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

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ABSTRACT

Purpose. Almost twice as many people with arthritis report being physically inactive compared to people without arthritis. The objective of this study was to examine whether psychological processes including fear of movement, explicit attitudes, and approach-avoidance tendencies toward physical activity, are associated with lower physical activity levels in people with arthritis.
Methods. An online observational study was conducted in 197 participants, including 68 with osteoarthritis and 13 with rheumatoid arthritis. Arthritis, fear of movement, usual level of physical activity, and explicit attitudes were assessed using questionnaires. Approach-avoidance tendencies, an indicator of implicit 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 than in those without 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. In addition, contrary to our hypothesis, higher fear of movement was associated with a stronger tendency to approach physical activity and avoid sedentary behaviors, suggesting that people who were most fearful of movement may also be those who unconsciously internalized the importance of physical activity the most.
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

1. 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.[1,2] 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.[3,4] However, some comorbidities may limit the ability of these patients 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.[5] Fear of movement may result not only from the accumulation of overwhelming emotions that develop into a phobia (i.e., kinesiophobia), but also from automatic processes, such as conditioning or learning processes.[6] The prevalence of fear of movement in patients with arthritis ranges from 58% in osteoarthritis[7] to 70% in rheumatoid arthritis.[8] This high prevalence, combined with the association between fear of movement and lower physical activity,[9] may explain why people with arthritis are less active than those without arthritis.[10,11] However, the mechanisms underlying this association remain poorly understood.

Fear of movement is likely to influence the motivational determinants of physical activity.[12] Specifically, the relationship between fear of movement and physical activity may be explained by motivation theories suggesting that the perception of a cue related to physical activity automatically activates the concept of physical activity, along with the pleasant (or unpleasant) affective memories associated with this concept.[13-15] This activation results in an impulse that favors the tendency to approach (or avoid) physical activity.[16] Thus, negative affective associations are likely to hinder physical activity engagement. 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. Considering their close relationship with both motivation and physical activity, explicit attitudes and approach-avoidance tendencies toward physical activity may play a pivotal role in the relationship between fear of movement and physical activity engagement.

Attitude is a psychological tendency to evaluate a stimulus with some degree of favor or unfavor.[17] This tendency is considered an indirect antecedent of physical activity.[13,14,18] Attitude can manifest as reflective (i.e., explicit attitudes) and automatic processes (i.e., automatic attitudes). Explicit attitudes are attitudes that people can report and for which activation can be consciously controlled.[19] Automatic attitudes are typically assessed with reaction-time tasks. They are traces of past experience that remain introspectively unidentified and mediate favorable or unfavorable evaluation of a behavior.[20] In other words, an automatic attitude is thought to result from the positive or negative value that our brain spontaneously assigns to a behavior, without that value being accurately accessible to cognition.[15] This implicit value of a stimulus results in an automatic positive or negative inclination toward this stimulus, which influences behavior. An illustration of this influence is approach-avoidance tendencies, an automatic preparation of the organism to execute a motor pattern toward or away from a behavior.[21]

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 or approach-avoidance tendencies would mediate or moderate the effect of fear of

movement on physical activity levels (Figure 1); and (3) higher fear of movement would be associated with stronger tendencies to avoid physical activity and approach sedentary behavior.

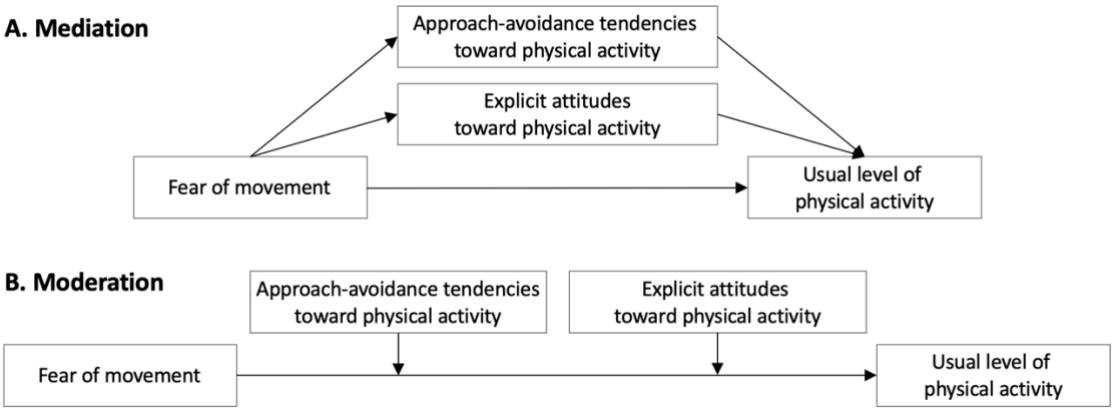

Figure 1. Hypothesized mediation (A) and moderation model (B)

2. METHODS

2.1. 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. Data were collected between July 2022 and December 2023. Participants were not compensated for their participation.

2.2. Power analysis

An a priori power analysis was conducted in G*power[22] to estimate the minimum sample required for $\alpha = 0.05$, power $(1-\beta) = 90\%$, and a medium effect size $f^2 = 0.2$[23]. The analysis based on an F test in a linear multiple regression (R^2 increase) that included two tested predictors and five control variables estimated that a minimum total sample size of n = 67 was required.

2.3. Experimental protocol

2.3.1. Procedures

Participants completed the study online using Inquisit[24] 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.' Implicit attitudes toward physical activity and sedentary behavior were tested using an approach-avoidance task.

2.3.2. 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.[25] '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 included as participants with rheumatoid arthritis in the analyses.

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 duodental 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'. The total number of chronic conditions was used as a control variable in the analyses.

Fear of movement. Fear of movement was assessed using an 11-item short version of the Tampa Scale of Kinesiophobia.[26,27] This scale 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.' The score ranged from 0 (only NAs) to 77.

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.[28] 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 …'.[29] The variable used in the analyses is the sum of these two scores.

Pain. Pain 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').

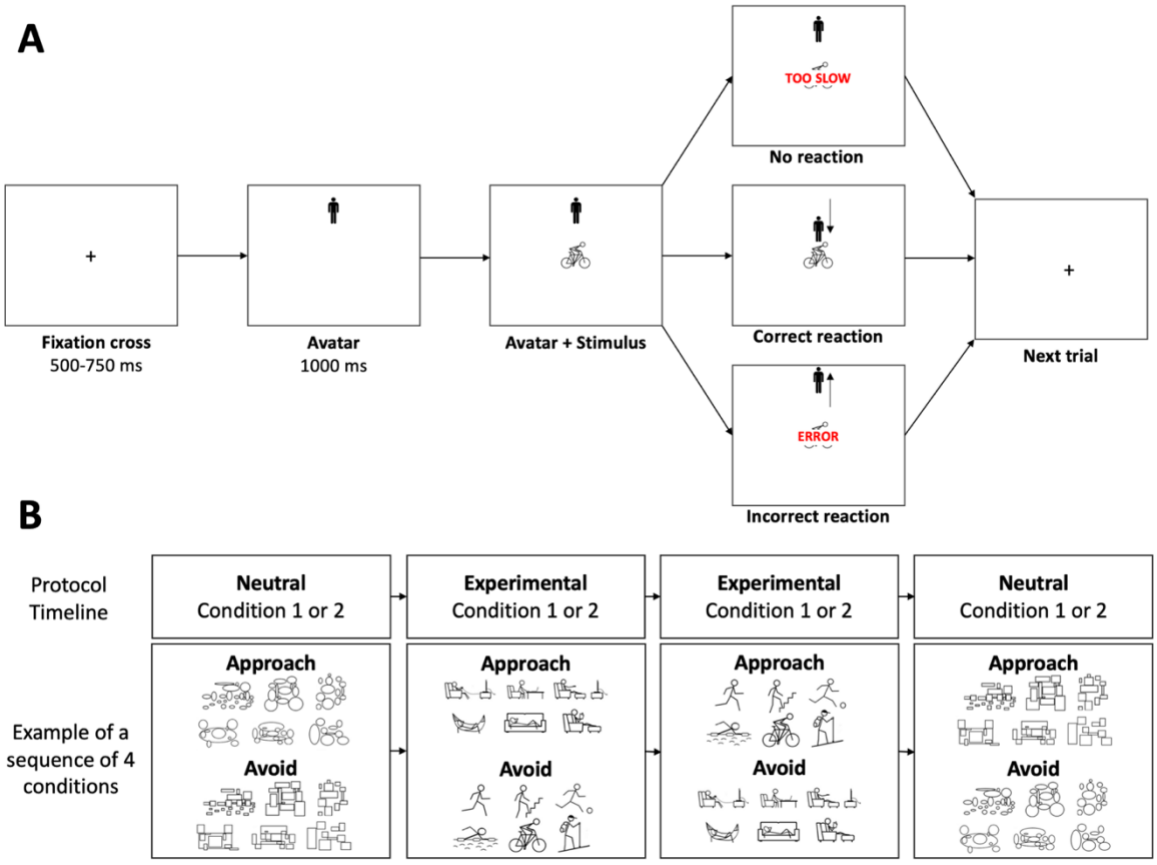

Figure 2. A. Illustration of a single trial of the approach-avoidance task in the condition where the participant is instructed to approach physical activity stimuli (and avoid sedentary stimuli – not shown). B. Timeline and stimuli of the approach-avoidance task. In Condition 1 (experimental and neutral), 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.

2.3.3. Automatic attitudes

Automatic attitudes were assessed using an approach-avoidance task, which has demonstrated good internal reliability (r = 0.83)[16] and has shown the most consistent pattern of associations with physical activity outcomes.[30] This task includes two experimental conditions and two neutral conditions.[16,31,32] 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 bottom 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 that might differ across participants.[16] 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. For each trial in the experimental conditions, reaction time was adjusted by subtracting the mean reaction time for approaching or avoiding neutral stimuli. These individual neutral-adjusted reaction times were used in the mixed effects models. The multiple linear regression used the averaged neutral-adjusted reaction times. 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.[16,32]

2.4. Statistical analyses

2.4.1. Arthritis status and fear of movement

To examine 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 (arthritis vs. no arthritis), ostseoarthritis status

(osteorthritis vs. no osteoarthritis), or rheumatoid arthritis (rheumatoid arthritis vs. no rheumatoid 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[33] were respectively used to conduct the models and compute 95% confidence intervals (95CI).

2.4.2. Mediation analysis

To examine the mediating effect of explicit attitudes and approach-avoidance tendencies toward physical activity on the association between fear of movement and usual physical activity levels in people with osteoarthritis, we used the component approach.[34] This approach to assessing mediation was preferred to the index approach[35] because the latter has shown a higher risk of false positives (type I errors).[34] The component approach involves three linear multiple regression models. Model 1 examines whether the independent variable (i.e., fear of movement) affects the outcome (i.e., physical activity). Model 2 examines the effect of the independent variable on the mediators [explicit attitudes (Model 2A) and approach-avoidance tendencies (Model 2B)]. Model 3 examines 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).

2.4.3. Moderation analysis

To examine the moderating effect of explicit attitudes and approach-avoidance tendencies toward physical activity on the association between fear of movement and the usual level of physical activity engagement in people with osteoarthritis, we used the same multiple linear regression as in Model 3 but with the addition of interaction terms between fear of movement and explicit attitudes, and between fear of movement and approach-avoidance tendencies toward physical activity.

2.4.4. Mixed-effects models

To examine the effect of fear of movement on approach-avoidance tendencies toward physical activity and sedentary stimuli, linear and logistic mixed-effect models[36,37] were built and fit by maximum likelihood using the lme4[38] and lmerTest package,[39] which approximates *p*-values using Satterthwaite's degrees of freedom method. Continuous variables were standardized. Restricted maximum likelihood (REML) was used as it provides less biased estimates of variance components than full maximum likelihood.[40] Fixed effects included a three-way interaction effect of fear of movement (continuous), stimulus (physical activity vs. sedentary behavior), and action direction (approach vs. avoid) on neutral-adjusted reaction time. The other fixed effects controlled for the effect of pain, usual moderate-to-vigorous physical activity, age, sex, body mass index, and the device used to complete the study (computer vs. tablet). Our balanced design was fully crossed: Each participants was tested in the approach and avoid condition of four types of stimuli (physical activity, sedentary behavior, rectangle, ellipses), with each type including 6 pictograms. Therefore, we intended to include the random effect of participant, action direction, stimulus, and pictogram.[36] However, the model converged only when the random effects of action direction and stimulus were removed.

To ensure that the results derived from the neutral-adjusted reaction times cannot be explained by the speed-accuracy trade-off,[41] we conducted a logistic mixed-effects model with the number of errors as the outcome variable. The structure of this model was similar to the linear mixed-effects models that used reaction time as the outcome. However, due to convergence issues when the three-way interaction was included, we conducted two models: One with a two-way interaction between fear of movement and action direction on reaction times toward physical activity stimuli, and another with the same interaction but for sedentary stimuli. To allow model convergence, we removed the fixed effects of age, sex, body mass index, device, and number of chronic conditions, as well as the random effect of pictograms. Because the binary nature of the outcome (error vs. no error), not allow for the same adjustment procedure as reaction times, the models were instead adjusted for the mean error in each participant's avoidance or approach of neutral stimuli.

3. RESULTS

3.1. 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 was 58.7 ± 17.1 years (mean ± standard deviation), with a usual level of moderate-to-vigorous physical activity of 432.3 ± 547.4 min per week, fear of movement of 29.6 ± 12.8, pain of 2.9 ± 1.4, body mass index of 27.6 ± 8.1 kg/m^2, and 1.8 ± 1.6 chronic health conditions. 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. The final sample included 68 participants with osteoarthritis (age: 65.4 ± 11.3 years, physical activity: 425.9 ± 548.1 min/week, fear of movement: 31.7 ± 13.0, pain: 3.2 ± 1.5, body mass index: 27.4 ± 7.2 kg/m^2, chronic diseases: 2.7 ± 1.3, 48 female participants, 20 male participants) and 13 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).

3.2. Statistical results

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

The multiple linear regression testing the moderating effect of arthritis status (arthritis vs. no arthritis) on the association between fear of movement and the usual level of moderate-to-vigorous physical activity showed no evidence of an interaction effect when participants with osteoarthritis and rheumatoid arthritis were merged in the same group (b = 126.5; 95CI = -34.2 to 287.3; p = .122). However, the interaction effect was statistically significant when focusing on osteoarthritis (b = 193.7; 95CI = -23.6 to 363.8; p = .026) (Supplementary 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 osteoarthritis (b = 43.3; 95CI = -71.5 to 158.1; p = .457) (Figure 3). Results showed no evidence of this interaction in people with rheumatoid arthritis (b = -203.8; 95CI = -138.5 to -1.5; p = .143).

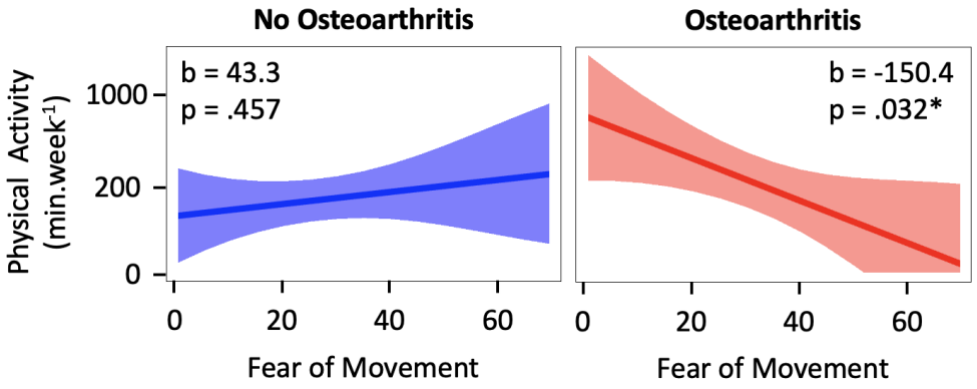

Figure 3. Simple effect of fear of movement on the usual physical activity level as a function of osteoarthritis status. *p<.05

3.2.2. 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 2A 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 2B 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 explicit attitudes or approach-avoidance tendencies toward physical activity (Figure 1A; Supplementary Table 2).

3.2.3. 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) (Figure 1B; Figure 4; Supplementary Table 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 4).

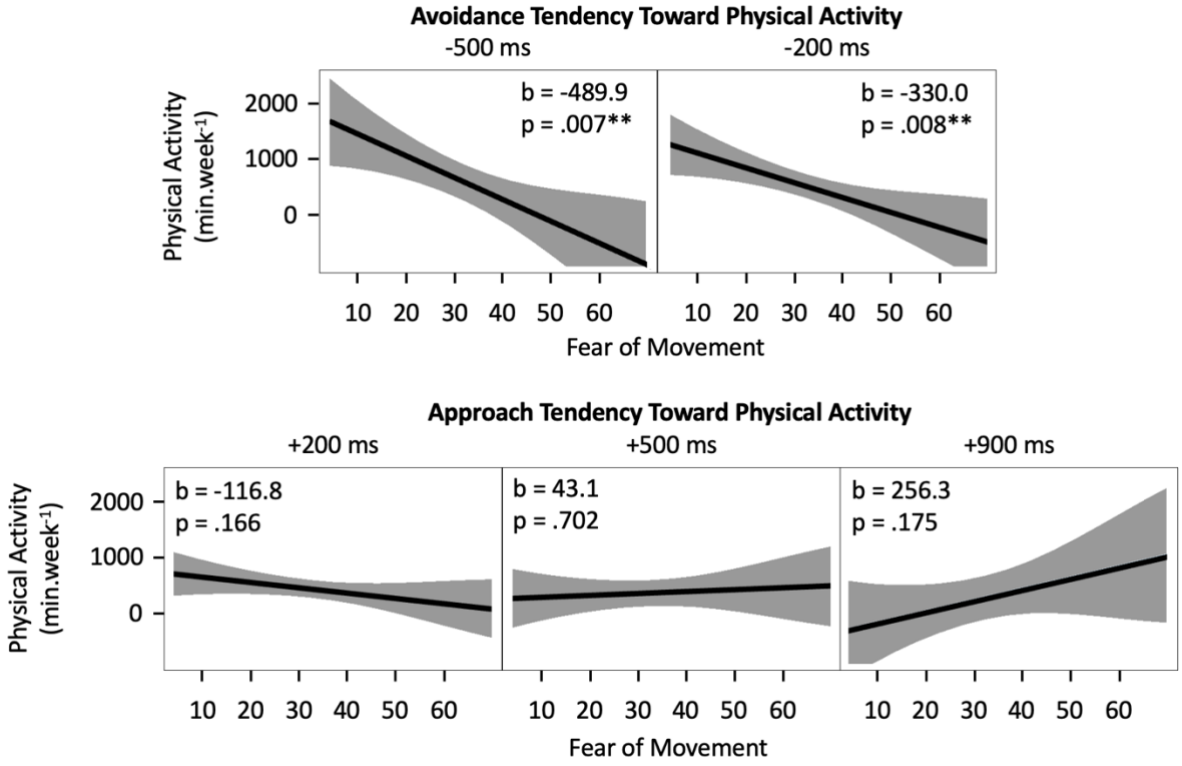

Figure 4. Simple effect of fear of movement on usual physical activity level as a function of approach or avoidance tendency toward physical activity, measured by mean neutral-adjusted reaction time difference (avoid physical activity stimuli – approach physical activity stimuli). A negative difference 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

3.2.4. Fear of movement and automatic approach-avoidance attitudes toward physical activity and sedentary behaviors

Resuls of the linear mixed-effects model showed a significant three-way interaction between fear of movement (continuous), stimulus (physical activity vs. sedentary behavior), and action direction (approach vs. avoid) on reaction time (b = 72.5; 95CI = 24.2 to 121.1; p = .003) (Supplementary Table 4). A simple effect analysis revealed that higher fear of movement was associated with a faster approach of physical activity stimuli (b = -79.8; 95CI = -136.3 to -23.2; p = .011) (Figure 5A) and a faster avoidance of sedentary stimuli (b = -76.2; 95CI = -132.8 to -19.5; p = .016) (Figure 5B). Results showed no evidence suggesting an effect of fear of movement when avoiding physical activity stimuli (b = 72.5; 95CI = -104.4 to 9.7; p = .130) or approaching sedentary stimuli (b = -36.0; 95CI = -93.1 to 21.2; p = .249). Results of the logistic mixed-effects models showed no evidence of an interaction between fear of movement and action direction on errors when reacting to physical activity (b = .054; p = .698) or sedentary stimuli (b = -.121; p = .441).

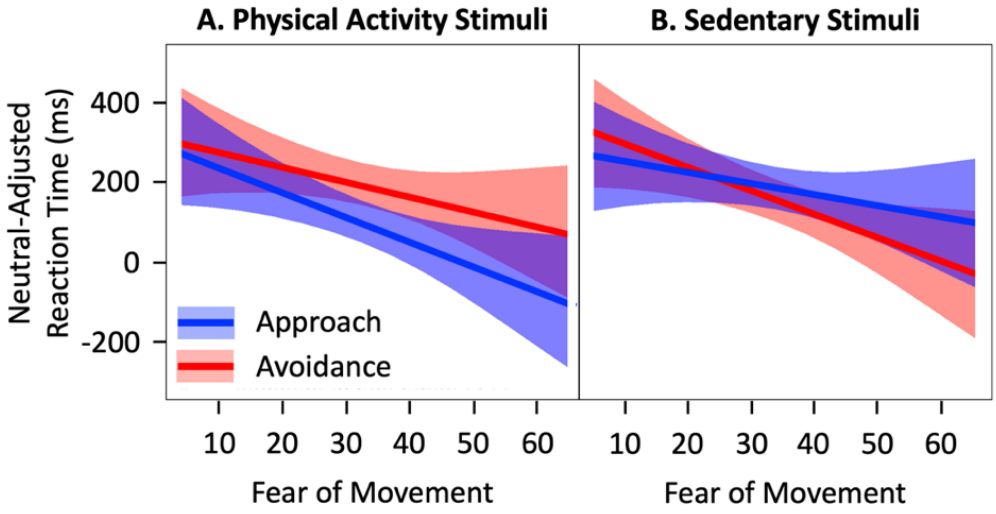

Figure 5. Resuls of the three-way interaction effect of fear of movement (continuous), stimulus (physical activity [A] vs. sedentary behavior [B]), and action direction (approach vs. avoid) on neutral-adjusted reaction time.

4. DISCUSSION

4.1. 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.

4.2. 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, but no evidence of this effect in people without osteoarthritis.[42-45] 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.

We found no evidence of this effect in adults with rheumatoid arthritis. However, this negative result may be explained by low statistical power (n = 13). Previous studies investigating the association between fear of falling and physical activity in people with rheumatoid arthritis have yielded mixed results,[9] with some studies supporting the existence of this association[46] and others showing no evidence.[47-49] Importantly, the study showing evidence of an association was based on a sample of 2569 participants,[46] whereas the sample size of the other studies ranged from 45 to 88 participants. Similar to our study, the smaller sample sizes in the latter studies may have limited their statistical power, increasing the likelihood of failing to detect the association even if it exists.

4.3. 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 implicit attitudes. These interventions have been successful in modifying unhealthy behaviors, such as alcohol consumption, smoking, and eating behavior.[50,51] Whether such interventions can improve physical activity engagement is currently being investigated.[52-54]

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.[13-15] 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. This suggestion is consistent with existing literature highlighting the role of pleasure and displeasure in physical activity engagement.[55,56]

4.4. Fear of movement and approach-avoidance tendencies

Our results in participants with osteoarthritis showed that greater fear of movement was associated with faster approach to physical activity stimuli and faster avoidance of sedentary stimuli. In other words, higher levels of movement fear were associated with stronger automatic tendencies to approach physical activity and avoid sedentary behavior. This finding suggests that individuals who are most fearful of movement may also have unconsciously internalized the importance of physical activity more strongly. Due to their fear of movement, this population may be more exposed and receptive to repeated messaging or personal experiences that emphasize the importance of physical activity in managing their arthritic condition. This internalized importance of physical activity may influence their automatic tendencies toward related cues.

4.5. 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.[57] Second, the usual level of physical activity was self-reported, which may not accurately reflect objective levels of physical activity. 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 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.[58]

4.6. 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.

5. DECLARATIONS

5.1. Data and code availability

According to good research practices,[60] the dataset and the R script are available in Zenodo.[61]

5.2. Authorship contribution statement

Based on the Contributor Roles Taxonomy (CRediT),[62] 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.

5.3. Reporting guidelines

This manuscript conforms to the STROBE guidelines for observational studies.[63]

5.4. Funding

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5.5. Conflict of interest

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

5.6. Acknowledgment

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SUPPLEMENTARY MATERIAL

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

Supplementary Table 3. Moderation analysis: Estimated effects on the usual level of moderate-to-vigorous physical activity (n = 68 participants with osteoarthritis).

Supplementary Table 4. Estimated effects on reaction time (68 participants with osteoarthritis; 5218 observations).

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).

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; 95CI = 95% confidence interval

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

	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 2A Approach-avoidance tendencies			**Model 2B** 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; 95CI = 95% confidence interval

Supplementary Table 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

Supplementary Table 4. Estimated effects on reaction time (68 participants with osteoarthritis; 5218 observations).

Fixed effects	b	95CI	*p*	
Intercept	154.8	-37.1;346.9	.146	
Age	49.9	-14.2;114.4	.160	
Sex	47.4	-37.8;132.0	.311	
Body mass index	-60.6	- 109.5;-11.1	.028	*
Pain	40.0	-2.6;82.3	.090	
Chronic conditions	6.8	-26.3;39.9	.707	
Usual level of moderate-to-vigorous physical activity	28.2	-14.8;71.3	.236	
Explicit attitudes	-29.9	-75.6;15.2	.232	
Device (computer vs. tablet)	-7.3	-196.5;181.9	.944	
Action (approach vs. avoidance)	-87.5	-121.7;-53.1	6.0×10^{-7}	***
Stimulus (physical activity vs. sedentary behavior)	-10.1	-46.9;26.9	.596	
Fear of movement	-47.4	-104.4;9.7	.130	
Action × Stimulus	111.2	62.1;159.9	8.6×10^{-6}	***
Action × Fear of movement	-32.4	-66.5;1.6	.063	
Stimulus × Fear of movement	-28.7	-63.0;5.3	.100	
Action × Stimulus × Fear of movement	72.5	24.2;121.1	.003	**
Random effects	SD	95CI		
Participant (intercept)	154.8	116.5;172.6		
Pictogram (intercept)	11.8	0.0;30.7		
Residual	445.4	436.7;453.9		

Notes: *p<.05; **p<.01; ***p<.001; 95CI = 95% confidence interval; SD = standard deviation