Physical Activity and Functional Dependence in People with Arthritis: Insights from a Psychological Perspective

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Dedication

I would like to thank my parents for all their unconditional love and support. They have been my rock throughout this process, and I could not have gotten to this point without them.

I would like to thank my supervisors Dr. Martin Bilodeau and Dr. Matthieu Boisgontier for mentoring me and shaping me into the researcher I have become today. I would also like to thank Dr. Tony Carlsen for his mentorship during the initial part of my PhD journey and for taking the time to be my internal examiner in my oral defence.

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Dissertation Abstract

Background: People with arthritis are less physically active than people without arthritis. Part of this difference may be explained by psychological factors, including attitudes toward physical activity as well as depression, and may affect functional independence.

Objectives: This doctoral thesis aims to better understand the relationship between fear of movement, physical activity, pain, depression (depressive symptoms), and functional status in people with arthritis.

Methods: First, a systematic review and a meta-analysis were conducted to assess the association between fear of movement and physical activity across several health conditions, including arthritis. Second, to examine the association between fear of movement and physical activity in people with arthritis, we assessed approach-avoidance tendencies towards physical activity in this population. Finally, data from the Canadian Longitudinal Study on Aging (CLSA) were analyzed to examine the potential mediating effects of depressive symptoms and physical activity on the relationship between pain and future functional dependence in people with arthritis.

Results: The first article showed a negative correlation between fear of movement and physical activity in people with arthritis. The second article showed that approach-avoidance tendencies toward physical activity moderated the association between fear of movement and self-reported weekly engagement in physical activity. The third article showed that baseline pain was directly associated with future functional independence in basic (ADL) and instrumental activities of daily living (IADL), as well as indirectly related through effects on depressive symptoms and physical activity.

Conclusions: This doctoral thesis highlights the importance of psychological processes for physical activity engagement in people with arthritis, suggesting that rehabilitation programs should go beyond pain management when aiming at improving functional status.

Résumé de la Thèse

Contexte : Les personnes atteintes d'arthrose sont physiquement moins actives que les personnes sans arthrose. Une partie de cette différence pourrait s'expliquer par des facteurs psychologiques, comme les attitudes envers l'activité physique ainsi que la dépression, et pourrait affecter l'indépendance fonctionnelle.

Objectifs : Cette thèse de doctorat vise à mieux comprendre la relation entre la peur du mouvement, l'activité physique, la douleur, la dépression (symptômes dépressifs) et l'état fonctionnel chez les personnes atteintes d'arthrose.

Méthodes : Dans un premier temps, une revue systématique et une méta-analyse ont été menées pour évaluer l'association entre la peur du mouvement et l'activité physique en fonction de différentes pathologies, incluant l'arthrose. Ensuite, pour examiner l'association entre la peur du mouvement et l'activité physique chez les personnes atteintes d'arthrose, nous avons évaluer les tendances d'approche-évitement dans cette population. Enfin, les données de l'Étude longitudinale canadienne sur le vieillissement (ELCV) ont été analysées pour examiner les effets de médiation potentiels des symptômes dépressifs et de l'activité physique sur la relation entre la douleur et la dépendance fonctionnelle future chez les personnes atteintes d'arthrose.

Résultats : Le premier article a montré une corrélation négative entre la peur du mouvement et l'activité physique chez les personnes atteintes d'arthrose. Le deuxième article a montré que les tendances d'approche-évitement de l'activité physique modéraient l'association entre la peur du mouvement et l'engagement hebdomadaire autodéclaré dans l'activité physique. Le troisième article a montré que la douleur est directement associée à l'indépendance fonctionnelle future dans les activités de la vie quotidienne (AVQ) et les AVQ instrumentales, ainsi qu'indirectement associée via les effets sur les symptômes dépressifs et l'activité physique.

Conclusions : Cette thèse de doctorat souligne l'importance des processus psychologiques pour l'engagement dans l'activité physique chez les personnes atteintes d'arthrose et suggère que les programmes de réadaptation devraient aller au-delà de la gestion de la douleur lorsqu'ils visent à améliorer l'indépendance fonctionnelle.

Plain Language Summary

People with arthritis are less physically active than those without arthritis. Many people with arthritis avoid exercise because they fear it will worsen their pain. To overcome this fear, it is important to understand both the causes of their fear and how exercise can help manage their condition. This thesis examines how fear of movement, depression, physical activity, and functional status are connected in people with arthritis.

The first article of this thesis is a review of the literature aimed to assess how fear of movement affects physical activity across several health conditions. This review showed that higher fear of movement was linked to lower physical activity in people with oarthritis. The second article tested affective attitudes toward physical activity using questionnaires and an approach-avoidance task. This study showed that, in people with osteoarthritis, the tendency to approach or avoid physical activity images influenced the relationship between fear of movement and self-reported weekly engagement in physical activity. The third article analyzed longitudinal data to examine how pain, depression, and exercise influence functional dependence. This study showed that pain at baseline predicted future functional independence, and that depression and physical activity contributed to explain this relationship.

Rehabilitation should focus on both physical and mental health. Rehabilitation specialists can benefit from considering psychological factors such as fear of movement and depression and physical factors such as pain and functional dependence when developing a treatment plan for their patients.

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Chapter 1: General Introduction

Statement of the Problem

People with arthritis tend to be less physically active than people without arthritis (Kelley et al., 2020). Specifically, Badley et al. (2019) reported that nearly double the proportion of people with arthritis are physically inactive (31%) compared to people without arthritis (17%). One of the reasons people with arthritis may present with this behavior is because they often fear that engaging in physical activity will worsen their arthritic pain (Medrado et al., 2024). For instance, the prevalence of fear of movement in patients with arthritis ranges from 58% in osteoarthritis (Tan et al., 2022) to 70% in rheumatoid arthritis (Ozturk et al., 2021). To address this fear of movement, it is important to understand attitudes towards physical activity (Lieber et al., 2025). Overcoming fear of movement requires not only understanding the underlying mechanism of that fear but also having a better understanding of the benefits of physical activity in the prognosis of the disease. Physical activity can lead to a reduction in pain and depressive symptoms and to an improvement in physical function in people with arthritis (Hu et al., 2021; Kelley et al., 2015). Exercise can induce both acute and long-term beneficial reductions in the arthritic inflammatory response in a dose-dependent manner (i.e., higher exercise intensities result in more pronounced beneficial effects) (Metsios & Kitas, 2018). Furthermore, it has been suggested that physical activity can significantly improve disease activity in people with rheumatoid arthritis (Metsios & Kitas, 2018), hence facilitating significant improvements in their functional ability and quality of life.

Objectives

The general aim of this doctoral thesis is to provide a better understanding of how fear of movement, pain, depression (depressive symptoms, both terms are used interchangeably in this thesis). and functional dependence can influence and interact with physical activity in individuals with arthritis. The thesis is comprised of three original articles, along with integrated introduction and discussion chapters. The first article is a systematic review and meta-analysis that aimed to examine whether fear of movement is negatively associated with the usual level of physical activity across several health conditions, including arthritis, and what factors may influence this relationship. The second article is an online study that aimed to examine whether psychological processes, including fear of movement, explicit attitudes, and implicit attitudes (i.e., approach-avoidance tendencies) toward physical activity, are associated with usual physical activity levels in people with arthritis. The third article is an analysis of data from the Canadian Longitudinal Study on Aging that aimed to examine the mediation effect of depressive symptoms and physical activity engagement on the relationship between pain and functional status in people with arthritis.

Background and Rationale

Physical activity plays an essential role in the primary, secondary, and tertiary prevention of disease. Physical activity contributes to the primary prevention of diseases by reducing the risk of cardiovascular disease (Wahid et al., 2016), obesity (Bleich et al., 2018), depression (Schuch et al., 2017), hypertension (Liu et al., 2017), cancer (Moore et al., 2016), and dementia (Najar et al., 2019). Nonetheless, one in four adults worldwide does not meet the recommended levels of physical activity (World Health Organization, 2024). Physical activity contributes to the secondary and tertiary prevention of disease by reducing the impact, slowing the progression, and preventing the recurrence of multiple health conditions, including cardiovascular disease (Molloy et al., 2023; Taylor et al., 2019), stroke (Turan et al., 2017; van Allen et al., 2024), cancer (Brenner & Chen, 2018), and osteoarthritis (Daste et al., 2021).

Physical inactivity is a behavior (Boisgontier & Iversen, 2020) that can result from environmental, interpersonal, and intrapersonal factors (O'Donoghue et al., 2016). For example, environmental factors can include lack of access, weather conditions, and safety concerns (Garcia et al., 2022). Interpersonal factors can include family responsibilities, lack of support, and lack of a gym partner (Biddle et al., 2023). Intrapersonal factors can include gender (Azevedo et al., 2007), age (Caspersen et al., 2000), cognitive function (Cheval et al., 2019, 2020), socioeconomic circumstances (Cheval et al., 2018), and fear of movement (Kori et al., 1990). This thesis initially focuses on fear of movement, which results from a sense of vulnerability to pain, injury, or a medical condition (Kori et al., 1990). In contrast, pain is an unpleasant sensory and emotional experience that is associated with actual or potential tissue damage (Raja et al., 2020). Therefore, an individual can experience fear of movement without experiencing pain (Larsson et al., 2016). The first article systematically reviews the literature to get a better understanding of the association between fear of movement and physical activity across several health conditions.

Fear of movement is likely to influence the desires and impulses for movement and rest (Stults-Kolehmainen et al., 2020), as well as affective determinants of physical activity in general (Stevens et al., 2020). In the context of this thesis, we consider two components to fear of movement: (1) accumulation of overwhelming emotions over time that develop into a phobia (i.e., kinesiophobia) and (2) automatic processes of conditioning via past experiences (Stevens et al., 2020; Stults-Kolehmainen et al., 2020). Thus, depending on whether an individual has had pleasant or unpleasant experiences with physical activity, the individual can automatically associate physical activity with these past positive or negative experiences (Brand & Ekkekakis, 2018; Cheval & Boisgontier, 2021, 2023; Conroy & Berry, 2017). If the individual had positive past experiences with physical activity, the individual may develop a tendency to engage in physical activity. On the other hand, if the individual had negative past experiences with physical activity, the individual may develop a tendency to avoid engaging in physical activity (Farajzadeh, Goubran, Beehler, et al., 2023; Hanel et al., 2020). Accordingly, an aversive fear of pain, injury, or aggravation of a medical condition that has been associated with the concept of movement could result in the development of automatic avoidance behaviors that contribute to the maintenance and exacerbation of this fear and ultimately lead to a diminished ability to engage in regular physical activity.

People with different health conditions experience this fear of movement (Igelström et al., 2013; Spaderna et al., 2020; Strandberg et al., 2022; Wasiuk-Zowada et al., 2022). For instance, the prevalence of fear of movement in patients with arthritis ranges from 58% in osteoarthritis (Tan et al., 2022) to 70% in rheumatoid arthritis (Ozturk et al., 2021). This high prevalence, combined with the association between fear of movement and lower physical activity levels (Goubran et al., 2025) may help explain why people with arthritis are less active than those without arthritis (Badley et al., 2019; Shih et al., 2006). The second article examines the tendencies to approach or avoid physical activity in people with arthritis and how they potentially influence the association between fear of movement and physical activity.

Low levels of physical activity can affect the prognosis of the disease in people with arthritis (Cijs et al., 2025). Pain is a common symptom of arthritis and affects functional status, which in turn may impact functional independence and quality of life (Araujo et al., 2016; Sieber et al., 2023). The literature has shown that pain is associated with functional decline (Pisters et al., 2012; Sharma et al., 2003; van Allen & Boisgontier, 2024; van Dijk et al., 2010). This relationship can be mediated by factors related to mental and physical health. Two mediators of interest are depressive symptoms and physical activity, as both are influenced by pain (Angst et al., 2020; Gay et al., 2019; Petursdottir et al., 2010; Wilcox et al., 2006) and predict functional independence (Boisgontier et al., 2020; Penninx et al., 2001; van Allen & Boisgontier, 2024).

The mediation effect of pain on functional status by depressive symptoms (i.e. transient depressive symptoms not clinical depression) is well documented in the pain literature (Garcia et al., 2021; Hall et al., 2011; Loew et al., 2016; Marshall et al., 2017; Ross et al., 2015; Seekatz et al., 2013; Talaei-Khoei et al., 2018; Wegener et al., 2011). However, those studies target populations with back pain (Garcia et al., 2021; Hall et al., 2011; Marshall et al., 2017; Seekatz et al., 2013) and traumatic injury (Ross et al., 2015; Talaei-Khoei et al., 2018; Wegener et al., 2011), but not a population with arthritis. The literature targeting people with arthritis is more centered around models where functional status is mediating the relationship between pain and depression (Hawker et al., 2011; Wang et al., 2015). Yet, having depression as the mediator is more in line with the biopsychosocial approach of pain rehabilitation, which emphasizes the psychological factors that come into play in physical functioning (Smart, 2023). Likewise, many studies in the literature demonstrated a mediation of the effect of pain on functional status through physical activity (Burrows et al., 2020; Fransen et al., 2015) in a population with back pain (Ekediegwu et al., 2024; Karklins et al., 2024), but not in a population with arthritis. Since physical activity has been linked to a reduction of pain and an improvement in functional status (Goh et al., 2019), understanding how depression comes into play could help better inform the rehabilitation of people with arthritis. The third article uses data from the Canadian Longitudinal Study on Aging to examine the interplay between pain, depression, physical activity, and functional status.

Chapter 2

Relationship between fear of movement and physical activity in patients with cardiac, rheumatologic, neurologic, pulmonary, or pain conditions: A systematic review and meta-analysis

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Preface

Based on the Contributor Roles Taxonomy (CRediT) individual author contributions to this work are as follows: Miriam Goubran: Conceptualization, Methodology (Systematic Review), Investigation, Data Curation, Writing (Original Draft), Writing (Review and Editing); Ata Farajzadeh: Methodology (Systematic Review), Investigation, Data Curation, Writing (Original Draft), Writing (Review and Editing); Ian M. Lahart: Methodology (Meta-Analysis), Formal Analysis, Visualization, Data Curation, Writing (Original Draft), Writing (Review and Editing); Martin Bilodeau: Conceptualization, Methodology (Systematic Review), Writing (Review and Editing), Supervision (MG); Matthieu P. Boisgontier: Conceptualization, Methodology (Systematic Review and Meta Analysis), Investigation, Formal Analysis, Data Curation, Visualization; Writing (Original Draft), Writing (Review and Editing), Supervision (MG, AF, ND), Project Administration, Funding Acquisition.

Abstract

Objective. Physical activity contributes to the primary, secondary, and tertiary prevention of multiple diseases. However, in some patients, an excessive, irrational, and debilitating fear of movement is thought to induce avoidance behaviors, contributing to decreased engagement in physical activity. The aim of this study was to examine whether fear of movement is negatively associated with physical activity in several health conditions and what factors may influence this relationship.

Methods. Five databases were searched for studies including both a measure of fear of movement and physical activity. Two reviewers screened articles for inclusion, assessed risk of bias, and extracted data from each study. Pearson product-moment correlations were pooled from eligible studies using the generic inverse pooling and random effects method to examine the relationship between fear of movement and physical activity.

Results. Seventy-four studies were included in the systematic review and 63 studies (83 estimates, 12,278 participants) in the main meta-analysis. Results showed a negative correlation between fear of movement and physical activity ($r = -0.19$; 95% confidence interval: -0.26 to -0.13; $I^2 = 85.5\%$; $p < 0.0001$). Funnel plot analysis showed evidence of publication bias, but p-curve analysis suggested that our results could not be caused by selective reporting. A subgroup meta-analysis showed that the correlation was statistically significant in patients with cardiac, rheumatologic, neurologic, or pulmonary conditions, but not in patients with chronic or acute pain.

Conclusion. Our results suggest that higher levels of fear of movement are associated with lower levels of physical activity in several health conditions that are not necessarily painful.

Impact. Fear of movement should be dissociated from pain and considered in relation to specific health conditions when implementing exercise therapy. Fear of movement may have prognostic

implications in patients for whom physical activity contributes to prevent recurrence or worsening of their condition.

Keywords. Exercise, Health Status; Kinesiophobia; Pain; Prevention; Psychology; Rehabilitation

Introduction

Seven decades ago, the seminal work of Morris et al. (1953)[1] showed that conductors on London double-decker buses, who were responsible for checking tickets, assisting passengers with luggage, and supervising the loading and unloading of passengers, had a lower incidence and less severe coronary heart disease than bus drivers. Since then, the scientific literature demonstrating the health benefits of physical activity has grown exponentially and expanded to include multiple health conditions[2]. These benefits include reduced risk of disability, disease, and mortality[2,3]. Specifically, higher levels of physical activity have been shown to contribute to a reduced risk of cardiovascular disease[4], obesity[5], depression[6], hypertension[7], cancer[8], and dementia[9]. Yet, one in four adults worldwide does not meet the recommendations for physical activity (150 minutes of moderate to vigorous physical activity per week)[10]. Physical activity also plays an important role in secondary and tertiary prevention by reducing the impact, slowing the progression, and preventing the recurrence of multiple health conditions, including cardiovascular disease[11,12], osteoarthritis[13], stroke[14,15], and cancer[16].

Several factors may explain physical inactivity[17], including environmental, interpersonal, and intrapersonal factors[18]. Environmental factors include lack of access, weather conditions, and safety concerns[19]. Interpersonal factors include family responsibilities, lack of support, and lack of a gym partner[20]. Intrapersonal factors include gender[21], age[22], cognitive function[23,24], and socioeconomic circumstances[25]. Another intrapersonal factor of interest is fear of movement, which can be defined as an excessive, irrational, and debilitating fear of movement and activity resulting from a sense of vulnerability to pain, injury, or a medical condition[26]. Fear of movement is typically measured using self-administered questionnaires, such as the Tampa Scale of Kinesiophobia (TSK)[27,28], which assesses an individual's belief that physical activity can lead to injury or pain and that the severity of their medical condition is underestimated. While fear of movement is often observed in the context of pain or a clinical condition, its presence in otherwise healthy adults is also possible[29] due to the irrational nature of this condition. The irrational fear that characterizes fear of movement is likely to influence the desires and impulses for movement and rest[30], as well as affective determinants of physical activity in general[31]. Here, we consider that fear of movement may result not only from the accumulation of overwhelming emotions over time that develop into a phobia (i.e., kinesiophobia), but also from automatic processes, such as conditioning, or from learning processes based on the integration of perceptual and environmental information.

The relationship between fear of movement and physical activity can be explained by theories suggesting that the perception of a cue related to physical activity automatically activates the concept of physical activity as well as the unpleasant (or pleasant) affective memories associated with this concept[32-35]. This activation results in an impulse that favors the tendency to avoid (or approach) physical activity[36]. Thus, negative affective associations are likely to hinder physical activity. Accordingly, an aversive fear of pain, injury, or aggravation of a medical condition that has been associated with the concept of movement may result in the development of automatic avoidance behaviors that contribute to the maintenance and exacerbation of this fear, and ultimately lead to a diminished ability to engage in regular physical activity.

Previous systematic syntheses of the literature on this topic include a meta-analysis[37] and two systematic reviews[38,39]. The main results of these reviews suggest that exercise interventions may reduce fear of movement in individuals with back pain. While back pain is one condition that may contribute to fear of movement, it is not the only one. The relationship between physical activity and fear of movement should be investigated in other conditions such as cardiac, neurological, and rheumatologic conditions.

The main objective of this study was to systematically review and meta-analyze the direct relationship between fear of movement and physical activity. We hypothesized that levels of fear of movement would be negatively associated with levels of physical activity. In addition, we examined the moderating effect of health status, physical activity measurement instruments (i.e., accelerometers, pedometers, questionnaires), physical activity outcomes (e.g., total physical activity, moderate or vigorous physical activity, steps per day), and fear of movement measurement instruments. Finally, because fear of movement and physical activity can vary with age, sex, and pain[40,41], we explored the influence of these factors on the association between fear of movement and physical activity.

Methods

Search Strategy

This review was reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines[42]. Potential studies were identified by searching the MEDLINE (via PubMed), PsychInfo, CINAHL, EMBASE, and SPORTDiscus databases. In October 2023, two reviewers (MG and AF) searched for all available records using the following combination of keywords in the title or abstract of the article: ("kinesiophobia" OR "fear avoidance" OR "fear of movement" OR "movement phobia" OR "movement fear") AND ("physical activity" OR "exercise" OR "walking"). In PsychInfo the limits "clinical trial", "quantitative study", "peer-reviewed journal", "English", and "human" were used. In PubMed the limits "clinical trial", "observational study", "RCT", "English" were used. In SPORTDiscus the limits “peer-reviewed”, “English”, “academic journal”, and “article” were used. In CINAHL the limits “peer-reviewed”, “English”, “research article”, “journal article”, and “humans” were used. To reduce literature bias[43,44], this systematic review was pre-registered in PROSPERO[45].

Eligibility Criteria and Study Selection

Inclusion Criteria

To be included in this systematic review, articles had to be published in a peer-reviewed journal, be written in English, report original data collected from human participants, include at least one self-reported measure of fear of movement and one measure of physical activity, and formally test the association between these two variables, be it a univariate or multivariate test. The physical activity measure could be derived from a self-reported measure of the level of physical activity or from a device (e.g., accelerometer, pedometer) worn while participants are engaged in their normal daily activities.

Exclusion Criteria

Studies were excluded if they were published as a book chapter, study protocol, conference abstract, or were based on laboratory-based measures of physical fitness (e.g., maximal muscle force, $\dot{V}O_2$ max) and not on a measure of physical activity.

Study Selection

Article screening was performed in Covidence systematic review software (Veritas Health Innovation, Melbourne, Australia; www.covidence.org), a web-based collaborative software platform that streamlines the production of systematic reviews. After removing duplicates, titles and abstracts were independently reviewed by two reviewers (MG, AF) according to the inclusion and exclusion criteria using a systematic 5-step process. If there was any doubt at any step, the full text was further reviewed. Step 1: Articles not written in English were excluded. Step 2: Articles that did not report original empirical data were excluded (e.g., reviews, meta-analyses, commentaries, technical reports, case studies). Step 3: Articles that did not involve human participants were excluded. Step 4: Articles that did not assess both fear of movement and physical activity were excluded. Step 5: Articles that did not formally test the association between fear of movement and physical activity were excluded. In addition, we performed reference screening and forward citation tracking on the articles remaining after step 5. Any disagreements between the two reviewers were resolved by consensus among three reviewers (MG, AF, MPB).

Data Extraction

Data extracted from selected articles included first author's name, article title, publication year, digital object identifier (DOI), number of participants, number of men and women, age range, mean age, mean weight, mean height, mean body mass index, health status, mean pain intensity, type of fear of movement measure, level of fear of movement, type of physical activity measure, type of physical activity outcome, level of physical activity (continuous or categorical), as well as statistical estimates and significance of the association between fear of movement and physical activity.

Methodological Quality and Risk of Bias Assessment

The risk of bias of the studies included in the systematic review was estimated using the National Institutes of Health (NIH) Quality Assessment Tool for Observational Cohort and Cross-

Sectional Studies[46], the Transparent Reporting of Evaluations with Non-Randomized Designs (TREND) reporting checklist[47], and the Consolidated Standards of Reporting Trials (CONSORT) reporting checklist for randomized trials[48]. All scores were normalized to a 0-10 scale to make them comparable across assessment instruments (Table 2.1).

Main Meta-Analysis

We pooled Pearson product-moment correlations from eligible studies to examine the relationship between fear of movement and physical activity. Correlations were pooled using the generic inverse pooling method via the 'metacor' function in the {meta} R package50. This function automatically performs a necessary Fisher's z-transformation on the original, untransformed correlations prior to pooling. The 'metacor' function also reconverts the pooled association back to its original form for ease of interpretation. Correlation estimates were nested within studies using the 'cluster' argument to account for the dependencies between these estimates, resulting in a three-level meta-analysis (level 1: participants, level 2: correlation estimates, level 3: studies). The distribution of variance across levels was assessed using the multilevel version of I^2 [54]. The performance of the 2-level and 3-level meta-analyses was assessed and compared using the {metafor} R package[51,52].

Table 2.1. Sample characteristics of studies included in the systematic review.

Study (Year	N (# women)	Mean age (SD or range)	Health status	Mean fear of movement (SD or range; measure)	Mean physical activity (SD or range; tool)	Level of pain (tool)	Study Design	Context of Assessment	Normalized Quality Score	Corr.	p-value
Alamam (2019)	100 (62)	40 (13.6)	Chronic low back pain	n.a. (FABQ)	n.a. (IPAQ)	4.8 (VAS)	Cohort	Clinical	7.0	r = -0.17	0.116
Alzahrani (2021)	26 (11)	43.6 (14.3)	Chronic low back pain	40.19 (9.20; TKS-17)	MPA: 76.07 min/day (34.45, wrist accelero.) VPA: 0.29 min/day (1.22; wrist accelero.) 13302 steps/day (5141; wrist accelero.)	4(3.VAS)	RCT	Clinical	8.8	r = 0.22 r = -0.05 r = -0.21	0.28‡ 0.003‡ 0.30‡
Alschuler (2011)	20 (9)	46.1 (9.35)	Chronic low back pain	30.55 (TSK-17)	228 counts/min (wrist accelero.)	4.87 (NRS)	Cross-Sectional	Clinical	6.0	r= -0.48‡	0.03
Altuğ (2016)	112 (73)	45.0 (14.6)	Chronic low back pain	44.30 (TSK-17)	5495 MET-min/week (IPAQ)	3.45 (VAS)	Cross-Sectional	Clinical	8.0	r = -0.096	0.313
Assadourian (2020)	147 (88)	49 (12)	Chronic low back pain	n.a. (TSK-17)	n.a. (diary; < vs. ≥ 1h/week)	6.7 (NRS)	Cross-Sectional	n.a.	8.0	r = -0.022†	0.813†
Atici (2022)	254 (171)	n.a. (>65)	Older adults	54.55 (KCS)	182.8 (PASE)	n.a.	Cross-Sectional	Online	9.0	ρ = -0.345	<0.001

Ayedemir (2022)	37 (25)	58.8 (8.6)	Knee osteoarthritis	40.3 (TSK-17)	4.8 (UCLA)	52.0 (KOOS-P)	Cross-Sectional	Clinical	7.0	r = -0.773	<0.05
Aykut Selcuk (2020)	67 (67) 29 (0)	60.6 (8.0) 61.6 (8.1)	Knee osteoarthritis Knee osteoarthritis	44.8 (TSK-17) 42.0 (TSK-17)	n.a. (IPAQ; low vs. moderate vs. high) n.a. (IPAQ; low vs. moderate vs. high)	4.6 (VAS) 2.9 (VAS)	Cross-Sectional	Clinical	7.0	r = -0.247 r = -0.309	0.019 0.116
Baday-Keskin (2022)	88 (67) 93 (67)	52 (n.a.) 45 (n.a.)	Rheumatoid arthritis Healthy adults	45 (TSK-17) 39 (TSK-17)	594 MET-min/week (IPAQ) 971 MET-min/week (IPAQ)	4.8 (VAS) n.a.	Cross-Sectional	Clinical	7.0	r = -0.12 n.a.	>0.05
Baez (2020)	40 (24)	24.3 (4.1)	Surgery (ACLR)	18.2 (TSK-11)	8 657 steps/day (hip pedo.) 7.7 (TAS)	81.5 (KOOS-P)	Cross-Sectional	Clinical	8.0	r = 0.181† n.a.	0.265† n.a.
Bahar Özdemir (2021)	101 (59)	33.9 (6.0)	Healthy	36.4 (5.8; TSK-17)	756 MET-min/week (1090; IPAQ)	3.1 (3.3; NRS)	Cross-Sectional	Online	8.0	r = -0.007†	0.944†
Barchek (2021)	19 (13)	22.9 (3.2)	Anterior cruciate ligament reconstruction	6 (8; FABQ)	11 237.7 steps/day (5667.7; wrist accelero.)	n.a.	Cross-Sectional	Clinical	7.0	$\rho_{steps/day}$ = 0.12 $\rho_{counts/min}$ = -0.13	0.63 0.59
Baykal Şahin (2021)	98 (35)	58.1 (10.4)	Coronary artery disease	41.4 (6.2; TSK-17)	839 MET-min/week (1212; IPAQ)	60.1 (27.2; SF-36)	Cross-Sectional	Clinical	8.0	r = -0.315	0.002
Bernard (2015)	121 (121)	65.5 (57-75)	Post-menopausal women	36 (TSK-17)	n.a. (PAQE)	n.a.	RCT	Clinical	8.8	r = -0.05†	0.55†

Carvalho (2017)	119 (82)	39.1 (11.2)	Chronic low back pain	41 (TSK-17)	6844 steps/day (hip accelero.) 296 counts/min (hip accelero.) 22 min MVPA/day (hip accelero.) 333 min LPA/day (hip accelero.) 6.7 (BHPAQ)	6.7 (NRS)	Cross-Sectional	Clinical	9.0	ρ = -0.15 r = -0.02 ρ = -0.13 r = 0.09 r = -0.18	>0.05 >0.05 >0.05 >0.05 <0.05
Coronado (2021)	248 (126)	62.2 (11.9)	Surgery (laminectomy)	28.4 (TSK-13)	427 counts/min (hip accelerometer)	3.1 (NRS)	Cohort	n.a.	8.0	r = -0.05	>0.05
Corrigan (2018)	53 (18)	54.8 (34-65)	Achilles tendinopathy	35.4 (TSK-17)	n.a. (SGPALS)	n.a.	Cross-Sectional	Clinical	8.0	r = -0.005‡	0.969
Crommert (2021)	139 (139)	37 (4.9)	Post-partum disability	n.a. (TSK-17)	n.a. (hip accelero.)	n.a.	Cross-Sectional	Online	7.0	r = -0.13	>0.05
Dąbek (2020)	130 (n.a) 119 (n.a) 27 (n.a) 72 (n.a) 86 (n.a) 18 (n.a)	n.a.	Coronary disease Hypertension Heart valve defect Myocardial infarction Rhythm disorder Stroke Other CVD	44.3 (TSK-Heart) 44.4 (TSK-Heart) 44.4 (TSK-Heart) 46.7 (TSK-Heart)	1545 MET-min/week (IPAQ) 1509 MET-min/week (IPAQ) 1308 MET-min/week (IPAQ) 1369 MET-min/week (IPAQ)	n.a.	Cross-Sectional	Clinical	8.0	r = -0.523 r = -0.410 r = -0.201 r = -0.428 r = -0.563 r = -0.868	<0.001 <0.001 >0.05 <0.001 <0.001 <0.001 0.01

	15 (n.a)			43.3 (TSK-Heart) 49.7 (TSK-Heart) 44.2 (TSK-Heart)	1660 MET-min/week (IPAQ) 1135 MET-min/week (IPAQ) 2207 MET-min/week (IPAQ)					r = -0.663	
Demmelmaier (2018)	2569 (1875)	60 (11)	Rheumatoid arthritis	n.a. (FABQ)	n.a. (IPAQ)	3.2 (VAS)	Cross-Sectional	Online	9.0	r =-0.07‡	<0.0001
Demirbüken (2016)	99 (65)	43.5 (12.8)	Chronic neck pain	41.82 (TSK-17)	3749 MET-min/week (IPAQ)	6.47 (VAS)	Cross-Sectional	Clinical	8.0	r = -0.153	0.13‡
Doğan (2022)	290 (178)	59.86 (15.64)	Knee Osteoarthritis	45.3 (8.6; TSK-17)	n.a. (IPAQ)	5.23 (1.52, VAS)	Cross-Sectional	Clinical	8.0	r = -0.061	0.299
Donnarumma (2017)	51 (12)	61.9 (13.9)	Surgery (laminectomy)	n.a. (TSK-17)	n.a. (IPAQ)	3.5 (GRS)	Cohort	Clinical	7.0	r= -0.35‡	0.01
Elfving (2007)	64 (39)	47 (19-64)	Chronic low back pain	n.a. (TSK-13)	n.a. (SGPALS)	n.a.	Cross-Sectional	Online	9.0	r = -0.31‡	0.010
Glaviano (2017)	20 (15)	22.2 (2.6)	Patellofemoral pain	13.6 (4.4; FABQ)	8629.7 steps/day (1665.3; wrist accelero.)	4.4 (1.9; VAS)	Cross-Sectional	Clinical	8.0	r = -0.481	0.02
González de La Flor (2022)	42 (32)	36.7 (13.2)	Chronic headache	9 (TSK-11)	n.a. (IPAQ)	7.14 (NRS)	Cross-Sectional	n.a.	8.0	ρ = 0.204	0.20‡

Helmus (2012)	53 (37)	39.9 (11.3)	Chronic MSK pain	35.4 (TSK-17)	138 counts/min (hip accelero.)	5.8 (VAS)	Cross-Sectional	Clinical	8.0	r = -0.05	0.75
Ho-A-Tham (2022)	210 (210)	48.7 (16.9)	Chronic low back pain	n.a. (FABQ)	2,240 MET-min/week (GPAQ)	n.a.(NRS)	Cross-Sectional	Home Visit	8.0	r = -0.04‡	0.49
Huijnen (2010)	111 (52)	44.1 (10.3)	Subacute low back pain	36.0 (TSK-17)	n.a. (trunk accelero.)	n.a. (NRS)	Cohort	Clinical	7.0	β = 0.12	>0.05
Igelström (2013)	63 (15)	55 (12)	Obstructive sleep apnea syndrome	12.4 (3.1, TSK-7)	7734 steps (3528; armband accelero.) 77 min (54)(MVPA; armband accelero.)	n.a.	Cross-Sectional	Clinical	8.0	r= -0.251 r= -0.115	0.049 0.37
Kilinç (2019)	200 (120)	53.2 (6.0)	Knee osteoarthritis	31.8. (TSK-17)	1947 MET-min/week (IPAQ)	24.1 (OKS)	Cross-Sectional	Clinical	8.0	r = -0.693	<0.001
Knapik (2019)	135 (59)	71.9 (4.8)	Coronary artery disease	43 (TSK-Heart)	2.60 (ad-hoc questionnaire)	n.a.	Cross-Sectional	Clinical	8.0	ρ = -0.8	$2.6\text{x}10^{-35}$‡
Koppenaal (2022)	204(102)	47.68 (49.05)	Chronic low back pain	26.5 (16.1; FABQ)	77.58 minutes/day (38.85; accelero,)	5.3 (2; NRS)	RCT	Clinical	9.2	r_{MPA}=-0.06 r_{VPA}=-0.03	0.39 0.69
Koho (2011)	93 (60)	44.0 (17-68)	Chronic pain	n.a. (TSK-17)	n.a. (LTPAQ)	6.4 (VAS)	Cohort	Clinical	7.0	r = 0.10	>0.05
Leonhardt (2009)	449 (224) 338 (17)	45.4 (12.3) 50.4 (13.2)	Acute back pain Chronic back pain	17 (FABQ) 18.4 (FABQ)	34.7 (FQPA) 44.1 (FQPA)	4.9 (1.7; NRS)	Cohort	Clinical	7.0	ρ= -0.93 ρ=-0.95	<0.05 >0.05

Lotzke (2018)	118 (63)	46 (8)	Chronic low back pain	38.1 (TSK-17)	198 min MVPA/week (accelero.) 7493.5 steps/day (accelero.)	6.1 (VAS)	Cross-Sectional	Clinical	9.0	n.a. r= -0.19‡	n.a. 0.034
Luthi (2018)	433 (n.a.)	n.a.	Chronic MSK pain	44.6 (TSK-17)	4.45 (BHPAQ)	4.45 (BPI-S)	Cross-Sectional	Clinical	8.0	r = 0.067†	0.759†
Marques-Sule (2022)	117 (51)	56 (12.1)	Heart transplantation	32.5 (TSK-11)	219 MET-min/week (IPAQ)	n.a.	Cross-Sectional	Clinical	9.0	r = -0.32	0.001
Marshall (2017)	218 (130)	36.3 (6.6)	Chronic low back pain	13.8 (5.6, FABQ))	n.a. (open-ended questions < vs. ≥ 30 min/week)	3.6 (2.3; VAS)	Cross-Sectional	Clinical	8.0	r = -0.24	0.0003 ‡
Marshall (2021)	508 (259)	38.2 (11.8)	Chronic low back pain	13.2 (5.7, FABQ)	n.a. (open-ended questions, < vs. ≥ 30 min/week)	4.5 (2.5, VAS)	Cross-Sectional	Clinical	8.0	r = -0.28	1.3x10^{-10}‡
Marshall (2022)	393 (193)	39.2 (12.2)	Chronic low back pain	13.3 (5.2, FABQ)	n.a. (AHS-derived questions, < vs. ≥ 30 min/week)	4.3 (2.3; VAS)	Cohort	Laboratory and Online	7.0	r = -0.01	0.84‡
Massé-Alarie (2016)	22 (8)	n.a	Chronic low back pain	n.a. (TSK-17)	n.a MET-min/week (GPAQ)	n.a (VAS)	RCT	Clinical	7.8	r = 0.09	0.69‡
Miller (2018)	52 (32)	67.4 (5.1)	Older Adults	18.9 (TSK-17)	6743 steps/day (hip accelero.)	1.4 (QWBS-P)	Cross-Sectional	Clinical	7.0	r = -0.54	<0.001

Minetama (2022)	71 (36)	71.6 (5.6)	Lumbar spinal stenosis	24.8 (TSK-11)	3601 steps/day (pedo.)	6.2 (NRS)	Cross-Sectional	Clinical	7.0	r = -0.229	0.055
Navarro-Ledesma (2022)	41 (41)	52.6 (8.0)	Fibromyalgia	27.5 (6.9; TSK-11)	29.1 (18.2; GLTEQ)	n.a.	Cross-Sectional	n.a.	7.0	r = -0.059	>0.05
Norte (2019)	77 (35)	21.6 (7.8)	Surgery (ACLR)	32.9 (6.0; TSK-17)	72.7 (34.9; GLTEQ)	91.4 (9.2; KOOS-P)	Cross-Sectional	Laboratory	7.0	r = -0.312	<0.05
Ohlman (2018)	52 (33)	67.4 (5.1)	Older adults	18.8 (4.5; TSK-11)	n.a. (hip accelero.)	n.a.	Cohort	Laboratory	8.0	ρ = -0.29	<0.05
Olsson (2014)	81 (12)	40.0 (9.6)	Achilles tendon rupture	35.9 (7.5; TSK-17)	2.9 (1.0; SGPALS)	n.a.	Cross-Sectional	Clinical and Laboratory	7.0	ρ = -0.275	0.013
Ozer (2022)	62 (30)	36.8 (6.1)	Asthma	39.6 (5.8; TSK-17)	2249 MET-min/week (1333; IPAQ)	n.a.	Cross-Sectional	n.a.	8.0	r = -0.889	0.001
Özlü (2022)	45 (45)	54.22 (8.2)	Rheumatoid arthritis	38.5 (15.7; TSK-17)	1980.7 MET-min/week (1104.8; IPAQ)	2.4 (1.7; VAS)	Controlled Trial	Clinical	7.3	r = 0.152	0.32
Palstam (2014)	73 (73)	50.4 (9.3)	Fibromyalgia	9.7 (6.08; FABQ)	4.47(3.64; LTPAI)	58.07 (20.29; FIQpain)	Cross-Sectional	Clinical	7.0	r_{MPA} = 0.03 r_{VPA} = -0.14	0.80‡ 0.23‡
Pastor-Mira (2020)	274 (274)	51.8 (9.1)	Fibromyalgia	27.5 (7.1; TSK-11)	3922.40 steps/week (n.a.; pedo.	6.51 (1.62; NRS)	Cohort	Clinical	8.0	r=0.01	>0.05
Pazzinatto (2022)	92 (92)	n.a. (18-35)	Patellofemoral pain	35.3 (6.8; TSK-17)	7.8 (1.5; BHPAQ)	5.1 (2.1; VAS)	Cross-Sectional	Clinical	8.0	ρ = -0.14	0.18‡

Pedler (2018)	103 (74)	39.7 (13.9)	Whiplash injury	26 (TSK-11)	9.9% of active time (8.2; trunk accelero.)	4.0 (2.4; VAS)	Cross-Sectional	n.a.	7.0	r = 0.140	>0.05
Peres (2023)	50 (38) 50 (31)	62.8 (10.9) 46.8 (12.3)	Rheumatoid arthritis Spondyloarthritis	42.7 (7.8; TSK-17) 40.8 (7.6; TSK-17)	3706.9 MET-min/week (2958.3; SQUASH) 5614.9 MET-min/week (3681.7; SQUASH)	n.a.	Cross-Sectional	n.a.	8.0	r = -0.251 r = 0.170	0.055 0.188
Polaski (2021)	38 (26)	37.6 (13.4)	Chronic low back pain	19.5 (12.6; FABQ)	2821 MET-min/week (IPAQ) 11 441 steps/day (accelero.)	3.1 (VAS)	RCT	Clinical	8.4	n.a. r = -0.033	n.a. 0.42
Priore (2020)	50 (37)	22.4 (3.9)	Patellofemoral pain	36.7 (TSK-17)	3088 MET-min/week (IPAQ)	n.a. (VAS)	RCT	Laboratory	9.2	r = -0.251†	0.072†
Rabey (2017)	266 (157)	51 (n.a.)	Chronic low back pain	14.3 (FABQ)	114 (0, 302.5) MET-min/week (IPAQ)	5.8 (NRS)	Cohort	Clinical	8.0	r = 0.077	0.25‡
Roaldsen (2009)	98 (62)	76 (60-86)	Leg ulcer	12 (FABQ)	2.6 (SGPALS)	1.3 (VRS)	Cross-Sectional	Online	8.0	r = -0.39†	7.1×10^{-5}‡
Sandal (2021)	461 (255)	45.7 (14.7)	Chronic low back pain	10.3 (5.4; FABQ)	n.a. (SGPALS)	4.9 (1.9; NRS)	RCT	Online	8.8	r = -0.024	0.66‡
Saulicz (2016)	105 (105)	n.a.	Older adults	45.2 (15.6; KCS)	n.a. (BHPAQ)	n.a.	Cross-Sectional	Online	7.0	r = -0.577†	<0.001†

Sertel (2021)	163 (76)	71.4 (6.0)	Chronic pain	44.4 (7.7; TSK-17)	171.3 (76.2; PASE)	n.a. (VAS)	Cross-Sectional	Home Visit	7.0	r = -0.021	>0.05
Smulligan (2023)	23 (11) 18 (9)	14.9 (1.8) 14.5 (2)	Concussion (no persistant symptoms) Concussion (persistant symptoms)	37 (TSK-17) 41 (TSK-17)	10545 steps/day (3405; wrist accelero.) 4.4 sessions/week (1.9; wrist accelero.) 46.8 min/session (26.2; wrist accelero.) 7047 steps/day (2499; wrist accelero.) 2.3 sessions/week (2.1; wrist accelero.) 38 min/session (12; wrist accelero.)	n.a. n.a.	Cohort	Clinical	8.0	r_{steps} = -0.18 $r_{frequency}$ = -0.34 $\rho_{duration}$ =0.10 r_{steps} = - 0.60 $r_{frequency}$ = -0.63 $\rho_{duration}$ = -0.12	0.41 0.12 0.67 0.008 0.05 0.65
Spaderna (2020)	61 (13)	67.5 (10.7)	Heart failure	1.5 (FActS)	2332 kcal/day (hip accelero.)	n.a.	Cross-Sectional	Laboratory	9.0	r = -0.28	<0.05
Strandberg (2022)	451[††] (n.a.)	n.a.	Cancer	n.a. (TSK-14)	n. 1.3 h MVPA/week (arm accelero.)	n.a.	RCT	Laboratory	8.8	r = -0.084[†]	0.074[†]
Sütçü (2021)	20 (10)	69.8 (9.4)	Parkinson's disease	39.8 (7.4; TSK-17)	3078 steps/day (arm accelero.)	n.a.	Cross-Sectional	n.a.	6.0	r = -0.32[‡]	0.157 0.013

					2055 kcal/day (475; arm accelero.)					r = -0.54‡	
Suttmiller (2022)	126 (107)	32.69 (4.38)	Chronic pain	21.36 (5.53; TSK-11)	n.a. (JPAS)	n.a. (ad-hoc questionnaire, Yes and No)	Cross-Sectional	Online	8.0	r = 0.219	0.014
Uritani (2020)	167 (105)	62.2 (7.5)	Knee osteoarthritis	12.5 (BFMSO)	7998 steps/day (thigh accelero.)	5.7 (NRS)	Cross-Sectional	n.a.	7.0	r = -0.163†	0.035†
Verbunt (2005)	123 (57)	44.1 (10.3)	Subacute low back pain	36.0 (TSK-17)	n.a. (hip accelero.)	4.2 (VAS)	Cross-Sectional	n.a.	7.0	ρ = 0.06	>0.05
Wang (2023)	223 (37)	72.35 (8.96)	Pulmonary (COPD)	20.72 (3.79; BBQ)	n.a. (IPAQ)	n.a.	Cross-Sectional	n.a.	7.0	r = −0.35	<0.001
Wasiuk-Zowada (2022)	80 (60)	45.5 (8.6)	Multiple sclerosis	36.6 (TSK-17)	5.1 (BHPAQ)	3.5 (VAS)	Cross-Sectional	Clinical	7.0	r = -0.363	0.001
Yuksel Karsli (2021)	34 (12) 33 (10)	41 (n.a.) 33 (n.a.)	Radiographic SpA Non-radiographic SpA	42 (TSK-17) 36 (TSK-17)	2203 min LPA/day (hip accelero.) 210 min MPA/day (hip accelero.) 0 min VPA/day (hip accelero.) 2576 min LPA/day (hip accelero.) 265 min MPA/day (hip accelero.)	n.a.	Cross-Sectional	Clinical	8.0	ρ = -0.16 ρ = -0.158 ρ = -0.394 ρ = -0.001 ρ = 0.013 ρ = -0.240	0.929 0.373 0.021 0.997 0.947 0.209

					2 min VPA/day (hip accelero.)						
Zadro (2019)	60 (31)	68.3 (5.7)	Chronic low back pain	34.2 (5.9; TSK-17)	n.a.	5 (1.7; NRS)	RCT	Laboratory	3.2	r_{MPA}= -0.18 r_{VPA}=-0.12	0.16‡ 0.36‡
Zelle (2016)	487 (209)	51.6 (12.5)	Renal transplantation	n.a. (TSK-11)	165 METs (MLTPAQ and TOAQ)	n.a.	Cross-Sectional	n.a.	7.0	r = -0.22	<0.001

Notes. Accelero. = Accelerometer, ACLR = anterior cruciate ligament reconstruction, BBQ = Breathlessness Beliefs Questionnaire (17-85), BFOMSO = Brief Fear of Movement Scale for Osteoarthritis (6 – 24), BHPAQ = Baecke Habitual Physical Activity Questionnaire (3 – 15), BPI-S = Brief Pain Inventory-Severity (1 – 10), COPD = Chronic Obstructive Pulmonary Disease, CVD = cardiovascular disease, FABQ = Fear-Avoidance Belief Questionnaire (0 – 24), FActS = Fear of Activity in Situations (0 – 30), GLTEQ = Godin Leisure Time Exercise Questionnaire (0 – 119), GPAQ = Global Physical Activity Questionnaire, GRS = Graphic Rating Scale (0 – 10), IPAQ = short form of the International Physical Activity Questionnaire, JPAS = Jurka Physical Activity Scale, KCS = Kinesiophobia Causes Scale (0 – 100), KOOS-P = Knee Injury and Osteoarthritis Outcome Score – Pain (0 – 100), LPA = light physical activity, LTPAI = Leisure Time Physical Activity Index, n.a. = not available, MLTPAQ = Minnesota Leisure Time Physical Activity Questionnaire, MPA = moderate physical activity, MSK = Musculoskeletal, MVPA = moderate-to-vigorous physical activity, NRS = Numeric Rating Scale (maximum score = 0 – 10), OKS = Oxford Knee Score – Pain (0-28), PA = Physical Activity, PAQE = Physical Activity Questionnaire for the Elderly (0-3), PASE = Physical Activity Scale for the Elderly, Pedo. = Pedometer, r = Pearson's correlation coefficient, RAPAQ = Rapid Assessment of Physical Activity questionnaire (0-3), ρ = Spearman's correlation coefficient, SF-36 = 36-Item Short Form Survey (0 – 100), QWBS-P = Quality of Well-Being Scale-Pain (0-5), SGPALS = Saltin-Grimby Physical Activity Level Scale (1 – 4), SpA = axial spondyloarthritis, SQUASH = Short Questionnaire to Assess Health Enhancing Questionnaires, TAS = Tegner Activity Scale (0 – 10), TOAQ = Tecumseh Occupational Activity Questionnaire, TSK = Tampa Scale of Kinesiophobia [TSK-17: 17 – 68, TSK-Heart = 17 – 68, TSK-14 = 14 – 56, TSK-13 = 13 – 52, TSK-11 = 11 – 44), UCLA = University of California Los Angeles activity score (1 – 10), VAS = Visual Analog Scale (0 – 10), VPA = vigorous physical activity, VRS = Verbal Rating Scale for pain assessment (0 – 5), †Obtained by email from authors, ††Number of participants used to calculate the correlation, according to the email sent by the authors, ‡When Pearson's correlation coefficient (r) was not reported in an article, but the exact p-value and sample size (n) were available and it was possible to know the sign of the correlation based on the information provided in the article, the r value was computed using an ad-hoc R code.. ‡When exact p-values were not reported in an article, but the sample size (n) and Pearson's correlation coefficient were available, the exact p-value was computed using an ad-hoc R code

Meta-Analysis

All analyses were performed in R Studio integrated development environment (IDE) (2023.06.1+524, "Mountain Hydrangea" release) for R software environment[49] using the {meta}[50] and {metafor}[51,52] R packages[53].

We anticipated considerable between-study heterogeneity, and therefore used a random-effects model to pool correlations. The restricted maximum likelihood (RML) estimator[55] was used to calculate the heterogeneity variance Tau^2. In addition to Tau^2, to quantify between-study heterogeneity, we report the I^2 statistic, which provides the percentage of variability in the correlations that is not caused by sampling error[56]. The I^2 statistic was interpreted as follows: 0-40%, may not be important; 30-60%, may represent moderate heterogeneity; 50-90%, may represent substantial heterogeneity; and 75-100%, may represent considerable heterogeneity. To reduce the risk of false positives, we used a Knapp-Hartung adjustment[57] to calculate the confidence interval around the pooled association. We also report the prediction interval, which provides a range within which we can expect the associations of future studies to fall based on the current evidence.[58]

Publication Bias Assessment

Publication bias was assessed using a funnel plot, which is a scatter plot of the studies' effect size expressed as the Fisher's z transformed correlation on the x-axis against a measure of their standard error (which is indicative of precision of the study's effect size) on the y-axis. When there is no publication bias, the data points in a funnel plot should form a roughly symmetrical, upside-down funnel. Studies in the top part of the plot, which have lower standard errors, are expected to lie closely together, and not far away from the pooled effect size. In the lower part of the plot, studies have higher standard errors, the funnel “opens up”, and effect sizes are expected to scatter more heavily to the left and right of the pooled effect. Egger’s regression[59] can be used to formally test funnel plot’s asymmetry. However, since there is no direct function to conduct Egger's test for 3-level models, we calculated it by using the standard errors of the effect size estimates as a predictor in the meta-regression[60].

P-curve analysis[61] was conducted to assess whether the distribution of the statistically significant results was consistent with what would be expected if only true effects were present. When the null hypothesis is true (i.e., there is no true effect), p-values are assumed to follow a uniform distribution: highly significant effects (e.g., $p = 0.01$) are as likely as barely significant effects (e.g., $p = 0.049$). However, when the null hypothesis is false (i.e., there is a true effect in our data), p-values are assumed to follow a right-skewed distribution: highly significant effects are more likely than barely significant effects. A left-skewed distribution would suggest that some studies used statistical tests to find significant results in ways that may not be reproducible or generalizable (i.e., p-hacking).

Secondary Meta-Analysis

A secondary meta-analysis was conducted using the same approach, but based on Spearman’s rho values, to further test the relationship between fear of movement and physical activity.

Subgroup analyses and meta-regressions

Subgroup analyses were conducted to examine the differences in correlations between studies including participants with different health conditions and using different types of physical activity measures (i.e., device-based versus self-reported), physical activity measurement instruments (i.e., type of questionnaires, type of devices), physical activity outcomes, and fear of movement measures.

Exploratory meta-regressions were conducted to examine if the average age of participants, the proportion of women, and pain in a study predicted the reported correlation between fear of movement and physical activity. Pain was normalized to a 0-100 scale to make the data comparable across pain scales. A sensitivity analysis was conducted to examine whether the quality of the studies affected the results.

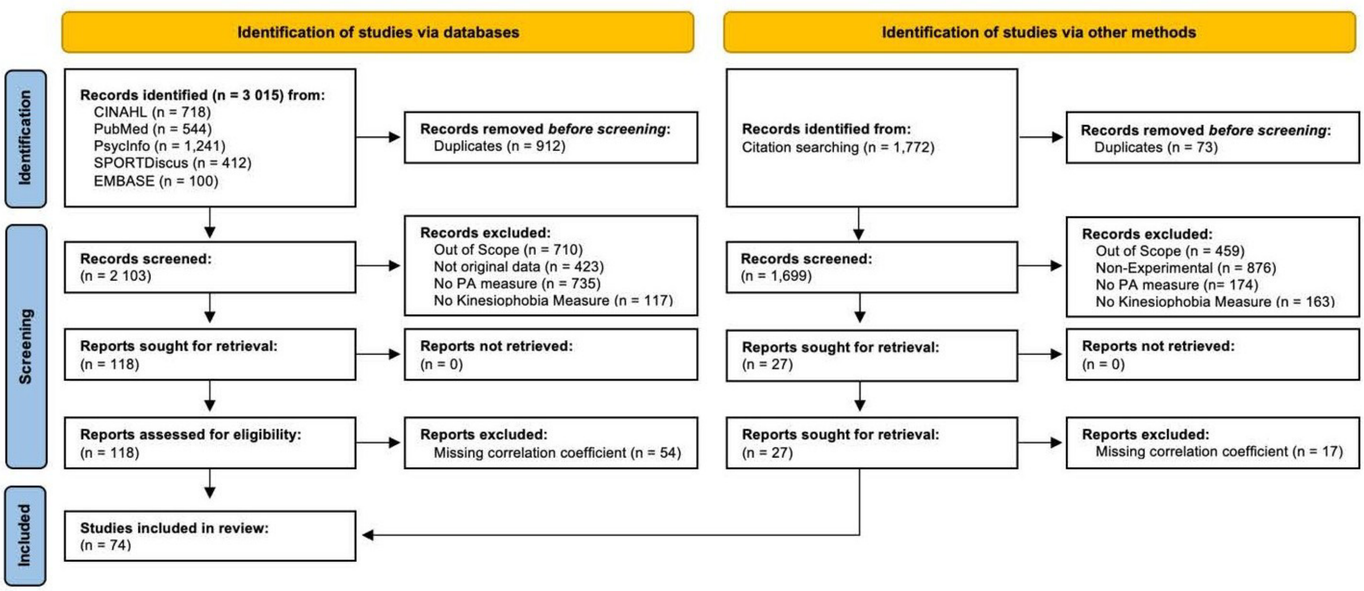
Results

Literature Search

The primary search identified 3,015 potentially relevant articles from the five databases (Figure 2.1), including 912 duplicates. Of the 2,103 articles screened, disagreement occurred in 210 cases (10%), all of which were resolved by consensus. All articles remained after step 1 as they were all written in English. 1,133 articles were excluded in step 2 because they were irrelevant (n = 710) or did not report original data (n = 423). No articles were excluded in step 3 because they all involved human participants. Eight hundred and fifty-two articles were excluded in step 4 because they did not assess fear of movement (n = 117) or physical activity (n = 735). Seventy-seven articles were initially excluded at step 5 because they did not formally test the correlation between fear of movement and physical activity or did not report the estimate of this correlation. However, the corresponding authors of these articles were contacted by email to request the Pearson correlation estimate of this association and the sample size used to calculate it. Nineteen authors replied to our email: Eight authors provided raw data for 10 studies[62-71] and 11 authors provided the Pearson's correlation estimate[29,72-81]. In addition, the Pearson's correlation estimate of two articles were calculated based on information reported in the article[82,83]. This process reduced the number of studies excluded at step 5 to 54, resulting in a total of 64 articles included from the databases.

Using reference screening and forward citation tracking, the authors identified 27 additional studies that assessed both physical activity and fear of movement, of which 8 reported an estimate of their relationship[84-91] and 19 did not[92-110]. The corresponding authors of these 19 studies were asked by email to provide this estimate or their data. Two authors sent the estimate[104,107]. Seventeen emails remained unanswered[92-103,105,106,108-110].

Figure 2.1. PRISMA 2020 flow diagram.



Descriptive Results

Participants

The 74 articles identified by the systematic review included a total of 13388 participants aged 11 to 85 years, including 7308 women, 4729 men, and 1351 participants whose gender and sex was not reported. The studies investigated populations with pain (n = 37)[62,64-71,73,76-81,83,88,89,111-128] cardiac conditions (n = 6)[86,87,104,129-131], surgery (n = 8)[63,131-137], arthritis (n = 10)[75,82,84,85,91,138-142], neurologic conditions (n = 3)[90,143,144], pulmonary conditions (n = 3)[145-147], cancer (n = 1)[74], women health conditions (n = 2)[72,148], as well as healthy adults (n = 6)[29,85,107,149-151] (Table 2.1).

Fear of Movement

In 54 of the 74 studies, fear of movement was assessed using the 17-item TSK (TSK-17; n = 38)[29,62,64,65,68,72,73,77,84,85,90,91,111-114,117-120,122-125,130,133-135,138-144,146,148,150] shorter versions of the TSK [(TSK-11[152]; n = 10)[63,81,88,116,121,122,128,131,136,151], (TSK-14; n = 1)[74], (TSK-13[153]; n = 2)[115,137], (TSK-7; n = 1)[145]], or its adaptation for patients with coronary artery disease (TSK-Heart[154]; n = 2)[86,87]. The TSK is a questionnaire that assesses the belief that movements can lead to (re)injury, pain, or aggravation of an underlying and serious medical condition[28]. Each item is rated on a Likert scale ranging from 1 (strongly disagree) to 4 (strongly agree). On the TSK-17, a score of 37 is used to distinguish between low (≤ 37) and high (> 37) levels of fear of movement[27]. On the TSK-13, scores inferior to 23 are considered sub-clinical[155]. The other measures that were used are the Fear-Avoidance Belief Questionnaire[156] (FABQ; n = 15)[66,67,69-71,76,78-80,82,83,104,126,127,132], Kinesiophobia Causes Scale[157] (KCS; n = 2)[107,149], the Fear of Activities in Situations scale (FActS; n = 1)[129], the Brief Fear of Movement Scale for Osteoarthritis[158] (BFMSO; n = 1)[75], and Breathlessness Beliefs Questionnaire (BBQ; n = 1)[147].

Sixty-four studies reported mean levels of fear of movement (Table 2.1). The studies based on the TSK-17 or TSK-Heart (mean range: 17 to 68) reporting the highest levels of fear of movement were those involving participants with a cardiovascular condition (41.4 to 49.7), followed by studies testing participants with arthritis (31.8 to 45.27) or chronic pain (30.5 to 44.6). Levels of fear of movement were lower in participants with a neurological (36.6 to 41), pulmonary (20.7 to 39.6), women health (36), or surgical condition (32.9 to 35.9), and in healthy adults (18.9 to 39.0).

Physical Activity

Fifty-one studies assessed physical activity using a self-reported measure (Table 2.1). Most of these questionnaire-based studies used the short form of the International Physical Activity Questionnaire (IPAQ-SF; n = 20)[29,73,76,78,79,82,85,86,112,114,116,130,131,133,138-141,146,147] which consists of 6 items assessing time spent in light (i.e., walking), moderate (e.g., carrying light loads, cycling at moderate speed, doubles tennis), and vigorous physical activity (e.g., digging, fast cycling, heavy lifting, aerobics) over the last 7 days[159]. Other questionnaires were used to assess physical activity, such as the Baecke Habitual Physical Activity Questionnaire[160] (BHPAQ; n = 5)[64,89,90,107,113], Saltin-Grimby Physical Activity Level Scale[161] (SGPALS; n = 5)[80,104,115,125,135], Godin-Shephard Leisure-Time Exercise Questionnaire[162] (GLTEQ; n = 2)[121,134], Minnesota Leisure Time Physical Activity Questionnaire[163] (MLTPAQ; n = 1)[136], Physical Activity Scale for the Elderly[164] (PASE; n = 2)[123,149], Physical Activity Questionnaire for the Elderly[164] (PAQE; n = 1)[72], Short Questionnaire to Assess Health Enhancing Physical Activity[165] (SQUASH; n = 1)[142], the Tegner Assessment Scale[166] (TAS; n = 1)[63], University of California Los Angeles (UCLA) activity score[167] (n = 1)[84], Leisure Time Physical Activity Index[168] (LTPAI; n = 1)[67], Global Physical Activity

Questionnaire[169] (GPAQ; n = 2)[77,83], Freiburger Questionnaire on Physical Activity[170] (FQPA; n = 1)[127], Jurka Physical Activity Scale[171] (JPAS; n = 1)[81], Rapid Assessment of Physical Activity questionnaire[172] (RAPAQ; n = 1)[68], Tecumseh Occupational Activity Questionnaire[173] (TOAQ; n = 1)[136], and Australian Health Survey-derived questions (AHS; n = 1)[71].

Physical activity was also assessed with devices such as accelerometers measuring accelerations in 3 dimensions (n = 23)[65,66,74,75,78,91,110,113,117,118,120,122,124,126,129,132,137,143-145,148,150,151] and pedometers measuring the number of steps (n = 3)[63,88,128] (Table 2.1). In most studies, the device was worn at the hip (n = 10)[63,91,113,117,124,129,137,148,150,151]. Other positions included wrist (n = 5)[65,111,126,132,143], arm (n = 3)[74,144,145], trunk (n = 2)[118,122], and thigh (n = 1)[75], with five studies not reporting where the device was worn[66,78,88,120,128]. Most studies that employed accelerometer-based measures used the ActiGraph (Actigraph, LLC, Pensacola, FL, USA) GT3X+ (n = 4)[120,137,150,151], wGT3X-BT (n = 2)[138,148] or GT9X Link (n = 2)[78,132]. The other accelerometers were the RT3 (Stayhealthy Inc., Monrovia, CA, USA; n = 3)[117,118,124], the SenseWear Pro3 Armband (BodyMedia, Pittsburgh, PA, USA; n = 3)[74,144,146], the Activity Sensory Move II (movisens GmbH, Karlsruhe, Germany; n = 1)[129], the LifeShirt (Vivometrics, Inc., Ventura, CA, USA; n = 1)[122], the ActiWatch (Mini Mitter Co., Inc., Bend, OR, USA; n = 1)[111], AX3 (Axtivity, Newcastle upon Tyne, UK; n = 1)[65], FitBit (FitBit Inc., San Francisco, CA) Charge HR (n = 1)[126], Charge 3 (n = 1)[143], and the Activ8 (2M Engineering, North Brabant, Netherland, n = 1)[66]. The type of accelerometer was not reported in one study[113]. The pedometers were the Digi-Walker SW-200 (New Lifestyles Inc., Lees Summit, MO, USA; n = 1)[63], the Active Style Pro HJA-350IT (Omron Heathcare, Kyoto, Japan; n = 1)[88] and Yamax Power-Walker EX-510 3D (Pedometer Express, Minnesota, USA; n = 1)[128]. These devices were worn for 5 days (n = 1)[111], 6 days (n = 1[129]), 7 days (n = 16)[63,65,75,88,91,113,117,118,120,124,132,137,144,148,150,151], or 14 days (n = 1)[126]. The remaining 7 studies did not specify the number of days the device was worn[66,74,78,122,128,143,145]. All studies provided the accelerometer or pedometer on the day fear of movement was assessed (n = 18)[63,65,66,75,78,88,89,111,113,120,122,126,132,137,143,148,150]. The remaining studies did not specify whether fear of movement was measured the day the device was provide or the last day of physical activity assessment (n = 7)[74,118,124,128,144,146,151].

To assess physical activity, the studies used the following outcomes: Score from a questionnaire (e.g., TAS, PAQE, BHPAQ, SGPALS, LTPAQ, n = 24)[63,64,67,68,72,80,81,84,87,89,90,104,107,113,115,119,121,123,125,127,134,137,149], MET-min/week (n = 23)[31,73,76,77-79,83,85,86,112,114,116,130,131,133,136,138-142,146,147], steps per day (n = 14)[63,65,75,78,88,113,120,126,128,132,143-145,150], hours per day or week (n = 12)[62,65,69-71,74,91,113,120,138,143,145], counts per minute (n = 4)[111,113,117,137], kilocalories per day (n = 2)[129,144], or percentage of active time (n = 1)[122]. Nine studies used multiple physical activity outcomes[63,65,78,91,113,120,143-145].

Association Between Physical Activity and Fear of Movement

Among the 74 articles included in the systematic review, 42 reported correlation coefficients of the association between physical activity and fear of movement. Specifically, 32 articles reported at least one Pearson's r correlation coefficient and 12 articles reported at least one Spearman's rho[87,89,91,113,116,124,127,132,135,143,149,151]. When a correlation coefficient was not reported, but the exact p-value (or t value) and sample size were available and it was possible to know the sign of the correlation, which was the case for 7 studies[83,111,115,120,125,133,144], the Pearson's r estimate was computed using an ad-hoc R code. For the studies that reported a relative p-value < 0.001 instead of an exact p-value, we used a p-value of 0.0009 to estimate an approximate r value[82].

Through email correspondence with the authors, we obtained 23 additional Pearson's r estimates[29,62-81,104,107]. In total, 83 Pearson's r estimates from 63 studies and 21 Spearman's rho estimates from 12 studies were used in the meta-analysis (Table 2.1). The remaining study did not report a correlation coefficient and was therefore not included in the meta-analysis[117]. This study reported a non-statistically significant positive association between physical activity and fear of movement based on a standardized beta coefficient.

Pain

Mean pain intensity at rest was reported in 45 out of the 74 articles included in the systematic review. Most studies used the Visual Analog Scale[174] (VAS; n = 21)[65,69-71,76,78,82,85,89,90,112,114,117,119,120,122,124,126,138,139,141] or the Numeric Rating Scale[175] (NRS; n = 15)[29,62,66,68,75,79,80,83,88,111,113,116,127,128,137]. Other studies used the Knee Injury Osteoarthritis Outcome Score pain subscale[176] (KOOS-P; n = 3)[63,84,134], Brief Pain Inventory[177] (n = 1)[64], Oxford Knee Score[178] (OKS; n = 1)[140], the Quality of Well-Being Scale – Self-administered Pain Scale[179] (QWBS-P; n = 1)[150], the Short Form 36 bodily pain[180] (SF-36; n = 1)[130], the Graphic Rating Scale[181] (GRS; n = 1)[133], Fibromyalgia Impact Questionnaire-Pain[182] (FIQ-Pain, n = 1)[67] and the Verbal Rating Scale[183] (VRS; n = 1)[104]. In the meta-analysis, scores that were not on a 0-100 scale in the initial measure were scaled to that range.

Meta-Analysis

Main Meta-Analysis

Our main meta-analysis of 63 studies, 83 Pearson's r correlation estimates, and 12278 participants revealed a statistically significant negative correlation between fear of movement and physical activity ($r = -0.19$; 95% confidence interval [95CI]: -0.26 to -0.13; $p < 0.0001$) (Table 2.2; Figure 2.4). However, we observed substantial-to-considerable between-study statistical heterogeneity ($Tau^2 = 0.06$, 95CI: 0.02 to 0.09; $I^2 = 85.5\%$, 95CI: 82.6 to 87.9%), and the prediction interval ranged from $r = -0.605$ to 0.300, indicating that a positive correlation cannot be ruled out for future studies.

The sampling error variance on level 1 and the value of I^2 on level 2, i.e., the amount of heterogeneity variance within studies, were small (10.3% and 8.2%, respectively). The largest share of heterogeneity variance was from level 3, with between-study heterogeneity making up 81.5% of the total variation in our data (Figure 2.2). Overall, this indicates that there is considerable between-study heterogeneity, and less than one tenth of the variance can be explained by differences within studies.

Figure 2.2. Heterogeneity variance.

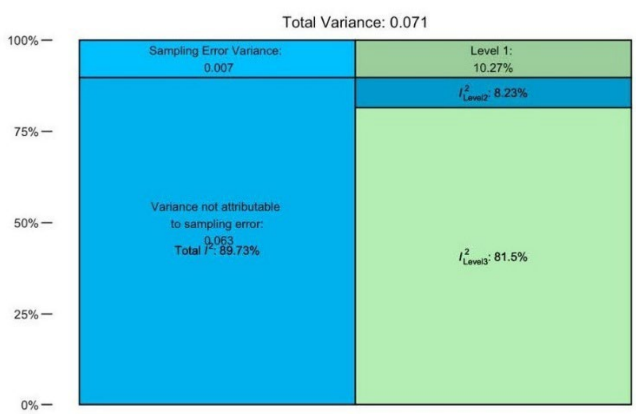


Table 2.2. Results of the main, secondary, and subgroup meta-analyses

	n	k	o	cor.	95% CI	I² (%)	*p*
Main: Pearson's r estimates							<.0001
Fear of movement and physical activity	63	83	12278	-.19	[-.26; -.13]	85	
Secondary: Spearman's rho estimates							.0486
Fear of movement and physical activity	12	21	2084	-.20	[-.38; .001]	86	
Subgroup: Health status							<.0001
Chronic pain	29	35	5091	-.07	[-.16; .01]	62	
Arthritis	9	11	3592	-.25	[-.39; -.10]	93	
Cardiovascular condition	5	10	823	-.30	[-.47; -.11]	29	
Neurological condition	4	8	220	-.53	[-.69; -.32]	56	
Surgery	5	5	903	-.16	[-.36; .05]	69	
Older adults	3	3	278	-.40	[-.60; -.14]	91	
Acute pain	2	2	103	-.13	[-.29; .04]	34	
Pulmonary condition	2	2	285	-.68	[-.82; -.46]	98	
Obstructive sleep apnea	1	2	146	-.18	[-.56; .26]	0	
Fibromyalgia	1	2	146	-.06	[-.46; .37]	2	
Cancer	1	1	451	-.19	[-.26; -.13]		
Post-partum women	1	1	139	-.13	[-.29; -.04]		
Young adults	1	1	101	-.01	[-.20; .19]		
Subgroup: Physical activity measure							.1714
Self-reported	44	54	9882	-.22	[-.29; -.14]	89	
Device-based	20	29	2396	-.13	[-.24; -.02]	57	
Subgroup: Physical activity instrument							.2092
Accelerometer	18	27	2462	-.17	[-.29; -.05]	55	
IPAQ	18	25	5034	-.28	[-.39; -.16]	93	
BHPAQ	4	4	737	-.34	[-.50; -.15]	94	
SGPALS	4	4	675	-.19	[-.43; .08]	80	
Ad-hoc questionnaire	4	4	1240	-.15	[-.39; .11]	85	
Pedometer	3	3	385	-.02	[-.33; .29]	59	
GPAQ	2	2	232	.01	[-.38; .40]	0	
MLTPAQ	2	2	580	-.07	[-.42; .29]	87	
GLTEQ	2	2	118	-.20	[-.54; .20]	43	

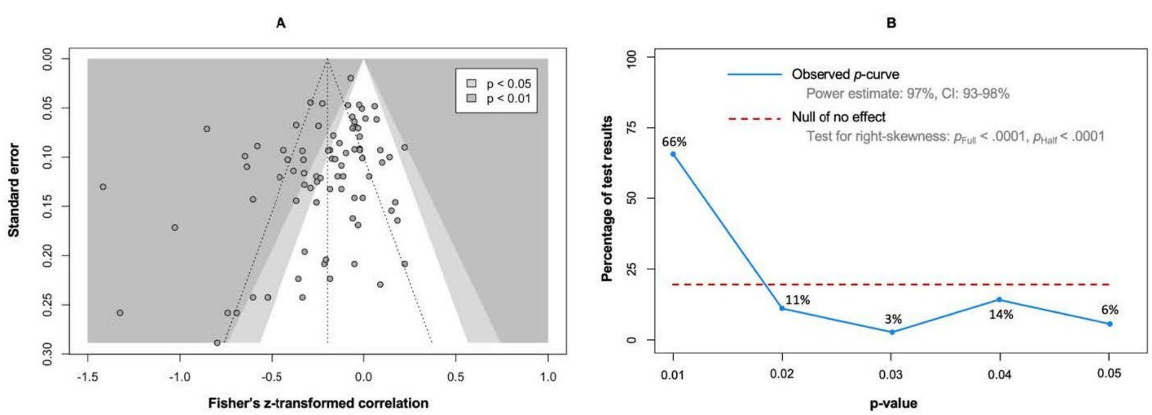
LTPAI	1	2	146	-.06	[-.52; .44]	2	
SQUASH	1	2	100	-.04	[-.52; .46]	77	
RAPAQ	1	2	120	-.15	[-.59; .30]	0	
JPAS	1	1	126	.22	[.05; .38]		
PASE	1	1	163	-.02	[-.17; .13]		
UCLA	1	1	37	-.77	[-.88; -.60]		
Diary	1	1	123	-.02	[-.20; .16]		
Subgroup: Physical activity outcome							.6098
MET-min/week	25	35	6439	-.20	[-.30; -.09]	91	
Score	15	16	2090	-.24	[-.36; -.11]	85	
Steps/day	12	13	945	-.18	[-.33; -.03]	56	
Active time	10	12	2144	-.11	[-.25; .03]	77	
Counts/min	5	5	579	-.14	[-.33; .05]	8	
Kcal/day	2	2	81	-.38	[-.67; .02]	24	
Subgroup: Fear of movement instrument							.4520
TSK-17	33	44	3679	-.23	[-.32; -.14]	86	
FABQ	13	15	5434	-.13	[-.27; .02]	74	
TSK-11	8	8	1259	-.04	[-.23; .15]	82	
TSK-Heart	1	7	467	-.51	[-.78; -.08]	61	
TSK-13	3	3	372	-.16	[-.44; .16]	44	
TSK-14	1	1	451	-.08	[-.17; .01]		
TSK-12	1	1	60	-.18	[-.41; .08]		
BBQ	1	1	223	-.35	[-.46; -.23]		
BFOMSO	1	1	167	-.16	[-.31; -.01]		
FActS	1	1	61	-.28	[-.50; -.03]		
KCS	1	1	105	-.57	[-.69; -.42]		

Notes. 95% CI = 95% confidence interval, BBQ = Breathlessness Beliefs Questionnaire, BFOMSO = Brief Fear of Movement Scale for Osteoarthritis, BHPAQ = Baecke Habitual Physical Activity Questionnaire, Cor. = Correlation estimate, FABQ = Fear-Avoidance Belief Questionnaire, FActS = Fear of Activity in Situations, GLTEQ = Godin Leisure Time Exercise Questionnaire, GPAQ = Global Physical Activity Questionnaire, IPAQ = short form of the International Physical Activity Questionnaire, JPAS = Jurka Physical Activity Scale, k = number of estimates, KCS = Kinesiophobia Causes Scale, LTPAI = Leisure Time Physical Activity Index, MLTPAQ = Minnesota Leisure Time Physical Activity Questionnaire, n = number of studies, o = number of observations (participants), p = p-value for between-group difference, PAQE = Physical Activity

Questionnaire for the Elderly, PASE = Physical Activity Scale for the Elderly, RAPAQ = Rapid Assessment of Physical Activity questionnaire, SGPALS = Saltin-Grimby Physical Activity Level Scale, SQUASH = Short Questionnaire to Assess Health Enhancing Questionnaires, TSK = Tampa Scale of Kinesiophobia, UCLA = University of California Los Angeles activity score

The 3-level model showed a better fit than the 2-level model with lower Akaike's information criterion (AIC) (28.4 vs. 39.0) and Bayesian information criterion (BIC) (35.6 vs. 43.8), indicating better performance. These lower AIC and BIC are consistent with the significant likelihood ratio test (LRT) comparing the two models ($\chi^2 = 12.67$, p = 0.0004). Therefore, although the 3-level model introduces an additional parameter, this added complexity has improved our estimate of the pooled effect.

Figure 2.3. Publication bias assessment.



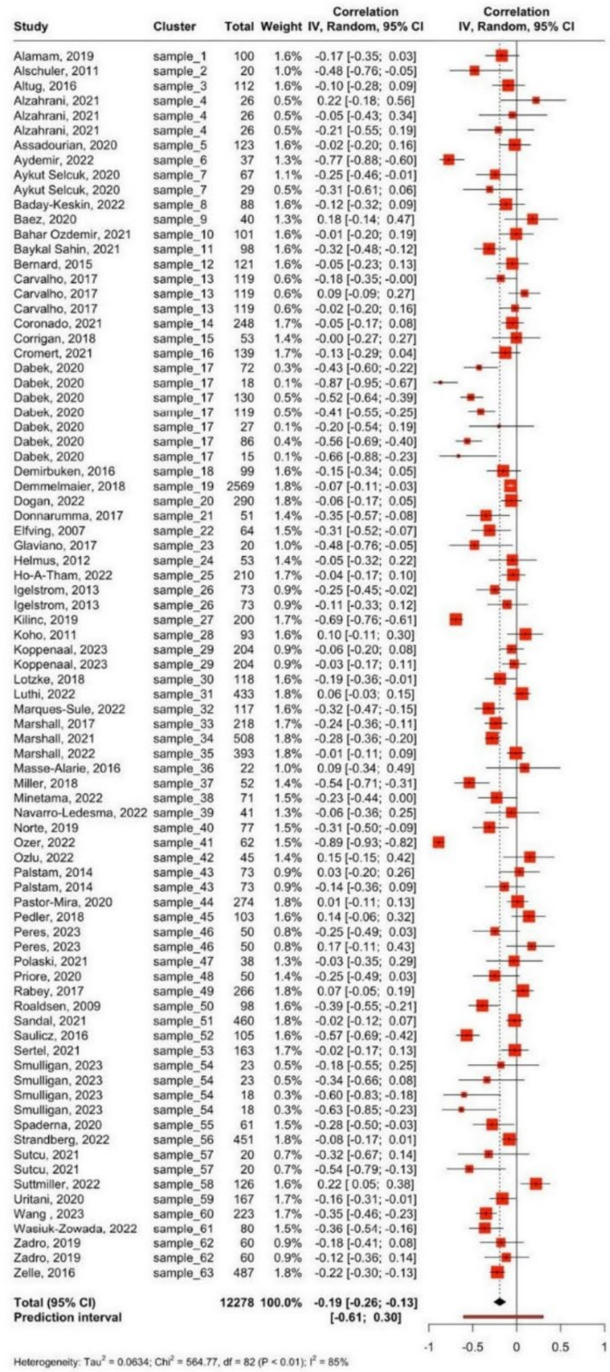
Note. Contour-enhanced funnel plot of the main meta-analysis (A). The vertical dashed line represents the average effect size. The two other dashed lines represent the idealized funnel-shape that studies are expected to follow. P-curve analysis (B). The blue line indicates the distribution of the analyzed p-values. The red dotted line illustrates a uniform distribution of the p-values, indicating the absence of a true effect.

Publication bias assessment

Egger's regression test using the standard errors of the effect size estimates as a predictor in the meta-regression showed that the coefficient of the standard error was significant ($b = -1.497$, 95CI: -2.618 to -0.3754, $p = 0.0095$), suggesting that the data in the funnel plot was asymmetrical (Figure 2.3A). This asymmetry may be explained by publication bias, but also by other potential causes, such as different study procedures and between-study heterogeneity[184], which was substantial-to-considerable here.

The 83 Pearson's r correlation estimates were provided to the p-curve analysis. The observed p-curve included 35 statistically significant results ($p < 0.05$), 27 of which were highly significant ($p < 0.025$), and was visually right-skewed (Figure 2.3B). The other results were excluded because they had a $p > 0.05$. The p-value of the right-skewness test was < 0.001 for both the half curve (curve of p-values ≤ 0.025) and the full curve (curve of p-values < 0.05), confirming that the p-curve was right-skewed and suggesting that the effect of our meta-analysis is true, i.e., that the effect we estimated is not an artifact caused by selective reporting (e.g., p-hacking) in the literature[185]. In addition, the statistical power of the studies that were included in the p-curve analysis was 97% (90CI: 93 to 98%), suggesting that approximately 90% of the significant results are expected to be replicable.

Figure 2.4. Main meta-analysis: Correlation between fear of movement and physical activity.

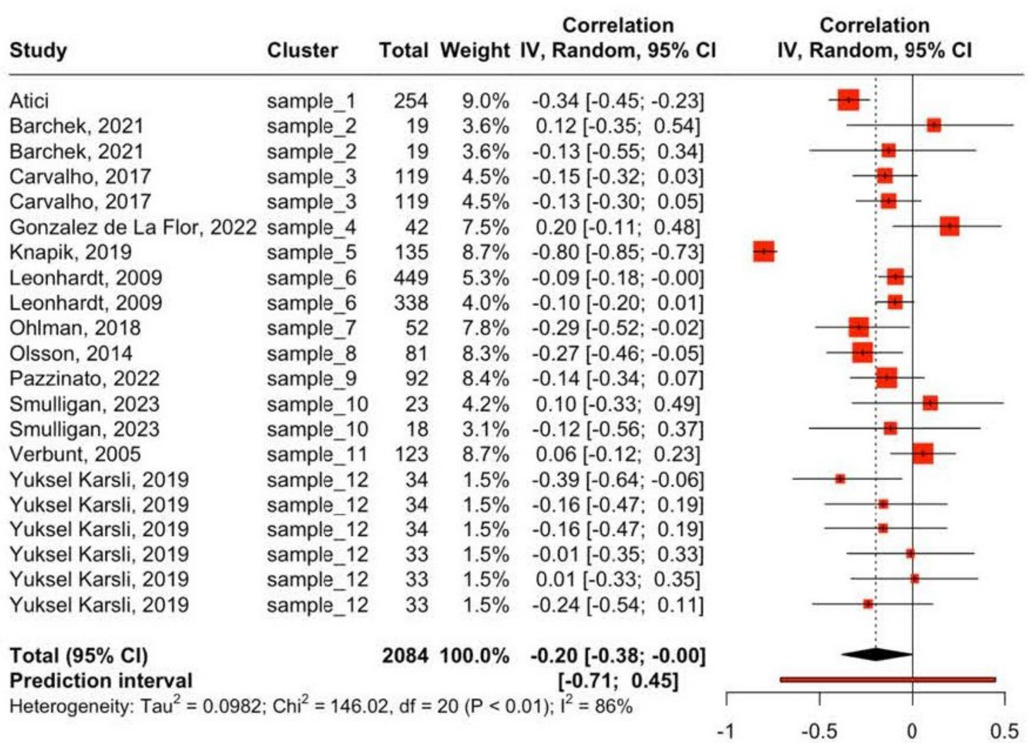


Note. 95% CI = 95% confidence interval, IV = Inverse variance method, Random = Random effects method.

Secondary Meta-Analyses

Results of the secondary meta-analysis of 12 studies, 21 Spearman's rho correlation estimates, and 2084 participants was consistent with the main meta-analysis as it showed a statistically significant negative correlation between fear of movement and physical activity (r = -0.20; 95CI: -0.38 to -0.01; p = 0.049) (Table 2.2; Figure 2.5). However, we observed substantial-to-considerable between-study statistical heterogeneity (Tau2 = 0.10, 95CI: 0.04 to 0.28; I2 = 86.3%) and the prediction interval ranged from r = -0.710 to 0.445, indicating that a positive correlation cannot be ruled out for future studies.

Figure 2.5. Secondary meta-analysis based on Pearson's rho estimates.



Subgroup Meta-Analyses

The test of subgroup differences between health status was conducted on studies comprising people with chronic (k = 35) or acute pain (k = 2), arthritis (k = 11), a cardiovascular condition (k = 10), a neurological condition (k = 8), surgery (k = 5), older age (k = 3), obstructive sleep apnea (k = 2), a pulmonary condition (k = 2), fibromyalgia (k = 2), cancer (k = 1), as well as in post-partum women (k = 1) and healthy young adults (k = 1) (Table 2.2; Figure 2.6).

We found a statistical moderating effect of health status ($p = 0.0014$). The relationship between fear of movement and physical activity was statistically significant only in studies that included participants with cardiac condition ($r = -0.30$; 95CI: -0.47 to -0.11), arthritis ($r = -0.25$; 95CI: -0.39 to -0.10), a neurologic condition ($r = -0.53$; 95CI: -0.69 to -0.32), a pulmonary condition ($r = -0.68$; 95CI: -0.82 to -0.46), or older adults ($r = -0.40$; 95CI: -0.60 to -0.14). We found no evidence of an association between fear of movement and physical activity in studies that included participants with chronic pain ($r = -0.07$; 95CI: -0.16 to 0.01) or acute pain ($r = -0.13$; 95CI: -0.45 to 0.23). Statistical heterogeneity was higher in the studies comprising people with a pulmonary condition (I2 = 98.1%), arthritis (I2 = 93.4%), or older adults (I2 = 91.2%) than in the studies comprising people with a cardiac (I2 = 28.7%) or neurologic condition (I2 = 55.9%).

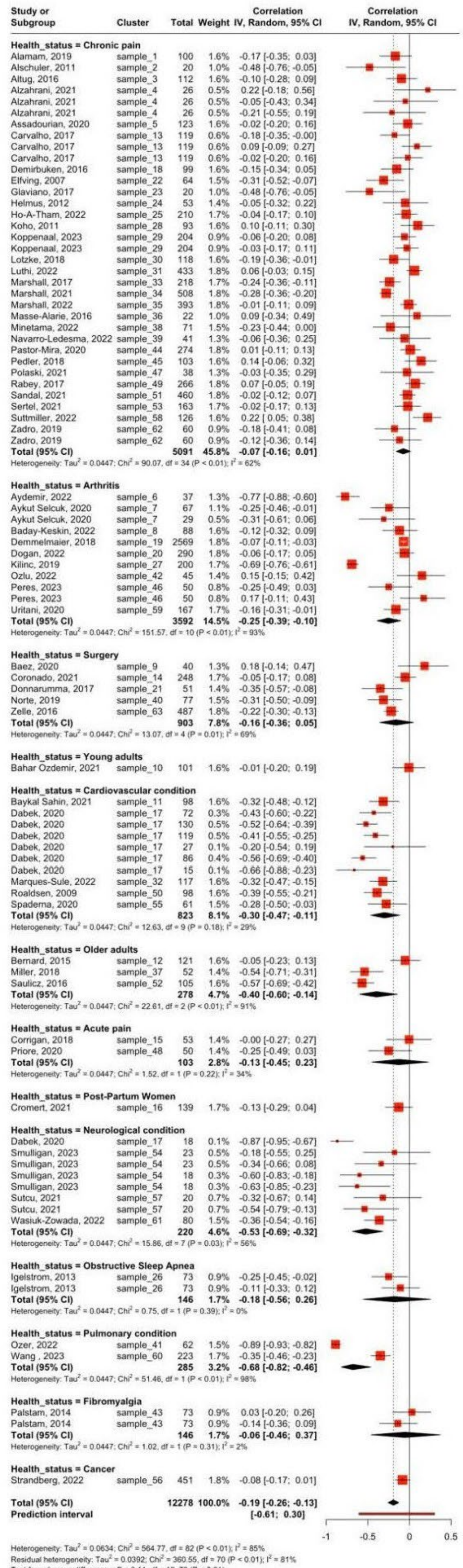


Figure 2.6. Subgroup meta-analysis: Differences according to health status.

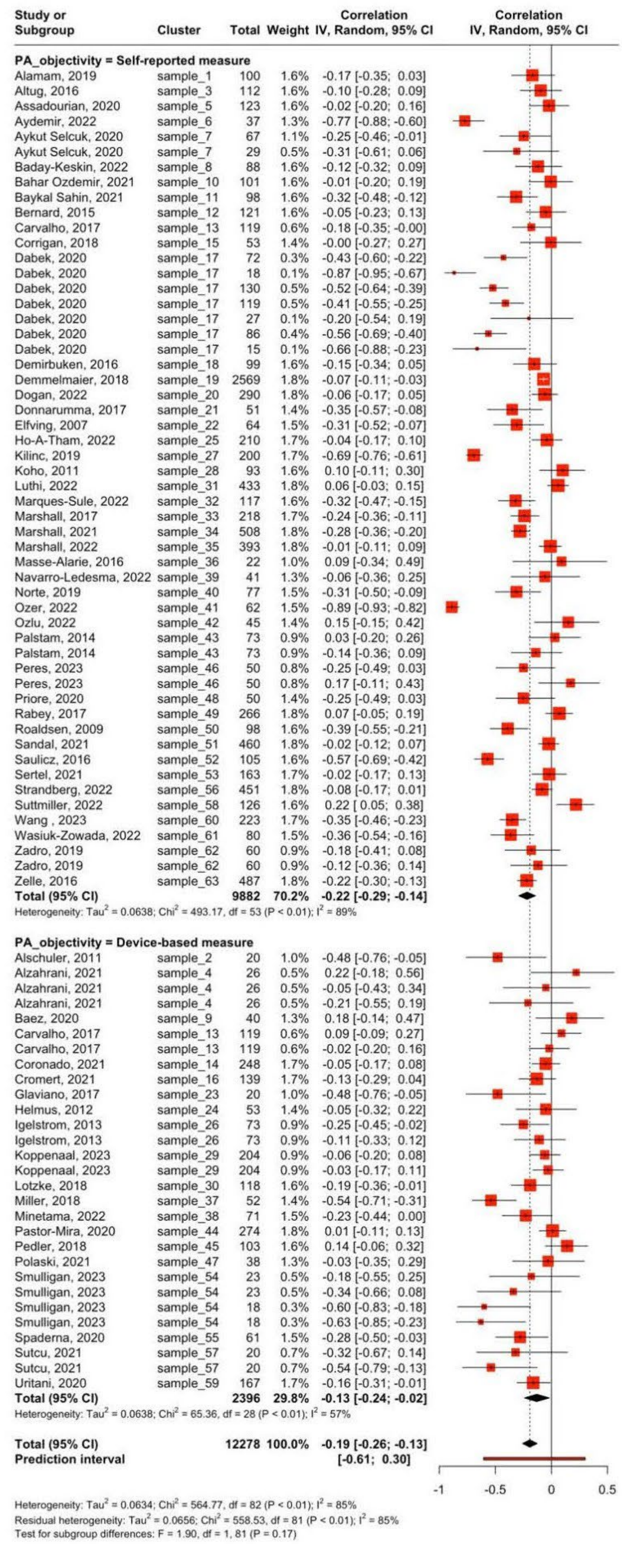
The test of subgroup differences between self-reported (k = 54) and device-based (k = 29) measures of physical activity showed no evidence of a moderating effect of the type of physical activity measure (p = 0.171; Table 2.2). Both self-reported measures (r = -0.22; 95CI: -0.29 to -0.14; I2 = 89.3%) and device-based measures (r = -0.13; 95CI: -0.24 to -0.02; I2 = 57.2%) (Figure 2.7) showed a negative association between fear of movement and physical activity.

We also found no evidence of a moderating effect of physical activity instruments (p = 0.209) (Figure 2.9), physical activity outcome (p = 0.685) (Figure 2.10), or fear of movement instrument (p = 0.452) (Figure 2.11).

Meta-Regressions

Age did not statistically influence the correlation estimates of the meta-analysis studies (k = 72; p = 0.349; Figure 2.8A). Similarly, the proportion of women (k = 72; p = 0.555; Figure 2.8B) and the mean level of pain in the studies (k = 49; p = 0.481; Figure 2.8C) did not influence correlation estimates.

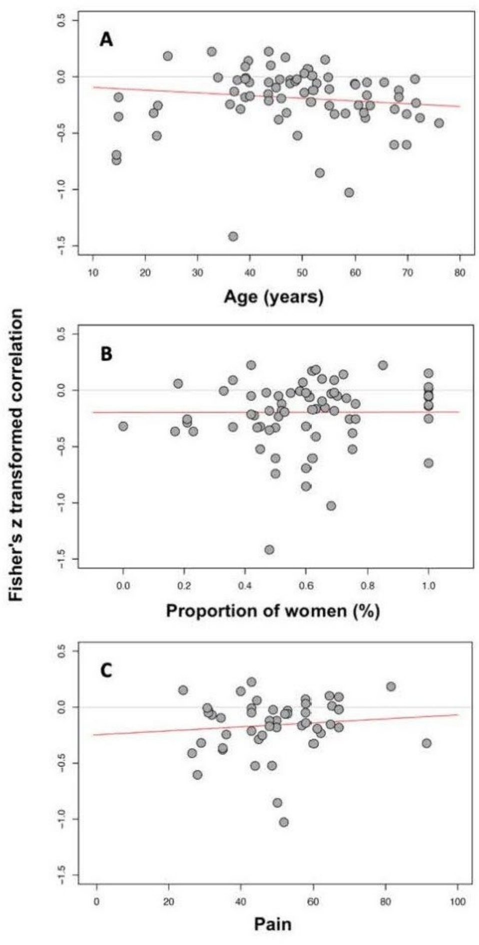
Figure 2.7. Subgroup meta-analysis: Differences according to physical activity measure (self-reported vs. device-based).



Sensitivity Analysis

The meta-regression by quality score showed that a study's quality did not influence correlation estimates (k = 83; p = 0.373).

Figure 2.8. Meta-regressions testing the influence of age, the proportion of women and pain intensity on the relationship between fear of movement and physical activity.



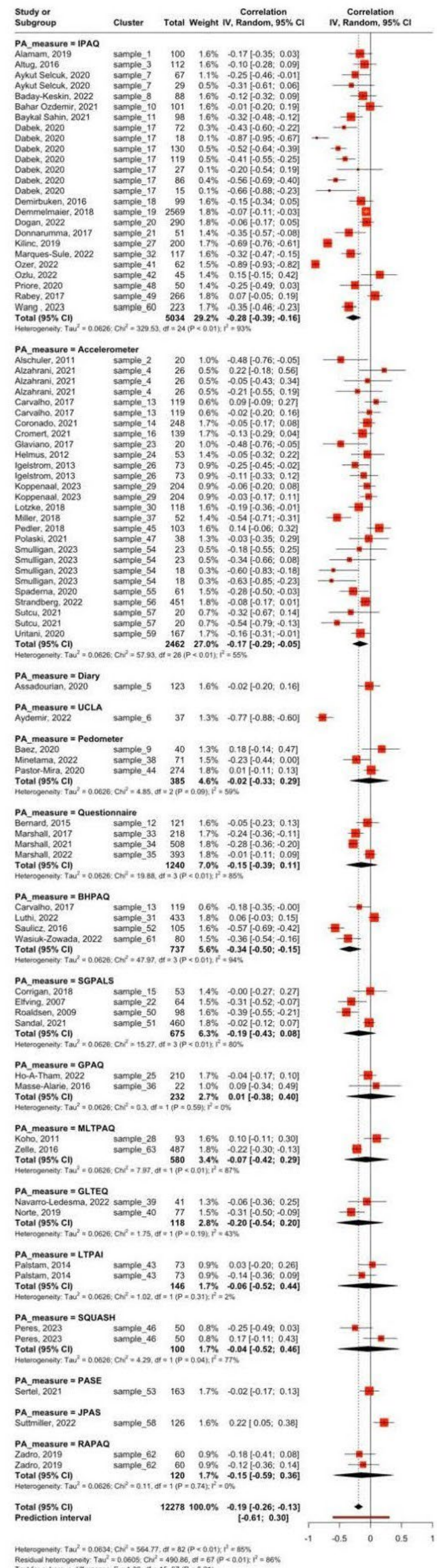


Figure 2.9. Subgroup meta-analysis: Differences by physical activity measurement instrument.

Figure 2.10. Subgroup meta-analysis: Differences by physical activity measurement outcome.

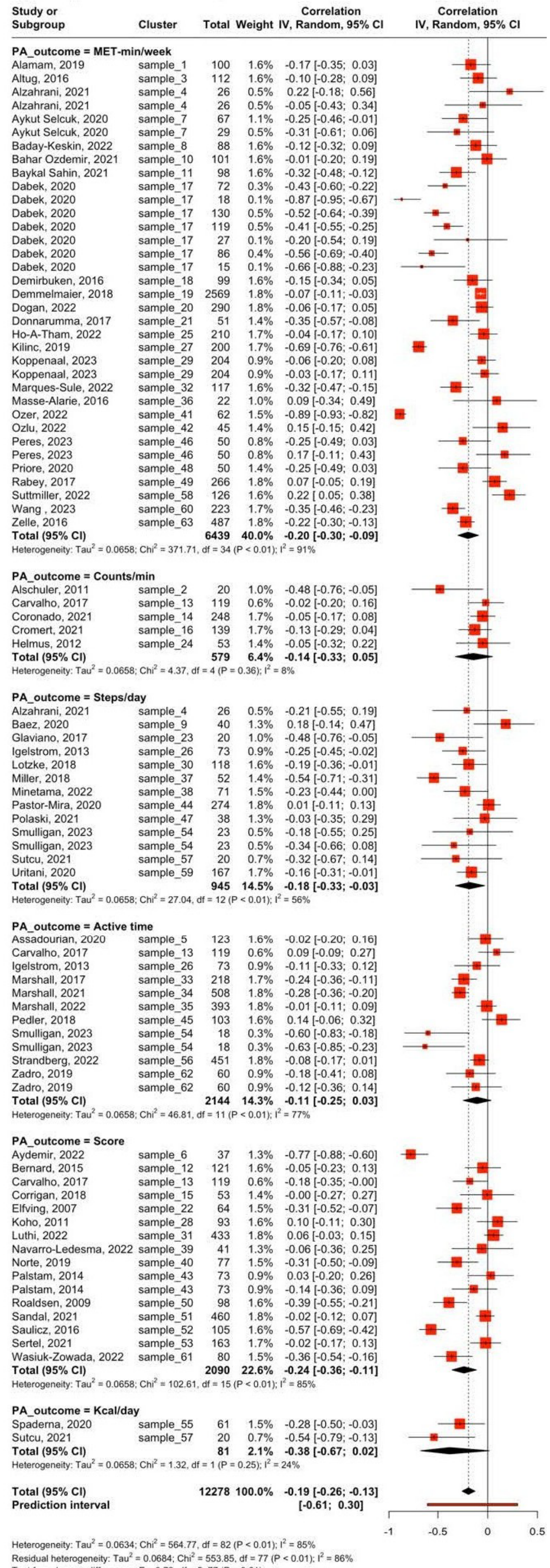
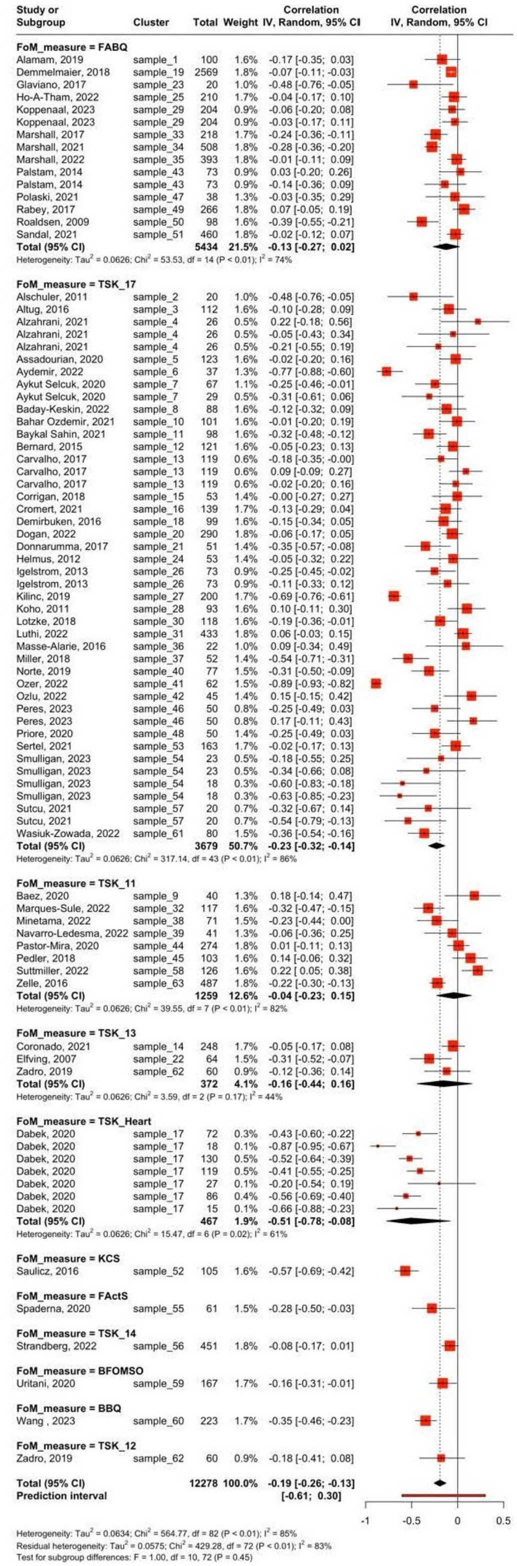


Figure 2.11. Subgroup meta-analysis: Differences by fear of movement measurement instrument.



Discussion

The main objective of this study was to systematically review and meta-analyze the direct relationship between fear of movement and physical activity. In addition, we examined the influence of potential moderators, such as health status. To our knowledge, this is the first review of its kind on this research topic.

Fear of Movement as a Barrier to Physical Activity

Both the main meta-analysis based on Pearson's r correlation estimates and the secondary meta-analysis based on Spearman's rho correlation estimates showed a negative correlation between fear of movement and physical activity. These results indicate that individuals with higher fear of movement are likely to engage in less physical activity, highlighting the importance of assessing fear of movement in clinical practice, as it may affect participation in exercise and rehabilitation programs. Rehabilitation professionals should be vigilant in identifying and assessing patients who may be experiencing fear of movement, as it may impede their recovery or ability to maintain a healthy lifestyle.

These results are consistent with our hypothesis and the dual models of physical activity[32-35]. According to these theoretical models, our findings suggest that the fear of movement characteristic of fear of movement triggers an impulse to avoid physical activity behaviors, which contributes to the maintenance or exacerbation of the initial fear. Accordingly, fear of movement and physical inactivity would be self-perpetuating or even self-reinforcing.

Patient-Specific Interventions

The subgroup analysis reveals that the negative relationship between fear of movement and physical activity is more pronounced in certain populations, including those with a cardiac condition, a neurological condition, a pulmonary condition, arthritis, as well as older adults. This result suggests that fear of movement should be included in the management plans of these specific populations. Specifically, physical therapists, in collaboration with other health professionals, may need to address not only the physical aspects of rehabilitation, but also the psychological components related to the fear of movement. Cognitive-behavioral therapy,[186] graded exposure therapy,[187] or psychoeducation[188] are potential approaches to consider for helping patients overcome this fear.

In individuals with a cardiac condition, fear of movement and its impact on physical activity may be explained by a fear of inducing a new cardiac event[189] or "causing more damage to the heart"[190], but also by breathlessness (i.e., dyspnea), which reduces the ability to be physically active and damages confidence, leading to persistent anticipation of negative outcomes from physical activity[191]. Dyspnea is also a major barrier to physical activity in people with a pulmonary condition, such as chronic obstructive pulmonary disease (COPD)[147]. Patients with asthma may have additional disease-related barriers to physical activity, such as the fear of provoking respiratory symptoms and exacerbations[192]. Regarding neurologic conditions, chest tightness reported in patients with Parkinson's disease as a barrier to exercise may be a factor contributing to the association between fear of movement and physical activity[193]. Another potential factor in these patients[193], as well as in stroke survivors[194] and healthy older adults[195], is fear of falling. In patients with osteoarthritis, the belief that physical activity will "damage the joints"[196] and the perceived fragility of their physical status[197] may be factors contributing to the relationship between fear of movement and physical activity.

Although our results showed no evidence of an association between fear of movement and physical activity in other health conditions such as cancer, post-surgery, post-partum, or obstructive sleep apnea, these effects cannot be fully ruled out, as the lack of statistical significance could be explained by a lack of statistical power in these subgroup meta-analyses including fewer estimates (k = 1 to 5).

Pain versus Fear

Our results showed no evidence of an association between fear of movement and physical activity in people with fibromyalgia, acute pain, or chronic pain. This finding was surprising because fear of pain is a key component of fear of movement assessment, appearing in 10 of the 17 items on the TSK-17 and TSK-Heart scales, and reinforces the importance of considering the multidimensional nature of fear of movement, which not only relates to pain but also reflects fear of injury and fear of worsening a health condition. Because pain could have influenced the results in other health conditions, we conducted a meta-regression analysis including all studies that assessed pain, irrespective of health condition. Again, results showed no statistical evidence suggesting that pain intensity at rest influenced the effect of fear of movement on physical activity, despite the substantial number of estimates included in this analysis (k = 49). These results are consistent with the weak relationship that has previously been reported between fear of movement and pain[198]. These results suggest that in these populations, other factors, such as psychological distress and actual pain intensity, may play a more prominent role than fear of movement in influencing physical activity levels.

However, this absence of evidence might be related to the methods used to assess pain, which may be better assessed by pain history (e.g., pain duration in months, whether it is transient or constant) or pain intensity during exercise. Another explanation may be that the assessments of physical activity in the included studies focused on differences in intensity but did not differentiate between types of activities (e.g., aerobic activities, strength training, stretching, balance activities). However, the relationship between fear of movement and physical activity may depend on the type of physical activity. Consistent with this potential explanation, studies of chronic pain suggest that physical activity is not always avoided altogether and that avoidance behaviors may be more subtle.[199] For example, some physical activities, such as strength training, may be fear-inducing in this population, whereas walking may not be because it is known to be painless and to improve spinal health. Therefore, future studies should examine whether the relationship between fear of movement and physical activity is moderated by the type of physical activity.

Self-Report versus Device-Based Measures of Physical Activity

Importantly, the negative correlation between fear of movement and physical activity was observed both in studies using self-report (e.g., IPAQ) and device-based measures of physical activity (i.e., accelerometers or pedometers), suggesting that they are similarly effective in capturing the relationship between fear of movement and physical activity. Self-report and device-based measures of physical activity have shown low to moderate correlations,[200] suggesting that they provide related, but distinct information. The information assessed by both measures is the level of physical activity; the distinct information is related to factors that specifically influence the self-report measure, such as social desirability, quality of life, well-being, and social support.[201,202] While device-based measures of physical activity are more valid than self-reports, our results suggest that the latter provide a sufficiently valid measure of physical activity for assessing its relationship with fear of movement.

Study Heterogeneity

The considerable heterogeneity across the included studies may be explained by the diversity of the methods used to assess physical activity (questionnaires vs. accelerometers vs. pedometers), the instruments used in these methods (14 different questionnaires, 14 different accelerometers and pedometers), and the physical activity outcomes (n = 6), but also by the different questionnaires used to assess fear of movement (n = 11). This heterogeneity underlines the need for individualized treatment approaches. Rehabilitation professionals should consider the broader context of each patient's condition, including their health status, psychological profile, and environmental factors, rather than applying a one-size-fits-all approach to reducing fear of movement.

Limitations

The results of this systematic review and meta-analysis should be interpreted with consideration of several limitations. (2) Because fear of movement is a state, i.e., a dynamic psychological variable, the time difference between the physical activity and fear of movement assessments, as well as the context of assessment, may have influenced the results. (3) While a subgroup meta-analysis showed no evidence of an effect of the type of TSK scale, inconsistencies have been noted in the purported dimensions assessed by different TSK scales or across populations[203], which may have influenced our results. (4) Only 21 of the 98 authors we contacted (21%) shared their estimates (n = 13) or raw data (n = 8) with us, which is more than reported in previous literature[204]. Including these missing data may have affected the results.

Conclusion

Higher levels of fear of movement were associated with lower levels of physical activity, especially in people with a cardiac, neurologic, arthritic, and pulmonary condition. According to theoretical models, this relationship between fear of movement and physical activity results from automatic processes that may be self-reinforcing and should therefore not be overlooked. However, heterogeneity between studies was substantial-to-considerable for some results, and the evidence for publication bias calls for cautious conclusions about this potential relationship. More evidence is required to determine the impact fear of movement should have on therapeutic decisions when aiming to maintain or increase physical activity. Particularly, prospective studies are needed to better understand the factors and mechanisms that influence the relationship between fear of movement and physical activity.

This study underscores the importance of integrating psychological care into physical rehabilitation, particularly for patient populations for whom fear of movement is a significant barrier to recovery. Rehabilitation professionals should be trained to recognize psychological barriers and be aware of evidence-based interventions that can modify maladaptive beliefs about movement, ultimately promoting more active lifestyles.

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Data and Code Sharing

According to good research practices[44], the dataset, R Markdown script, and supplemental material are freely available in Zenodo[205]. A preprint version of this manuscript is publicly available online[206] and has been recommended by Peer Community In Health & Movement Sciences[207].

Conflict of Interest Disclosure

The authors declare they have no conflict of interest relating to the content of this article.

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Chapter 3

Approach-Avoidance Tendencies Influence the Relationship Between Fear of Movement and Physical Activity in Osteoarthritis

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Preface

This study has been approved by the University of Ottawa research Ethics Board (REB#: H-05-21-6791). The ethics approval letter, approved consent forms (both the French and English) and approved online questionnaires (both the French and English) can be found in the thesis appendix. Based on the Contributor Roles Taxonomy (CRediT), individual author contributions to this work are as follows: Miriam Goubran: Conceptualization; Investigation; Writing – Original Draft. Christian Zammar: Investigation. Santiago Tellez Alvarez: Investigation. Élodie Heran: Investigation. Sara Proulx: Investigation. Martin Bilodeau: Conceptualization; Writing – Original Draft; Supervision (MG); Project Administration. Matthieu P. Boisgontier: Conceptualization (Lead); Methodology; Formal Analysis; Data Curation; Visualization; Writing – Original Draft (Lead); Writing – Review and Editing; Supervision (MG, CZ, STA, EH, SP); Project Administration; Funding Acquisition.

Abstract

Research question. Do psychological processes, such as explicit attitudes and approach-avoidance tendencies toward physical activity, mediate or moderate the relationship between fear of movement and usual physical activity levels in people with osteoarthritis?

Methods. An online observational study was conducted in 197 participants, including 68 with osteoarthritis. Arthritis, fear of movement, usual physical activity level, and explicit attitudes were assessed using questionnaires. Approach-avoidance tendencies, an indicator of automatic attitudes, was derived from reaction times in an approach-avoidance task.

Results. Results showed that higher fear of movement was associated with lower physical activity levels in participants with osteoarthritis. This association was moderated by approach-avoidance tendencies toward physical activity, with a significant effect only in participants with an automatic tendency to avoid physical activity or a weak tendency to approach it.

Conclusion. This study suggests that in adults with osteoarthritis, the detrimental effect of fear of movement on usual physical activity levels may be mitigated by strong automatic tendencies to approach physical activity. Since these tendencies result from the automatic activation of affective memories, health professionals should consider not only promoting physical activity but also ensuring its association with positive emotional experiences.

Keywords. Arthritis, Exercise, Health, Kinesiophobia, Motivation, Neuroscience, Psychology

Introduction

Arthritis is an inflammatory disease that primarily affects synovial joints and is often associated with pain, stiffness, swelling, and reduced range of motion, which can ultimately lead to permanent disability.[1-3] Exercise programs have been shown to be safe and effective in improving the condition of patients with arthritis, particularly in reducing pain and enhancing muscle strength.[4,5] However, physical inactivity is almost twice as common in people with arthritis (31%) as in people without arthritis (17%).[6] In addition, some comorbidities may further limit the ability to participate in physical activity.

One of these comorbidities is fear of movement, defined as an excessive, irrational, and debilitating fear of moving, resulting from a sense of vulnerability to pain, injury, or a medical condition.[7] Fear of movement results from the repeated expression of negative affective responses in relation to physical activity.[8] Here, we propose that this repetition underpins the formation of negative associations driving automatic processes that manifest as attitudes and triggering avoidance impulses to physical activity. The prevalence of fear of movement in patients with osteoarthritis is 58%.[9] This high prevalence, combined with the association between higher fear of movement and lower physical activity reported in a recent meta-analysis ($r = -.25$; 95% confidence intervals [95CI] = -.39 to -.10),[10] may explain why people with arthritis are less active than those without arthritis.[6] However, the mechanisms underlying this association remain poorly understood.

Attitude is defined as a psychological tendency to evaluate a stimulus with some degree of favor or disfavor that operates on two levels: automatic and explicit.[11] Automatic (formerly implicit)[12] attitudes are traces of past experience that remain introspectively unidentified and mediate favorable or unfavorable evaluation of a behavior.[13] This evaluation results in an automatic positive or negative inclination toward that behavior.[11-13] For instance, when an individual perceives a cue related to bodily movement, this may automatically activate affective memories (positive or negative) associated with the concept of physical activity.[14] This activation may generate an impulse, or motor readiness, that favors either the approach or avoidance of physical activity.[15,16] In contrast, explicit attitudes are deliberate, reflective evaluations that individuals are consciously aware of, can articulate, and have some control over.[17]

Stronger automatic tendencies to approach images depicting physical activity[18] and more positive explicit attitudes toward physical activity[19] have been shown to be associated with higher levels of physical activity engagement. In addition, both approach-avoidance tendencies and have been explicit attitudes shown to be influenced by health conditions, such as apathy.[19] Therefore, these two psychological constructs may affect the relationship between another health condition, fear of movement, and physical activity engagement.

The objective of this study was to examine the relationship between fear of movement, explicit attitudes toward physical activity, approach-avoidance tendencies toward physical activity, and usual physical activity levels in adults with arthritis. We hypothesized that (1) fear of movement would be higher in people with arthritis than in those without arthritis; (2) explicit attitudes and approach-avoidance tendencies would mediate or moderate the effect of fear of movement on physical activity levels (Figure 1).

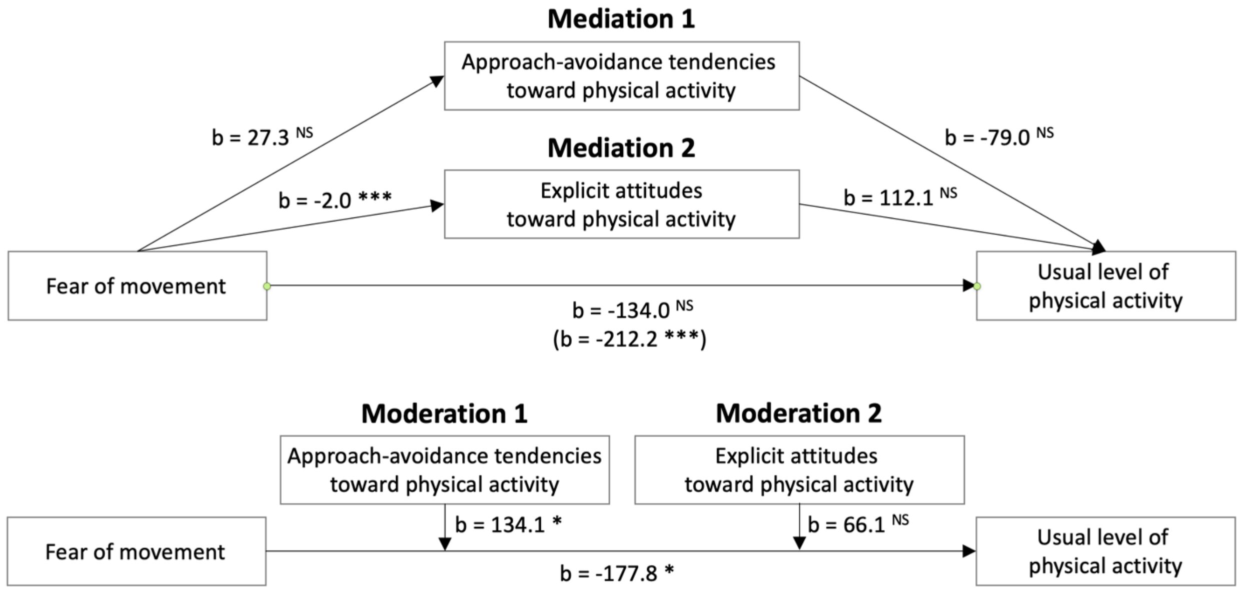

Figure 3.1. Tested mediation and moderation models in people with osteoarthritis. Notes: *p<.05; ***p<.001; NS = not significant; Notes: b = regression coefficient.

Methods

Population

Participants were recruited through social media (Facebook), posters at the Faculty of Health Sciences, University of Ottawa, and emails to associations of patients with arthritis and caregivers. Inclusion criteria were age 20–90 years and access to a personal computer, a laptop, or a tablet with internet. Informed consent was collected in accordance with the Declaration of Helsinki. The study was approved by University of Ottawa's Research Ethics Boards (H-05-21-6791). All participants provided informed consent.

Power analysis

An a priori power analysis was conducted in G*power[20] to estimate the minimum sample required for a two-tailed test with $\alpha = 0.05$, power $(1-\beta) = 90\%$, and a medium effect size $f^2 = 0.2$.[21]

The analysis based on an F test in a linear multiple regression (R^2 increase) that included two tested predictors and eight control variables estimated that a minimum total sample size of n = 67 was required for the moderation analysis. The sample size for the mediation analysis was lower as the models had one tested predictor per model and a maximum of 7 control variables.

Experimental protocol

Procedures

Participants remotely and anonymously completed the study online using Inquisit software[22] and provided information related to their arthritic condition, fear of movement, pain during exercise, usual level of moderate-to-vigorous physical activity, age, sex (male, female), gender (man, woman, non-binary, transgender man, transgender woman, other), weight, height, and explicit attitudes toward physical activity. One attention check question was included in the questionnaires: 'Please answer '5' to this question that allows us to verify that you actually read the questions.' Automatic attitudes toward physical activity and sedentary behavior were tested using an approach-avoidance task.

Self-reported variables

Arthritis. The presence of arthritis was derived from a question based on item PH006 of the Survey of Health, Ageing and Retirement in Europe.[23] 'Has a doctor ever told you that you had any of the following conditions?' The participants who selected 'arthritis, including osteoarthritis, or rheumatism' but not 'rheumatoid arthritis' were considered as participants with osteoarthritis. The participants who selected both options (n = 12) or 'rheumatoid arthritis' only (n = 1) were not included in the analyses.

Chronic conditions. The total number of chronic conditions was used as a control variable in the analyses (Suppl. Material 1).

Fear of movement. Fear of movement was assessed using a modified version of the 11-item Tampa Scale of Kinesiophobia.[24]

Usual level of moderate-to-vigorous physical activity. The usual level of physical activity was derived from the short form of the International Physical Activity Questionnaire (IPAQ-SF), a self-administered questionnaire that identifies the frequency and duration of moderate and vigorous physical activity during the past seven days.[25] The usual level of moderate-to-vigorous physical activity in minutes per week was used in the analyses.

Explicit attitudes. Explicit attitudes toward physical activity were assessed through two items based on two bipolar semantic differential adjectives on a 7-point scale (unpleasant-pleasant; unenjoyable-enjoyable). The statement begins with 'For me, to participate in regular physical activity is …'.[18,26] These two scores showed a very strong correlation ($r = .939$; $p < 2.2\times10^{-16}$), and their sum was used as an indicator of explicit attitudes in the statistical analyses.

Pain. Pain was measured to account for its potential confounding effect and was dervived from the statement: 'During physical activity, I experience ...' with the possible responses ranging from 0 ('no pain') to 7 ('pain as bad as it can possibly be').

Automatic approach-avoidance tendencies

Participants performed an approach-avoidance task (Figure 2A; Suppl. Material 1).[18,19,26] Automatic tendencies were derived from reaction times (i.e., the time between stimulus appearance and key press) to approach or avoid stimuli depicting neutral, sedentary, and physical activity stimuli (Figure 2B).

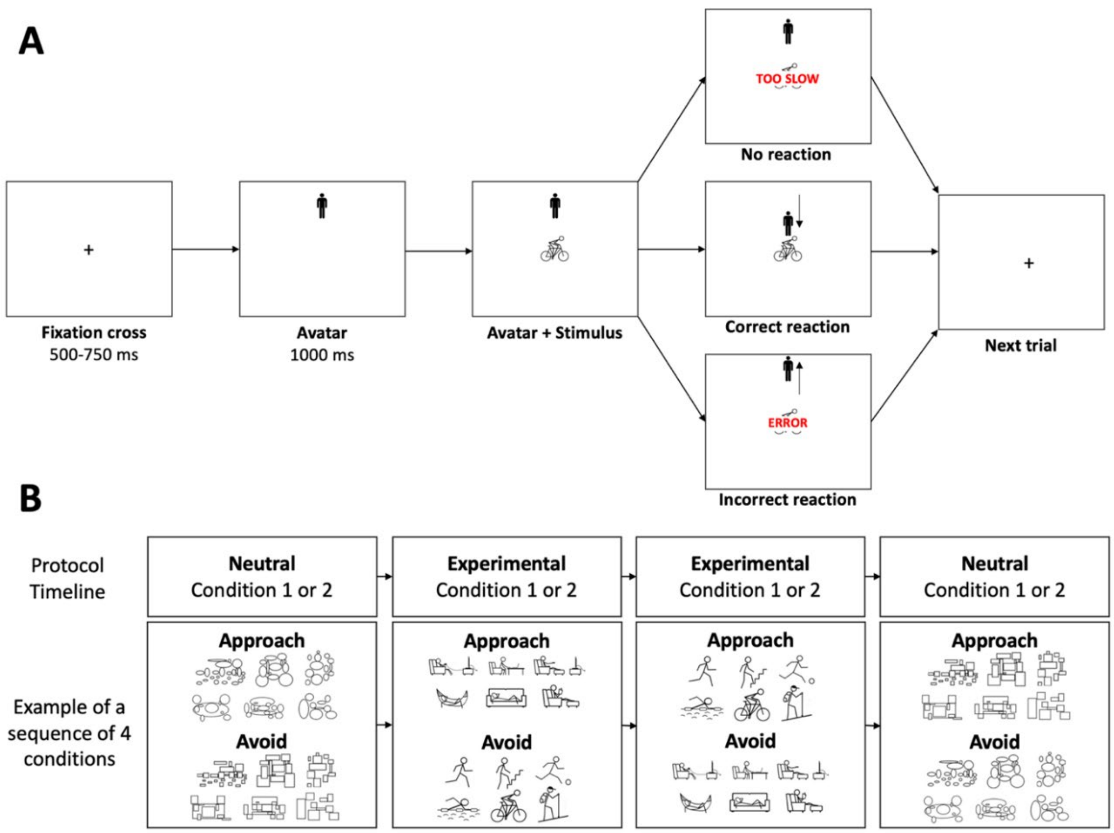

Figure 3.2. Illustration of a single trial of the approach-avoidance task and types of stimuli.

A. Illustration of a single trial of the approach-avoidance task in the condition where the participant is instructed to approach physical activity stimuli (and avoid sedentary stimuli – not shown). B. Timeline and stimuli of the approach-avoidance task. In Condition 1 (experimental and neutral), participants are instructed to move the avatar toward (approach) a specific type of stimuli (physical activity stimuli or rectangles) and away from (avoid) the other type of stimuli (sedentary behavior or ellipses, respectively). In Condition 2, the instructions are reversed: Participants move away from physical activity or rectangle stimuli and toward sedentary behavior or ellipse stimuli.

Statistical analyses

Arthritis status and fear of movement

To test the effect of fear of movement on usual physical activity levels in people with and without arthritis, we performed multiple linear regression analyses testing the interaction between fear of movement and arthritis status (any arthritis vs. no arthritis) and ostseoarthritis status (osteorthritis vs. no arthritis), and including five control variables (age, sex, body mass index, pain, and number of chronic conditions). The lm() and confint() function from the 'stats' package in the R software environment[27] were respectively used to conduct the models and compute 95CI. A separate analysis of participants with rheumatoid arthritis is reported in Suppl. Material 2.

Mediation analysis

To examine the mediating effect of approach-avoidance tendencies and explicit attitudes toward physical activity on the association between fear of movement and usual physical activity levels in people with osteoarthritis only, we used the component approach, which involves three linear multiple regression models.[28] Model 1 tests whether the independent variable (i.e., fear of movement) affects the outcome (i.e., physical activity). Model 2 tests the effect of the independent variable on the mediators (approach-avoidance tendencies [Mediation 1] or explicit attitudes [Mediation 2]). Model 3 tests both the independent variable and the mediators as simultaneous predictors of the outcome. Mediation is claimed if the above-mentioned effects are observed and if the 'total effect' of the dependent variable in Model 1 is larger in absolute value than its 'residual effect' in Model 3. Five control variables were included in these models (age, sex, body mass index, pain, and number of chronic conditions).

Moderation analysis

To examine the moderating effect of approach-avoidance tendencies (Moderation 1) and explicit attitudes toward physical activity (Moderation 2) on the association between fear of movement and the usual level of physical activity engagement in people with osteoarthritis only, we examined the interaction effects of fear of movement with explicit attitudes and approach-avoidance tendencies toward physical activity on the dependent variable (usual level of physical activity). The control variables were the same as in the other models (age, sex, body mass index, pain, chronic conditions).

Results

Descriptive results

Two hundred and fifty-six participants initiated the study. Fifty-six were excluded because they stopped the session before completing the study. Three participants who completed the full study were excluded because they answered the check question incorrectly. When participants reported height <50 cm or >250 cm or weight <30 kg or >250 kg, the data was removed and imputed by the mean value of the sample. The final sample of 197 participants included 116 participants without arthritis, 68 participants with osteoarthritis but no rheumatoid arthritis, and 13 participants with rheumatoid arthritis, including 12 participants who also had osteoarthritis (Table 1; Suppl. Figure 1). Participants with both osteoarthritis and rheumatoid arthritis were not included in the analyses. One male without arthritis identified themselves as a woman. All the other male (n = 75) and female participants (n = 121) identified themselves as men and women, respectively.

Table 3.1. Descriptive statistics stratified by arthritis status

Variable	No Arthritis (n = 116)	Osteoarthritis (n = 68)	Cohen's d	*p*	
Number of male / female participants	53 / 63	20 / 48			
Fear of movement (mean ± SD)	27.2 ± 11.6	31.7 ± 13.0	0.368	.021	*
Physical activity (mean ± SD)	449.4 ± 537.2	425.9 ± 548.1	-0.043	.778	
Age (mean ± SD)	55.3 ± 18.5	65.4 ± 11.3	0.621	$<2\times10^{-16}$	***
Pain (mean ± SD)	2.64 ± 1.3	3.2 ± 1.5	0.427	.009	**
Body mass index (mean ± SD)	27.6 ± 8.8	27.4 ± 7.2	-0.023	.876	
Chronic Conditions (mean ± SD)	1.1 ± 1.3	2.7 ± 1.3	1.178	$<2\times10^{-16}$	***

Note: *p<.05; **p<.01; ***p<.001

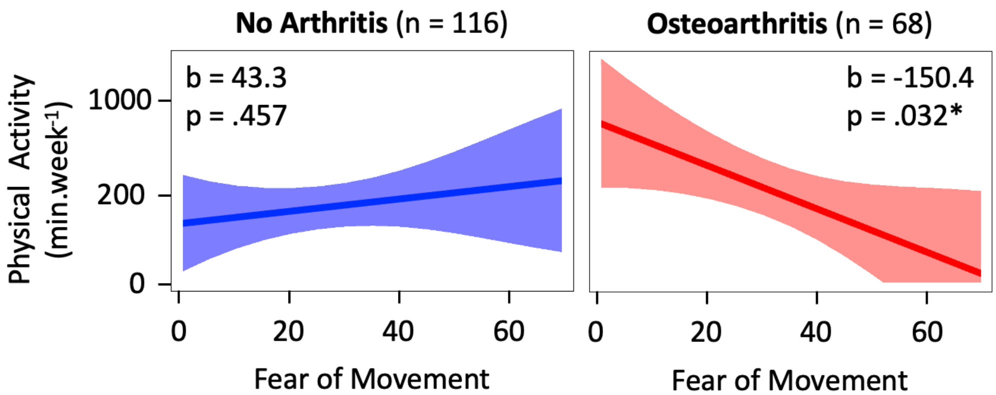

Figure 3.3. Simple effect of fear of movement on the usual physical activity level in participants without arthritis and with osteoarthritis.

*p<.05; b = regression coefficients per standard deviation change in fear of movement; x axis is in raw scale to facilitate interpretation.

Statistical results

Effect of arthritis on the association between fear of movement and physical activity

The multiple linear regression showed a moderating effect of arthritis status (osteoarthritis vs. no osteoarthritis) on the association between fear of movement and the usual level of moderate-to-vigorous physical activity (b = 193.7; 95CI = -23.6 to 363.8; p = .026) (Suppl. Table 1). A simple effects analysis revealed that higher fear of movement was associated with lower physical activity in people with osteoarthritis (b = -150.4; 95CI = -287.5 to -13.2; p = .032), but showed no evidence in people without arthritis (b = 43.3; 95CI = -71.5 to 158.1; p = .457) (Figure 3).

Table 3.2. Mediation analysis: Estimated effects on the outcome measure (Model 1 and Model 3) and on the hypothesized mediators (Model 2A and 2B) in participants with osteoarthritis (n = 68)

	Model 1 Usual level of physical activity				**Model 3** Usual level of physical activity			
Variables	b	95CI	*p*		b	95CI	*p*	
(Intercept)	553.1	255.8;850.4	4.3×10^{-4}	***	512.1	216.1;808.0	.001	**
Age	-234.6	-441.0;-28.1	.027	*	-240.8	-446.3;-35.3	.022	*
Sex	186.4	-96.3;469.0	.192		179.3	-98.3;456.9	.201	
Body mass index	101.1	-57.0;259.3	.206		110.6	-46.6;267.8	.164	
Pain	85.0	-59.6;229.6	.244		88.9	-52.9;230.6	.214	
Chronic conditions	-26.2	-136.4;83.9	.636		-9.0	-118.1;100.1	.870	
Approach tendencies					-79.0	-183.0;25.1	.122	
Explicit attitudes					112.1	-30.8;255.0	.134	
Fear of movement	-212.2	-360.7;-63.6	5.8×10^{-3}	***	-134.0	-305.0;808.0	.547	

	Model 2 for Mediation 1 Approach-avoidance tendencies				**Model 2B for Mediation 2** Explicit attitudes			
Variables	b	95CI	*p*		b	95CI	*p*	
(Intercept)	86.2	-94.2;266.6	.343		12.0	10.3;13.7	$<2\times10^{-16}$	***
Age	-73.3	-198.6;117.4	.246		-0.5	-1.7;0.7	.412	
Sex	-44.0	-215.5;127.5	.610		-0.2	-1.8;1.4	.810	
Body mass index	-29.1	-125.1;66.8	.546		-0.5	-1.5;0.4	.237	
Pain	13.7	-74.0;101.4	.756		0.01	-0.8;0.8	.976	
Chronic conditions	24.5	-42.3;91.3	.467		-0.3	-0.9;0.4	.382	
Fear of movement	27.3	-62.9;117.4	.547		-2.0	-2.9;-1.2	1.2×10^{-5}	***

Notes: *p<.05; **p<.01; ***p<.001; b = regression coefficient; 95CI = 95% confidence interval

Mediation analysis

In the sample of participants with osteoarthritis (n = 68), Model 1 of the mediation analysis showed an association between fear of movement and the usual physical activity levels (b = -212.2; 95CI = -360.7 to -63.6; p = 5.8×10^{-3}). Model 2 for Mediation 1 showed no evidence of an association between fear of movement and approach-avoidance tendencies toward physical activity (b = 27.3; 95CI = -62.9 to 117.4; p = .547), ruling out these tendencies as a mediator. Model 2 for Mediation 2 showed an association between fear of movement and explicit attitudes toward physical activity (b = -2.0; 95CI = -2.9 to -1.2; p = 1.2×10^{-5}). However, Model 3 showed no evidence of an association between explicit attitudes and the usual physical activity levels (b = 112.1; 95CI = -30.8 to 255.0; p = .134). Taken together, these results suggest that the relationship between fear of movement and usual physical activity levels is not mediated by approach-avoidance tendencies or explicit attitudes toward physical activity (Figure 1; Table 3.2.).

Moderation analysis

In the sample of participants with osteoarthritis (n = 68), the moderation analysis showed an interaction effect between fear of movement and approach-avoidance tendencies toward physical activity on usual physical activity levels (b = 134.1; 95CI = 18.0 to 250.2; p = .024) (Moderation 1; Figure 3.1.; Figure 3.4.; Table 3.3.). A simple effects analysis revealed that fear of movement was negatively associated with usual physical activity levels when participants had a tendency to avoid physical activity (i.e., mean neutral-adjusted reaction time to avoid physical activity stimuli – mean neutral-adjusted reaction time to approach this type of stimulus < 0 ms) or a weak tendency to approach physical activity (< 101 ms). However, when the mean neutral-adjusted reaction time required to approach physical activity stimuli was 101 ms or faster than the mean neutral-adjusted reaction time to avoid such stimuli (indicating a stronger tendency to approach physical activity), fear of movement was no longer associated with lower levels of physical activity (Figure 3.4.). The interaction between fear of movement and explicit attitudes was not significant (b = 66.1; 95CI = -35.0 to 167.3; p = .196) (Moderation 2; Table 3.3.).

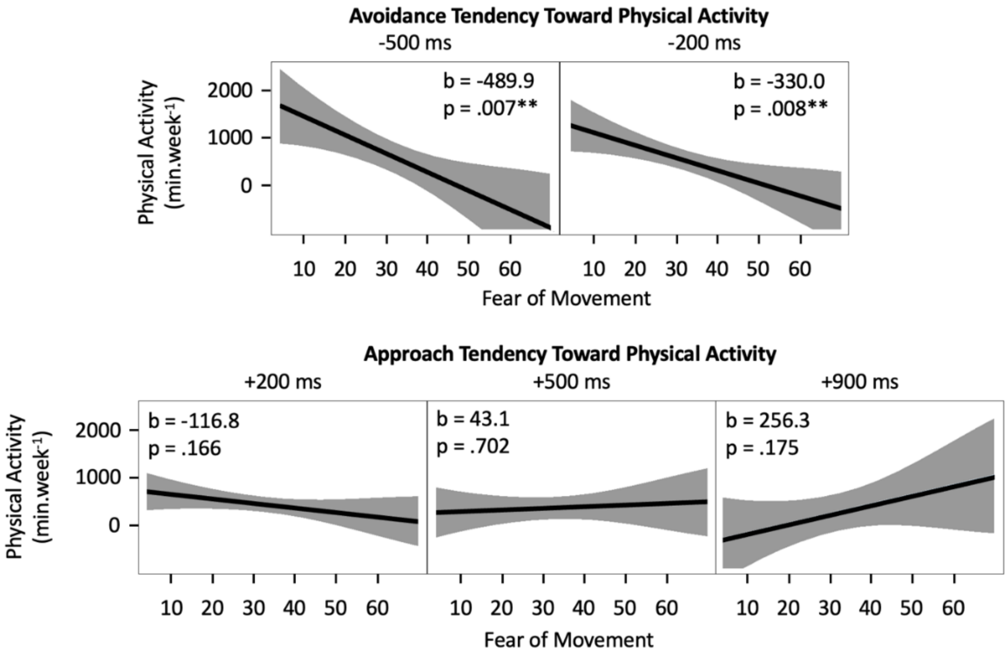

Figure 3.4. Illustration of Moderation 1 Simple effect of fear of movement on usual physical activity level as a function of approach or avoidance tendency toward physical activity

*Measured by mean neutral-adjusted reaction time difference (avoid physical activity stimuli approach physical activity stimuli). A negative difference indicates faster avoidance of physical activity stimuli (i.e., avoidance tendency; top panel), and a positive difference indicates faster approach (i.e., approach tendency; bottom panel). **p<.01*

Table 3.3. Moderation analysis: Estimated effects on the usual level of moderate-to-vigorous physical activity (n = 68 participants with osteoarthritis).

Variables	b	95CI	*p*	
(Intercept)	474.1	182.0;766.1	.002	**
Age	-297.1	-502.3;-92.0	.005	**
Sex	250.3	-33.7;534.2	.083	
Body mass index	76.2	-79.1;232.2	.332	
Pain	94.6	-43.1;232.3	.174	
Chronic conditions	15.6	-92.7;124.0	.774	
Approach-avoidance tendencies	-84.9	-187.1;17.2	.101	
Explicit attitudes	84.1	-68.1;236.3	.273	
Fear of movement	-177.8	-349.0;-6.6	.042	*
Fear of movement × Tendencies	134.1	18.0;250.2	.024	*
Fear of movement × Attitudes	66.1	-35.0;167.3	.196	

Notes: *p<.05; **p<.01; 95CI = 95% confidence interval

Discussion

Main findings

Our results showed an association between fear of movement and usual moderate-to-vigorous physical activity levels in people with osteoarthritis. In this population, higher fear of movement was associated with lower physical activity engagement, but only in participants with an automatic tendency to avoid physical activity stimuli or a weak tendency to approach them. In addition, contrary to our hypothesis, greater fear of movement was associated with stronger automatic tendencies to approach physical activity and to avoid sedentary behaviors.

Fear of movement and physical activity in people with arthritis

Our results support previous literature showing a negative association between fear of movement and physical activity in people with osteoarthritis.[29-32] These results suggest that osteoarthritis creates physical and psychological conditions[1] that make people more susceptible to the effects of fear of movement, thereby moderating its relationship with physical activity. Promoting gradual and supervised physical activity through education and reassurance from a health professional may help to mitigate this moderation effect.[33] However, this process may be challenging in patients with chronic conditions such as arthritis, where pain is a common symptom that reduces the capacity to associate enjoyment and physical activity. Future work is needed to better understand how intervention targeting this association can be tailored to individuals with chronic conditions.

Moderation by approach-avoidance tendencies

Our results showed that the negative association between fear of movement and physical activity was dependent on the automatic tendency to approach or avoid physical activity stimuli. Specifically, this association became nonsignificant when approach tendencies toward physical activity were stronger. This finding highlights the importance of approach-avoidance tendencies in regulating physical activity behavior and is consistent with intervention studies targeting automatic attitudes. These interventions have been successful in modifying unhealthy behaviors, such as alcohol consumption, smoking, and eating behavior.[34,35] Whether such interventions can improve physical activity engagement is currently being investigated[36-39] and could benefit from new robotic tools.[40]

Avoidance tendencies toward physical activity result from the automatic activation of unpleasant affective memories that have been associated with the concept of physical activity during past experiences.[11] Because our results suggest that avoidance tendencies potentialize and amplify the detrimental effects of fear of movement, health professionals should aim to minimize the risk for such an association in their interventions by fostering pleasurable and emotionally positive physical activity experiences. This suggestion is consistent with existing literature highlighting the role of pleasure and displeasure in physical activity engagement.[41,42]

Limitations

Our results should be considered in light of potential limitations. First, arthritis status was self-reported, which may introduce measurement bias and lead to misclassification of participants. However, the agreement between self-reported arthritis and medical records ranges from 71% for osteoarthritis to 91% for rheumatoid arthritis.[43] Second, the high self-reported physical activity levels should be considered in light of evidence that the IPAQ-SF overestimates physical activity by an average of 84% when compared to objective measures.[44] Assessing physical activity and sedentary behaviors using device-based measures would have provided more reliable estimates. Third, the online nature of the study made it impossible to limit the influence of potential distractions in the participant's environment (e.g., noise that would detract from the task) and to control whether participants were using their two index fingers to perform the task as instructed and whether they were sitting or standing, which may have influenced the results.[45] Fourth, the format of the modified version of the Tampa Scale of Kinesiophobia, which uses a 7-point scale instead of the 4-point scale, has not been validated. However, statistical properties (e.g., variance, skewness) have been shown to be similar across scale format.[46] In addition, the items of this modified scale are validated as they are the same as in the original scale. Fifth, the level of arthritis was not assessed, which may influence psychological processes and contribute to heterogeneity within the osteoarthritis group. Future studies should control or test for the potential effect of arthritis severity.

Conclusion

Although fear of movement hinders engagement in physical activity in people with osteoarthritis, interventions that target the underlying mechanisms of approach-avoidance tendencies may overcome this barrier. Physical therapists[59] and other health professionals should not only promote physical activity, but also ensure that it is associated with positive emotional experiences. These positive associations may reshape automatic tendencies to counteract avoidance behaviors driven by fear of movement and contribute to increased engagement in physical activity.

Declarations

Data and code availability

According to good research practices,[47] the dataset and the R script are available in Zenodo.[48] This manuscript was published before peer review on the MedRxiv preprint repository on January 25, 2025.[49] This preprint version includes additional analyses based on linear mixed effects models testing whether fear of movement was associated with approach-avoidance tendencies. This analysis was not included in the present article due to word limit policy

Reporting guidelines

This manuscript conforms to the STROBE guidelines for observational studies.[62] This manuscript conforms to the STROBE guidelines for observational studies.[51]

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Conflict of interest

The authors declare that there are no conflicts of interest related to the content of this article.

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Supplementary Materials

Approach-Avoidance Tendencies Moderate the Relationship Between Fear of Movement and Physical Activity in Osteoarthritis

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Supplementary Table 1. Estimated effects on the usual level of moderate-to-vigorous physical activity (n = 184 including 68 participants with osteoarthritis and 126 without osteoarthritis).

Supplementary Figure 1. Participant flowchart

Supplementary Material 1. Variables

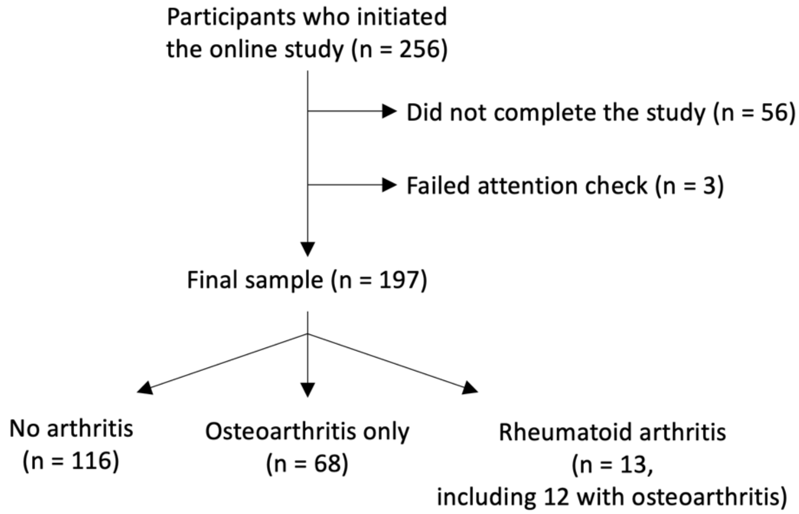
Supplementary Material 2. Rheumatoid arthritis

Supplementary Table 3.1. Estimated effects on the usual level of moderate-to-vigorous physical activity (n = 184 including 68 participants with osteoarthritis and 116 without arthritis).

Variables	b	95CI	*p*	
(Intercept)	470.9	254.4;687.4	2.9×10^{-5}	***
Age	-42.0	-135.6;51.0	.373	
Sex	196.4	34.0;358.9	.018	*
Body mass index	35.7	-43.8;115.1	.377	
Pain	-3.3	-95.3;88.6	.943	
Chronic conditions	-22.6	-90.6;45.3	.511	
Osteoarthritis status (presence vs. absence)	-86.7	-275.8;-13.2	.366	
Fear of movement	-150.4	-287.5;-13.2	.032	*
Fear of movement × Arthritis status	193.7	-23.6;363.8	.026	*

Notes: *p<.05; ***p<.001; b = regression coefficient; 95CI = 95% confidence interval

Supplementary Figure 3.1. Participant flowchart



Supplementary Material 1. Variables

Chronic conditions

The other possible answers to the question based on item PH006 of the Survey of Health, Ageing and Retirement in Europe were ‘A stroke or cerebral vascular disease’, ‘High blood pressure or hypertension’, ‘High blood cholesterol’, ‘Diabetes or high blood sugar’, ‘Chronic lung disease such as chronic bronchitis or emphysema’, ‘Asthma’, ‘Osteoporosis’, ‘Cancer or malignant tumour, including leukaemia or lymphoma, but excluding minor skin cancers’, ‘Stomach or duodenal ulcer, peptic ulcer’, ‘Parkinson’s disease’, ‘Hip fracture or femoral fracture’, ‘Alzheimer’s disease, dementia, organic brain syndrome, senility or any other serious memory impairment’, ‘Other affective or emotional disorders, including anxiety, nervous or psychiatric problems’, ‘Chronic kidney disease’, ‘Other conditions, not yet mentioned’, and ‘None’.

Fear of movement

A modified version of the 11-item Tampa Scale of Kinesiophobia (TSK) assessed the participants’ fear of injury during exercise, their susceptibility to injury, the evolution of their pain should they try to overcome it or to exercise, and the safety of physical activity for people with their condition. The instructions to the participants were as follows: ‘Please answer the following questions according to your true feelings, not according to what others think you should believe. Score each statement from strongly disagree (1) to strongly agree (7) by tapping the appropriate box. Select ‘NA’ if the statement is not applicable to you.’ Therefore, the score ranged from 0 (only NAs) to 77. The 7-point scale was used instead of the 4-point scale to avoid forcing the participant to commit to a certain position when they did not have a definite opinion on the statement. The “NA” option was added so that participants could choose not to respond if the statement was not applicable to them (e.g., statements related to pain increase for participants who did not experience any pain).

Automatic approach-avoidance tendencies

The approach-avoidance task includes two experimental conditions and two neutral conditions (Cheval et al., 2018; Farajzadeh et al., 2023, 2024). In the experimental conditions, each trial begins with a fixation cross displayed in the center of the screen for a random amount of time ranging from 500 to 750 ms (Figure 2A). An avatar then appears in either the upper or lower third of the screen for 1 second, followed by a pictogram in the center of the screen representing an active or sedentary behavior (Figure 2A). The participant, seated in front of the computer with their index fingers positioned on the ‘U’ (top) and ‘N’ (bottom) keys, is instructed that pressing the top key moves the avatar upward and pressing the bottom key moves it downward. The action (approach or avoidance) depends on the avatar’s initial position. When the avatar appears below the stimulus, the top key performs an approach movement, while the ‘N’ key performs an avoidance movement. Conversely, when the avatar appears above the stimulus, the approach and avoidance movements are reversed: The top key performs an avoidance movement and the bottom key performs an approach movement.

In one experimental condition, participants were instructed to quickly move the avatar toward (approach) pictograms depicting physical activity and move the avatar away from (avoid) pictograms depicting sedentary behavior (Figure 2B). In the other experimental condition, the instructions were reversed: Participants moved the avatar away from physical activity and toward sedentary stimuli. The order of the experimental conditions was randomized across participants. The neutral conditions were included to account for generic approach-avoidance tendencies (i.e., not tied to a specific type of stimulus) that might differ across participants (Farajzadeh et al., 2023).

In these neutral conditions, the pictograms representing physical activity and sedentary behaviors were replaced with abstract stimuli (rectangles or ellipses) that matched the number and size of information present in three physical activity stimuli (swimming, hiking, cycling) and three sedentary stimuli (couch, hammock, reading). Two neutral conditions were tested. In one condition, participants were instructed to move the avatar toward stimuli with circles and away from stimuli with squares. In the other condition, the instructions were reversed. The order of the neutral conditions was randomized.

One neutral condition was tested before and the other neutral condition was tested after the two experimental conditions. Each condition contained 96 stimuli, 48 of each type (physical activity and sedentary stimuli in the experimental conditions; rectangles and ellipses in the neutral conditions), presented in random order. Task familiarization was performed during the first 15 trials of the study, which were excluded from the analyses. Additionally, the first three trials of each subsequent condition served as familiarization for that condition and were also excluded from the analyses. Before starting each experimental condition, all physical activity and sedentary stimuli were displayed on the screen for seven seconds to ensure participants were familiar with the stimuli. Participants were allowed to rest for as long as needed between conditions, resuming the task by pressing the space bar. During the task, if the participant pressed the incorrect key, the message ‘error’ was displayed on the screen for 800 ms before the next trial. Similarly, if the reaction time, measured as the interval between stimulus appearance and key press, exceeded seven seconds, the message 'too slow' was displayed for 800 ms before the next trial (Figure 2A).

Automatic approach-avoidance tendencies were derived from reaction times, i.e., the time between stimulus appearance and key press. For each trial in the experimental conditions (i.e., physical activity and sedentary stimuli), reaction time was adjusted by subtracting the mean reaction time for approaching or avoiding neutral stimuli from the raw reaction time of that trial. The tendency to approach physical activity stimuli was computed by subtracting the mean neutral-adjusted reaction time to approach these stimuli from the neutral-adjusted reaction time to avoid them. This subtraction (avoid – approah) resulted in positive values indicating a tendency to approach physical activity (faster approach), whereas negative values indicated a tendency to avoid physical activity (faster avoidance). Incorrect responses, responses faster than 150 ms, and responses slower than 3,000 ms were excluded from the analyses to account for outliers and lapses in attention (Farajzadeh et al., 2023, 2024).

A previous study (Farajzadeh et al., 2023) showed good internal consistency (Spearman-Brown corrected splithalf = 0.83; 95 Confidence Interval = 0.77 – 0.88).

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Supplementary Material 2. Rheumatoid arthritis

To test the effect of fear of movement on usual physical activity levels in people with and without rheumatoid arthritis, we performed a multiple linear regression analysis testing the interaction between fear of movement and arthritis status (rheumatoid arthritis vs. no rheumatoid arthritis) and including five control variables (age, sex, body mass index, pain, and number of chronic conditions).

Thirteen participants with rheumatoid arthritis (age: 55.2 ± 19.5 years, physical activity: 313.8 ± 658.5 min/week, fear of movement: 40.0 ± 15.4, pain: 4.4 ± 1.3, body mass index: 28.4 ± 7.0 kg/m^2, chronic diseases: 3.8 ± 2.0, 10 female participants, 3 male participants; including 12 participants who also had osteoarthritis) were included in this analysis.

Results showed no evidence of this interaction in people with rheumatoid arthritis (b = -203.8; 95CI = -477.0 to 69.4; p = .143). However, this analysis was not adequately powered. If the sample size is too small to achieve adequate statistical power, variability in the data is high. As a result, any significant or nonsignificant effect may be due to an overestimation or underestimation of the true effect size, respectively (Brysbaert, 2019). In such cases, as for our rheumatoid arthritis subgroup, the results should be considered exploratory and should be confirmed in subsequent studies with adequate power.

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Chapter 4

Depressive Symptoms and Physical Activity Mediate the Adverse Effect of Pain on Functional Dependence in Patients With Arthritis: Evidence From the Canadian Longitudinal Study On Aging

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Preface

This article received ethics approval from the University of Ottawas Research Ethics Board (REB#: H-10-23-9760). The ethics approval letter can be found in the thesis appendix. Based on the Contributor Roles Taxonomy (CRediT), individual author contributions to this work are as follows: Miriam Goubran: Conceptualization; Writing (Original Draft); Writing (Review and Editing); Zachary M. van Allen: Methodology; Formal Analysis; Writing - Original Draft; Writing (Review and Editing); Martin Bilodeau: Conceptualization; Writing (Review and Editing); Supervision (MG); Project Administration; Matthieu P. Boisgontier: Conceptualization (Lead); Methodology; Formal Analysis; Visualization; Writing (Original Draft) (Lead); Writing (Review and Editing); Supervision (MG and ZMvA); Project Administration; Funding Acquisition.

Abstract

Objective. Arthritis is a chronic condition affecting hundreds of millions of people worldwide, often leading to pain and functional limitations. This study aimed to investigate the direct and indirect effects of pain on functional dependence in individuals with arthritis. Depressive symptoms and physical activity were examined as potential mediators of this relationship.

Methods. A total of 6972 participants with arthritis (4930 with osteoarthritis and 694 with rheumatoid arthritis) were included from the Canadian Longitudinal Study on Aging. Linear and logistic regression models were used to assess the relationships between baseline usual presence of pain or discomfort, depressive symptoms, physical activity, and functional dependence at follow-up.

Results. Baseline pain was positively associated with depressive symptoms ($b = 0.356$ [95% CI: 0.310 to 0.402]) and negatively associated with physical activity ($b = -0.083$ [95% CI: -0.125 to -0.042]). Functional dependence at follow-up was significantly predicted by baseline pain (log OR = 0.607 [95% CI: 0.261 to 0.952]), depressive symptoms (log OR = 0.358 [95% CI: 0.184 to 0.533]), and physical activity (log OR = -0.598 [95% CI: -0.818 to -0.378]). Mediation analysis showed that 23.3% of the total effect of pain on functional dependence was accounted for by the indirect effect through depressive symptoms (16.2%), physical activity (6.3%), and their serial combination (0.8%).

Conclusions. The presence of pain at baseline was associated with higher odds of functional dependence in basic and instrumental activities of daily living after a mean follow-up period of 6.3 years, with depressive symptoms and lower physical activity acting as mediators.

Impact. Our findings highlight the need for arthritis care to extend beyond pain management by incorporating strategies that address depressive symptoms and promote physical activity to preserve functional independence.

Keywords. Aged Adults; Cohort Studies; Depression; Exercise; Mental Health; Rheumatology

Introduction

The global prevalence of arthritis, particularly osteoarthritis, has risen significantly in recent decades, with cases increasing by 137% from 256 million in 1990 to 607 million in 2021.[1] If trends continue, projections indicate that 1 billion people will have osteoarthritis by 2050.[2] As a result, the burden of arthritis on society will continue to grow, since pain, a primary symptom, has been shown to predict functional decline.[3-6]

The current study builds on two theoretical frameworks explaining the relationship between pain and functional dependence. The fear-avoidance model (Vlaeyen and Linton, 2012) describes how individuals who catastrophize pain may develop pain-related fear, leading to avoidance behaviors, physical disuse, depression, and disability.[7] Similarly, the avoidance model, specifically applied to osteoarthritis, describes how pain and psychological distress can initiate a cascade starting with the avoidance of activities and leading to muscle weakness and activity limitations.[8] More recently, meta-analytic evidence has further supported the association between fear of movement and reduced physical activity across clinical populations, including rheumatologic conditions such as arthritis.[9] These models and results emphasize the role of psychological and behavioral variables in the pathway from pain to functional dependence. Informed by these frameworks, our study tested depressive symptoms and physical activity as mediators of the effect of pain on functional dependence in individuals with arthritis, using a longitudinal dataset (Fig. 1). This empirical approach aimed to clarify the extent to which these mediators operate in parallel to influence functional dependence.

Understanding the relationship between pain and functional dependence has important implications, as loss of independence significantly affects quality of life and healthcare costs.[10,11] While pain directly contributes to functional decline,[3-6] this effect may be mediated by factors related to mental and physical health. Two relevant candidate mediators of the relationship between pain and functional independence are depressive symptoms and physical activity, as both are influenced by pain[12-16] and predict functional dependence.[6,17,18] Understanding the complex relationships between pain, depressive symptoms, and physical activity, and how they collectively influence functional dependence in individuals with arthritis may inform targeted interventions in this population.

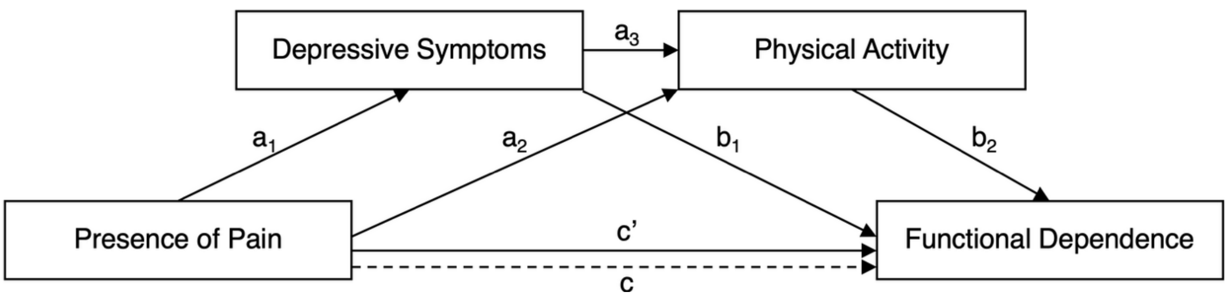

Figure 4.1. Path diagram of the serial mediation model testing the indirect effect of baseline pain on follow-up functional dependence via depressive symptoms and physical activity.

c = total effect of pain when mediators are not adjusted for; c' = direct effect of pain after adjusting for both mediators; a paths = effects of the independent variables on the mediators; b paths = effects of the mediators on the outcome variable, controlling for the independent variable; $a_1 \times b_1$ *= indirect effect through depressive symptoms;* $a_2 \times b_2$ *= indirect effect through physical activity;* $a_2 \times a_3 \times b_2$ *= indirect effect through depressive symptoms and physical activity. All paths are adjusted for age, sex, and baseline functional dependence.*

Depression is one of the most common comorbidities in arthritis, with recent meta-analyses suggesting that it affects approximately one-third of this population.[19,20] The relationship between pain and depressive symptoms has been consistently reported in the literature[21] and may be bidirectional.[22] Longitudinal studies investigating osteoarthritis have shown that greater pain symptoms prospectively predict the incidence of depression,[23-25] while other studies have shown that depressive symptomology may exacerbate the experience of pain.[26,27] However, in the context of arthritis, the mechanistic explanations supporting the effect of pain on depression are stronger than those supporting the reverse, mainly because pain is a primary and more direct symptom resulting from joint inflammation, whereas depression is a comorbidity that develops secondary to the chronic pain.

The mediation of the effect of pain on functional dependence by depressive symptoms is well documented in the pain literature,[28-35] particularly in studies on back pain[28-31] and traumatic injury.[32-34] However, to the best of our knowledge, this mediation has not been examined in people with arthritis. This is a notable gap, given that arthritis is one of the leading causes of chronic pain and disability. Understanding the mechanisms underlying the relationship between pain and functional dependence in this population may inform interventions aimed at improving functional outcomes.

In contrast to the proposed model (Fig. 1), studies in arthritis populations have primarily tested a different mediation model in which functional dependence is the mediator and depressive symptoms are the outcome,[36,37] a model more relevant to mental health professionals. However, from a rehabilitation perspective, the focus is more on understanding the mechanisms that may improve functional outcomes. Moreover, conceptualizing depressive symptoms as a mediator aligns with the biopsychosocial approach to pain in rehabilitation,[38] which emphasizes psychological contributions to physical functioning. The mechanistic basis for this mediation model is well supported, as depressive symptoms can reduce motivation,[39] increase fatigue,[36,40,41] and promote avoidance behaviors,[42] all of which can affect physical function.[43]

Another potential mediator of the effect of pain on functional dependence is physical activity, as pain has been shown to predict physical activity levels,[44] which in turn have been shown to improve physical functioning.[45] While this indirect effect through physical activity has recently been examined in individuals with back pain,[46,47] this mediating effect has not been examined in individuals with arthritis. As physical activity has been shown to be an effective intervention for improving pain and function,[48] refining our understanding of this relationship, accounting for the influence of depressive symptoms, could further inform rehabilitation programs for patients with arthritis.

The aim of this study was to examine the relationship between pain and functional dependence in people with arthritis using the Canadian Longitudinal Study on Aging datasets. Specifically, we tested whether depressive symptoms and physical activity mediate the effect of baseline pain on functional dependence at follow-up (Fig. 1). We hypothesized that the presence of pain would have a direct effect on functional dependence. In addition, we hypothesized an indirect effect, whereby the presence of pain would be associated with higher depressive symptoms and lower physical activity levels, both of which would, in turn, predict higher odds of functional dependence, over and above the direct effect of pain.

Methods

Participants

Participants were recruited in the Canadian Longitudinal Study on Aging (CLSA) through Canada's provincial health registries, random-digit dialing, and the Canadian Community Health Survey on Healthy Aging.[49,50] Exclusion criteria included residents living in Canada's three territories and First Nations reserves, full-time members of the Canadian Armed Forces, individuals living with cognitive impairments, and individuals living in institutions, including 24-hour nursing homes.[49] All participants with baseline measures of pain, depressive symptoms, physical activity, age, and sex, as well as measures of functional limitations at both baseline and follow-up, were included in the analyses. The study was approved by the University of Ottawa Research Ethics Board (H-10-23-9760).

Data of the 'baseline' assessment was collected between 2010 and 2015 using two approaches: data collection from a 'tracking' cohort of participants via 60-minute computer-assisted phone interviews and data collection from a 'comprehensive' cohort via 90-minute in-person interviews in addition to a data-collection site visit. Additionally, a 'maintaining contact questionnaire' was administered by phone to the comprehensive and tracking cohorts. The maintaining contact questionnaire, tracking cohort, and comprehensive cohort were used as baseline in our analyses. Between 2018 and 2021 another wave of data was collected during the follow-up assessment.

Variables

Arthritis

At the baseline assessment, participants self-reported whether they had ever been diagnosed with rheumatoid arthritis, osteoarthritis, or any other type of arthritis. Five single-item questions were used: "Has a doctor ever told you that you have [osteoarthritis in the knee / osteoarthritis in the hip / osteoarthritis in one or both hands / rheumatoid arthritis / any other type of arthritis]?". Responses were yes or no. The dataset was initially filtered to include individuals with any type of arthritis for the main analyses. In addition, sensitivity analyses were conducted on two specific subsets: one comprising individuals with osteoarthritis and the other consisting of those with rheumatoid arthritis.

Functional Status

Functional dependence in basic and instrumental activities of daily life (I/ADL) at baseline and follow-up was measured with a modified version of the Older Americans' Resources and Services Multidimensional Functional Assessment Questionnaire (OARS).[51,52] Twenty questions were asked to participants regarding their ability to complete seven basic activities of daily life (ADL) (e.g., can you eat without help, can you walk without help) in addition to 21 questions regarding seven instrumental activities of daily living (IADL) (e.g., can you use the telephone without help, can you prepare you own meals without help). The 'Basic and Instrumental Activities of Daily Living Classification' is a derived variable in the CLSA dataset that produces the following scores: 1 (no functional limitations), 2 (mild functional limitations), 3 (moderate functional limitations), 4 (severe functional limitations), and 5 (total functional limitations). The method used to derive this variable assigns extra weight to the ability to prepare meals and was scored to be similar to variables used in Statistics Canada's Canadian Community Health Survey.[53] A binary variable of the Basic and Instrumental Activities of Daily Living Classification was computed for measures assessed at baseline and follow-up assessment. These variables classify participants with no or mild functional limitations as functionally independent, and participants with moderate, severe, or total functional limitations as functionally dependent.

Pain

The usual presence of pain or discomfort was assessed with the question "Are you usually free of pain or discomfort?" Responses were yes or no. We acknowledge that this item may reflect intermittent or persistent pain rather than constant presence or absence of pain, and that it captures both pain and discomfort. However, for readability, we often refer to this variable as "pain".

Depression Symptoms

The Center for Epidemiological Studies Short Depression Scale (CESD-10)[54] was used to assess depressive symptoms at baseline. The CESD-10 contains 10 items measuring depressive feelings, restless sleep, hopefulness for the future, and loneliness (e.g., "How often did you feel hopeful about the future?"; "How often did you feel that everything you did was an effort?"). Response options range from 3 ["All of the time (5-7days)"] to 0 ["Rarely or never (less than 1 day)"]. A sum score ranging from 0-30 was used in the analyses. When one response was missing, CLSA imputed the value using the mean of the remaining nine items to compute the sum score. Participants with more than one missing item were excluded from the analyses. Since the distribution for the CESD-10 was highly skewed, a log-transformed version of the variable was used in the analyses.

Physical Activity

Physical activity was measured at baseline with the Physical Activity Scale for the Elderly (PASE),[55] which assesses the frequency of walking, light physical activity, moderate physical activity, strenuous physical activity, and exercise. Items asked participants to report on their activity levels over the previous 7 days on a 1 (never) to 4 (often, 5-7 days) scale and to indicate the time per day engaged in each of these activities on a 1 (less than 30 minutes) to 5 (four hours or more) scale. A total physical activity score was derived from these items according to the PASE administration and scoring instruction manual,[56] resulting in scores from 0 to 485, with higher scores indicating higher levels of physical activity (see Suppl. Material 1 for scoring scheme).

Statistical Analyses

All analyses were conducted in R version 4.4.1,[57] and analysis scripts are publicly available.[58] A serial mediation model, based on the process.R script (Model 6),**[59]** was used to estimate total, direct, and indirect effects of baseline pain on functional dependence at follow-up. This regression-based approach[60] was selected for its transparency and interpretability. To assess the robustness of the results, sensitivity analyses based on structural equation modeling and a causal inference framework were conducted.

Functional dependence was assessed both at baseline (2011-2015) and at follow-up (2018-2021), while all the other variables were collected at baseline only. The independent variable was the usual presence of pain or discomfort (binary: 0 = usually free of pain, 1 = usually not free of pain), and the dependent variable was functional dependence at follow-up (binary: 0 = functionally independent, 1 = functionally dependent). The two mediating factors, physical activity and depressive symptoms, were measured as continuous variables. Untransformed values for the PASE (physical activity) and log-transformed values for CESD-10 (depressive symptoms) were standardized and included in statistical models in terms of standard deviations from their mean values in the cohort. All models were adjusted for age (standardized), sex (0 = female, 1 = male), and baseline functional dependence.

The total effect of pain on functional dependence (path c; Fig. 1) was estimated using a logistic regression model in which pain was the predictor, adjusted for control variables (age, sex, baseline functional dependence). The direct effect (path c') was estimated using a logistic regression model including both mediators. Coefficients for path a_1, a_2, and a_3 were estimated as unstandardized betas using linear regression. Coefficients for path b_1 and b_2 were estimated as log-odds coefficients (also known as logit coefficients or log odds ratios [log OR]) using logistic regression. The indirect effects were estimated using the product-of-coefficients approach.

Because the outcome variable was binary, and in line with methodological recommendations[59,61,62] , indirect effects were calculated on the log OR scale as the product of the unstandardized regression coefficient from the linear regression (path a) and the untransformed coefficient from the logistic regression (path b). Interpretation of log ORs follows the convention for logistic regression: positive values indicate increased odds, and negative values indicate decreased odds. This combination of linear and nonlinear link functions means that the sum of the direct and indirect effects does not necessarily equal the total effect, especially on the odds ratio scale. Statistical inference for the indirect effects was conducted via empirical bootstrapping with 5000 resamples. This approach is recommended for multivariate non-normal data as it provides adequate control of Type I error rates and confidence interval coverage.[63] Confidence intervals (95% CI) that did not include zero were interpreted as evidence of statistical significance.

The indirect effect of pain on functional dependence was estimated as the sum of three indirect pathways: (1) pain → depressive symptoms → functional dependence; (2) pain → physical activity → functional dependence; and (3) pain → depressive symptoms → physical activity → functional dependence (serial pathway).

Statistical significance was assessed using a two-tailed α level of 0.05. The percentage of the total effect mediated by the mediators was calculated using the difference in log OR between the total effect (model without mediators) and the direct effect (model with mediators), using the following formula: $(\log OR_{total} - \log OR_{direct}) \times 100 / \log OR_{total}$.

Sensitivity Analyses

Six sensitivity analyses were conducted to assess the robustness of our results. The first sensitivity analysis used a different binary classification of functional dependence at follow-up, classifying participants with no functional limitations as functionally independent and those with mild, moderate, severe, or total functional limitations as functionally dependent. In the second sensitivity analysis, the functional dependence variable was redefined to exclude meal preparation, which may be less relevant for participants with lower limb arthritis. The third and fourth analyses were stratified by arthritis type, focusing respectively on participants with osteoarthritis and those with rheumatoid arthritis. The fifth sensitivity analysis replicated the main mediation model using structural equation modeling with the *lavaan* package[64] (Suppl. Material 2). The sixth analysis used a causal inference framework implemented through the *mediation* package[65] to estimate natural direct and indirect effects (Suppl. Material 3).

Results

Descriptive Results

A total of 6972 participants reported having arthritis, including 4930 with osteoarthritis, and 694 with rheumatoid arthritis. Among the 6,972 participants with any type of arthritis (Table 4.1), baseline data showed that 58.7% were female, more than half of them reported experiencing pain (52.8%), the mean physical activity score was 185.0 ± 75.8, and the mean depression score was 5.5 ± 4.6. The majority (90.5%) reported no functional limitations, while 8.8% had mild limitations, and fewer than 1% had moderate or severe limitations. Most participants were aged 55–64 years (37.5%), followed by those aged 45–54 years (24.7%) and 65–74 years (24.4%), with the smallest proportion in the 75–85 age group (13.5%). The distribution of demographic and clinical characteristics for participants with osteoarthritis and rheumatoid arthritis is presented in Table 1. The average time between baseline and follow-up measures was 6.3 ± 0.8 years, with a range of 4.0 to 9.6 years.

Main Analyses

We used multiple linear regression models, generalized linear models, and bootstrapping to investigate the direct and indirect effects of baseline pain on functional status 6.3 ± 0.8 years later. Depressive symptoms and physical activity were examined as potential mediators. The analysis controlled for covariates of sex; age, and baseline functional status, and was based on a sample 6972 participants with any type of arthritis.

Table 4.1. Sample characteristics at baseline by arthritis type

	Any Arthritis (n = 6972)	**Osteoarthritis** (n = 4930)	**Rheumatoid Arthritis** (n = 694)
Variables	Count (%) or Mean (SD)	Count (%) or Mean (SD)	Count (%) or Mean (SD)
Presence of Pain			
No Pain	3288 (47.2%)	2229 (45.2%)	270 (38.9%)
Pain	3684 (52.8%)	2701 (54.8%)	424 (61.1%)
Physical Activity	185.0 (75.8)	180.2 (76.0)	190.9 (75.7)
Depressive Symptoms	5.5 (4.6)	5.5 (4.7)	5.9 (4.8)
Sex			
Male	2882 (41.3%)	1943 (39.4%)	280 (40.3%)
Female	4090 (58.7%)	2987 (60.6%)	414 (59.7%)
Age Group			
45-54 years	1720 (24.7%)	1002 (20.3%)	207 (29.8%)
55-64 years	2612 (37.5%)	1858 (37.7%)	236 (34.0%)
65-74 years	1698 (24.4%)	1332 (27.0%)	169 (24.4%)
75-85 years	942 (13.5%)	738 (15.0%)	82 (11.8%)
Functional Limitations			
None	6310 (90.5%)	4417 (89.6%)	614 (88.5%)
Mild	611 (8.8%)	473 (9.6%)	71 (10.2%)
Moderate	43 (0.6%)	34 (0.7%)	5 (0.7%)
Severe	5 (0.1%)	4 (0.1%)	2 (0.3%)

Total	3 (0.05%)	2 (0.05%)	2 (0.3%)

Table 4.2. Regression coefficients and odds ratios for the mediation paths in the main serial mediation model (n = 6972)

	Path c (outcome = functional dependence)			**Path a_1** (outcome = depressive symptoms)		
Variables	Log OR	95CI	*p*	b	95CI	*p*
(Intercept)	-4.473	-4.822; -4.150	$<2\times10^{-16}$	-0.137	-0.176; -0.098	6.3×10^{-12}
Age	0.839	0.684; 0.997	$<2\times10^{-16}$	-0.072	-0.095; -0.049	8.0×10^{-10}
Sex	-0.291	-0.625; 0.033	0.082	-0.136	-0.183; -0.089	1.1×10^{-8}
Baseline Dependence	3.439	2.810; 4.068	$<2\times10^{-16}$	0.723	0.453; 0.992	1.5×10^{-7}
Presence of Pain	**0.791**	**0.458; 1.138**	$\mathbf{4.8\times10^{-6}}$	**0.356**	**0.310; 0.402**	$\mathbf{<2\times10^{-16}}$

	Path a_2 and a_3 (outcome = physical activity)			**Path b_1, b_2, and c'** (outcome = functional dependence)		
Variables	b	95CI	*p*	Log OR	95CI	*p*
(Intercept)	-0.116	-0.151; -0.082	5.2×10^{-11}	-4.684	-5.042; -4.326	$<2\times10^{-16}$
Age	-0.450	-0.470; -0.430	$<2\times10^{-16}$	0.640	0.465; 0.814	6.6×10^{-13}
Sex	0.401	0.360; 0.443	$<2\times10^{-16}$	-0.009	-0.348; 0.329	0.958
Baseline Dependence	-0.744	-0.983; -0.505	1.1×10^{-9}	2.886	2.256; 3.516	$<2\times10^{-16}$
Presence of Pain	**-0.083**	**-0.125; -0.042**	$\mathbf{8.0\times10^{-5}}$	**0.607**	**0.261; 0.952**	$\mathbf{5.8\times10^{-4}}$
Depressive Symptoms	**-0.030**	**-0.050; -0.009**	$\mathbf{5.3\times10^{-3}}$	**0.358**	**0.184; 0.533**	$\mathbf{5.7\times10^{-5}}$
Physical Activity				**-0.598**	**-0.818; -0.378**	$\mathbf{9.4\times10^{-8}}$

Notes: b = regression coefficient (beta); log OR = log(Odds Ratio); 95CI = 95% confidence interval

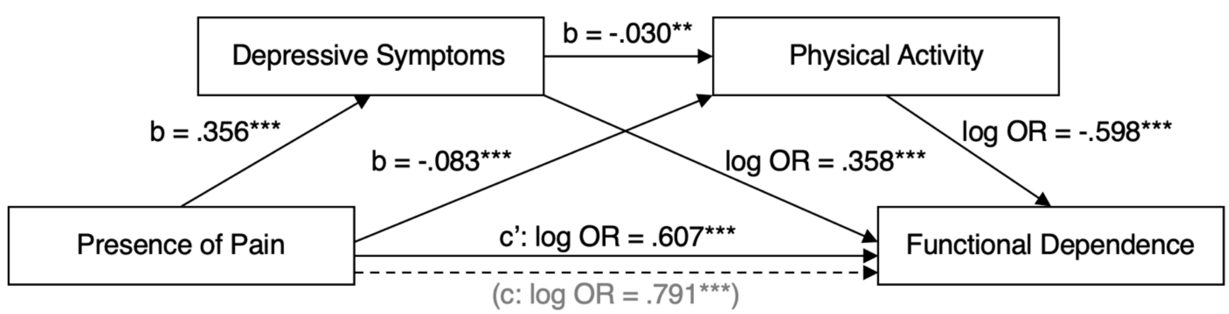

Figure 4.2. Path diagram displaying regression coefficients used to estimate direct and indirect effects of pain on functional dependence.

*b = beta, log OR = log(odds ratio), c = total effect, c' (dash arrow) = direct effect, **p<.01, ***p<.001.*

Path c (Presence of Pain → Functional Dependence without mediators)

Results showed a total effect (path c) of baseline pain on follow-up functional dependence (log OR = 0.791 [95% CI: 0.458 to 1.138]; P = 4.8×10^{-6}) (Table 2, Fig. 2). Older participants had significantly higher odds of functional dependence (log OR = 0.839 [95% CI: 0.684 to 0.997]; P < 2.0×10^{-16}). Results showed no evidence of an effect of sex on functional dependence (log OR = -0.291 [95% CI: -0.625 to 0.033]; P = 0.082). Baseline functional dependence was associated with higher odds of functional dependence at follow-up (log OR = 3.439 [95% CI: 2.810 to 4.068]; P < 2.0×10^{-16}). This logistic regression model accounted for 15.0% of the variance in functional dependence (McFadden's $R^2 = 0.150$).

Path a_1 (Presence of Pain → Depressive Symptoms)

Results showed a positive association between pain and depressive symptoms (b = 0.356 [95% CI: 0.310 to 0.402]; $P < 2.0 \times 10^{-16}$) (Table 2, Fig. 2). Male participants exhibited lower levels of depressive symptoms than female participants (b = -0.136 [95% CI: -0.183 to -0.089]; $P = 1.1 \times 10^{-8}$). Older participants reported lower levels of depression than younger ones (b = -0.072 [95% CI: -0.095 to -0.049]; $P = 8.0 \times 10^{-10}$). Baseline functional dependence was associated with depressive symptoms (b = 0.723 [95% CI: 0.453 to 0.992]; $P = 1.5 \times 10^{-7}$). This linear regression model accounted for 4.7% of the variance in depressive symptoms (adjusted $R^2 = 0.047$).

Path a_2 (Presence of Pain → Physical Activity) and a_3 (Depressive Symptoms → Physical Activity)

Results showed that pain (b = -0.083 [95% CI: -0.125 to -0.042]; $P = 8.0 \times 10^{-5}$) and depressive symptoms (b = -0.030 [95% CI: -0.050 to -0.009]; $P = .005$) were negatively associated with physical activity (Table 2, Fig. 2). Male participants exhibited higher levels of physical activity than female participants (b = 0.401 [95% CI: 0.360 to 0.443]; $P < 2.0 \times 10^{-16}$). Older participants reported lower levels of physical activity than younger ones (b = 0.450 [95% CI: -0.470 to -0.430]; $P < 2.0 \times 10^{-16}$). Baseline functional dependence was associated with physical activity (b = -0.743 [95% CI: -0.983 to -0.505]; $P = 1.1 \times 10^{-9}$). This linear regression model accounted for 25.3% of the variance in physical activity (adjusted $R^2 = 0.253$).

Path b1 (Depressive Symptoms → Functional Dependence) and b2 (Physical Activity → Functional Dependence with both mediators)

Results showed a direct effect of baseline pain on functional dependence at follow-up (log OR = 0.607 [95% CI: 0.261 to 0.952]; $P = 5.8 \times 10^{-4}$) (Table 2, Fig. 2), indicating that participants with pain had higher log-odds of being functionally dependent 4.0 to 9.6 years compared to those without pain. Similarly, depressive symptoms (log OR = 0.358 [95% CI: 0.184 to 0.533]; $P = 5.7 \times 10^{-5}$) and physical activity (log OR = -0.598 [95% CI: -0.818 to -0.378]; $P = 9.4 \times 10^{-8}$) were significant predictors of functional dependence. Older participants had higher log-odds of being functionally dependent at follow-up than younger participants (log OR = 0.640 [95% CI: 0.465 to 0.814]; $P = 6.6 \times 10^{-13}$). Results showed no evidence of an effect of sex (log OR = -0.009 [95% CI: -0.348 to 0.329]; $P = .958$). Baseline functional dependence predicted follow-up functional dependence (log OR = 2.886 [95% CI: 2.256 to 3.516]; $P < 2.0 \times 10^{-16}$). This logistic regression model accounted for 18.0% of the variance in functional dependence (McFadden's $R^2 = 0.180$).

Indirect Effect

Results based on the product of the path coefficients (a × b) showed an indirect effect of baseline pain on functional dependence at follow-up (log OR = 0.184 [95% CI: 0.111 to

0.265]), which was partitioned into three indirect pathways through depressive symptoms (log OR = 0.128 [95% CI: 0.064 to 0.200]), physical activity (log OR = 0.050 [95% CI: 0.019 to 0.090]), and their serial combination (log OR = 0.006 [95% CI: 0.001 to 0.013]) (Fig. 3). The serial pathway with physical activity as the first mediator and depressive symptoms as the second mediator was also examined and yielded similar results (log OR = 0.0013 [95% CI: 0.0003 to 0.0028]). The exclusion of zero from all bootstrapped 95% CI indicated that each indirect effect was statistically significant.

The comparison of the total effect (path c) and the direct effect (path c') showed that 23.3% of the total effect of baseline pain on functional dependence was mediated by the indirect effect through the mediators: 16.2% through depressive symptoms, 6.3% through physical activity, and 0.8% through the serial mediation of depressive symptoms and physical activity.

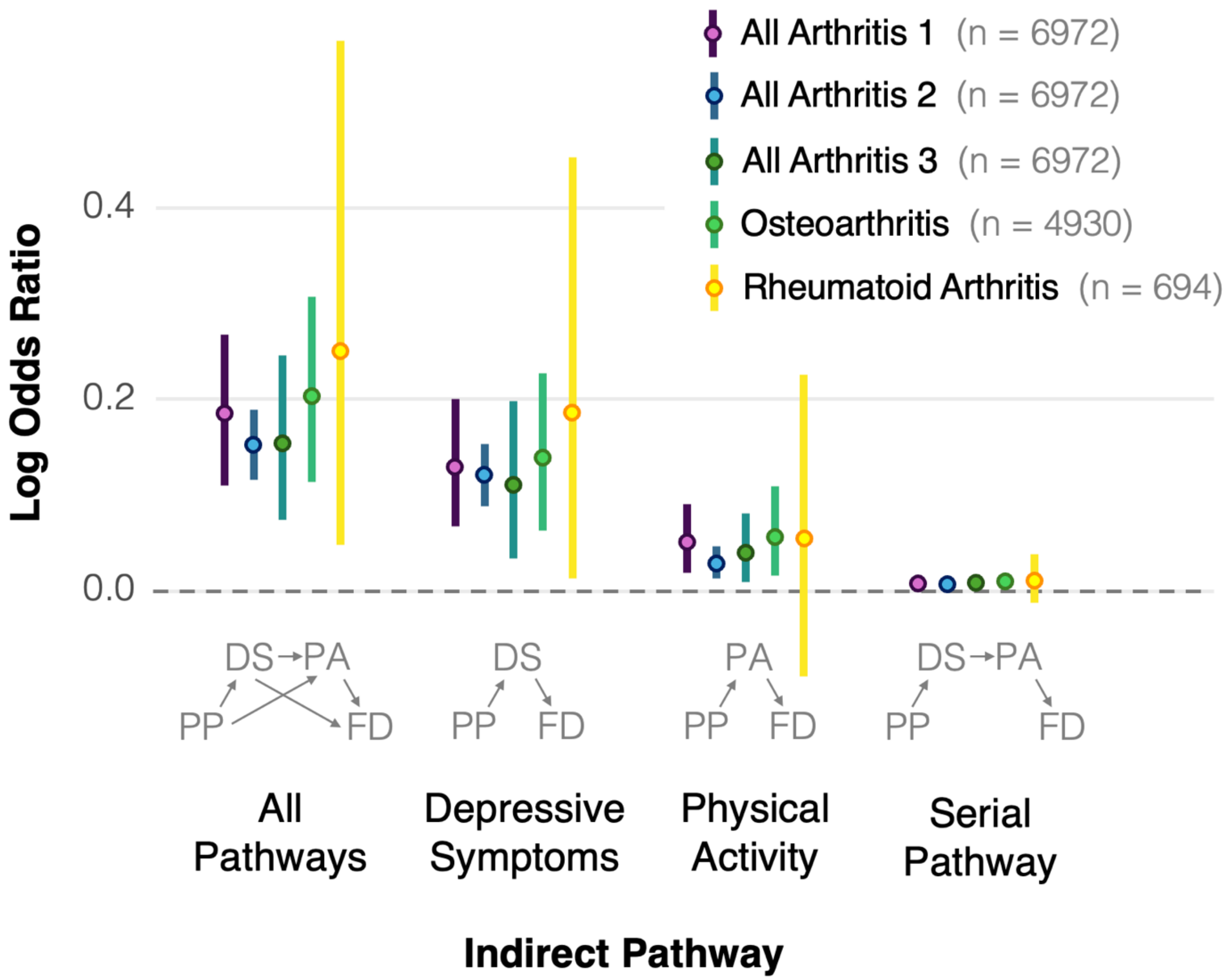

Figure 4.3. Indirect effect of baseline presence of pain on follow-up functional dependence.

The indirect effect is partitioned into three indirect pathways through depressive symptoms (PP→DS→FD), physical activity (PP→PA→FD), and their serial combination (PP→DS→PA→FD). The horizontal dotted line at 0 indicates no effect, the dots represent estimated log odds ratios, and the vertical lines represent the 95% confidence intervals. Indirect pathways are presented for the main analysis, which included participants with any type of arthritis and classified them as functionally independent if they had no or mild functional limitations, and as functionally dependent if they had moderate, severe, or total functional limitations (All Arthritis 1). Four sensitivity analyses are also shown: participants with no functional limitations classified as functionally independent and those with mild, moderate, severe, or total functional limitations as functionally dependent (All Arthritis 2), measure functional dependence excluding meal preparation (All Arthritis 3), participants with osteoarthritis, and participants with rheumatoid arthritis. PP = presence of pain, DS = depressive symptoms, PA = physical activity, FD = functional dependence.

Sensitivity Analyses

Different classification of functional status

The sensitivity analysis that classified participants with mild functional limitations as functionally independent rather than functionally dependent, yielded results similar to those of the main analysis. Results showed an indirect effect of baseline pain on functional dependence at follow-up (log OR= 0.152 [95% CI: 0.117 to 0.189]) (Fig. 3), which was partitioned into three indirect pathways: through depressive symptoms (log OR = 0.120 [95% CI: 0.089 to 0.154]), physical activity (log OR = 0.028 [95% CI: 0.013 to 0.046]), and their serial combination (log OR = 0.004 [95% CI: 0.001 to 0.007]).

Functional Dependence Excluding Meal Preparation

The sensitivity analysis based on a measure of functional dependence that excluded meal preparation yielded results similar to those of the main analysis. Results showed an indirect effect of baseline pain on functional dependence at follow-up (log OR= 0.154 [95% CI: 0.072 to 0.247]) (Fig. 3), which was partitioned into three indirect pathways: through depressive symptoms (log OR = 0.112 [95% CI: 0.036 to 0.199]), physical activity (log OR = 0.038 [95% CI: 0.009 to 0.079]), and their serial combination (log OR = 0.005 [95% CI: 0.001 to 0.011]) (Fig. 3).

Osteoarthritis

Results of the sensitivity analysis focusing on participants with osteoarthritis (n = 4930) were similar to those of the main analysis. Results showed an indirect effect of baseline pain on functional dependence at follow-up (log OR = 0.203 [95% CI: 0.113 to 0.307]), which was partitioned into three indirect pathways: through depressive symptoms (log OR = 0.139 [95% CI: 0.062 to 0.227]), physical activity (log OR = 0.055 [95% CI: 0.016 to 0.109]), and their serial combination (log OR = 0.009 [95% CI: 0.002 to 0.019]) (Fig. 3).

Rheumatoid Arthritis

Results of the sensitivity analysis focusing on participants with rheumatoid arthritis (n = 694) suggested that the total mediation (log OR = 0.250 [95% CI: 0.049 to 0.574]) was primarily driven by the pathway through depressive symptoms (log OR = 0.185 [95% CI: 0.013 to 0.453]) as the pathway through physical activity (log OR = 0.055 [95% CI: -0.089 to 0.226]) and the serial mediation pathway through both depressive symptoms and physical activity (log OR = 0.010 [95% CI: -0.013 to 0.038]) had bootstrapped 95% CI that included zero (Fig. 3), indicating that these indirect effects were not statistically significant.

Other Types of Mediation Models

Sensitivity analyses using structural equation modeling (Suppl. Material 2) and a causal inference approach (Suppl. Material 3) yielded results consistent with the main analysis, further supporting the mediating roles of depressive symptoms and physical activity.

Discussion

Main Findings

This study examined depressive symptoms and physical activity as potential mediators of the longitudinal relationship between baseline usual presence of pain or discomfort and functional dependence over a mean follow-up of 6.3 years in people with arthritis. Our results provide empirical evidence for a total effect of baseline pain on future functional dependence in ADLs and IADLs. Notably, 23.3% of this total effect was mediated by depressive symptoms and physical activity. Consistent with the biopsychosocial approach to pain in rehabilitation,[38] these findings highlight the importance of addressing both psychological and behavioral pathways in rehabilitation programs for patients with arthritis.

Comparison With the Literature

Our results indicate that individuals experiencing pain at baseline had higher odds of functional dependence at follow-up, while adjusting for sex, age, and baseline functional dependence. This direct association between baseline pain and future functional dependence aligns with previous research demonstrating that pain is a key determinant of disability in individuals with arthritis.[3-6] Taken together, these results suggests that early pain management may be critical in preventing long-term declines in functional abilities of individuals with arthritis.

Depressive symptoms were found to mediate the relationship between pain and functional dependence, accounting for 69.5% of the indirect effect. Specifically, our results suggest that individuals who reported being usually in pain or discomfort at baseline were more likely to experience depressive symptoms, which in turn increased the odds of functional dependence at follow-up. These results are consistent with those from studies of low back pain and post-traumatic pain that have documented the mediating role of depressive symptoms in the relationship between pain and functional dependence.[28-35] Importantly, our findings extend this evidence to individuals with arthritis, highlighting the broader relevance of these mechanisms across pain-related conditions. As depression is both modifiable and treatable, these findings suggest that rehabilitation professionals should consider mental health when implementing interventions aimed at pain-related functional decline in individuals with arthritis.

Physical activity was also a mediator, accounting for 27.0% of the total indirect effect of pain on functional dependence. This finding is consistent with studies showing similar indirect effects in individuals with low back pain.[46,47] Importantly, our findings extend this evidence to individuals with arthritis, reinforcing the importance of physical activity in maintaining functional independence in this population. The mediating effect is consistent with recent work in osteoarthritis showing that individuals with stronger tendencies to approach than avoid physical activity are less likely to reduce activity levels, even when experiencing high fear of movement.[66] These results suggest that targeting both fear and motivational attitudes may improve physical activity and functional outcomes. Accordingly, exercise therapy should be considered as a component of rehabilitation programs aimed at restoring or preserving ADL and IADL independence in individuals with arthritis.

The mediation analysis suggested a small but significant serial pathway in which depressive symptoms contributed to lower physical activity, which in turn affected functional dependence. Although this serial effect accounted for only 3.5% of the total indirect effect, it suggests that individuals who develop depressive symptoms due to pain may subsequently reduce their physical activity, further exacerbating their risk of functional decline.

Our sensitivity analyses confirmed the robustness of our findings across different functional dependence classifications, statistical approaches, and arthritis subtypes. Particularly, analyses restricted to participants with osteoarthritis showed comparable mediation patterns, suggesting that the observed effects apply to the most common form of arthritis. However, in rheumatoid arthritis, the mediation effect was primarily driven by depressive symptoms, while the indirect effects through physical activity and the serial pathway were not statistically significant. This lack of significance may be due to the lower statistical power of this subsample but may also suggest that the mechanisms linking pain to functional decline differ between arthritis subtypes and warrant further investigation.

While age and sex were not the primary focus of our study, these variables may influence the pathways we analysed, deserving clinical attention. Results showed that age was positively associated with functional dependence while controlling for pain, depressive symptoms, and physical activity, supporting the idea that advancing age is independently associated with functional dependence.[6] As such, age should be considered for proactive functional screening of arthritic patients and tailored interventions to prevent decline. Similarly, sex-based differences in physical activity[67] and depressive symptoms[68] highlight the need for targeted care strategies to mitigate risks of functional dependence. Although sex was not a significant predictor of functional dependence in our models, it was associated with more depressive symptoms and lower physical activity levels in female than male participants, indicating that sex may influence these mediating variables, and thus, exert indirect effects on functional dependence. These sex-based differences in the mediator variables support the need for promoting physical activity engagement and addressing depressive symptoms among female patients with arthritis to mitigate risks of functional dependence.

Strengths and Limitations

This study has several strengths, including a large sample size of 6972 participants, a long follow-up period ranging from 4.0 to 9.6 years after baseline, the use of multiple mediation analyses, and bootstrapping to robustly estimate the significance of indirect effects. Several limitations should also be noted. First, the outcome and mediator variables were self-reported, which may have introduced measurement bias, especially in the context of a chronic condition like arthritis with a gradual onset. However, this limitation is common and often unavoidable in large cohort studies. Second, despite adjusting for key confounders, unmeasured variables such as medication use, disease severity, and comorbidities could have influenced the results. Third, since depressive symptoms and physical activity were both assessed at baseline, our mediation estimates may reflect concurrent associations rather than true causal pathways. Fourth, while CLSA has implemented sampling strategy designed to produce a nationally representative sample of adults aged 45 to 85 years at the time of recruitment, selection bias cannot be ruled out and may limit the generalizability of findings to individuals without access to a telephone, the internet, proficiency in English or French, or the ability to travel to a data collection site. Fifth, the operationalization of pain was based on a single binary item asking whether participants were usually free of pain or discomfort. This phrasing does not directly measure the presence, intensity, or duration of pain and may be subject to interpretation. Finally, although mediation analysis provides insight into potential causal pathways, the observational nature of the study precludes definitive causal conclusions.

Conclusion

This study provides evidence suggesting that experiencing ongoing pain or discomfort contributes to long-term functional dependence both directly and indirectly through depressive symptoms and physical activity. The direct effect shows that individuals reporting pain have higher odds of being functionally dependent in ADLs and IADLs compared to those without pain. In addition, depressive symptoms and physical activity mediate this relationship.

Our findings underscore the need for a comprehensive approach to arthritis care that goes beyond pain management alone. They suggest that interventions should include strategies to address depressive symptoms and promote physical activity to mitigate the long-term impact of pain on functional dependence. A biopsychosocial framework that integrates physical, psychological, and behavioral components may provide a more effective approach to maintaining, restoring, or improving physical function in individuals with arthritis.

Declarations

Author Contributions

Miriam Goubran: Conceptualization, Writing (Original Draft), Writing (Review and Editing); Zachary M. van Allen: Methodology, Data Curation, Formal Analysis, Writing (Original Draft), Writing (Review and Editing); Martin Bilodeau: Conceptualization, Writing (Review and Editing), Supervision (MG), Project Administration; Matthieu P. Boisgontier: Conceptualization (Lead), Methodology, Data Curation, Formal Analysis, Visualization, Writing (Original Draft) (Lead), Writing (Review and Editing), Supervision (MG and ZMvA), Project Administration, Funding Acquisition.

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Data and Code Sharing

In accordance with good research practices,[69] the R scripts used to analyse the data are publicly available in Zenodo.[58] This research was made possible using the data collected by the Canadian Longitudinal Study on Aging (CLSA) and was conducted using the CLSA Baseline Comprehensive Dataset version 7.0, Follow-Up 1 Comprehensive Dataset version 5.0, and Follow-Up 2 Comprehensive dataset version 2.0 under application number 2304015. This dataset is available for researchers who meet the criteria (http://www.clsa-elcv.ca/). This manuscript was posted before peer review on the MedRxiv preprint repository on February 12, 2025.[70]

Reporting Guidelines

This manuscript conforms to the AGReMA guidelines for mediation analyses of observational studies.[71]

Disclaimer

The opinions expressed in this manuscript are the author's own and do not reflect the views of the Canadian Longitudinal Study on Aging.

Disclosure

The authors completed the ICMJE Form for Disclosure of Potential Conflicts of Interest and reported no conflicts of interest.

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Supplementary Materials

Depressive symptoms and physical activity mediate the adverse effect of pain on functional dependence in patients with arthritis:

Evidence from the Canadian Longitudinal Study on Aging

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Suppl. Material 1. Scoring scheme for the Physical Activity Scale for the Elderly (PASE)

Suppl. Material 2. Sensitivity analysis based on structural equation modeling (SEM)

Suppl. Material 3. Sensitivity analysis based on causal inference

Supplementary Material 1. Scoring scheme for PASE.

PASE Item	Type of Activity	Activity Weight	Activity Frequency	Weight times Frequency
2.	Walk outside home	20	a.	
3.	Light sport / recreational activities	21	a.	
4.	Moderate sport / recreational activities	23	a.	
5.	Strenuous sport / recreational activities	23	a.	
6.	Muscle strength / endurance exercises	30	a.	
7.	Light housework	25	b.	
8.	Heavy housework or chores	25	b.	
9a.	Home repairs	30	b.	
9b.	Lawn work or yard care	36	b.	
9c.	Outdoor gardening	20	b.	
9d.	Caring for another person	35	b.	
10.	Work for pay or as volunteer	21	c.	
			PASE SCORE:	

Activity Frequency Values:

a. Use hours per day conversion table below
b. 1 = activity reported in past week, 0 = activity not reported
c. Divide work hours reported in Item 10.1 by seven; if no work hours or if job involves mainly sitting with slight arm movements (Item 10.2 = 1), then activity frequency = 0.

ACTIVITY TIME TO HOURS PER DAY CONVERSION TABLE

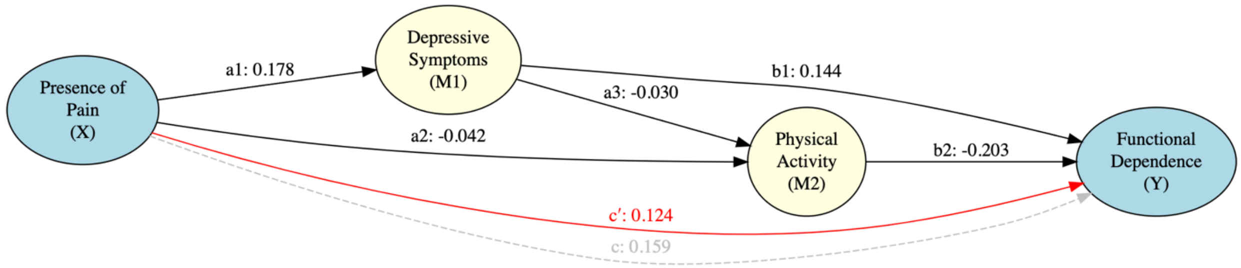
Days of Activity	Hours Per Day of Activity	Hours Per Day
0. Never		0
1. Seldom	1. Less than 1 hour	.11
	2. 1-2 hours	.32
	3. 2-4 hours	.64
	4. More than 4 hours	1.07
2. Sometimes	1. Less than 1 hour	.25
	2. 1-2 hours	.75
	3. 2-4 hours	1.50
	4. More than 4 hours	2.50
3. Often	1. Less than 1 hour	.43
	2. 1-2 hours	1.29
	3. 2-4 hours	2.57
	4. More than 4 hours	4.29

Full administration and scoring instruction manual available at
https://meetinstrumentenzorg.nl/wp-content/uploads/instrumenten/PASE-handl.pdf

Supplementary Material 2. Sensitivity analysis based on SEM.

As a sensitivity analysis, we conducted a serial mediation model using structural equation modeling (SEM) with the *lavaan* package in R. The model specifies paths from pain to depressive symptoms and physical activity, with both mediators modeled as predictors of functional dependence at follow-up. Covariates included sex, age, and baseline functional dependence. The outcome was treated as an ordered categorical variable, and the model was estimated using the Weighted Least Squares Mean and Variance (WLSMV) estimator, which is appropriate for binary outcomes. Indirect effects were computed for three pathways: through depressive symptoms, through physical activity, and through the serial path.

Results showed that the direct effect of baseline pain on functional dependence at follow-up remained statistically significant after accounting for both mediators (log OR = 0.270, $p < .001$). In addition, the total indirect effect of pain on functional dependence was statistically significant (log OR = 0.077, $p < .001$). This total indirect effect was composed of three distinct pathways. The indirect effect through depressive symptoms alone was statistically significant (log OR = 0.056, $p < .001$), as was the indirect effect through physical activity alone (log OR = 0.018, $p = .001$). The serial pathway also yielded a small but significant indirect effect (log OR = 0.002, $p = .008$). The total effect of pain on functional dependence, combining both direct and indirect components, was estimated at log OR = 0.347 ($p < .001$). The model explained 4.7% of the variance in depressive symptoms, 25.4% of the variance in physical activity, and 21.3% of the variance in functional dependence.



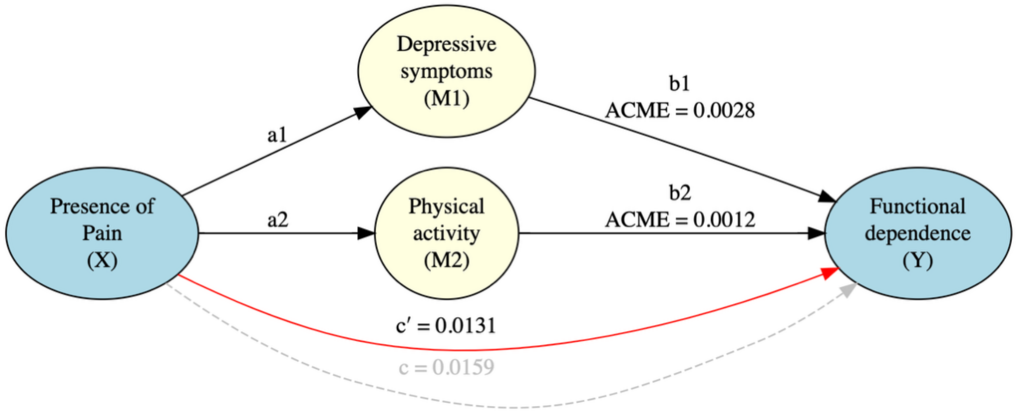
Supplementary Figure 4.1. Serial multiple mediation model based on structural equation modeling using the *lavaan* package.

Dash arrow = total effect (c); red arrow = direct effects (c'); a paths = effect of the independent variable on the mediators; b paths = effect of the mediators on the outcome variable, controlling for the independent variable.

Supplementary Material 3. Sensitivity analysis based on causal inference

As a sensitivity analysis, we conducted mediation analyses using a causal inference framework implemented via the *mediation* package in R. Two separate models were tested: one with depressive symptoms and one with physical activity as the mediator. Linear regression was used to model the mediator as a function of pain and covariates, and logistic regression was used for the outcome model, including both mediators and the same covariates. Causal mediation analysis was performed using nonparametric bootstrapping with 5000 simulations. The average causal mediation effect (ACME), average direct effect (ADE), total effect, and proportion mediated were reported, along with 95% bootstrap confidence intervals.

Results showed that when depressive symptoms were considered as the sole mediator, the ACME was 0.00281 (95% CI: 0.00137 to 0.00500, $p < .001$), and the ADE was 0.01311 (95% CI: 0.00615 to 0.02000, $p < .001$). The total effect was 0.01592, and the proportion of the total effect mediated by depressive symptoms was estimated at 17.7% (95% CI: 8.5% to 34.0%). When physical activity was tested as a separate mediator, the ACME was 0.00124 (95% CI: 0.00052 to 0.00200, $p < .001$), and the ADE was 0.01315 (95% CI: 0.00650 to 0.02000, $p < .001$). The proportion mediated in this model was 8.6% (95% CI: 3.6% to 19.0%). These results suggest that both depressive symptoms and physical activity contribute to explaining the pathway from pain to functional dependence.



Supplementary Figure 4.2. Mediation model based on the causal inference framework using the *mediation* package.

Dash arrow = total effect (c); red arrow = direct effects (c'); a paths = effect of the independent variable on the mediators; b paths = effect of the mediators on the outcome variable, controlling for the independent variable; ACME = Average Causal Mediation Effect.

Chapter 5: General Discussion

This doctoral thesis is comprised of three original articles. The first article is a systematic review with a meta-analysis that aimed to examine whether fear of movement is negatively associated with physical activity across several health conditions, including arthritis, and what factors may influence this relationship. The second article is a study conducted online that aimed to examine whether psychological processes including fear of movement, explicit attitudes, and approach-avoidance tendencies toward physical activity, are associated with physical activity levels in people with arthritis. The last article is an analysis of data from the Canadian Longitudinal Study on Aging that aimed to examine the indirect effect of depressive symptoms and physical activity engagement in the relationship between pain and functional status in people with arthritis. This research aims to contribute to the growing body of evidence on how psychological factors influence physical health outcomes in individuals with arthritis.

Summary and General Discussion

The meta-analysis included 63 studies that collectively had a total of 12,278 participants. The results showed that there is a negative correlation between fear of movement and physical activity, with individuals with higher fear of movement being less likely to engage in physical activity. This finding aligns with dual-process models of physical activity behavior, which posit that individuals are influenced by both reflective processes (e.g., conscious intentions, beliefs) and impulsive processes (Brand & Ekkekakis, 2018; Cheval & Boisgontier, 2021, 2023; Conroy & Berry, 2017; Meeus et al., 2016). According to this model, an accumulation of negative experiences or associations with physical activity (e.g., pain or injury) can lead to an automatic tendency towards avoidance behaviors (Brand & Ekkekakis, 2018; Cheval & Boisgontier, 2021, 2023; Conroy & Berry, 2017; Meeus et al., 2016).

In the context of arthritis, the simultaneous occurrence of pain and physical activity may, over time, lead to the association of negative affects with physical activity and, as a result, a tendency to avoid physical activity. Pain during or after physical activity may lead individuals to associate movement with harm or discomfort, reinforcing avoidance behaviors. Over time, this avoidance may contribute to muscular deconditioning, especially in less physically active populations (Aydemir et al., 2022; Medrado et al., 2024), and in turn may lead to physical impairment (Medrado et al., 2024; Xueying et al., 2025) and ultimately disability (Lozano-Meca et al., 2024). This fear-avoidance cycle may become self-perpetuating, as avoidance behavior reinforces fear, which in turn leads to further avoidance (Varangot-Reille et al., 2024).

The association between fear of movement and reduced physical activity was especially pronounced in certain populations, such as those with a cardiac condition (Liu et al., 2024), a neurological condition (Wasiuk-Zowada et al., 2021) a pulmonary condition (Liang et al., 2023), arthritis (Lozano-Meca et al., 2024), as well as older adults (Alpalhão et al., 2022). For these populations, clinicians should be particularly attentive to the presence of fear of movement, as it may hinder recovery and participation in rehabilitation programs. Addressing psychological barriers to physical activity through cognitive-behavioral therapy (Cai et al., 2018), graded exposure therapy (Woods & Asmundson, 2008), or psychoeducation (Vergeld et al., 2021) could enhance treatment outcomes and support long-term engagement in physical activity.

The reasons underlying fear of movement can vary across chronic health conditions (Wlazło et al., 2025). For instance, individuals with cardiovascular conditions may fear triggering another cardiac event (Coull & Pugh, 2021; Rogerson et al., 2012), while those with pulmonary conditions may fear breathlessness or dyspnea during exertion (Freeman et al., 2020; Wang et al., 2023). In neurological conditions, such as Parkinson's disease or stroke survivors, concerns about balance and falls are common (Ellis et al., 2013; Ramsey et al., 2022; Simpson et al., 2011). Among individuals with arthritis, particularly those with rheumatic diseases, there is often a fear of joint damage or aggravating inflammation through movement (Gay et al., 2018). These condition-specific fears underscore the need for tailored interventions that address patients' unique concerns and beliefs.

Given the particularly strong relationship between fear of movement and physical activity in individuals with arthritis, the second and third articles focused on this population. The second article used an online experimental design to explore the role of implicit and explicit attitudes in modulating the relationship between fear of movement and physical activity. This study included a total of 197 participants including 68 participants with osteoarthritis and 13 participants with rheumatoid arthritis. Specifically, this study tested whether implicit tendencies to approach or avoid physical activity stimuli could moderate the relationship between fear of movement and physical activity. Participants were individuals who self-identified as having osteoarthritis or rheumatoid arthritis. Their attitudes were measured using reaction-time tasks that gauged automatic responses to physical activity versus sedentary images. The study found that the negative association between fear of movement and physical activity was significant only in individuals with osteoarthritis, and only when these individuals exhibited a weak or neutral tendency to approach physical activity. In contrast, individuals with stronger approach tendencies did not exhibit this negative association, suggesting a protective role of automatic motivational orientations. These findings support the notion that implicit processes can buffer against the detrimental effects of fear-based avoidance, and may be promising targets for behavior change interventions (Kakoschke et al., 2017; Marteau et al., 2012). Ongoing research is currently investigating whether implicit attitude training, such as evaluative conditioning or approach bias modification, can be used to enhance physical activity in clinical populations (Cheval et al., 2021; Farajzadeh, Goubran, Fessler, et al., 2023; Preis et al., 2021).

The lack of evidence of a significant relationship between fear of movement and physical activity in people with rheumatoid arthritis may be due to a lack of statistical power since the sample had only 13 participants with rheumatoid arthritis. Similar studies in the literature have yielded mixed results (Baday-Keskin & Ekinci, 2022; Demmelmaier et al., 2018; Özlü & Leblebicier, 2022; Peres et al., 2023). The only study that found evidence of the association between fear of movement and physical activity had a sample size of 2569 participants with rheumatoid arthritis (Demmelmaier et al., 2018). Sample size for other studies ranged from 45 to 88 participants with rheumatoid arthritis (Baday-Keskin & Ekinci, 2022; Özlü & Leblebicier, 2022; Peres et al., 2023). The much smaller sample size of the latter studies may have similarly contributed to the lack of statistical significance in the relationship between fear of movement and physical activity.

The third article analyzed data from the Canadian Longitudinal Study on Aging to examine how pain, depression, and physical activity interact and relate long-term functional status in individuals with arthritis. A total of 6972 participants with arthritis (4930 with osteoarthritis and 694 with rheumatoid arthritis) were included. Using a mediation model, the study assessed whether depressive symptoms and physical activity mediated the relationship between baseline pain and future functional dependence in activities of daily living (ADLs) and instrumental activities of daily living (IADLs). The findings confirmed that pain at baseline not only directly predicted future functional decline but also indirectly influenced it via increased depressive symptoms and reduced physical activity.

This is consistent with the biopsychosocial approach to pain in rehabilitation(Smart, 2023), and highlights the importance of addressing both psychological and behavioral pathways in rehabilitation programs for patients with arthritis. More specifically, the first stage of the mediation model examined the effect of baseline pain on depression. We found that individuals with higher pain levels at baseline were more likely to experience depressive symptoms, which was associated with a greater likelihood of functional dependence in ADLs and IADLs at follow-up. This mediating role of depressive symptoms in the relationship between pain and functional status is in line with findings from studies on other populations, such as those with low back pain and pain following traumatic injury (Garcia et al., 2021; Hall et al., 2011; Loew et al., 2016; Marshall et al., 2017; Ross et al., 2015; Seekatz et al., 2013; Talaei-Khoei et al., 2018; Wegener et al., 2011). The fact that the results from other populations also apply to individuals with arthritis, suggests that similar factors may play a role across pain-related conditions. Fortunately, given that depression is both a modifiable and a treatable condition, it is important for rehabilitation professionals to address mental health while discussing interventions aimed at pain-related functional decline in individuals with arthritis.

The second stage of the mediation model examined the effect of pain and depression on physical activity. The results suggest that individuals who are more physically active are less likely to experience pain and depression and more likely to experience better functional outcomes. This finding is consistent with studies showing similar indirect effects in individuals with low back pain (Ekediegwu et al., 2024; Karklins et al., 2024). This shows the importance of physical activity in maintaining functional independence across pain-related conditions, and emphasizes the need to incorporate physical activity in rehabilitation programs to be able to preserve ADL and IADL independence in individuals with arthritis.

Limitations

While the three studies provide novel insights, several limitations should be acknowledged. All three relied primarily on self-reported measures, which are susceptible to response biases and may not accurately reflect actual behavior (Grimmond et al., 2025). Aspects of the questionnaires such as the scale's underlying construct, the way that questions are worded, the number of responses available can influence how someone responds to them (Grimmond et al., 2025). The meta-analysis included papers that used device-based measures in parallel with self-reported measures. However, articles 2 and 3 only used self-reported measures. The arthritic status was self-reported in the second article, which may introduce misclassification of participants. A limitation that only applied to the second article is that the online nature of the study made it impossible to limit the influence of potential distractions in the participant's environment and to control whether participants were using their two index fingers to perform the task as instructed and whether they were sitting or standing, which may have influenced the results. Finally, a limitation that only applied to the third article is that despite adjusting for key confounders, unmeasured variables such as medication use, disease severity, and comorbidities could have influenced the results.

Conclusion

This thesis expands the knowledge on the role of fear of movement in limiting physical activity, particularly among individuals with osteoarthritis. People with osteoarthritis are especially vulnerable to experiencing fear of movement, which in turn leads to a decline in engagement in physical activity. When focusing on the broader factors that influence the prognosis of the disease, physical activity and depression were both mediating factors in the relationship between baseline pain and future functional dependence in ADLs and IADLs. Moreover, baseline pain was also directly related to future functional dependence in ADLs and IADLs.

A key insight from this work is the potential for implicit motivational processes to either exacerbate or buffer the effects of fear-based avoidance of physical activity. By targeting both reflective (e.g., beliefs and intentions) and automatic processes (e.g., approach tendencies), future interventions can take a more comprehensive approach to behavior change. Moreover, the finding that physical activity mediates the relationship between psychological states and functional outcomes emphasizes the centrality of movement in preserving independence and quality of life in people with arthritis.

Clinically, these findings underscore the importance of addressing not only the physical, but also the psychological barriers to physical activity in arthritis care. Repeated positive messaging about the value of physical activity should help foster more adaptive attitudes and behaviors. These messages could be delivered by trusted healthcare providers, peers, and community programs. Rehabilitation specialists should be tailoring their interventions to the unique fears and motivations of individuals with arthritis which could improve both short- and long-term health outcomes.

Future research should aim to develop and test multi-component interventions that integrate the physical, psychological, and social dimensions of care. Longitudinal studies with larger and more diverse samples will be important for validating and expanding upon the findings presented in this thesis.

Another area of future research is to address the dynamic nature of fear of movement by measuring physical activity repeatedly over a period of time. Finally, ensuring that future studies document additional variables such as medication use, disease severity, and comorbidities could show important relationships.

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Chapter 6: Appendix

Article 2 Ethics Approval Letter

27/09/2024

Université d'Ottawa | University of Ottawa
Bureau d'éthique et d'intégrité de la recherche | Office of Research Ethics and Integrity

CERTIFICAT D'APPROBATION ÉTHIQUE | CERTIFICATE OF ETHICS APPROVAL

Numéro du dossier / Ethics File Number	H-05-21-6791
Titre du projet / Project Title	Automatic processes associated with physical activity and sedentary behaviors from a lifespan perspective
Type de projet / Project Type	Recherche de professeur / Professor's research project
Statut du projet / Project Status	Renouvelé / Renewed
Date d'approbation (jj/mm/aaaa) / Approval Date (dd/mm/yyyy)	27/07/2021
Date d'expiration (jj/mm/aaaa) / Expiry Date (dd/mm/yyyy)	26/07/2025

Équipe de recherche / Research Team

Chercheur / Researcher	Affiliation	Role
Matthieu BOISGONTIER	École des sciences de la réadaptation / School of Rehabilitation Sciences	Chercheur Principal / Principal Investigator
Miriam GOUBRAN	École des sciences de la réadaptation / School of Rehabilitation Sciences	Étudiant-chercheur / Student-researcher
Ataallah FARAJZADEH	École des sciences de la réadaptation / School of Rehabilitation Sciences	Étudiant-chercheur / Student-researcher

Conditions spéciales ou commentaires / Special conditions or comments

Article 2 Consent Form (English)

Please read this consent document carefully before you decide to participate in this study.

Title of the study: Automatic processes associated with physical activity and sedentary behavior from a lifespan perspective

Invitation to Participate: I am invited to participate in the above-mentioned research study conducted for academic purposes by Alexa Beehler, Noura Cherkawi, and Paula Hondius under the supervision of Dr. Matthieu Boisgontier.

Purpose of the Study: The purpose of the study is to improve our understanding of the mechanisms underlying the engagement in physical activity across the lifespan.

Participation: My participation in this 30-min online study will consist of responding to questionnaires and performing a reaction-time task on my computer using the Inquisit software. Questionnaires include question related to demographic information, self-control resources, weight perception, body satisfaction, and apathy. In the reaction-time task, I will be asked to move an avatar toward or away from images presented on my computer screen by pressing keys on the keyboard.

Risks: My participation in this study will not cause me any risk or discomfort other than those of everyday life. However, if you feel any discomfort during the experiment, you may stop at any time by pressing the keys "ctrl + Q" to leave the experiment.

Benefits: My participation in this study will contribute to better understand the factors that facilitate or inhibit the engagement in physical activity, thereby helping individuals to adopt a more active and healthier lifestyle. My participation in this project will also help masters' students in Physiotherapy at the University of Ottawa to develop their knowledge and skills in scientific research.

Confidentiality and Privacy: My anonymity will be guaranteed by a unique confidential identification code. My responses to the questionnaires will remain strictly confidential. My name and contact information will not be collected, and my responses are therefore anonymous.

Conservation of Data: The data collected through the Inquisit website will be stored in world-class data center facilities of Inquisit in Oregon, USA and will not be moved to other locations. During data analyses, data will be stored on the University of Ottawa Microsoft OneDrive account of the principal investigator which is protected by a two-factor authentication.

Voluntary Participation: I am under no obligation to participate and if I choose to participate, I can withdraw from the study at any time and/or refuse to answer any questions, without suffering any negative consequences. If I choose to withdraw, I can contact the principal investigator and ask the data related to my unique confidential identification code to be removed. All data gathered until the time of withdrawal will then be removed from the dataset and not used in the study.

Agreement: I have read the above description of the study and I voluntarily agree to participate.

If I have any questions about the study, I may contact Principal Investigator of the project via the contact information below. If I have any questions regarding the ethical conduct of this study, I may contact the Office of Research Ethics and Integrity via email (ethics@uottawa.ca) or telephone (613-562-5387). To get a copy of this consent and get additional information about your rights as a research participant in the study, I can email Dr. Matthieu Boisgontier (matthieu.boisgontier@uottawa.ca) at the School of rehabilitation sciences, Faculty of health sciences, University of Ottawa. Participants are encouraged to save a copy of the consent form.

Acceptance: By selecting the consent statement below, I agree or disagree to participate in this research study.

Yes, I want to participate.
No, I do not want to participate.

Article 2 Consent Form (French)

Veuillez s'il-vous-plait lire attentivement ce document de consentement avant de décider de participer à cette étude.

Titre de l'étude : Processus automatiques associés aux comportements d'activité physique et de sédentarité tout au long de la vie.

Objectif de l'étude : L'objectif de l'étude est d'améliorer notre compréhension des mécanismes qui sous-tendent l'engagement dans l'activité physique tout au long de la vie.

Participation : Ma participation à cette étude en ligne de 30 minutes consistera à répondre à des questionnaires et à effectuer une tâche de temps de réaction sur mon ordinateur à l'aide du logiciel Inquisit. Les questionnaires comprennent des questions relatives à des informations démographiques, aux ressources de maîtrise de soi, à la perception du poids, à la satisfaction corporelle et à l'apathie. Dans la tâche de temps de réaction, on me demandera d'approcher ou d'écarter un avatar d'images présentés sur l'écran de mon ordinateur en appuyant sur les touches du clavier.

Risques : Ma participation à cette étude ne comporte aucun risque et aucune gêne autres que ceux de la vie quotidienne. Cependant, si vous ressentez un quelconque inconfort pendant l'étude, vous pouvez arrêter à tout moment en cliquant sur la combinaison de touches "ctrl + Q" pour quitter l'expérience.

Avantages : Ma participation à cette étude contribuera à mieux comprendre les facteurs qui facilitent ou inhibent l'engagement dans une activité physique, aidant ainsi les individus à adopter un mode de vie plus actif et plus sain. Ma participation à ce projet aidera également les étudiants en master de physiothérapie de l'Université d'Ottawa à développer leurs connaissances et leurs compétences en matière de recherche scientifique.

Confidentialité et vie privée : Mon anonymat sera garanti par un code d'identification confidentiel unique. Mes réponses aux questionnaires resteront strictement confidentielles. Mon nom et mes coordonnées ne seront pas recueillis et mes réponses sont donc anonymes.

Conservation des données : Les données recueillies par le biais du site Web d'Inquisit seront conservées dans les installations du centre de données de classe mondiale d'Inquisit dans l'Oregon, aux États-Unis, et ne seront pas déplacées vers d'autres endroits. Pendant l'analyse de données, ces dernières seront stockées sur le compte Microsoft OneDrive de l'Université d'Ottawa du chercheur principal qui est protégé par une authentification à deux facteurs.

Participation volontaire : Je n'ai aucune obligation de participer et si je choisis de participer, je peux me retirer de l'étude à tout moment et/ou refuser de répondre à toute question, sans subir de conséquences négatives. Si je choisis de me retirer, je peux contacter le chercheur principal et lui demander que les données relatives à mon code d'identification confidentiel unique soient supprimées. Toutes les données recueillies jusqu'au moment du retrait seront alors supprimées de l'ensemble de données et ne seront pas utilisées dans l'étude.

Accord : J'ai lu description de l'étude ci-dessus et j'accepte volontairement de participer.

Si j'ai des questions concernant l'étude, je peux contacter le chercheur principal du projet via les coordonnées ci-dessous. Si j'ai des questions concernant l'éthique de cette étude, je peux contacter le Bureau de l'éthique et de l'intégrité de la recherche par courriel (ethics@uottawa.ca) ou par téléphone (613-562-5387). Pour obtenir une copie de ce consentement et obtenir des renseignements supplémentaires sur vos droits en tant que participant à l'étude, je peux envoyer un courriel au Dr Matthieu Boisgontier (matthieu.boisgontier@uottawa.ca) à l'École des sciences de la réadaptation, Faculté des sciences de la santé, Université d'Ottawa. Les participants sont encouragés à conserver une copie du formulaire de consentement.

Acceptation : En choisissant la phrase ci-dessous, je consens ou ne consens pas à participer à cette recherche.

Oui, je veux participer.
Non, je ne veux pas participer

Article 2 Questionnaires (English)

International Physical Activity Questionnaire

(Craig et al., 2003)

We are interested in finding out about the kinds of physical activities that people do as part of their everyday lives. The questions will ask you about the time you spent being physically active in the **last 7 days**. Please answer each question even if you do not consider yourself to be an active person. Please think about the activities you do at work, as part of your house and yard work, to get from place to place, and in your spare time for recreation, exercise or sport.

Moderate to vigorous physical activity

- Think about all the **vigorous** activities that you did in the **last 7 days**. **Vigorous** physical activities refer to activities that take hard physical effort and make you breathe much harder than normal. Think *only* about those physical activities that you did for at least 10 minutes at a time.

  During the **last 7 days**, on how many days did you do **vigorous** physical activities like heavy lifting, digging, aerobics, or fast bicycling?
  Number of days per week :
  Number of minutes per day :

- Think about all the **moderate** activities that you did in the **last 7 days**. **Moderate** activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal. Think only about those physical activities that you did for at least 10 minutes at a time.

  During the **last 7 days**, on how many days did you do **moderate** physical activities like carrying light loads, bicycling at a regular pace, or doubles tennis? Do not include walking.

  Number of days per week:
  Number of minutes per day:

Sedentary behavior

The last question is about the time you spent **sitting** on weekdays during the **last 7 days**. Include time spent at work, at home, while doing course work and during leisure time. This may include time spent sitting at a desk, visiting friends, reading, or sitting or lying down to watch television.

During the **last 7 days**, how much time did you spend **sitting**?

Number of days per week:

Number of minutes per day:

Effortful Control Scale

(Atherton et al., 2020)

Scale:
1 – Not at all true
7 – Completely true

For each of the sentences, select the number that best describes you:

Attention control:

1. You are good at keeping track of several different things that are happening around you.
2. You pay close attention when someone tells you how to do something.
3. You tend to get in the middle of one thing, then go off and do something else. (R)
4. When you are trying to focus your attention, you are easily distracted. (R)
5. It's often hard for you to alternate between two different tasks. (R)
6. When interrupted or distracted, you usually can easily shift your attention back to whatever you were doing before.

Inhibitory control:

1. When someone tells you to stop doing something, it is easy for you to stop.
2. The more you try to stop yourself from doing something you shouldn't, the more likely you are to do it. (R)
3. It's easy for you to keep a secret.
4. You can stick with your plans and goals.
5. You usually have trouble resisting your cravings for food, drink, etc. (R)
6. You often avoid taking care of responsibilities by indulging in pleasurable activities. (R)

Activation control:

1. You have a hard time finishing things on time. (R)
2. If you have a hard assignment to do, you get started right away.
3. You put off working on projects until right before they're due. (R)
4. You usually finish doing things before they are actually due (e.g., paying bills, finishing homework, etc.)
5. You can keep performing a task even when you would rather not do it.
6. You often make plans you do not follow through with. (R)

Brief Self-Control Scale

(Tangney et al., 2004)

Scale:

1 – Not true at all

2 – Completely true

		Not at all true						Completely true
	I am good at resisting temptation.	1	2	3	4	5	6	7
R	I have a hard time breaking bad habits.	1	2	3	4	5	6	7
R	I am lazy.	1	2	3	4	5	6	7
R	I say inappropriate things.	1	2	3	4	5	6	7
R	I do certain things that are bad for me, if they are fun.	1	2	3	4	5	6	7
	I refuse things that are bad for me.	1	2	3	4	5	6	7
R	I wish I had more self-discipline.	1	2	3	4	5	6	7
	People would say that I have iron self- discipline.	1	2	3	4	5	6	7
R	Pleasure and fun sometimes keep me from getting work done.	1	2	3	4	5	6	7
R	I have trouble concentrating.	1	2	3	4	5	6	7
	I am able to work effectively toward long-term goals.	1	2	3	4	5	6	7
R	Sometimes I can't stop myself from doing something, even if I know it is wrong.	1	2	3	4	5	6	7
R	I often act without thinking through all the alternatives.	1	2	3	4	5	6	7

		Not at all true						Completely true
	I am good at resisting temptation.	1	2	3	4	5	6	7
R	I have a hard time breaking bad habits.	1	2	3	4	5	6	7
R	I am lazy.	1	2	3	4	5	6	7
R	I say inappropriate things.	1	2	3	4	5	6	7
R	I do certain things that are bad for me, if they are fun.	1	2	3	4	5	6	7
	I refuse things that are bad for me.	1	2	3	4	5	6	7
R	I wish I had more self-discipline.	1	2	3	4	5	6	7
	People would say that I have iron self- discipline.	1	2	3	4	5	6	7

R	Pleasure and fun sometimes keep me from getting work done.	1	2	3	4	5	6	7
R	I have trouble concentrating.	1	2	3	4	5	6	7
	I am able to work effectively toward long-term goals.	1	2	3	4	5	6	7
R	Sometimes I can't stop myself from doing something, even if I know it is wrong.	1	2	3	4	5	6	7
R	I often act without thinking through all the alternatives.	1	2	3	4	5	6	7
		Not at all true				Completely true		
	I am good at resisting temptation.	1	2	3	4	5	6	7
R	I have a hard time breaking bad habits.	1	2	3	4	5	6	7
R	I am lazy.	1	2	3	4	5	6	7
R	I say inappropriate things.	1	2	3	4	5	6	7
R	I do certain things that are bad for me, if they are fun.	1	2	3	4	5	6	7
	I refuse things that are bad for me.	1	2	3	4	5	6	7
R	I wish I had more self-discipline.	1	2	3	4	5	6	7
	People would say that I have iron self- discipline.	1	2	3	4	5	6	7
R	Pleasure and fun sometimes keep me from getting work done.	1	2	3	4	5	6	7
R	I have trouble concentrating.	1	2	3	4	5	6	7
	I am able to work effectively toward long-term goals.	1	2	3	4	5	6	7
R	Sometimes I can't stop myself from doing something, even if I know it is wrong.	1	2	3	4	5	6	7
R	I often act without thinking through all the alternatives.	1	2	3	4	5	6	7

R = reverse items

Subjective Vitality Scale

(Ryan & Frederick, 1997)

Scale:
1 – Not at all true
7 – Completely true

Indicate how well each of the following sentences match the general feelings you have experienced over the **past 7 days**:

1. I feel alive and vital
2. I have energy and spirit
3. I look forward to each new day
4. I nearly always feel alert and awake
5. I feel energized

Weight perception

(Major et al., 2020)

Scale:
1 – Very underweight 7
– Very overweight

"How would you describe your body size?''

Weight stigma

(Major et al., 2014)

Scale:
1 – Not at all true
7 – Completely true

How much do you agree with following statements:
"I am concerned that I will not be treated fairly because of my weight" "I
am concerned that others will reject me because of my weight"
"When interacting with people, I am concerned that their opinion of me will be based on my weight.

Lille apathy rating scale (LARS) – Action Initiation Subscale (Behavioral apathy)

(Bonnelle et al., 2015)

Below are a number of statements. Each statement asks you to think about your life over the last 2 weeks.

For each statement, circle a number 1-5 to indicate how true the statement is of you over the last 2 weeks, i.e. how appropriately it describes your life right now.

Select “1” if the statement does not describe you at all over the last 2 weeks, “5” if the statement describes you perfectly, and select the numbers in between accordingly. Select “NA” if the statement is not applicable to you over the last 2 weeks.

1 = Completely UNTRUE: The statement is exactly the opposite of me over the last 2 weeks
2 = Mostly untrue of me over the last 2 weeks
3 = Moderately untrue of me over the last 2 weeks
4 = NEITHER UNTRUE NOR TRUE of me over the last 2 weeks
5 = Moderately true of me over the last 2 weeks
6 = Mostly true of me over the last 2 weeks
7 = Completely TRUE: The statement exactly describes me over the last 2 weeks

	In the last 2 weeks …	Completely UNTRUE						Completely TRUE	
1	I didn’t like to laze around.	1	2	3	4	5	6	7	NA
2	I liked to have a busy schedule	1	2	3	4	5	6	7	NA
3	I usually got up in the morning event if I didn’t have to go to work	1	2	3	4	5	6	7	NA
4	I got things done when they need to be done, without being reminded by others	1	2	3	4	5	6	7	NA
5	I made decisions firmly and without hesitation	1	2	3	4	5	6	7	NA
6	When I had something I needed to do, I did it straightaway so it was out of the way	1	2	3	4	5	6	7	NA
7	I liked being in charge	1	2	3	4	5	6	7	NA
8	I didn’t achieve my goals for the day, I got annoyed	1	2	3	4	5	6	7	NA
9	If I had to RSVP to and invitation, I did it promptly, without needing a reminder.	1	2	3	4	5	6	7	NA
10	I was easily able to decide to do things by myself, without needing someone to push or encourage me.	1	2	3	4	5	6	7	NA
11	Getting something done by 9 am gave me a sense of satisfaction	1	2	3	4	5	6	7	NA

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Article 2 Questionnaires (French)

(Craig et al., 2003; Forestier et al., 2018)

Questionnaire Internationale de l'Activité Physique

Les questions ci-dessous portent sur votre le temps que vous avez passé les 7 derniers jours à faire de l'activité physique modérée et intense, et à être sédentaire. Prenez votre temps pour vous rappeler et calculer le plus précisément possible les différentes durées qui vous seront demandées. La précision de vos réponses est importante

<u>Activité physique modérée à intense :</u>

Pensez à toutes les activités intenses que vous avez faites au cours des 7 derniers jours.

Les activités physiques intenses font référence aux activités qui vous demandent un effort physique important et vous font respirer beaucoup plus difficilement que normalement. Pensez seulement aux activités que vous avez effectuées pendant au moins 10 minutes d'affilée.

> Au cours des 7 derniers jours, combien y a-t-il eu de jours au cours desquels vous avez fait des activités physiques intenses comme porter des charges lourdes, bêcher, faire du VTT ou jouer au football et combien de temps y avez-vous passé ?
>
> **Nombre de jours :**
>
> **Nombre de minutes par jour :**

Pensez à toutes les activités modérées que vous avez faites au cours des 7 derniers jours. Les activités physiques modérées font référence aux activités qui vous demandent un effort physique modéré et vous font respirer un peu plus difficilement que normalement. Pensez seulement aux activités que vous avez effectuées pendant au moins 10 minutes d'affilée.

> Au cours des 7 derniers jours, combien y a-t-il eu de jours au cours desquels vous avez fait des activités physiques modérées comme porter des charges légères, passer l'aspirateur, faire du vélo tranquillement ou jouer au volley-ball ? Ne pas inclure la marche.
>
> **Nombre de jours :**
>
> **Nombre de minutes par jour :**

<u>Sédentarité :</u>

Cette question porte sur le temps total que vous avez passé assis au cours des 7 derniers jours **durant votre temps libre**. Cela comprend le temps passé assis à la maison pendant votre temps libre (exemple : temps passé assis à un bureau, assis ou allongé pour regarder la télévision, devant un écran, sur les réseaux sociaux, à jouer à des jeux vidéo, chez des amis, à lire), **mais ne comprend pas le temps passé à étudier.**

> Au cours des 7 derniers jours, au total, combien de temps, avez-vous passé assis ?
>
> **Nombre de jours :**
>
> **Nombre de minutes par jour :**

Échelle de Contrôle de l'Effort

(Atherton et al., 2020)

Échelle :
1 – Pas du tout d’accord
7 – Complètement d’accord

Pour chacune des phrases, sélectionnez le chiffre qui vous correspond le plus :

Attention control FR:

1. Vous êtes doués pour suivre plusieurs choses différentes à la fois.
2. Vous êtes très attentif lorsque quelqu'un vous dit comment faire quelque chose.
3. Vous avez tendance à commencer quelque chose, puis à arrêter et partir sur autre chose. (R)
4. Lorsque vous êtes en train d’essayer de focaliser votre attention, vous êtes facilement distrait. (R)
5. Il est souvent difficile pour vous d'alterner entre deux tâches différentes. (R)
6. Lorsque vous êtes interrompu ou distrait~~,~~ vous pouvez généralement vous reconcentrer facilement sur ce que vous étiez en train de faire.

Inhibitory control FR :

1. Lorsque quelqu'un vous dit d'arrêter de faire quelque chose, il est facile pour vous de vous arrêter.
2. Plus vous essayez de vous empêcher de faire quelque chose que vous ne devriez pas, plus vous avez de chances de le faire quand même. (R)
3. Il est facile pour vous de garder un secret.
4. Vous arrivez à vous en tenir à vos plans et à vos objectifs.
5. Vous avez généralement du mal à résister à vos envies de nourriture, de boisson, etc. (R)
6. Vous évitez souvent de prendre vos responsabilités~~,~~ en vous livrant à des activités agréables (R)

Activation control FR:

1. Vous avez du mal à finir les choses à temps. (R)
2. Si vous avez une tâche qui est difficile à faire, vous vous y mettez sur-le-champ.
3. Vous repoussez votre travail sur des projets, jusqu’au dernier moment avant l’échéance. (R)
4. Vous finissez généralement vos tâches avant leur échéance (par exemple, payer les factures, finir ses devoirs, etc.)
5. Vous êtes capable de continuer à réaliser une tâche, même quand vous préféreriez ne pas la faire.
6. Vous faites souvent des plans que vous ne menez pas à terme. (R)

Brève Échelle de Maîtrise de Soi

(Brevers et al., 2017; Tangney et al., 2004)

Échelle :
1 – Pas du tout d'accord
7 – Complètement d'accord

Pour chacune des phrases, sélectionnez le chiffre qui vous correspond le plus :

		Pas du tout d'accord						Complètement d'accord
	Je résiste facilement à la tentation	1	2	3	4	5	6	7
R	J'ai du mal à me débarrasser des mauvaises habitudes.	1	2	3	4	5	6	7
R	Je suis paresseux.	1	2	3	4	5	6	7
R	Je dis des choses inappropriées.	1	2	3	4	5	6	7
R	Je fais certaines choses mauvaises pour moi, si elles sont amusantes.	1	2	3	4	5	6	7
	Je refuse de faire des choses qui sont mauvaises pour moi	1	2	3	4	5	6	7
R	J'aimerais avoir plus d'auto-discipline.	1	2	3	4	5	6	7
	On dit de moi que j'ai une bonne auto-discipline.	1	2	3	4	5	6	7
R	Le plaisir et l'amusement m'empêchent parfois de finir mon travail.	1	2	3	4	5	6	7
R	J'éprouve des difficultés à me concentrer.	1	2	3	4	5	6	7
	Je suis capable de mener à bien mes objectifs à long terme.	1	2	3	4	5	6	7
R	Parfois je ne peux pas m'empêcher de faire quelque chose, même si je sais que c'est mal.	1	2	3	4	5	6	7
R	J'agis souvent sans avoir réfléchi à toutes les alternatives.	1	2	3	4	5	6	7

R = reverse items

Échelle de Vitalité Subjective

(Forestier et al., 2018; Ryan & Frederick, 1997)

Échelle :
1 – Pas du tout d’accord
7 – Complètement d’accord

Indiquez à quel point chacune des phrases suivantes correspond aux sentiments généraux que vous avez ressentis durant les 7 derniers jours, en sélectionnant le chiffre qui vous correspond le plus :

1. Je me suis senti(e) en pleine forme, plein de vitalité
2. J’avais de l’énergie et de l’entrain
3. J’ai attendu avec impatience chaque nouveau jour
4. Je me suis presque toujours senti(e) vif(ve) et en forme
5. J’ai trouvé que j’avais beaucoup d’énergie

Perception du poids

(Major et al., 2020)

Échelle :
1 – Poids très faible 4
– Poids moyen
7 – Poids très élevé

« Comment décririez-vous votre corpulence ? »

Stigmatisation liée au poids

(Major et al., 2014)

Échelle :
1 – Pas du tout d’accord
7 – Complètement d’accord

Dans quelle mesure êtes-vous d'accord avec les affirmations suivantes :
"Je crains de ne pas être traité(e) équitablement à cause de mon poids".
"Je crains que les autres me rejettent à cause de mon poids.
"Lorsque j'interagis avec les gens, je crains que leur opinion de moi soit basée sur mon poids"

Échelle d'Évaluation de l'Apathie de Lille -Sous-échelle d'initiation à l'action (apathie comportementale) (Bonnelle et al., 2015)

Pour chaque énoncé ci-dessous, entourez un chiffre de 1 à 5 pour indiquer dans quelle mesure l'énoncé est vrai pour vous au cours des **2 dernières semaines**, c'est-à-dire dans quelle mesure il décrit de manière appropriée à votre vie en ce moment.
<u>Entourez "1"</u> si l'affirmation ne vous décrit pas du tout au cours des 2 dernières semaines, "5" si l'affirmation vous décrit parfaitement, et utilisez les chiffres intermédiaires en conséquence.
<u>Encerclez "S.O."</u> (sans objet) si l'affirmation ne s'applique pas à vous au cours des deux dernières semaines.

1 = Complètement faux : L'affirmation est exactement le contraire de ce que j'ai vécu au cours des 2 dernières semaines.

2 = L'affirmation est **en grande partie fausse** pour moi au cours des deux dernières semaines.

3 = L'affirmation est **modérément fausse** pour moi au cours des 2 dernières semaines.

4 = L'affirmation n'est **ni fausse ni vraie** pour moi au cours des 2 dernières semaines.

5 = L'affirmation est **modérément vraie** pour moi au cours des 2 dernières semaines.

6 = Tout à fait vrai pour moi au cours des 2 dernières semaines.

7 = Complètement vrai : L'affirmation me décrit exactement au cours des 2 dernières semaines.

	Au cours des 2 dernières semaines …	Complètement fau					Complètement vrai		
1	I didn't like to laze around.	1	2	3	4	5	6	7	S.O.
2	I liked to have a busy schedule	1	2	3	4	5	6	7	S.O.
3	I usually got up in the morning event if I didn't have to go to work	1	2	3	4	5	6	7	S.O.
4	I got things done when they need to be done, without being reminded by others	1	2	3	4	5	6	7	S.O.
5	I made decisions firmly and without hesitation	1	2	3	4	5	6	7	S.O.
6	When I had something I needed to do, I did it straightaway so it was out of the way	1	2	3	4	5	6	7	S.O.
7	I liked being in charge	1	2	3	4	5	6	7	S.O.
8	I didn't achieve my goals for the day, I got annoyed	1	2	3	4	5	6	7	S.O.
9	If I had to RSVP to and invitation, I did it promptly, without needing a reminder.	1	2	3	4	5	6	7	S.O.
10	I was easily able to decide to do things by myself, without needing someone to push or encourage me.	1	2	3	4	5	6	7	S.O.
11	Getting something done by 9 am gave me a sense of satisfaction	1	2	3	4	5	6	7	S.O.

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Article 3 Ethics Approval Letter

13/09/2024

Université d'Ottawa | University of Ottawa

Bureau d'éthique et d'intégrité de la recherche | Office of Research Ethics and Integrity

CERTIFICAT D'APPROBATION ÉTHIQUE | CERTIFICATE OF ETHICS APPROVAL

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Conditions spéciales ou commentaires / Special conditions or comments