conduct qualitative and mixed-methods studies to understand whether mental fatigue as a state is a condition that affects healthy older people and deserves our attention and resources.

## 5. Conclusion

Mental fatigue had no effect on the physical function, perception of effort and enjoyment to exercise of older people. Participants, however, presented a higher affinity, characterized by higher enjoyment, for walking and dynamic balance compared to strength exercise.

## References

1. Cella D, Yount SE, Rothrock NE, Gershon RC, Cook KF, Reeve BB, et al. The Patient-Reported Outcomes Measurement Information System (PROMIS): Progress of an NIH Roadmap Cooperative Group During its First Two Years. Medical Care. 2007;45:S3-S11; https://doi.org/10.1016/j.jclinepi.2010.04.011.
2. Bruce B, Fries JF, Ambrosini D, Lingala B, Gandek B, Rose M, et al. Better assessment of physical function: item improvement is neglected but essential. Arthritis Res Ther. 2009;11(6):R191; https://doi.org/10.1186/ar2890.
3. Dias JM. Physical Functioning (PF). In: Michalos AC, editor. Encyclopedia of Quality of Life and Well-Being Research. Dordrecht: Springer Netherlands; 2014. p. 4793-5.
4. Lexell J. Human aging, muscle mass, and fiber type composition. J Gerontol A Biol Sci Med Sci. 1995 Nov;50 Spec No:11-6; 10.1093/gerona/50a.special_issue.11.
5. Janssen I, Heymsfield SB, Ross R. Low relative skeletal muscle mass (sarcopenia) in older persons is associated with functional impairment and physical disability. J Am Geriatr Soc. 2002 May;50(5):889-96; 10.1046/j.1532-5415.2002.50216.x.
6. Landi F, Liperoti R, Fusco D, Mastropaolo S, Quattrociocchi D, Proia A, et al. Sarcopenia and mortality among older nursing home residents. J Am Med Dir Assoc. 2012 Feb;13(2):121-6; 10.1016/j.jamda.2011.07.004.
7. Sherrington C, Michaleff ZA, Fairhall N, Paul SS, Tiedemann A, Whitney J, et al. Exercise to prevent falls in older adults: an updated systematic review and meta-analysis. British Journal of Sports Medicine. 2017;51(24):1750-8; 10.1136/bjsports-2016-096547.
8. Bouaziz W, Vogel T, Schmitt E, Kaltenbach G, Geny B, Lang PO. Health benefits of aerobic training programs in adults aged 70 and over: a systematic review. Archives of Gerontology and Geriatrics. 2017 2017/03/01/;69:110-27; https://doi.org/10.1016/j.archger.2016.10.012.
9. Marques EA, Figueiredo 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 Jan-Feb;68:106-12; 10.1016/j.archger.2016.10.002.
10. Sousa N, Mendes R, Silva A, Oliveira J. Combined exercise is more effective than aerobic exercise in the improvement of fall risk factors: A randomized controlled trial in community-dwelling older men. Clinical Rehabilitation. 2016 06/29;31:1–9; 10.1177/0269215516655857.
11. Health AIo, Welfare. Physical activity across the life stages. Canberra: AIHW; 2018.
12. Aartolahti E, Tolppanen AM, Lönnroos E, Hartikainen S, Häkkinen A. Health condition and physical function as predictors of adherence in long-term strength and balance

training among community-dwelling older adults. Arch Gerontol Geriatr. 2015 Nov-Dec;61(3):452-7; 10.1016/j.archger.2015.06.016.
13. Tiedemann A, Sherrington C, Lord SR. Predictors of exercise adherence in older people living in retirement villages. Prev Med. 2011 Jun;52(6):480-1; 10.1016/j.ypmed.2011.03.015.
14. Schutzer KA, Graves BS. Barriers and motivations to exercise in older adults. Prev Med. 2004 Nov;39(5):1056-61; 10.1016/j.ypmed.2004.04.003.
15. Bandura A. Self-efficacy: Toward a unifying theory of behavioral change. Psychological Review. 1977;84:191-215; 10.1037/0033-295X.84.2.191.
16. Lacharité-Lemieux M, Brunelle JP, Dionne IJ. Adherence to exercise and affective responses: comparison between outdoor and indoor training. Menopause. 2015 Jul;22(7):731-40; 10.1097/gme.0000000000000366.
17. Collado-Mateo D, Lavín-Pérez AM, Peñacoba C, Del Coso J, Leyton-Román M, Luque-Casado A, et al. Key Factors Associated with Adherence to Physical Exercise in Patients with Chronic Diseases and Older Adults: An Umbrella Review. Int J Environ Res Public Health. 2021 Feb 19;18(4); 10.3390/ijerph18042023.
18. Hess TM, Knight RC. Adult Age Differences in the Effects of Chronic Mental Fatigue on Task-Related Fatigue, Appraisals, and Performance. Motiv Sci. 2021 Jun;7(2):122-32; 10.1037/mot0000216.
19. Hess TM, Lothary AF, O'Brien EL, Growney CM, DeLaRosa J. Predictors of engagement in young and older adults: The role of specific activity experience. Psychol Aging. 2021 Mar;36(2):131-42; 10.1037/pag0000561.
20. Boksem MA, Tops M. Mental fatigue: costs and benefits. Brain research reviews. 2008 Nov;59(1):125-39; 10.1016/j.brainresrev.2008.07.001.
21. Marcora SM, Staiano W, Manning V. Mental fatigue impairs physical performance in humans. Journal of Applied Physiology. 2009 2009/03/01;106(3):857-64; 10.1152/japplphysiol.91324.2008.
22. Hardy SE, Studenski SA. Fatigue predicts mortality in older adults. JOURNAL OF THE AMERICAN GERIATRICS SOCIETY. 2008 2008 OCT;56(10):1910-4; 10.1111/j.1532-5415.2008.01957.x.
23. Cohen RW, Meinhardt AJ, Gmelin T, Qiao YS, Moored KD, Katz RD, et al. Prevalence and severity of perceived mental fatigability in older adults: The Long Life Family Study. J Am Geriatr Soc. 2021 May;69(5):1401-3; https://doi.org/10.1111/jgs.17075.
24. Meng H, Hale L, Friedberg F. Prevalence and predictors of fatigue in middle-aged and older adults: evidence from the health and retirement study. J Am Geriatr Soc. 2010 Oct;58(10):2033-4; https://doi.org/10.1111/j.1532-5415.2010.03088.x.
25. Zengarini E, Ruggiero C, Pérez-Zepeda MU, Hoogendijk EO, Vellas B, Mecocci P, et al. Fatigue: Relevance and implications in the aging population. Exp Gerontol. 2015 Oct;70:78-83; https://doi.org/10.1016/j.exger.2015.07.011.
26. Terentjeviene A, Maciuleviciene E, Vadopalas K, Mickeviciene D, Karanauskiene D, Valanciene D, et al. Prefrontal Cortex Activity Predicts Mental Fatigue in Young and Elderly Men During a 2 h "Go/NoGo" Task. Frontiers in Neuroscience. 2018 2018-August-31;12; 10.3389/fnins.2018.00620.
27. Shortz AE, Pickens A, Zheng Q, Mehta RK. The effect of cognitive fatigue on prefrontal cortex correlates of neuromuscular fatigue in older women. Journal of NeuroEngineering and Rehabilitation. 2015 2015/12/21;12(1):115; https://doi.org/10.1186/s12984-015-0108-3.
28. Santos Henriques RPD, Tomas-Carus P, Filipe Marmeleira JF. Association Between Neuropsychological Functions and Activities of Daily Living in People with Mild Cognitive

Impairment. Exp Aging Res. 2023 Oct-Dec;49(5):457-71; https://doi.org/10.1080/0361073x.2022.2133292.
29. de Dieuleveult AL, Siemonsma PC, van Erp JB, Brouwer AM. Effects of Aging in Multisensory Integration: A Systematic Review. Front Aging Neurosci. 2017;9:80; https://doi.org/10.3389/fnagi.2017.00080.
30. Noé F, Hachard B, Ceyte H, Bru N, Paillard T. Relationship between the level of mental fatigue induced by a prolonged cognitive task and the degree of balance disturbance. Exp Brain Res. 2021 Jul;239(7):2273-83; 10.1007/s00221-021-06139-z.
31. Salehi NE, Fard JS, Jaberzadeh S. Mental Fatigue Impairs Postural Stability in Older Adults. Res Q Exerc Sport. 2023 Jun;94(2):401-8; https://doi.org/10.1080/02701367.2021.1999892.
32. Brahms M, Heinzel S, Rapp M, Mückstein M, Hortobágyi T, Stelzel C, et al. The acute effects of mental fatigue on balance performance in healthy young and older adults - A systematic review and meta-analysis. Acta Psychol (Amst). 2022 May;225:103540; https://doi.org/10.1016/j.actpsy.2022.103540.
33. Jackson D, Turner R. Power analysis for random-effects meta-analysis. Res Synth Methods. 2017 Sep;8(3):290-302; https://doi.org/10.1002/jrsm.1240.
34. Sims J, Hill K, Hunt S, Haralambous B, Brown A, Engel L, et al. National physical activity recommendations for older Australians: Discussion document. In: Ageing AGDoHa, editor. Canberra; 2006.
35. Medicine ACoS. ACSM's Guidelines of Exercise Testing and Prescription. 9th ed. Philadelphia: Wolters Kluwer/Lippincott Williams & Wilkins; 2014.
36. Grosicki GJ, Miller ME, Marsh AP. Resistance exercise performance variability at submaximal intensities in older and younger adults. Clin Interv Aging. 2014;9:209-18; 10.2147/cia.S55719.
37. Coelho-Júnior HJ, Silva Aguiar S, Calvani R, Picca A, de Azevedo Carvalho D, Rodrigues B, et al. Acute and chronic effects of traditional and high-speed resistance training on blood pressure in older adults: A crossover study and systematic review and meta-analysis. Experimental Gerontology. 2022 2022/06/15/;163:111775; https://doi.org/10.1016/j.exger.2022.111775.
38. Steffen TM, Hacker TA, Mollinger L. Age- and gender-related test performance in community-dwelling elderly people: Six-Minute Walk Test, Berg Balance Scale, Timed Up & Go Test, and gait speeds. Phys Ther. 2002 Feb;82(2):128-37; 10.1093/ptj/82.2.128.
39. Janaudis-Ferreira T, Sundelin G, Wadell K. Comparison of the 6-minute walk distance test performed on a non-motorised treadmill and in a corridor in healthy elderly subjects. Physiotherapy. 2010 Sep;96(3):234-9; 10.1016/j.physio.2009.11.015.
40. ATS statement: guidelines for the six-minute walk test. Am J Respir Crit Care Med. 2002 Jul 1;166(1):111-7; 10.1164/ajrccm.166.1.at1102.
41. Beauchamp MK, Hao Q, Kuspinar A, D'Amore C, Scime G, Ma J, et al. Reliability and Minimal Detectable Change Values for Performance-Based Measures of Physical Functioning in the Canadian Longitudinal Study on Aging. J Gerontol A Biol Sci Med Sci. 2021 Oct 13;76(11):2030-8; 10.1093/gerona/glab175.
42. Rose DJ, Jones CJ, Lucchese N. 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 01 Oct. 2002;10(4):466-75; 10.1123/japa.10.4.466.
43. Hardy CJ, Rejeski WJ. Not what, but how one feels: The measurement of affect during exercise. Journal of Sport & Exercise Psychology. 1989;11:304-17;

44. Lins-Filho OL, Santos TM, Ritti-Dias RM, Damasceno VO, Ferreira DKS. The Absolute and Relative Reliability of Psychophysiological Responses to Self-Selected Exercise Intensity in Elderly Women. Res Q Exerc Sport. 2019 Sep;90(3):270-5; 10.1080/02701367.2019.1593922.
45. Frazão DT, de Farias Junior LF, Dantas TC, Krinski K, Elsangedy HM, Prestes J, et al. Feeling of Pleasure to High-Intensity Interval Exercise Is Dependent of the Number of Work Bouts and Physical Activity Status. PLoS One. 2016;11(3):e0152752; 10.1371/journal.pone.0152752.
46. Norton L, Thomas J, Bevan N, Norton K. Agreement between pre-exercise screening questionnaires completed online versus face-to-face. PLoS One. 2018;13(6):e0199836; 10.1371/journal.pone.0199836.
47. Norton K. New Australian standard for adult pre-exercise screening. Sport Health. 2012;30(2);
48. Mioshi E, Dawson K, Mitchell J, Arnold R, Hodges JR. The Addenbrooke's Cognitive Examination Revised (ACE-R): a brief cognitive test battery for dementia screening. Int J Geriatr Psychiatry. 2006 Nov;21(11):1078-85; 10.1002/gps.1610.
49. So M, Foxe D, Kumfor F, Murray C, Hsieh S, Savage G, et al. Addenbrooke's Cognitive Examination III: Psychometric Characteristics and Relations to Functional Ability in Dementia. J Int Neuropsychol Soc. 2018 Sep;24(8):854-63; 10.1017/s1355617718000541.
50. Yesavage JA, Brink TL, Rose TL, Lum O, Huang V, Adey M, et al. Development and validation of a geriatric depression screening scale: a preliminary report. J Psychiatr Res. 1982;17(1):37-49; 10.1016/0022-3956(82)90033-4.
51. Yesavage J, Brink T, Rose TL. Geriatric depression scale (GDS). Handbook of Psychiatric Measures: American Psychiatric Association: Washington; 2000.
52. Byrne G, Pachana N, Gonçalves Bradley D, Arnold E, King R, Khoo S. Psychometric properties and health correlates of the Geriatric Anxiety Inventory in Australian community-residing older women. Aging & mental health. 2010 04/01;14:247-54; 10.1080/13607861003587628.
53. Stroop JR. Studies of interference in serial verbal reactions. Journal of Experimental Psychology. 1935;18(6):643-62; 10.1037/h0054651.
54. Fortes L, Lima-Junior D, Nascimento-Júnior J, Costa E, Matta M, Ferreira M. Effect of exposure time to smartphone apps on passing decision-making in male soccer athletes. Psychology of Sport and Exercise. 2019 2019/09/01/;44:35-41; https://doi.org/10.1016/j.psychsport.2019.05.001.
55. Fortes L, Lima-Júnior D, Vieira L, Nascimento-Júnior J, Mortatti A, Ferreira M. The effect of smartphones and playing video games on decision-making in soccer players: a crossover and randomized study. Journal of Sports Science. 2019;
56. Fortes LS, Nakamura FY, Lima-Junior D, Ferreira MEC, Fonseca FS. Does Social Media Use on Smartphones Influence Endurance, Power, and Swimming Performance in High-Level Swimmers? Res Q Exerc Sport. 2022 Mar;93(1):120-9; 10.1080/02701367.2020.1810848.
57. Hooper B, Faria L, Fortes L, Wanner S, Albuquerque M. Development and reliability of a test for assessing executive functions during exercise. Applied Neuropsychology: Adult. 2020 08/28:1-11; 10.1080/23279095.2020.1807984.
58. Faria LO, Thais FS, Bertola L, Fortes LS, Albuquerque MR. Construct validity, test-retest reliability, and sensibility to mental fatigue of the Stroop task in older adults. 2024;
59. Smith M, Coutts A, Merlini M, Deprez D, Lenoir M, Marcora S. Mental Fatigue Impairs Soccer-Specific Physical and Technical Performance. Medicine and Science in Sports and Exercise. 2016 Feb;48(2):267-76; 10.1249/mss.0000000000000762.

60. Diamond A, Barnett WS, Thomas J, Munro S. Preschool program improves cognitive control. Science. 2007 Nov 30;318(5855):1387-8; 10.1126/science.1151148.
61. Noguchi K, Gel YR, Brunner E, Konietschke F. nparLD: An R Software Package for the Nonparametric Analysis of Longitudinal Data in Factorial Experiments. Journal of Statistical Software. 2012 09/18;50(12):1 - 23; 10.18637/jss.v050.i12.
62. Terwee CB, Bot SD, de Boer MR, van der Windt DA, Knol DL, Dekker J, et al. Quality criteria were proposed for measurement properties of health status questionnaires. J Clin Epidemiol. 2007 Jan;60(1):34-42; 10.1016/j.jclinepi.2006.03.012.
63. Hooper B, Faria LO, Fortes LS, Wanner SP, Albuquerque MR. Development and reliability of a test for assessing executive functions during exercise. Appl Neuropsychol Adult. 2022 Jul-Aug;29(4):750-60; 10.1080/23279095.2020.1807984.
64. Hausknecht JP, Halpert JA, Di Paolo NT, Moriarty Gerrard MO. Retesting in selection: a meta-analysis of coaching and practice effects for tests of cognitive ability. J Appl Psychol. 2007 Mar;92(2):373-85; 10.1037/0021-9010.92.2.373.
65. Hassan EK, Jones AM, Buckingham G. A novel protocol to induce mental fatigue. Behavior Research Methods. 2023 2023/08/03; https://doi.org/10.3758/s13428-023-02191-5.
66. Bray SR, Martin Ginis KA, Hicks AL, Woodgate J. Effects of self-regulatory strength depletion on muscular performance and EMG activation. Psychophysiology. 2008 Mar;45(2):337-43; 10.1111/j.1469-8986.2007.00625.x.
67. Tyler JM, Burns KC. After Depletion: The Replenishment of the Self's Regulatory Resources. Self and Identity. 2008 2008/07/01;7(3):305-21; 10.1080/15298860701799997.
68. Dallaway N, Lucas SJE, Ring C. Cognitive tasks elicit mental fatigue and impair subsequent physical task endurance: Effects of task duration and type. Psychophysiology. 2022 Dec;59(12):e14126; 10.1111/psyp.14126.
69. Goodwin A, Avolio A, Boolani A. The impact of cognitive fatigue on aerobic output in a 6-minute walk test among older adults. The FASEB Journal. 2018 04/01;32; https://doi.org/10.1096/fasebj.2018.32.1_supplement.877.13.
70. Giboin L-S, Wolff W. The effect of ego depletion or mental fatigue on subsequent physical endurance performance: A meta-analysis. Performance Enhancement & Health. 2019 2019/09/01/;7(1):100150; https://doi.org/10.1016/j.peh.2019.100150.
71. Behrens M, Mau-Moeller A, Lischke A, Katlun F, Gube M, Zschorlich V, et al. Mental Fatigue Increases Gait Variability During Dual-task Walking in Old Adults. J Gerontol A Biol Sci Med Sci. 2018 May 9;73(6):792-7; https://doi.org/10.1093/gerona/glx210.
72. Fletcher LJ, Osler CJ. Effects of mental fatigue on static upright stance and functional balance in older adults. Aging and Health Research. 2021 2021/12/01/;1(4):100043; https://doi.org/10.1016/j.ahr.2021.100043.
73. Varas-Diaz G, Kannan L, Bhatt T. Effect of Mental Fatigue on Postural Sway in Healthy Older Adults and Stroke Populations. Brain Sciences. 2020;10(6):388; https://doi.org/10.3390/brainsci10060388.
74. Queiros VSd, Dantas M, Fortes LdS, Silva LFd, Silva GMd, Dantas PMS, et al. Mental Fatigue Reduces Training Volume in Resistance Exercise: A Cross-Over and Randomized Study. Perceptual and Motor Skills. 2020 2021/02/01;128(1):409-23; 10.1177/0031512520958935.
75. Gantois P, de Lima-Junior D, Fortes L, Batista G, Nakamura F, Fonseca F. Mental Fatigue From Smartphone Use Reduces Volume-Load in Resistance Training: A Randomized, Single-Blinded Cross-Over Study. Perceptual and Motor Skills. 2021 04/22; 10.1177/00315125211016233.

76. Martin K, Meeusen R, Thompson KG, Keegan R, Rattray B. Mental Fatigue Impairs Endurance Performance: A Physiological Explanation. Sports Med. 2018 Sep;48(9):2041-51; https://doi.org/10.1007/s40279-018-0946-9.
77. Smith M, Thompson C, Marcora S, Skorski S, Meyer T, Coutts A. Mental Fatigue and Soccer: Current Knowledge and Future Directions. Sports Medicine. 2018 04/01;48:1-8; 10.1007/s40279-018-0908-2.
78. Vanden Noven ML, Pereira HM, Yoon T, Stevens AA, Nielson KA, Hunter SK. Motor Variability during Sustained Contractions Increases with Cognitive Demand in Older Adults. Front Aging Neurosci. 2014;6:97; https://doi.org/10.3389/fnagi.2014.00097.
79. Santos PCRd, Hortobágyi T, Zijdewind I, Bucken Gobbi LT, Barbieri FA, Lamoth C. Minimal effects of age and prolonged physical and mental exercise on healthy adults' gait. Gait & Posture. 2019 2019/10/01/;74:205-11; https://doi.org/10.1016/j.gaitpost.2019.09.017.
80. Pereira HM, Spears VC, Schlinder-Delap B, Yoon T, Harkins A, Nielson KA, et al. Sex Differences in Arm Muscle Fatigability With Cognitive Demand in Older Adults. Clinical Orthopaedics and Related Research®. 2015;473(8); https://doi.org/10.1007/s11999-015-4205-1.
81. Morris AJ, Christie AD. The effect of a mentally fatiguing task on postural balance control in young and older women. Experimental Gerontology. 2020 2020/04/01/;132:110840; https://doi.org/10.1016/j.exger.2020.110840.
82. Morris AJ, Christie AD. The Effect of Mental Fatigue on Neuromuscular Function is Similar in Young and Older Women. Brain Sci. 2020 Mar 25;10(4); https://doi.org/10.3390/brainsci10040191.
83. Shortz AE, Mehta RK. Cognitive challenges, aging, and neuromuscular fatigue. Physiol Behav. 2017 Mar 1;170:19-26; https://doi.org/10.1016/j.physbeh.2016.11.034.
84. McMorris T. Developing the catecholamines hypothesis for the acute exercise-cognition interaction in humans: Lessons from animal studies. Physiology & Behavior. 2016 2016/10/15/;165:291-9; https://doi.org/10.1016/j.physbeh.2016.08.011.
85. McMorris T. The acute exercise-cognition interaction: From the catecholamines hypothesis to an interoception model. International Journal of Psychophysiology. 2021 2021/12/01/;170:75-88; https://doi.org/10.1016/j.ijpsycho.2021.10.005.
86. McMorris T, Turner A, Hale BJ, Sproule J. Chapter 4 - Beyond the Catecholamines Hypothesis for an Acute Exercise–Cognition Interaction: A Neurochemical Perspective. In: McMorris T, editor. Exercise-Cognition Interaction. San Diego: Academic Press; 2016. p. 65-103.
87. Albuquerque MR, Hooper B, Viana IOdS, Mesquita PHC, Santos TM, Apolinário-Souza T, et al. Do executive function performance, gaze behavior, and pupil size change during incremental acute physical exercise? Psychophysiology. 2023;60(5):e14233-n/a; 10.1111/psyp.14233.
88. Van Roie E, Bautmans I, Coudyzer W, Boen F, Delecluse C. Low- and High-Resistance Exercise: Long-Term Adherence and Motivation among Older Adults. Gerontology. 2015;61(6):551-60; 10.1159/000381473.
89. Kekäläinen T, Kokko K, Tammelin T, Sipilä S, Walker S. Motivational characteristics and resistance training in older adults: A randomized controlled trial and 1-year follow-up. Scandinavian Journal of Medicine & Science in Sports. 2018 2018/11/01;28(11):2416-26; https://doi.org/10.1111/sms.13236.
90. Pedersen MT, Vorup J, Nistrup A, Wikman JM, Alstrøm JM, Melcher PS, et al. Effect of team sports and resistance training on physical function, quality of life, and motivation in older adults. Scand J Med Sci Sports. 2017 Aug;27(8):852-64; 10.1111/sms.12823.

91. Liu CJ, Latham NK. Progressive resistance strength training for improving physical function in older adults. Cochrane Database Syst Rev. 2009 Jul 8;2009(3):Cd002759; 10.1002/14651858.CD002759.pub2.
92. Latham NK, Bennett DA, Stretton CM, Anderson CS. Systematic Review of Progressive Resistance Strength Training in Older Adults. The Journals of Gerontology: Series A. 2004;59(1):M48-M61; 10.1093/gerona/59.1.M48.
93. Damluji AA, Alfaraidhy M, AlHajri N, Rohant NN, Kumar M, Al Malouf C, et al. Sarcopenia and Cardiovascular Diseases. Circulation. 2023 2023/05/16;147(20):1534-53; https://doi.org/10.1161/CIRCULATIONAHA.123.064071.
94. Bennie JA, Pedisic Z, Suni JH, Tokola K, Husu P, Biddle SJH, et al. Self-reported health-enhancing physical activity recommendation adherence among 64,380 finnish adults. Scand J Med Sci Sports. 2017 Dec;27(12):1842-53; 10.1111/sms.12863.
95. Conlon JA, Haff GG, Tufano JJ, Newton RU. Training Load Indices, Perceived Tolerance, and Enjoyment Among Different Models of Resistance Training in Older Adults. J Strength Cond Res. 2018 Mar;32(3):867-75; 10.1519/jsc.0000000000002281.
96. Gluchowski A, Bilsborough H, McDermott J, Hawley-Hague H, Todd C. 'A Lot of People Just Go for Walks, and Don't Do Anything Else': Older Adults in the UK Are Not Aware of the Strength Component Embedded in the Chief Medical Officers' Physical Activity Guideline - A Qualitative Study. International Journal of Environmental Research and Public Health; 2022.
97. Wylie GR, Pra Sisto AJ, Genova HM, DeLuca J. Fatigue Across the Lifespan in Men and Women: State vs. Trait. Frontiers in Human Neuroscience. 2022 2022-May-09;16; https://doi.org/10.3389/fnhum.2022.790006.
98. Lou JS. Physical and mental fatigue in Parkinson's disease: epidemiology, pathophysiology and treatment. Drugs Aging. 2009;26(3):195-208; https://doi.org/10.2165/00002512-200926030-00002.
99. Lou JS, Kearns G, Oken B, Sexton G, Nutt J. Exacerbated physical fatigue and mental fatigue in Parkinson's disease. Mov Disord. 2001 Mar;16(2):190-6; 10.1002/mds.1042.
100. Vancampfort D, Brunner E, McGrath RL, Hemmings L, Van Damme T. Correlates of sedentary behavior in people with fibromyalgia: A systematic review. Int J Rheum Dis. 2023 May;26(5):841-9; 10.1111/1756-185x.14678.
101. Linnhoff S, Fiene M, Heinze HJ, Zaehle T. Cognitive Fatigue in Multiple Sclerosis: An Objective Approach to Diagnosis and Treatment by Transcranial Electrical Stimulation. Brain Sci. 2019 May 2;9(5); https://doi.org/10.3390/brainsci9050100.

# 4. CONSIDERAÇÕES FINAIS

A presente tese foi composta por uma revisão de escopo e um estudo cross-over randomizado. A revisão indicou que as publicações sobre os efeitos da fadiga mental na função física de idosos são relativamente recentes; portanto, escassas. O método combinado mais comum para induzir e controlar fadiga mental foi matemática mental e repouso, respectivamente. Entretanto, quando analisamos as condições de forma independente, os métodos mais comuns foram testes cognitivos de laboratório com baixa validade ecológica para indução e; filme, documentário ou leitura para condição controle. A revisão também sugeriu a falta de estudos experimentais verdadeiros, assim como a falta de estudos com participantes não saudáveis. A presente tese indicou que não está claro se o estado de fadiga mental é realmente um problema que afeta idosos saudáveis e que pode ser benéfico conduzir estudos qualitativos e de métodos mistos para melhor entender a relevância prática do tema para esta população.

O estudo experimental indicou que a fadiga mental não afeta a função física e as respostas afetivas de pessoas idosas. O estudo reforça a ideia de que fadiga mental não prejudica as respostas comportamentais em tarefas cognitivas de laboratório, provavelmente devido a melhoras relacionadas à idade na resiliência e à mecanismos neurais compensatórios. Mostramos também que os idosos são mais propensos a realizar tarefas de caminhada e equilíbrio em comparação aos exercícios resistidos. Porém, devido à relevância dos exercícios resistidos para a saúde, médicos e gerentes de academias devem alocar recursos para programas de educação sobre a importância dos exercícios resistidos para a saúde no curto e longo prazo, incluir oportunidades de interação social nos programas de exercícios físicos e prescrever exercícios adequados ao nível de habilidade dos participantes.

Finalmente, reconhecemos que o nosso estudo experimental não abordou muitas das limitações levantadas pela revisão de escopo (por exemplo, delineamento experimental verdadeiro, baixa validade ecológica da tarefa utilizada para indução da fadiga mental, participantes saudáveis), o que pode ser explicado pelo fato de ambos os estudos foram conduzidos ao mesmo tempo. No entanto, acreditamos que fizemos melhorias em relação a alguns dos estudos incluídos na revisão (por exemplo, registo do protocolo do estudo e método claro de randomização). Estudos futuros devem tentar cobrir as lacunas apresentadas na revisão de escopo e abordar o tema através de uma visão mais holística (ou seja, estudos de métodos mistos.

# REFERÊNCIAS

AARTOLAHTI, E.*, et al.* Health condition and physical function as predictors of adherence in long-term strength and balance training among community-dwelling older adults. Arch Gerontol Geriatr, 61, n. 3, p. 452-457, Nov-Dec 2015.

ALBUQUERQUE, M. R.*, et al.* Do executive function performance, gaze behavior, and pupil size change during incremental acute physical exercise? Psychophysiology, 60, n. 5, p. e14233-n/a, 2023.

ARNAU, S.*, et al.* The interconnection of mental fatigue and aging: An EEG study. Int J Psychophysiol, 117, p. 17-25, Jul 2017.

ATS statement: guidelines for the six-minute walk test. Am J Respir Crit Care Med, 166, n. 1, p. 111-117, Jul 1 2002.

BANDURA, A. Self-efficacy: Toward a unifying theory of behavioral change. Psychological Review, 84, p. 191-215, 1977.

BARRY, B. K.*, et al.* Rate coding is compressed but variability is unaltered for motor units in a hand muscle of old adults. J Neurophysiol, 97, n. 5, p. 3206-3218, May 2007.

BEAUCHAMP, M. K.*, et al.* Reliability and Minimal Detectable Change Values for Performance-Based Measures of Physical Functioning in the Canadian Longitudinal Study on Aging. J Gerontol A Biol Sci Med Sci, 76, n. 11, p. 2030-2038, Oct 13 2021.

BEHRENS, M.*, et al.* Mental Fatigue Increases Gait Variability During Dual-task Walking in Old Adults. J Gerontol A Biol Sci Med Sci, 73, n. 6, p. 792-797, May 9 2018.

BENNIE, J. A.*, et al.* Self-reported health-enhancing physical activity recommendation adherence among 64,380 finnish adults. Scand J Med Sci Sports, 27, n. 12, p. 1842-1853, Dec 2017.

BOKSEM, M. A.;TOPS, M. Mental fatigue: costs and benefits. Brain Res Rev, 59, n. 1, p. 125-139, Nov 2008a.

_____. Mental fatigue: costs and benefits. Brain research reviews, 59, n. 1, p. 125-139, Nov 2008b.

BOUAZIZ, W.*, et al.* Health benefits of aerobic training programs in adults aged 70 and over: a systematic review. Archives of Gerontology and Geriatrics, 69, p. 110-127, 2017/03/01/ 2017.

BRAHMS, M.*, et al.* The acute effects of mental fatigue on balance performance in healthy young and older adults - A systematic review and meta-analysis. Acta Psychol (Amst), 225, p. 103540, May 2022.

BRAY, S. R.*, et al.* Effects of self-regulatory strength depletion on muscular performance and EMG activation. Psychophysiology, 45, n. 2, p. 337-343, Mar 2008.

BRUCE, B.*, et al.* Better assessment of physical function: item improvement is neglected but essential. Arthritis Res Ther, 11, n. 6, p. R191, 2009.

BYRNE, G.*, et al.* Psychometric properties and health correlates of the Geriatric Anxiety Inventory in Australian community-residing older women. Aging & mental health, 14, p. 247-254, 04/01 2010.

CATALA, P.*, et al.* Do Cognitive Abilities Influence Physical and Mental Fatigue in Patients with Chronic Pain after Walking According to a Clinical Guideline for Physical Exercise? Int J Environ Res Public Health, 18, n. 24, Dec 13 2021.

CELLA, D.*, et al.* The Patient-Reported Outcomes Measurement Information System (PROMIS): Progress of an NIH Roadmap Cooperative Group During its First Two Years. Medical Care, 45, p. S3-S11, 2007.

CHENG, Y.*, et al.* Healthcare Utilization and Physical Functioning in Older Adults in the United States. J Am Geriatr Soc, 68, n. 2, p. 266-271, Feb 2020.

COELHO-JÚNIOR, H. J.*, et al.* Acute and chronic effects of traditional and high-speed resistance training on blood pressure in older adults: A crossover study and systematic review and meta-analysis. Experimental Gerontology, 163, p. 111775, 2022/06/15/ 2022.

COHEN, R. W.*, et al.* Prevalence and severity of perceived mental fatigability in older adults: The Long Life Family Study. J Am Geriatr Soc, 69, n. 5, p. 1401-1403, May 2021.

COILE, C. The Demography of Retirement. In: MAJMUNDAR, M. K.eHAYWARD, M. D. (Ed.). Future Directions for the Demography of Aging: proceedings of a workshop. Washington (DC): National Academies Press (US): Division of Behavioral and Social Sciences and Education, 2018.

COLLADO-MATEO, D.*, et al.* Key Factors Associated with Adherence to Physical Exercise in Patients with Chronic Diseases and Older Adults: An Umbrella Review. Int J Environ Res Public Health, 18, n. 4, Feb 19 2021.

CONLON, J. A., *et al.* Training Load Indices, Perceived Tolerance, and Enjoyment Among Different Models of Resistance Training in Older Adults. J Strength Cond Res, 32, n. 3, p. 867-875, Mar 2018.

COSTA, D. L. The evolution of retirement: an American economic history, 1880-1990 / Dora L. Costa. Chicago: University of Chicago Press, 1998. (NBER series on long-term factors in economic development., v. Accessed from https://nla.gov.au/nla.cat-vn397978). 0226116085

DAILEY, D. L.;KEFFALA, V. J.;SLUKA, K. A. Do cognitive and physical fatigue tasks enhance pain, cognitive fatigue, and physical fatigue in people with fibromyalgia? Arthritis Care Res (Hoboken), 67, n. 2, p. 288-296, Feb 2015.

DALLAWAY, N.;LUCAS, S. J. E.;RING, C. Cognitive tasks elicit mental fatigue and impair subsequent physical task endurance: Effects of task duration and type. Psychophysiology, 59, n. 12, p. e14126, Dec 2022.

DAMLUJI, A. A., *et al.* Sarcopenia and Cardiovascular Diseases. Circulation, 147, n. 20, p. 1534-1553, 2023/05/16 2023.

DE DIEULEVEULT, A. L., *et al.* Effects of Aging in Multisensory Integration: A Systematic Review. Front Aging Neurosci, 9, p. 80, 2017.

DE MUNTER, L., *et al.* Trajectories and prognostic factors for recovery after hip fracture: a longitudinal cohort study. Int Orthop, 46, n. 12, p. 2913-2926, Dec 2022a.

DE MUNTER, L., *et al.* Trajectories and prognostic factors for recovery after hip fracture: a longitudinal cohort study. Int Orthop, Sep 6 2022b.

DIAMOND, A., *et al.* Preschool program improves cognitive control. Science, 318, n. 5855, p. 1387-1388, Nov 30 2007.

DIAS, J. M. Physical Functioning (PF). In: MICHALOS, A. C. (Ed.). Encyclopedia of Quality of Life and Well-Being Research. Dordrecht: Springer Netherlands, 2014. p. 4793-4795.

EDWARDS, J. D., *et al.* Driving cessation and health trajectories in older adults. J Gerontol A Biol Sci Med Sci, 64, n. 12, p. 1290-1295, Dec 2009.

FARIA, L. O., *et al.* Construct validity, test-retest reliability, and sensibility to mental fatigue of the Stroop task in older adults. 2024.

FELDMAN, R. What is resilience: an affiliative neuroscience approach. World Psychiatry, 19, n. 2, p. 132-150, Jun 2020.

FLETCHER, L. J.;OSLER, C. J. Effects of mental fatigue on static upright stance and functional balance in older adults. Aging and Health Research, 1, n. 4, p. 100043, 2021/12/01/ 2021.

FORTES, L.*, et al.* Effect of exposure time to smartphone apps on passing decision-making in male soccer athletes. Psychology of Sport and Exercise, 44, p. 35-41, 2019/09/01/ 2019a.

FORTES, L.*, et al.* The effect of smartphones and playing video games on decision-making in soccer players: a crossover and randomized study. Journal of Sports Science, 2019b.

FORTES, L. S.*, et al.* Effect of exposure time to smartphone apps on passing decision-making in male soccer athletes. Psychology of Sport and Exercise, 44, p. 35-41, 2019/09/01/ 2019c.

FORTES, L. S.*, et al.* Does Social Media Use on Smartphones Influence Endurance, Power, and Swimming Performance in High-Level Swimmers? Res Q Exerc Sport, 93, n. 1, p. 120-129, Mar 2022.

FRALEY, R. C.;VAZIRE, S. The N-Pact Factor: Evaluating the Quality of Empirical Journals with Respect to Sample Size and Statistical Power. PLoS One, 9, n. 10, p. e109019, 2014.

FRAZÃO, D. T.*, et al.* Feeling of Pleasure to High-Intensity Interval Exercise Is Dependent of the Number of Work Bouts and Physical Activity Status. PLoS One, 11, n. 3, p. e0152752, 2016.

GALGANSKI, M. E.;FUGLEVAND, A. J.;ENOKA, R. M. Reduced control of motor output in a human hand muscle of elderly subjects during submaximal contractions. J Neurophysiol, 69, n. 6, p. 2108-2115, Jun 1993.

GANTOIS, P.*, et al.* Mental Fatigue From Smartphone Use Reduces Volume-Load in Resistance Training: A Randomized, Single-Blinded Cross-Over Study. Perceptual and Motor Skills, 04/22 2021.

GIBOIN, L.-S.;WOLFF, W. The effect of ego depletion or mental fatigue on subsequent physical endurance performance: A meta-analysis. Performance Enhancement & Health, 7, n. 1, p. 100150, 2019/09/01/ 2019.

GLUCHOWSKI, A.*, et al.* 'A Lot of People Just Go for Walks, and Don't Do Anything Else': Older Adults in the UK Are Not Aware of the Strength Component Embedded in the Chief Medical Officers' Physical Activity Guideline - A Qualitative Study. International Journal of Environmental Research and Public Health, v.19, n. 16, DOI: 10.3390/ijerph191610002.

GOODWIN, A.;AVOLIO, A.;BOOLANI, A. The impact of cognitive fatigue on aerobic output in a 6-minute walk test among older adults. The FASEB Journal, 32, 04/01 2018.

GROSICKI, G. J.;MILLER, M. E.;MARSH, A. P. Resistance exercise performance variability at submaximal intensities in older and younger adults. Clin Interv Aging, 9, p. 209-218, 2014.

HALSEY, L. G.*, et al.* The fickle P value generates irreproducible results. Nature Methods, 12, n. 3, p. 179-185, 2015/03/01 2015.

HARDY, C. J.;REJESKI, W. J. Not what, but how one feels: The measurement of affect during exercise. Journal of Sport & Exercise Psychology, 11, p. 304-317, 1989.

HARDY, S. E.;STUDENSKI, S. A. Fatigue predicts mortality in older adults. Journal of the American Geriatrics Society, 56, n. 10, p. 1910-1914, 2008 OCT 2008a. Article.

HARDY, S. E.;STUDENSKI, S. A. Fatigue predicts mortality in older adults. J Am Geriatr Soc, 56, n. 10, p. 1910-1914, Oct 2008b.

HASSAN, E. K.;JONES, A. M.;BUCKINGHAM, G. A novel protocol to induce mental fatigue. Behavior Research Methods, 2023/08/03 2023.

HAUSKNECHT, J. P.*, et al.* Retesting in selection: a meta-analysis of coaching and practice effects for tests of cognitive ability. J Appl Psychol, 92, n. 2, p. 373-385, Mar 2007.

HEALTH, A. I. O.;WELFARE. Physical activity across the life stages. Canberra: AIHW 2018.

HESS, T. M.;KNIGHT, R. C. Adult Age Differences in the Effects of Chronic Mental Fatigue on Task-Related Fatigue, Appraisals, and Performance. Motiv Sci, 7, n. 2, p. 122-132, Jun 2021.

HESS, T. M.*, et al.* Predictors of engagement in young and older adults: The role of specific activity experience. Psychol Aging, 36, n. 2, p. 131-142, Mar 2021.

HOOPER, B.*, et al.* Development and reliability of a test for assessing executive functions during exercise. Applied Neuropsychology: Adult, p. 1-11, 08/28 2020.

HOOPER, B.*, et al.* Development and reliability of a test for assessing executive functions during exercise. Appl Neuropsychol Adult, 29, n. 4, p. 750-760, Jul-Aug 2022.

HULLEY, S. B.*, et al.* Designing clinical research. Fourth edition ed. Philadelphia: Wolters Kluwer Health/Lippincott Williams & Wilkins Philadelphia, 2013. 9781608318049; 1608318044; 9781469840543; 1469840545; 1469875330; 9781469875330; 9781469840536; 1469840537

ISHII, A.;TANAKA, M.;WATANABE, Y. Neural mechanisms of mental fatigue. Rev Neurosci, 25, n. 4, p. 469-479, 2014.

JACKSON, D.;TURNER, R. Power analysis for random-effects meta-analysis. Res Synth Methods, 8, n. 3, p. 290-302, Sep 2017.

JANAUDIS-FERREIRA, T.;SUNDELIN, G.;WADELL, K. Comparison of the 6-minute walk distance test performed on a non-motorised treadmill and in a corridor in healthy elderly subjects. Physiotherapy, 96, n. 3, p. 234-239, Sep 2010.

JANSSEN, I.;HEYMSFIELD, S. B.;ROSS, R. Low relative skeletal muscle mass (sarcopenia) in older persons is associated with functional impairment and physical disability. J Am Geriatr Soc, 50, n. 5, p. 889-896, May 2002.

KEKÄLÄINEN, T.*, et al.* Motivational characteristics and resistance training in older adults: A randomized controlled trial and 1-year follow-up. SCANDINAVIAN JOURNAL OF MEDICINE & SCIENCE IN SPORTS, 28, n. 11, p. 2416-2426, 2018/11/01 2018.

KRAUS, W. E.*, et al.* Daily Step Counts for Measuring Physical Activity Exposure and Its Relation to Health. Med Sci Sports Exerc, 51, n. 6, p. 1206-1212, Jun 2019.

LACHARITÉ-LEMIEUX, M.;BRUNELLE, J. P.;DIONNE, I. J. Adherence to exercise and affective responses: comparison between outdoor and indoor training. Menopause, 22, n. 7, p. 731-740, Jul 2015.

LAIDLAW, D. H.;BILODEAU, M.;ENOKA, R. M. Steadiness is reduced and motor unit discharge is more variable in old adults. Muscle Nerve, 23, n. 4, p. 600-612, Apr 2000.

LANDI, F.*, et al.* Sarcopenia and mortality among older nursing home residents. J Am Med Dir Assoc, 13, n. 2, p. 121-126, Feb 2012.

LATHAM, N. K.*, et al.* Systematic Review of Progressive Resistance Strength Training in Older Adults. The Journals of Gerontology: Series A, 59, n. 1, p. M48-M61, 2004.

LEXELL, J. Human aging, muscle mass, and fiber type composition. J Gerontol A Biol Sci Med Sci, 50 Spec No, p. 11-16, Nov 1995.

LINNHOFF, S.*, et al.* Cognitive Fatigue in Multiple Sclerosis: An Objective Approach to Diagnosis and Treatment by Transcranial Electrical Stimulation. Brain Sci, 9, n. 5, May 2 2019.

LINS-FILHO, O. L.*, et al.* The Absolute and Relative Reliability of Psychophysiological Responses to Self-Selected Exercise Intensity in Elderly Women. Res Q Exerc Sport, 90, n. 3, p. 270-275, Sep 2019.

LIU, C. J.;LATHAM, N. K. Progressive resistance strength training for improving physical function in older adults. Cochrane Database Syst Rev, 2009, n. 3, p. Cd002759, Jul 8 2009.

LOU, J. S. Physical and mental fatigue in Parkinson's disease: epidemiology, pathophysiology and treatment. Drugs Aging, 26, n. 3, p. 195-208, 2009.

LOU, J. S.*, et al.* Exacerbated physical fatigue and mental fatigue in Parkinson's disease. Movement Disorders, 16, n. 2, p. 190-196, 2001/03/01 2001a.

LOU, J. S.*, et al.* Exacerbated physical fatigue and mental fatigue in Parkinson's disease. Mov Disord, 16, n. 2, p. 190-196, Mar 2001b.

MARCORA, S. M.;STAIANO, W.;MANNING, V. Mental fatigue impairs physical performance in humans. Journal of Applied Physiology, 106, n. 3, p. 857-864, 2009/03/01 2009a.

MARCORA, S. M.;STAIANO, W.;MANNING, V. Mental fatigue impairs physical performance in humans. J Appl Physiol, 106, n. 3, p. 857-864, Mar 2009b.

MARQUES, E. A.*, et al.* Are resistance and aerobic exercise training equally effective at improving knee muscle strength and balance in older women? Arch Gerontol Geriatr, 68, p. 106-112, Jan-Feb 2017.

MARTIN, K.*, et al.* Mental Fatigue Impairs Endurance Performance: A Physiological Explanation. Sports Med, 48, n. 9, p. 2041-2051, Sep 2018.

MCMORRIS, T. Developing the catecholamines hypothesis for the acute exercise-cognition interaction in humans: Lessons from animal studies. Physiology & Behavior, 165, p. 291-299, 2016/10/15/ 2016.

_____. The acute exercise-cognition interaction: From the catecholamines hypothesis to an interoception model. International Journal of Psychophysiology, 170, p. 75-88, 2021/12/01/ 2021.

MCMORRIS, T.*, et al.* Chapter 4 - Beyond the Catecholamines Hypothesis for an Acute Exercise–Cognition Interaction: A Neurochemical Perspective. In: MCMORRIS, T. (Ed.). Exercise-Cognition Interaction. San Diego: Academic Press, 2016. p. 65-103.

MEDICINE, A. C. O. S. ACSM's Guidelines of Exercise Testing and Prescription. Philadelphia: Wolters Kluwer/Lippincott Williams & Wilkins 2014.

MENG, H.;HALE, L.;FRIEDBERG, F. Prevalence and predictors of fatigue in middle-aged and older adults: evidence from the health and retirement study. J Am Geriatr Soc, 58, n. 10, p. 2033-2034, Oct 2010.

MESQUIDA, C.*, et al.* Replication concerns in sports and exercise science: a narrative review of selected methodological issues in the field. ROYAL SOCIETY OPEN SCIENCE, 9, n. 12, p. 220946, 2022/12/14 2022.

MIGEOT, J.*, et al.* Socioeconomic status impacts cognitive and socioemotional processes in healthy ageing. Sci Rep, 12, n. 1, p. 6048, Apr 11 2022.

MIOSHI, E.*, et al.* The Addenbrooke's Cognitive Examination Revised (ACE-R): a brief cognitive test battery for dementia screening. Int J Geriatr Psychiatry, 21, n. 11, p. 1078-1085, Nov 2006.

MOREIRA, M. N.*, et al.* What are the Main Physical Functioning Factors Associated With Falls Among Older People With Different Perceived Fall Risk? Physiother Res Int, 22, n. 3, Jul 2017.

MORRIS, A. J.;CHRISTIE, A. D. The effect of a mentally fatiguing task on postural balance control in young and older women. Experimental Gerontology, 132, p. 110840, 2020/04/01/ 2020a.

MORRIS, A. J.;CHRISTIE, A. D. The Effect of Mental Fatigue on Neuromuscular Function is Similar in Young and Older Women. Brain Sci, 10, n. 4, Mar 25 2020b.

MUNN, Z.*, et al.* Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach. BMC Medical Research Methodology, 18, n. 1, p. 143, 2018/11/19 2018.

MYERS, S.;PUGSLEY, T. A. Decrease in rat striatal dopamine synthesis and metabolism in vivo by metabolically stable adenosine receptor agonists. Brain Res, 375, n. 1, p. 193-197, Jun 4 1986.

NARUSE, M.;TRAPPE, S.;TRAPPE, T. A. Human skeletal muscle-specific atrophy with aging: a comprehensive review. J Appl Physiol (1985), 134, n. 4, p. 900-914, Apr 1 2023.

NEGRO, F.;HOLOBAR, A.;FARINA, D. Fluctuations in isometric muscle force can be described by one linear projection of low-frequency components of motor unit discharge rates. J Physiol, 587, n. Pt 24, p. 5925-5938, Dec 15 2009.

NIEOULLON, A. Nieoullon A. Dopamine and the regulation of cognition and attention. Prog Neurobiol 67: 53-83. Progress in neurobiology, 67, p. 53-83, 06/01 2002.

NOÉ, F.*, et al.* Relationship between the level of mental fatigue induced by a prolonged cognitive task and the degree of balance disturbance. Exp Brain Res, 239, n. 7, p. 2273-2283, Jul 2021.

NOGUCHI, K.*, et al.* nparLD: An R Software Package for the Nonparametric Analysis of Longitudinal Data in Factorial Experiments. Journal of Statistical Software, 50, n. 12, p. 1 - 23, 09/18 2012.

NORTON, K. New Australian standard for adult pre-exercise screening. Sport Health, 30, n. 2, 2012. Other Journal Article.

NORTON, L.*, et al.* Agreement between pre-exercise screening questionnaires completed online versus face-to-face. PLoS One, 13, n. 6, p. e0199836, 2018.

OSOBA, M. Y.*, et al.* Balance and gait in the elderly: A contemporary review. Laryngoscope Investig Otolaryngol, 4, n. 1, p. 143-153, Feb 2019.

PAGEAUX, B.*, et al.* Response inhibition impairs subsequent self-paced endurance performance. Eur J Appl Physiol, 114, n. 5, p. 1095-1105, May 2014.

PEDERSEN, M. T.*, et al.* Effect of team sports and resistance training on physical function, quality of life, and motivation in older adults. Scand J Med Sci Sports, 27, n. 8, p. 852-864, Aug 2017.

PEREIRA, H. M.*, et al.* Oscillations in neural drive and age-related reductions in force steadiness with a cognitive challenge. J Appl Physiol (1985), 126, n. 4, p. 1056-1065, Apr 1 2019.

PEREIRA, H. M.*, et al.* Sex Differences in Arm Muscle Fatigability With Cognitive Demand in Older Adults. Clinical Orthopaedics and Related Research®, 473, n. 8, 2015a.

PEREIRA, H. M.*, et al.* Age and sex differences in steadiness of elbow flexor muscles with imposed cognitive demand. Eur J Appl Physiol, 115, n. 6, p. 1367-1379, Jun 2015b.

PETERS, M. D.*, et al.* Guidance for conducting systematic scoping reviews. Int J Evid Based Healthc, 13, n. 3, p. 141-146, Sep 2015.

PETERS, M. D. J.*, et al.* Updated methodological guidance for the conduct of scoping reviews. JBI evidence synthesis, 18, n. 10, 2020.

PICHE, E.*, et al.* Effects of muscular and mental fatigue on spatiotemporal gait parameters in dual task walking in young, non-frail and frail older adults. Aging Clin Exp Res, Aug 3 2023.

QUEIROS, V. S. D.*, et al.* Mental Fatigue Reduces Training Volume in Resistance Exercise: A Cross-Over and Randomized Study. Perceptual and Motor Skills, 128, n. 1, p. 409-423, 2021/02/01 2020.

ROSE, D. J.;JONES, C. J.;LUCCHESE, N. 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, 10, n. 4, p. 466-475, 01 Oct. 2002 2002.

SALEHI, N. E.;FARD, J. S.;JABERZADEH, S. Mental Fatigue Impairs Postural Stability in Older Adults. Res Q Exerc Sport, 94, n. 2, p. 401-408, Jun 2023.

SANTAMARIA, J.;CHIAPPA, K. H. The EEG of drowsiness in normal adults. J Clin Neurophysiol, 4, n. 4, p. 327-382, Oct 1987.

SANTOS HENRIQUES, R. P. D.;TOMAS-CARUS, P.;FILIPE MARMELEIRA, J. F. Association Between Neuropsychological Functions and Activities of Daily Living in People with Mild Cognitive Impairment. Exp Aging Res, 49, n. 5, p. 457-471, Oct-Dec 2023.

SANTOS, P. C. R. D.*, et al.* Minimal effects of age and prolonged physical and mental exercise on healthy adults' gait. Gait & Posture, 74, p. 205-211, 2019/10/01/ 2019.

SCHUTZER, K. A.;GRAVES, B. S. Barriers and motivations to exercise in older adults. Prev Med, 39, n. 5, p. 1056-1061, Nov 2004.

SHERRINGTON, C.*, et al.* Exercise to prevent falls in older adults: an updated systematic review and meta-analysis. British Journal of Sports Medicine, 51, n. 24, p. 1750-1758, 2017.

SHORTZ, A. E.;MEHTA, R. K. Cognitive challenges, aging, and neuromuscular fatigue. Physiol Behav, 170, p. 19-26, Mar 1 2017.

SHORTZ, A. E.*, et al.* The effect of cognitive fatigue on prefrontal cortex correlates of neuromuscular fatigue in older women. Journal of NeuroEngineering and Rehabilitation, 12, n. 1, p. 115, 2015/12/21 2015.

SIMS, J.*, et al.* National physical activity recommendations for older Australians: Discussion document. AGEING, A. G. D. O. H. A. Canberra 2006.

SMITH, M.*, et al.* Mental Fatigue Impairs Soccer-Specific Physical and Technical Performance. Medicine and Science in Sports and Exercise, 48, n. 2, p. 267-276, Feb 2016.

SMITH, M.*, et al.* Mental Fatigue and Soccer: Current Knowledge and Future Directions. Sports Medicine, 48, p. 1-8, 04/01 2018.

SO, M.*, et al.* Addenbrooke's Cognitive Examination III: Psychometric Characteristics and Relations to Functional Ability in Dementia. J Int Neuropsychol Soc, 24, n. 8, p. 854-863, Sep 2018.

SOUSA, N.*, et al.* Combined exercise is more effective than aerobic exercise in the improvement of fall risk factors: A randomized controlled trial in community-dwelling older men. Clinical Rehabilitation, 31, p. 1–9, 06/29 2016.

STEFFEN, T. M.;HACKER, T. A.;MOLLINGER, L. Age- and gender-related test performance in community-dwelling elderly people: Six-Minute Walk Test, Berg Balance Scale, Timed Up & Go Test, and gait speeds. Phys Ther, 82, n. 2, p. 128-137, Feb 2002.

STERNE, J. A.*, et al.* ROBINS-I: a tool for assessing risk of bias in non-randomised studies of interventions. Bmj, 355, p. i4919, Oct 12 2016.

STERNE, J. A. C.*, et al.* RoB 2: a revised tool for assessing risk of bias in randomised trials. Bmj, 366, p. l4898, Aug 28 2019.

STROOP, J. R. Studies of interference in serial verbal reactions. Journal of Experimental Psychology, 18, n. 6, p. 643-662, 1935.

SWARTZ, A. M.*, et al.* Glucose control and walking in a multiethnic sample of older adults. Gerontology, 53, n. 6, p. 454-461, 2007.

TERENTJEVIENE, A.*, et al.* Prefrontal Cortex Activity Predicts Mental Fatigue in Young and Elderly Men During a 2 h "Go/NoGo" Task. Front Neurosci, 12, p. 620, 2018a.

TERENTJEVIENE, A.*, et al.* Prefrontal Cortex Activity Predicts Mental Fatigue in Young and Elderly Men During a 2 h “Go/NoGo” Task. Frontiers in Neuroscience, 12, 2018-August-31 2018b. Original Research.

TERWEE, C. B.*, et al.* Quality criteria were proposed for measurement properties of health status questionnaires. J Clin Epidemiol, 60, n. 1, p. 34-42, Jan 2007.

TIEDEMANN, A.;SHERRINGTON, C.;LORD, S. R. Predictors of exercise adherence in older people living in retirement villages. Prev Med, 52, n. 6, p. 480-481, Jun 2011.

TRACY, B. L.;ENOKA, R. M. Older adults are less steady during submaximal isometric contractions with the knee extensor muscles. J Appl Physiol (1985), 92, n. 3, p. 1004-1012, Mar 2002.

TRAN, Y.*, et al.* The influence of mental fatigue on brain activity: Evidence from a systematic review with meta-analyses. Psychophysiology, 57, n. 5, p. e13554, May 2020.

TRICCO, A. C.*, et al.* PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation. Ann Intern Med, 169, n. 7, p. 467-473, Oct 2 2018.

TYLER, J. M.;BURNS, K. C. After Depletion: The Replenishment of the Self's Regulatory Resources. Self and Identity, 7, n. 3, p. 305-321, 2008/07/01 2008.

VAN DER KOOIJ, K.*, et al.* Gamification as a Sustainable Source of Enjoyment During Balance and Gait Exercises. Front Psychol, 10, p. 294, 2019.

VAN OOSTROM, S. H.*, et al.* Time Trends in Prevalence of Chronic Diseases and Multimorbidity Not Only due to Aging: Data from General Practices and Health Surveys. PLoS One, 11, n. 8, p. e0160264, 2016.

VAN ROIE, E.*, et al.* Low- and High-Resistance Exercise: Long-Term Adherence and Motivation among Older Adults. Gerontology, 61, n. 6, p. 551-560, 2015.

VANCAMPFORT, D.*, et al.* Correlates of sedentary behavior in people with fibromyalgia: A systematic review. Int J Rheum Dis, 26, n. 5, p. 841-849, May 2023a.

VANCAMPFORT, D.*, et al.* Correlates of sedentary behavior in people with fibromyalgia: A systematic review. International Journal of Rheumatic Diseases, 26, n. 5, p. 841-849, 2023/05/01 2023b.

VANDEN NOVEN, M. L.*, et al.* Motor Variability during Sustained Contractions Increases with Cognitive Demand in Older Adults. Front Aging Neurosci, 6, p. 97, 2014.

VARAS-DIAZ, G.;KANNAN, L.;BHATT, T. Effect of Mental Fatigue on Postural Sway in Healthy Older Adults and Stroke Populations. Brain Sciences, 10, n. 6, p. 388, 2020.

VARELA, S.;AYÁN, C.;CANCELA, J. M. Batteries assessing health related fitness in the elderly: a brief review. European Review of Aging and Physical Activity, 5, n. 2, p. 97-105, 2008/10/01 2008.

WORLD HEALTH ORGANIZATION, W. Falls. 2021. Disponível em: https://www.who.int/news-room/fact-sheets/detail/falls. Acesso em: 02 August 2023.

WYLIE, G. R.*, et al.* Fatigue Across the Lifespan in Men and Women: State vs. Trait. FRONTIERS IN HUMAN NEUROSCIENCE, 16, 2022-May-09 2022. Original Research.

YESAVAGE, J.;BRINK, T.;ROSE, T. L. Geriatric depression scale (GDS). Handbook of Psychiatric Measures: American Psychiatric Association: Washington, 2000.

YESAVAGE, J. A.*, et al.* Development and validation of a geriatric depression screening scale: a preliminary report. J Psychiatr Res, 17, n. 1, p. 37-49, 1982.

ZENGARINI, E.*, et al.* Fatigue: Relevance and implications in the aging population. Exp Gerontol, 70, p. 78-83, Oct 2015.

**MATERIAL SUPLEMENTAR – ESTUDO 1**

# Mental Fatigue and Physical Function of Older People: A Scoping Review

Larissa Oliveira Faria, Nathálya Gardênia de Holanda Marinho Nogueira, Thais Frois de Sousa, Aaron James Coutts, Maicon Rodrigues Albuquerque

**Contact details for the corresponding author:**

Larissa Oliveira Faria, Departamento de Esportes, Escola de Educação Física, Fisioterapia e Terapia Ocupacional (EEFFTO), Universidade Federal de Minas Gerais, Avenida Presidente Carlos Luz, 4664 - Pampulha, Belo Horizonte, Minas Gerais CEP 31120-901, Brazil; lof.ufv@gmail.com, +61420205814.

**Table 3. Search Strategy by Database**

| Database | Search Strategy |
|---|---|
| Web of Science | ((TS=("old* adults" OR elderly OR senior OR aged)) AND TS=(fatigue OR depletion OR exertion OR exhaustion OR fatigability) AND TS = (mental OR central OR cognitive) AND TS=("physical function" OR walk OR "muscular function" OR "daily activit*" OR balance OR gait OR postural)) |
| Pubmed | (("old* adults" OR elderly OR senior OR aged) AND ((fatigue OR depletion OR exertion OR exhaustion OR fatigability) AND (mental OR central OR cognitive)) AND ("physical function" OR walk OR "muscular function" OR "daily activit*" OR balance OR gait OR postural)) |
| Scopus | ( ( "old* adults" OR elderly OR senior OR aged ) AND ( ( fatigue OR depletion OR exertion OR exhaustion OR fatigability ) AND ( mental OR central OR cognitive ) ) AND ( "physical function" OR walk OR "muscular function" OR "daily activit*" OR balance OR gait OR postural ) ) |

**Table 4. Inter-rater reliability data exported from Covidence**

| Reviewer | | Stage | |
|---|---|---|---|
| **LOF** | **TFS** | **Title and Abstracts** | **Full-Text Review** |
| Yes | No | 10 | 2 |
| No | Yes | 0 | 0 |
| Yes | Yes | 26 | 7 |
| No | No | 4975 | 18 |
| **Agreement** | | 99.80% | 92.59 |
| **Cohen's Kappa** | | 0.84 | 0.82 |
| **Cohen's Kappa Classification** | | Almost perfect agrément | Almost perfect agreement |

## Components of Physical Function

Most studies were interested to investigate the effects of mental fatigue in force steadiness (n = 8) and muscle activation (n = 6). There was a similar mix of studies involving balance/posture (n = 4) and neuromuscular fatigue (n=4). The remaining studies measured gait (n = 3) and aerobic output (n = 1).

**Table 5. Components of Physical Function investigated by studies research designs.**

| | Experimental | Quasi-Experimental | | |
|---|---|---|---|---|
| Physical Function | Randomised Controlled Trial | Randomised Crossover | Time Series | Non-randomised between-group Trial |
| Gait | | [1] | [2] | [3] |
| Aerobic Output | | [4] | | |
| Balance/Posture | [5, 6] | [7, 8] | | |
| Neuromuscular Fatigue | | [9-11] | [12] | |
| Force Steadiness | | [9-11, 13, 14] | [2, 12, 15] | |
| Muscle Activity | | [7, 11, 14] | [2, 12, 15] | |

**References**

1. Behrens M, Mau-Moeller A, Lischke A, Katlun F, Gube M, Zschorlich V, et al. Mental Fatigue Increases Gait Variability During Dual-task Walking in Old Adults. J Gerontol A Biol Sci Med Sci. 2018 May 9;73(6):792-7.
2. Santos PCRd, Hortobágyi T, Zijdewind I, Bucken Gobbi LT, Barbieri FA, Lamoth C. Minimal effects of age and prolonged physical and mental exercise on healthy adults' gait. Gait & Posture. 2019 2019/10/01/;74:205-11.
3. Piche E, Gerus P, Zory R, Jaafar A, Guerin O, Chorin F. Effects of muscular and mental fatigue on spatiotemporal gait parameters in dual task walking in young, non-frail and frail older adults. Aging Clin Exp Res. 2023 Aug 3.
4. Goodwin A, Avolio A, Boolani A. The impact of cognitive fatigue on aerobic output in a 6-minute walk test among older adults. The FASEB Journal. 2018 04/01;32.
5. Varas-Diaz G, Kannan L, Bhatt T. Effect of Mental Fatigue on Postural Sway in Healthy Older Adults and Stroke Populations. Brain Sci. 2020 Jun 19;10(6).
6. Salehi NE, Fard JS, Jaberzadeh S. Mental Fatigue Impairs Postural Stability in Older Adults. Res Q Exerc Sport. 2023 Jun;94(2):401-8.
7. Morris AJ, Christie AD. The effect of a mentally fatiguing task on postural balance control in young and older women. Experimental Gerontology. 2020 2020/04/01/;132:110840.
8. Fletcher LJ, Osler CJ. Effects of mental fatigue on static upright stance and functional balance in older adults. Aging and Health Research. 2021 2021/12/01/;1(4):100043.
9. Vanden Noven ML, Pereira HM, Yoon T, Stevens AA, Nielson KA, Hunter SK. Motor Variability during Sustained Contractions Increases with Cognitive Demand in Older Adults. Front Aging Neurosci. 2014;6:97.
10. Pereira HM, Spears VC, Schlinder-Delap B, Yoon T, Harkins A, Nielson KA, et al. Sex Differences in Arm Muscle Fatigability With Cognitive Demand in Older Adults. Clin Orthop Relat Res. 2015 Aug;473(8):2568-77.
11. Shortz AE, Pickens A, Zheng Q, Mehta RK. The effect of cognitive fatigue on prefrontal cortex correlates of neuromuscular fatigue in older women. Journal of NeuroEngineering and Rehabilitation. 2015 2015/12/21;12(1):115.
12. Shortz AE, Mehta RK. Cognitive challenges, aging, and neuromuscular fatigue. Physiol Behav. 2017 Mar 1;170:19-26.
13. Pereira HM, Spears VC, Schlinder-Delap B, Yoon T, Nielson KA, Hunter SK. Age and sex differences in steadiness of elbow flexor muscles with imposed cognitive demand. Eur J Appl Physiol. 2015 Jun;115(6):1367-79.
14. Pereira HM, Schlinder-DeLap B, Keenan KG, Negro F, Farina D, Hyngstrom AS, et al. Oscillations in neural drive and age-related reductions in force steadiness with a cognitive challenge. J Appl Physiol (1985). 2019 Apr 1;126(4):1056-65.
15. Morris AJ, Christie AD. The Effect of Mental Fatigue on Neuromuscular Function is Similar in Young and Older Women. Brain Sci. 2020 Mar 25;10(4).

# MATERIAL SUPLEMENTAR – ESTUDO 2

## The influence of mental fatigue on physical performance and factors that affect exercise adherence in older adults

Larissa Oliveira Faria[1,2]; Maicon Rodrigues Albuquerque[1]; Aaron James Coutts[2]

### Familiarisation – Physical Tests

Participants reported, on average, RPE classified as somewhat strong, very week and very strong for the 6MWT, TUG and 10RM, respectively. Overall, participants enjoyed performing the 6MWT and TUG, whereas the enjoyment for the 10RM test tended to be lower (Table 1).

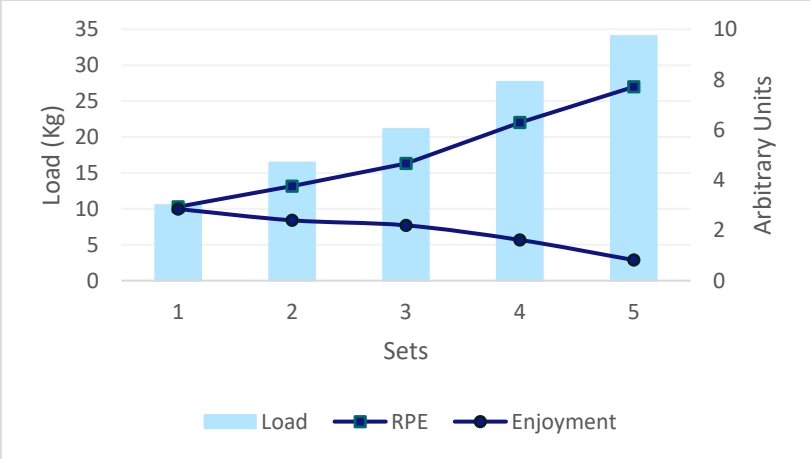
Table 1. Mean and standard deviation for performance, RPE and Enjoyment during the familiarisation

| Measured Variables | Performance | RPE | Enjoyment |
|---|---|---|---|
| 6MWT (m) | 599.8±68.2 | 4.0±1.7 | 7.89±2.21 |
| TUG (s) | 5.7±0.9 | 1.0±1.3 | 8.11±1.94 |
| 10RM (Kg) | 31.7±11.8 | 7.7±1.8 | 5.80±1.98 |

| Calculated Variables | Performance |
|---|---|
| Speed/6MWT (m/s) | 1.67±0.2 |

We observed a trend for decrease in enjoyment and increase in RPE with the increase of the load in the 10RM test (Figure 1).

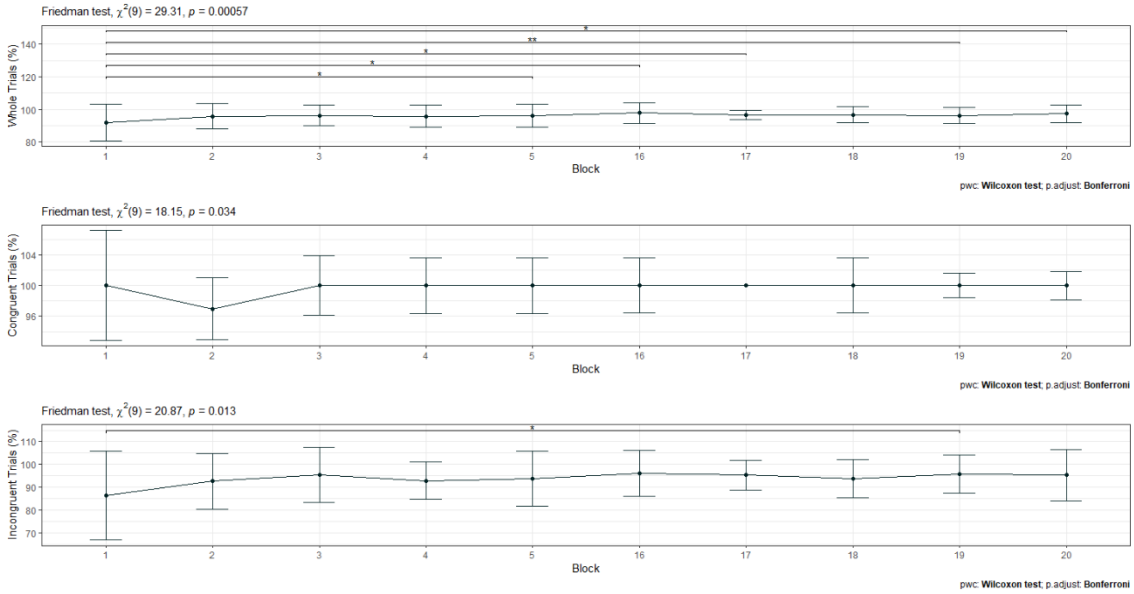
Figure 1. Average load, RPE and enjoyment in each set of the 10RM test



**Induction**
**Flanker Test**

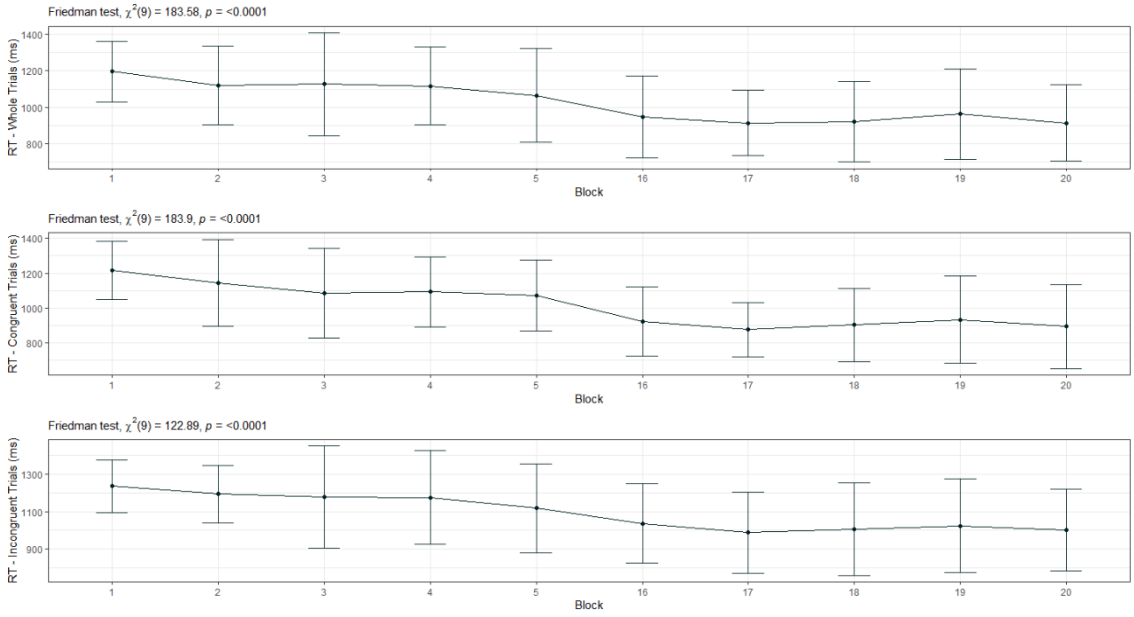
The Friedman Test indicated significant differences, for the whole trials (W = 0.093), congruent (W = 0.058) and incongruent analysis (W = 0.066), in the comparison of the blocks of the Flanker Test with small effect sizes. The post-hoc suggested that the percentage of correct responses was significantly lower in the first block compared to blocks 5, 16, 17, 19 and 20 in the whole trials analysis. The p-adjusted were not significant for the comparisons of the congruent analysis. For the incongruent trials, accuracy was significant higher in block 19 compared to the first one (Figure 2).

Figure 2. Accuracy (whole trials, congruent trials and incongruent trials) comparison between blocks of the flanker test




The comparison between blocks was statistically different for all the analysis (p<0001) with moderate to large effect sizes [Whole Trials, W = 0.583 (large); Congruent Trials, W = 0.584 (large); Incongruent Trials, W = 0.390 (moderate)]. The post-hoc pointed out a significant and constant decrease in the response time from the first to the last block (Figure 3).

Figure 3. Response time (whole trials, congruent trials and incongruent trials) comparison between the blocks of the Flanker Test.




The descriptive statistics of the cognitive tasks used for mental fatigue induction suggested that all the participants remained engaged in the tasks during the induction period (Table 2).

Table 2. Descriptive statistics of the cognitive tasks used to induce mental fatigue

| | Accuracy (%) | | Response Time (ms) | |
|---|---|---|---|---|
| | CT/ Var | Min-Max | CT/Var | Min-Max |
| Stroop – Colour | 98.89(1.50) | 94.83-100.00 | 851.20±138.41 | 596.80-1127.80 |
| Stroop – Meaning | 97.63(2.30) | 85.77-99.70 | 1005.00(253.82) | 684.00-1946 |

Legend: CT: central tendency measure (mean or median); Var: Variability Measure (standard deviation or IQR), Min: Minimum Value; Max: Maximum Value; ms: milliseconds.

# ANEXOS
# ATTACHMENT 1. Ethics approval

ResearchMaster

## Ethics Application

| | |
|---|---|
| Application ID : | ETH23-8158 |
| Application Title : | The influence of mental fatigue on physical performance and factors that affect exercise adherence in older adults |
| Date of Submission : | 13/03/2023 |
| Primary Investigator : | PROF Aaron James Coutts (Chief Investigator) |
| Other Personnel : | Ms Larissa Oliveira Faria (Chief Investigator) |



**Section 1: Ethics Portal**

**Select your application type**

What type of application are you looking for?
Please **do not** change your application type without first consulting with the Ethics Secretariat (9514 9772).*

- ○ New application (including scope-checking for nil/negligible risk research)
- ○ Ratification of existing approval
- ○ Transfer of existing approval
- ○ Evaluation of teaching and learning activities
- ◉ Amendment to existing approval
- ○ Program approval

You have selected "amendment application". This option allows you to amend an existing UTS HREC approved protocol **EXCEPT** for approved negligible risk declarations. If you want to update an approved negligible risk declaration, please submit a new application.
Please click "save" before continuing.

Please refer to the amendment table on our website regarding the requirements for amendments to existing approval before continuing.

Please indicate the risk classification of the original ethics approval?*

- ○ Nil/Neg risk
- ○ Low risk
- ◉ High risk

**What should I know before I start?**

Would you like more information on:

- ◉ This system
- ○ The ethics process
- ○ Purpose of the ethics review process

**This system**

The purpose of this online system is to streamline the ethics application process.

Mandatory questions in the application form are marked with a red asterisk (*) and must be answered before submitting this form. If a question is left unanswered on a page the form menu will show a red exclamation mark (!) on the left side of the page name and the question will be highlighted in pink.

The navigation menu allows you to view all sections and pages of the application, and also keeps track of what pages have been visited and/or completed and which pages are incomplete.

Action buttons (located on the right) shows the actions that the person viewing the form can make, and will differ between each role, e.g. student, supervisor, staff member, faculty member, HREC member, Research Ethics Officer, etc.

**'Next page':** Each time you click on the blue 'next page' button, your application is saved automatically.

**Save:** This button allows you to save the page before moving to other pages.

**Comments:** This allows you to make comments on the application.

**Reports:** Allows you to view or print a PDF the application form.

**Section 1A: Risk evaluation**

**Risk A**

**Determining the level of risk and review**

- Please answer each question carefully **and consecutively**.
- For assistance with answering these questions please refer to the National Statement on Ethical Conduct in Human Research as per the chapters listed below.
- If you need to contact the Research Ethics Office you can call (02) 9514 9772
- Click on the help buttons (?) for more information
- You can save your application at any time by clicking on the save button on the left hand side in the toolbar. For further information and help in completing your application go to our website.

**Does your research involve:**

**Projects involving covert observation, active concealment, or planned deception of participants**

**e.g. covert observation of the hand-washing behaviour of hospital employees, undisclosed role-playing by a researcher, etc. Does NOT include observation in a public place WITHOUT the use of photographs, images, video or audio footage (Chapter 2.3, p.19)**

*

○ Yes
◉ No

**Targeted recruitment or analysis of data(?) from any of the groups listed below (or where any of these groups are likely to be significantly over-represented in the group being studied)**

- Women who are pregnant and the human fetus (Chapter 4.1, p. 61)
- Children and young people (under 18 years) (Chapter 4.2, p. 65)
- People in dependent or unequal relationships (e.g. lecturer/student Texcept TBL). doctor/patient, employer/employee) (Chapter 4.3, p.68)
- People highly dependent on medical care who may be unable to give consent Chapter 4.4, p.68)
- People with a cognitive impairment, an intellectual disability, or a mental illness (may include the disadvantaged/homeless) (Chapter 4.5, p. 70)
- People who may be involved in illegal activities (including those affected e.g. victims of domestic violence) (Chapter 4.6, p.73)
- Aboriginal and Torres Strait Islander Peoples (Chapter 4.7, p.77)

*

○ Yes
◉ No

**Targeted recruitment of people in / from countries that score <50 on the Corruption Perception Index (CPI) (check here)**
**This includes any cohorts from these countries, i.e. it is not restricted to marginalised groups within these countries***

○ Yes
◉ No

**Collection, use or disclosure of personal information without consent of the participant(?)**

- **a record which may include your name, address and other details about the participant (e.g. date of birth, financial information etc.)**
- **photographs, images, video or audio footage**
- **fingerprints, blood or DNA samples**

*

○ Yes
◉ No

**Collection, use or disclosure of health information(?)**

- personal information that is information or an opinion about:
  - the physical or mental health or a disability (at any time) of an individual; or
  - an individual's expressed wishes about the future provision of health services to him or her, or
  - a health service provided, or to be provided, to an individual or
- other personal information collected to provide, or in providing, a health service, or
- other personal information about an individual collected in connection with the donation, or intended donation, of a individual's body parts, organs, body substances, or
- other personal information that is genetic information about an individual arising from a health service provided to the individual in a form that is or could be predictive of the health (at any time) of the individual or of a genetic relative of the individual, or
- healthcare identifiers

N.B Includes information collected through physiological testing or assessment. Examples include but are not limited to EEG, EMG, BMI, blood pressure, DEXA, etc.*

○ Yes
◉ No

**Collection, use or disclosure of sensitive information**
**Racial, ethnic information, political, religious and philosophical beliefs, sexual activity or identity, and trade union membership**
*

○ Yes
◉ No

**Activity that potentially infringes the privacy or professional reputation of participants, providers or organisations**
**e.g. observation in the workplace, collection of commercially confidential information, etc.**
**Commercially confidential information = Any information which is not in the public domain or publicly available, and where disclosure may undermine the economic interest or competitive position of the owner of the information (TGA adopted definition from European Medicines Agency (EMA)).**

**N.B. If canvassing opinion via consensus methods i.e. Delphi (?), answer "No" here**
*

○ Yes
◉ No

**Establishment of a register or databank of identifiable data for possible use in future research projects (Chapter 3.2, p.27) (?)**
*

○ Yes
◉ No

**Collection, transfer(?) and/or banking of human biospecimens.**
e.g. tissue, blood, urine, sputum etc.(?)
*



○ Yes
◉ No

**Any significant alteration to routine care or service provided to participants**
e.g. deviation from standard care or usual practice
*

○ Yes
◉ No

**Prospective assignment of human participants or groups of humans to one or more health-related interventions to evaluate the effects on health outcomes(?) (Chapter 3.14-3.17)** *

○ Yes
◉ No

**Potential for participants to experience harm (i.e. anything more than discomfort)(?)**
e.g. physical, psychological, devaluation of personal worth, social, economic and/or legal (Chapter 2.1, p.12)
*

◉ Yes
○ No

High Risk

## Section 2: Project information

**Project title**

We recommend you save your application regularly while editing. You can save your application at any time by clicking on the save button.
For further information and help in completing your application go to our website

Application ID (automatically generated):
ETH23-8158

Application Title:*
The influence of mental fatigue on physical performance and factors that affect exercise adherence in older adults

Ethics category code (automatically selected):*
Human

Please search for your original ethics application by clicking on 'More criteria'.
Please note that you can only search for previously submitted applications where personnel listed on this application were also listed on the original one.
*

| | | |
|---|---|---|
| 1 | Ethics Category | Human |
| | Ethics Application Code | ETH22-7745 |
| | Ethics Title | The influence of mental fatigue on physical performance and factors that affect exercise adherence in older adults |
| | Start Date | 21/02/2023 |
| | End Date | 21/02/2028 |
| | Review Date | 13/12/2022 |
| | Application Status | Approved |
| | Other Comments | |

**Please save and continue to the next page**

## Section 3: Personnel

**Investigators**

We recommend you save your application regularly while editing. You can save your application at any time by clicking on the save button.
For further information and help in completing your application go to our website

Please note that for amendment applications you only need to add the Chief Investigator/Supervisor, student(s) and any new personnel

Have new external investigators been added to this protocol?*
- (•) Yes
- ( ) No

Is this application for a student project?*
- ( ) Yes
- (•) No

**Positions in the personnel table**

| Position type: | In the personnel table use the following positions from the drop-down list: |
|---|---|
| Chief Investigator/Supervisor | 1Chief Investigator (students must **not** be listed as Chief Investigator) |
| Co Investigator | 3Assoc. Investigator |
| Co Supervisor | Co-Supervisor |
| Research Student | 5Research Student |
| Project Administrator | 7Project Administrator |

**Note:** Further options are available in the drop down list.

**Instructions on how to add a person to the personnel table:**

1. Click on "Add"
2. Start typing the details (first name, last name or Staff ID) in the search bar.
3. Click on "Add selected"
4. The extra information panel will open, select their position from the drop-down list. If they are the primary contact (e.g. Chief Investigator/Supervisor), tick "Yes" under 'Primary contact' and then select "OK"

- **Student research:** Students must add their supervisors to their application and must mark their primary supervisor as a Chief Investigator and as a primary contact. Students must be listed as "5Research student" under the column 'Position' to ensure the application is properly submitted to their supervisor.
- **Ratifications/Transfers:** If this list differs from that of the original application, you must provide evidence that any additional investigators have been added via amendment to the lead/external HREC [attach relevant amendments and evidence of approval].

**Internal personnel listed on this ethics protocol:***

| | | |
|---|---|---|
| 1 | Primary | No |
| | ID | 158901 |
| | Surname | Faria |
| | Given Name | Larissa |
| | Full Name | Ms Larissa Oliveira Faria |
| | Position | Chief Investigator |
| | Type | Honorary |
| | AOU | FoH.School of Sport, Exercise and Rehabilitation |
| | Managing Unit | Faculty of Health |
| | Email Address | Larissa.Faria@uts.edu.au |
| | Work Number | |

If any details are incorrect or missing please contact the Ethics Secretariat on (02) 9514 9772 or by email.

The ResearchMaster database has a very large number of external personnel so please conduct a search for them before adding them in the text box below. Please contact the Ethics Secretariat on 9514 9772 if you cannot find an external investigator through the system.

**External personnel listed on this ethics protocol:**
*



| | | |
|---|---|---|
| 1 | Primary | Yes |
| | ID | PER18-4907 |
| | Surname | Coutts |
| | Given Name | Aaron |
| | Full Name | PROF Aaron James Coutts |
| | Position | Chief Investigator |
| | Type | Internal |
| | AOU | |
| | Managing Unit | |
| | Email Address | |
| | Work Number | |

Please provide additional (or preferred) contact details of any of the people listed on the project if necessary (4000 character limit)

*This question is not answered.*

Primary AOU*

FoH.School of Sport, Exercise and Rehabilitation

Managing Unit

Faculty of Health

**Please save and continue to the next page**

## Section 5: Amendment form

**Amendment details**

We recommend you save your application regularly while editing. You can save your application at any time by clicking on the save button.
For further information and help in completing your application go to our website

Has your project title changed?*
- ( ) Yes
- (•) No

Please provide a brief summary of your research proposal based on your original ethics application and specify what stage the research is at (e.g. recruitment, data collection, etc).
*

Participants will perform four sessions. In the first session (1:00h), the scales Addenbrooke's Cognitive Examination – Revised, Adult Pre-Exercise Screening System, Geriatric Depression Scale, Geriatric Anxiety Inventory will be administered. Then, we will measure participants' height and body mass, as well as, familiarize them with the Stroop Test used for mental fatigue assessment. In the second session (1:00h), participants will familiarize with the 6-minutes' walk test and TUG. We will conduct the 10-RM on knee extension machine to define exercise intensity during experimental conditions. Lastly, in the third (1:30h) and fourth sessions (1:30h), they will do the following experimental conditions in a counterbalanced randomized design: 1) computerized cognitive test for 30 minutes, followed by the walking test. Then, computerized cognitive test twice for 15 minutes followed by the balance and the resistance exercise; and 2) watch a documentary 30 minutes, followed by the walking test. Then, watch a documentary twice for 15 minutes followed by the balance and the resistance exercise. The feeling scale and the VAS will be administered before, between and after each physical test to measure affective responses; whereas the RPE will be administered after each physical test. The research is at data collection stage.

Does your amendment involve any of the following changes:*
- [ ] Change to completion date
- [ ] Change to personnel
- [ ] Change to research instruments/participant material
- [x] Change to research methodology
- [ ] Change to recruitment of participants
- [ ] Other

Does your amendment involve the addition of children as participants? (not as incidental)*
- ( ) Yes
- (•) No

Will changes include research be conducted using UTS staff and/or students? (not previously approved for)*
- ( ) Yes
- (•) No

What changes to your original ethics application are you proposing? (1500 character limit)*

I would like to include people with significant symptoms of anxiety, depression or lower scores on the cognitive test (Addenbrooke's Cognitive Examination), instead of excluding them. Also, I would like to do the walking test and the balance test with people with cardiovascular issues or smokers since those tests do not offer major risks. Finally, I would like to include those people in the whole data collection if they present GP permission.

Why do you wish to make these changes?*

Because some people with those characteristics are contacting me. I could just consider the anxiety, and depression symptons on the analysis. The two physical tests do not offer risks for independent and functional people and the strength exercise could be done with anyone as long as people with heart conditions present medical consent.

**Please save and continue to the next page**

**Impact of amendment on research participants part 1**

We recommend you save your application regularly while editing. You can save your application at any time by clicking on the save button.
For further information and help in completing your application go to our website

**This section requires you to consider the ways in which your proposed amendments may impact upon the ethical issues raised on your original application. Specifically, we ask you to outline the effects (if any) of your amendments on the following areas, and how you intend to deal with them. Does your amendment affect any of the following:**

Outcome of your research?
**Note:** If you are making changes to data collection instruments, please specify what your intention is for the data which has already been collected. If the data which has already been included will still be used, how will this be analysed with new data, and how might this impact the validity of results / impact originally stated outcomes?*

- (●) Yes
- ( ) No

Please provide further information on how your amendment effects the outcome of your research*

Depression and anxiety will be included as covariates in the analysis if we have a big quantity of subjects with these conditions. Otherwise, we will just describe it in participants characteristics. All the other health conditions will be described in the participants' characteristics.

Current or future applications for funding?*

- ( ) Yes
- (●) No

Recruitment of participants (quantity, methods)*

- ( ) Yes
- (●) No

Anticipated risk or harm to participants and/or researchers?*

- ( ) Yes
- (●) No

Relationships (if any) between researchers and participants?*

- ( ) Yes
- (●) No

**Please continue to the next page**

**Impact of amendment on research participants part 2**

We recommend you save your application regularly while editing. You can save your application at any time by clicking on the save button.
For further information and help in completing your application go to our website

**This section requires you to consider the ways in which your proposed amendments may impact upon the ethical issues raised on your original application. Specifically, we ask you to outline the effects (if any) of your amendments on the following areas, and how you intend to deal with them. Does your amendment affect any of the following:**

Consent from Participants? *

- (●) Yes
- ( ) No



Please provide further information on how your amendment effects the consent from participants. Please attach revised consent form and information sheet if applicable (using tracked changes).*

The inclusion and exclusion criteria will change.

Data collection, interpretation, storage and/or disposal? *

- ( ) Yes
- (●) No

Privacy and confidentiality of participants?*

- ( ) Yes
- (●) No

Are you required to submit requests for amendment to any external bodies to UTS? (e.g. an Area Health Service, other university)*

- ( ) Yes
- (●) No

Are there any other relevant ethical issues in relation to the proposed amendment? *

- ( ) Yes
- (●) No

**Please continue to the next page**

**Amendment attachments**

We recommend you save your application regularly while editing. You can save your application at any time by clicking on the save button.
For further information and help in completing your application go to our website

I have attached the following supporting (track changed) documents that require amendment from the approval of my original application:*

- [x] consent form/information letter(s)
- [ ] surveys/questionnaires/outline of questions
- [ ] instruments for data collection
- [ ] approval for amendment from other institution
- [ ] other relevant attachments

Documents attached to this application:

How to attach documents

1. Click on 'Add'
   Ensure the fields are as follows:
   - Document type- soft copy
   - Name: Include the document name and version number
   - Description: This field is optional
2. You can then either select the file you want to upload OR drag and drop it where it says 'Drop file here'
3. Click on 'OK'

*

| | | |
|---|---|---|
| 1 | Document type | Soft copy |
| | Name | PIS - ammendment |
| | Reference (Document Title) | Participant information sheet - consent form_Suggested edits.docx |
| | Description | |
| 2 | Document type | Soft copy |
| | Name | Standard Operating Procedures |
| | Reference (Document Title) | Standard Operating Procedures.docx |
| | Description | |
| 3 | Document type | Soft copy |
| | Name | ETH23-8158 - COUTTS - Reply |
| | Reference (Document Title) | ETH23-8158 - COUTTS - Reply.docx |
| | Description | |

**Please continue to the next page**

**Declaration**

**Declaration**

I have answered all questions in the risk assessment truly and completely to the best of my knowledge

I will notify the UTS Human Research Ethics Committee of any variation to this research that may alter the level of risk associated with it

This research will be undertaken in compliance with the UTS Research Policy or any replacement or amendment thereof

This research will be undertaken in compliance with the Australian Code for the Responsible Conduct of Research and National Statement on Ethical Conduct in Human Research

Please click on the "Submit" button in the Actions menu.

**Confirmation**

**Confirmation by Local Research Office High Risk**

Application type*

Amendment to existing approval

Internal personnel listed on this ethics protocol*

| | | |
|---|---|---|
| 1 | Primary | No |
| | ID | 158901 |
| | Surname | Faria |
| | Given Name | Larissa |
| | Full Name | Ms Larissa Oliveira Faria |
| | Position | Chief Investigator |
| | Type | Honorary |
| | AOU | FoH.School of Sport, Exercise and Rehabilitation |
| | Managing Unit | Faculty of Health |
| | Email Address | Larissa.Faria@uts.edu.au |
| | Work Number | |

Please indicate the risk classification of the original ethics approval?*

- ○ Nil/Neg risk
- ○ Low risk
- ◉ High risk

**Please contact the Ethics Secretariat.**

Checked by:*

Ed Dharmadji

Date of review:*

22/03/2023

The Local Research Office has confirmed that: All information in this application and supporting documentation is correct and as complete as possible *

- ◉ Yes
- ○ No

**Confirmation by ADR**

Application type

Human

Internal personnel listed on this ethics protocol



| | | |
|---|---|---|
| 1 | Primary | No |
| | ID | 158901 |
| | Surname | Faria |
| | Given Name | Larissa |
| | Full Name | Ms Larissa Oliveira Faria |
| | Position | Chief Investigator |
| | Type | Honorary |
| | AOU | FoH.School of Sport, Exercise and Rehabilitation |
| | Managing Unit | Faculty of Health |
| | Email Address | Larissa.Faria@uts.edu.au |
| | Work Number | |

Date of LRO review

22/03/2023

**Declaration:**

- I am aware that this research is being conducted within this Faculty/School/Centre.
- I am satisfied that the researchers have met all Faculty/School/Centre requirements in relation to this research
- This research will be undertaken in compliance with the UTS Research Ethics and Integrity Policy or any replacement or amendment thereof
- This research will be undertaken in compliance with the Australian Code for the Responsible Conduct of Research and National Statement on Ethical Conduct in Human Research

*

- ◉ Yes
- ○ No

Comments

*This question is not answered.*

**Research Office use only**

**Research Office use only**

Application Status

Approved

Approval Purpose

Amendment to existing approval

Current Committee

1Human Ethics Committee

TRIM number

RES23/547

Date received

13/03/2023

Date Reviewed

11/04/2023

Date Approved

12/05/2023

Start date

12/05/2023

End date