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Kinesiophobia, but not strength is associated with altered movement in women with patellofemoral pain

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ABSTRACT

Background: Evidence indicates the presence of both kinesiophobia and knee extension strength deficits in women with patellofemoral pain (PFP). Both impairments may contribute to apparent compensatory gait patterns including reduced cadence and peak knee flexion during stair negotiation.
Research question: Is kinesiophobia or knee extension strength associated with movement pattern in women with patellofemoral pain?
Methods: Forty women with PFP were assessed with three-dimensional kinematic analyses during stair descent; isokinetic dynamometry of the knee extensors (isometric, concentric and eccentric); and the Tampa scale for kinesiophobia. Pearson coefficients were calculated to determine relationship among variables.
Results: Kinesiophobia correlated significantly with cadence ($r = -0.62$, $p < 0.001$), and peak knee flexion ($r = -0.76$, $p < 0.001$). No significant correlations were found between any knee extensor strength variables and kinematics (cadence or peak knee flexion); or kinesiophobia ($p > 0.05$).
Significance: Findings of this study could suggest addressing strength impairments alone may not adequately address kinesiophobia and movement pattern impairments in women with PFP. However, high-quality randomised controlled trials are needed to test this assumption. Further value may be added if currently evidence-based knee strengthening exercise is combined with education and/or graded exposure to address kinesiophobia, and consideration to gait retraining to address altered movement patterns at the knee.

1. Introduction

Patellofemoral pain (PFP) has high incidence and prevalence [1], with women twice as likely to experience symptoms compared with men [1]. PFP is characterized by altered lower limb mechanics [2] with symptoms exacerbated by activities loading the patellofemoral joint (PFJ) [3] such as stair negotiation [4,5]. Currently, evidence-based exercise therapy programs are considered efficacious in the short-term compared to control interventions [6], but unfavorable outcomes in more than 50% of patients with PFP are still reported [7].

People with PFP may adopt compensatory movement strategies in response to pain to avoid excessive PFJ stress [5]. For instance, reduced knee flexion during stair negotiation has been reported by several studies [8–11], which may be a protection mechanism to reduce PFJ stress and consequently reduce pain. However, such compensatory movement pattern should be addressed as it may be linked to increased vertical ground reaction force loading rates which could lead to deleterious effects on the PFJ [10]. Similarly, people with PFP negotiate

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stairs with slower cadence than pain-free controls [4,5,9]. Brechter and Powers [5] reported that reduced cadence descending stairs might contribute to reduce PFJ reaction force, which is closely linked to PFJ stress.

Reduced peak knee extensor moment has been reported in people with PFP negotiating stairs, suggesting that a quadriceps avoidance may also be present during these tasks [4]. This apparent protective mechanism may lead to the lower knee extensor strength frequently reported in people with PFP due to quadriceps disuse over time [12]. However, prospective evidence indicating lower knee extensor strength as a risk factor [12] to PFP challenges the theory that impaired strength is secondary to kinetics and kinematics compensatory mechanisms. Instead, lower knee extensor strength may drive altered kinematics during stair negotiation reducing the capacity of people with PFP to walk through stairs or reducing the range of knee flexion they can control. Regardless, no study has reported evaluating the relationship between knee extensor strength and kinematics during tasks that load the PFJ such as stair descent to date.

Another driver of impaired kinematics during stair negotiation may be the presence of kinesiophobia in people with PFP [13]. Theoretically, associated fear of movement may result in reduced knee flexion and slower cadence in an attempt to protect the knee [9]. The potential importance of addressing kinesiophobia in PFP has been highlighted by recent reports that a reduction in kinesiophobia was moderately associated with lower pain and higher function following intervention [14]. To date, no one has reported evaluating the relationship between kinesiophobia and kinematics during tasks that load the PFJ such as stair descent. Therefore, the aims of this study were to evaluate relationships between (i) kinematics with knee extensor strength; and (ii) kinematics with kinesiophobia in women with PFP descending stairs.

2. Methods

2.1. Study design and participants

Forty women aged 18–35 years were recruited to participate in this cross-sectional study via advertisements at fitness centers and on social media. The study was approved by the Local Human Ethics Committee, and all participants provided written informed consent (number: 1.484.129).

The eligibility criteria were based on the recommendations of the most recent consensus from the International Patellofemoral Pain Research Retreat [3]. An experienced physiotherapist (> 5 years) applied the eligibility criteria to make the diagnosis of PFP. The inclusion criteria for PFP participants were as follows: anterior knee pain when performing at least two of the following activities: sitting for prolonged time, squatting, kneeling, running, climbing and descending stairs, jumping and landing; insidious onset symptoms lasting at least 4 months; and the worst pain level in the previous month corresponding to at least 30 mm in the visual analogue pain scale (VAS). Exclusion criteria were as follows [9]: sign or symptoms of any other knee dysfunction; history of surgery in any lower limb joint; history of patellar subluxation or clinical evidence of meniscal injury or ligament instability; symptomatic osteoarthritis in any lower limb joint [15]; patellar tendon pathology; referred pain coming from the lumbar spine, hips, ankles, or feet.

2.2. Procedures

Demographic data were collected prior to testing. All participants were asked to rate their worst knee pain intensity during the last month measured on a 0–100 mm VAS. Participants were also administered the Tampa Scale of Kinesiophobia (Tampa). The Tampa is 17-item questionnaire to quantify fear of movement and re-injury due to movement and physical activity on a scale of 17–68, where 68 indicates greatest fear of movement and re-injury [16]. Tampa is reported to have acceptable internal consistency (Cronbach's alpha: 0.68–0.91) and test–retest reliability (ICC: 0.64–0.91) for several musculoskeletal conditions [17]. Additionally, duration of knee-related symptoms (months) and self-reported knee function (Anterior Knee Pain Scale - AKPS) were obtained.

Kinematic and strength assessments were performed on two different days with interval of 48 h to one week to prevent any possible influence of neuromuscular fatigue or muscle soreness (pain level was recorded before each assessment). Participants were asked to avoid any change in physical activity level between assessments. Data collection was performed in participant's symptomatic limb (unilateral symptoms) or most symptomatic limb (bilateral symptoms) [9].

2.3. Kinematic assessment

The kinematic assessment was performed during a stair descent task. Kinematic data was collected using a three-dimensional motion analysis system (Vicon Motion Systems Inc.; Denver EUA) combined with 9 cameras (type Bonita®B10) operating at a sampling frequency of 100 Hz with a resolution of 1 megapixel. Vertical ground reaction force was collected using a force plate (Bertec Corporation, Columbus, OH, model FP4060) at a sampling frequency of 4000 Hz. The force plate was embedded in the fourth step of the staircase, mechanically coupled to the ground (i.e. independent and uncoupled from the stair structure) [18]. The force plate and motion system were synchronized by the Vicon Lock® device. Retroreflective markers (9.5 mm) were placed on participants in accordance with the plug-in gait model, which was previously reported as a valid and reliable model [19]. The anatomical landmarks are described in appendix 1.

Prior to data collection, the motion system was calibrated with a relaxed standing calibration trial. Then, participants performed three practice stair descent trials to allow familiarization with the instrumentation and environment. Each participant was asked to walk down a seven-step staircase (Fig. 1) at their natural comfortable speed because we were interested in their natural cadence. Five successful trials were collected for each participant and the mean value of these five trials was used for data analyses. A trial was considered successful when the tested limb touched the fourth step (where force plate was allocated). If the trial was not considered valid, an additional trial was performed. Just the fourth step was considered for the measurement and analyses related to peak knee flexion.

2.4. Knee extensor strength assessment

Maximal voluntary isometric, concentric and eccentric contractions were evaluated during knee extension using an isokinetic dynamometer (*Biodex System 4 Pro,* New York, USA). The order of contraction assessments was randomized to avoid systematic bias, the dynamometer was calibrated at the beginning of each data collection period. Participants were assessed in the seated position with the hip and non-tested knee flexed at 90°. The center of the knee joint was aligned with the axis of the dynamometer and four belts were used to stabilize the trunk and limb under test, two crossing the trunk, one around the pelvis and one on the distal thigh. For isometric testing knee extensor muscles were evaluated at a joint angle of 60°, for isokinetic testing at a joint

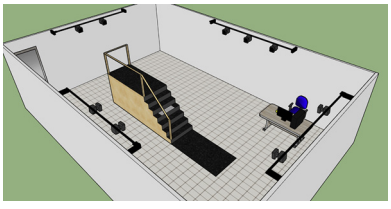

Fig. 1. Experimental set up used to collect the kinematic data. The light gray color onto the fourth step represents the force plate.

angle range from 0 to 90° [20].

For the isometric test, two submaximal practice contractions of 6-seconds with an interval of 1-minute between trials were performed as a familiarization procedure. Then, two maximal isometric contractions of 6-seconds with an interval of 1-minute between each trial were performed to determine the maximum isometric strength. For concentric and eccentric tests participants also performed a familiarization procedure, consisting of one series of five submaximal contractions and one series of two maximal contractions, with a 1-minute interval between series [20,21]. Then, they performed two series of five maximal repetitions with a 3-minute rest period between the series. To correct the influence of gravity, the assessed limb was weighed before each test and the data acquisition software automatically corrected the output data. Concentric and eccentric strength tests were performed at an angular velocity of 30°/s [20,21].

2.5. Data analysis

All kinematic data were filtered with a fourth-order Butterworth low-pass filter with a cutoff frequency of 6 Hz labeled and reconstructed within the Vicon Nexus® software. The vertical ground reaction force signals were used to identify the stance phase from which the measurements of interest were computed. Events of the foot-strike and foot-off were identified using a threshold of 10N [18]. The cadence was calculated based on the time of one entire gait cycle: single leg stance between toe-off of the opposite leg from the third step until foot contact on the fifth step. Each event was inspected manually by viewing the animated visualization of the motion data [9,22].

The kinematic and strength data were analyzed using a custom code in MatLab (MATLAB; The MathWorks, Inc, Natick, MA). The kinematic variable of interest was peak knee flexion at stance phase. The strength variables of interest were peak isometric, concentric and eccentric knee extensor strength. Isometric contraction was measured as the average of the middle 4 s of contraction, not considering the first 1 s and the last second [20]. Concentric and eccentric contractions were measured as the average of the middle 3 repetitions for each strength test to eliminate the possibility of learning (trial 1) and fatigue effects (trial 5) [20,21]. All torque data (N.m) were normalized by body mass ([N.m/kg] × 100).

2.6. Statistical analysis

Due to the novelty of our proposal, we did not find a study with PFP participants that correlated kinesiophobia with kinematics or strength. Therefore, we performed the sample size calculation with a study [13] that correlated kinesiophobia with function and pain. With expected $r = 0.6$ and $p < 0.05$ the number of participants required for a test with a power of 80% ($1\text{-}\beta = 0.80$) was at least 26 participants.

Prior to statistical analysis, all variables were assessed for normality and found to be normally distributed based on obtainment of $p > 0.05$ in the Shapiro-Wilk test. Pearson coefficient correlations were calculated to quantify the relationship between kinesiophobia, kinematics parameters while descending stairs and knee extensor strength. The classification of correlation was defined as $r = 0.8$–1 very high; 0.6–0.79 high; 0.40–0.59 moderate; 0.20–0.39 low; < 0.19 very low. The significance level was set at 0.05 for all statistical analyses. Statistical analysis was performed using SPSS (IBM version 23, SPSS inc., Chicago, Il).

3. Results

Descriptive characteristics of the participants including demographics, self-reported measures, kinematics while descending stairs and knee extensor strength are reported in Table 1. Participant's current pain was found to be similar before isokinetic testing (mean [SD] 26.82 [14.01]) and stair descent task (24.13 [18.15]).

Table 1
Characteristics of the participants with PFP.

Variables	Mean (SD)
Demographics	
Age (years)	22.23 (3.20)
Body Mass (kg)	64.27 (10.16)
Height (m)	1.61 (0.05)
Body Mass Index (BMI)	19.87 (3.10)
Self-reported measures	
Worst pain in the last month (VAS)	52.00 (16.90)
Symptoms duration (months)	55.15 (4.94)
Anterior Knee Pain Scale (AKPS)	71.45 (12.36)
Kinesiophobia (TAMPA)	36.38 (6.53)
Kinematics – Stair descent	
Cadence (steps/minute)	62.67 (9.51)
Peak knee flexion (degrees)	40.61 (7.25)
Peak knee extensor strength	
Isometric (N·m/kg × 100)	205.44 (65.33)
Concentric (N·m/kg × 100)	167.12 (44.13)
Eccentric (N·m/kg × 100)	216.65 (58.60)

Greater kinesiophobia correlated significantly with reduced cadence (high, $r = -0.622$, $p < 0.001$), and peak knee flexion (high, $r = -0.643$, $p < 0.001$) (Fig. 2), explaining 38% and 41% of the variance respectively. No significant correlations were found between kinesiophobia and isometric, concentric or eccentric knee extensor strength ($p > 0.05$) (Table 2).

No significant correlations were found between kinematics (cadence or peak knee flexion) while descending stairs and isometric, concentric or eccentric knee extensor strength ($p > 0.05$) (Table 2).

4. Discussion

Findings from this study indicate strong relationships between kinesiophobia and potentially protective kinematic impairments (reduced peak knee flexion and cadence) during stair descent in women with PFP. However, knee extensor strength (isometric, concentric and eccentric) does not appear to be associated with kinematics (peak knee flexion or cadence) during stair descent, or kinesiophobia. Put together, these findings indicate that kinesiophobia is likely to have greater influence on movement impairments than strength in women with PFP.

Previous case-control studies have reported reduced peak knee flexion [8,9,11] and cadence [4,5] in people with PFP during stair negotiation. Mean (SD) values for cadence in our study 63 (10) step/min were similar to Salsich et al. [4] which reported a rate of 74 step/min. Values for peak knee flexion descending stairs in our study 40.6° (7.5°) were similar to McKenzie et al. [11] and Crossley et al. [8] who reported 39.9° (6.6°) and 33.1° (5.1°), respectively. Additionally, our cohort of women with PFP presented lower knee extensor strength compared to normative data of pain-free people for isometric (29.8%), concentric (31.8%) and eccentric (31.9%) contractions [23].

Reduced peak knee flexion and cadence descending stairs may theoretically serve to decrease PFJ reaction forces [5], and subsequently reduce knee pain. Our findings support the hypothesis that kinesiophobia may strongly influence these adaptations to gait in people with PFP. Importantly, if people with PFP change their behavior due to kinesiophobia (e.g. reducing physical activity level, consequently unloading the knee cartilage), detrimental effects may occur at the PFJ. Additionally, considering previous reported relationships between reduced kinesiophobia and improved pain and symptoms in people with PFP [14], evaluating whether intervention to address kinesiophobia can assist in restoring proper movement pattern, along with reducing pain and symptoms is warranted.

The relationship between knee extensor strength and kinematics in women with PFP was not supported by our study. Rationale for this hypothesis was that impaired knee extensor strength could theoretically reduce the capacity of someone to descend stairs, possibly slowing their

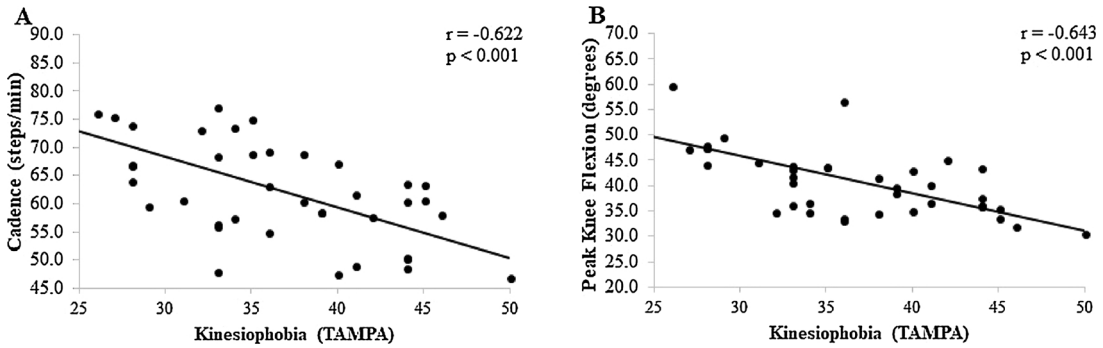

Fig. 2. Scatterplot representing the significant correlation between kinesiophobia (Tampa scale) with kinematics (peak knee flexion and cadence) descending stairs.

Table 2
Correlations among cadence and peak knee flexion while descending stairs, kinesiophobia and knee extensor strength.

Variables	Cadence	
	r	p
Peak knee extensor strength		
Isometric	−0.098	0.548
Concentric	0.004	0.982
Eccentric	0.192	0.235
	Peak knee flexion	
Peak knee extensor strength		
Isometric	0.159	0.192
Concentric	0.128	0.430
Eccentric	0.122	0.498
	Kinesiophobia (Tampa Scale)	
Peak knee extensor strength		
Isometric	−0.124	0.380
Concentric	−0.111	0.496
Eccentric	−0.241	0.134

step rate and reducing the range of knee flexion they can control [5]. Looking at things another way, gait pattern impairments such as reduced knee flexion and reduced cadence could also be hypothesized to lead to a further deleterious effect in knee extensor muscles of people with PFP including lower knee extensor strength [20] and quadriceps atrophy [24]. However, our findings may indicate that knee extensor strength may not drive movement pattern impairments during stair descent.

One possible explanation for the lack of relationship between strength and kinematic impairments is that deficits in maximal strength found in women with PFP may not be sufficient to have an effect on a low impact task like stair descent. Future studies could consider exploring the relationship between strength and movement patterns during high impact activities such as running and landing. Our strength analysis was conducted at 30°/sec, which could be considered slow in comparison to requirements of quadriceps contraction during a stair descent task. Future studies should consider also measuring higher contraction velocities, which may have a greater relationship with stair descent kinematic alterations seen in people with PFP. Additionally, other muscle function variables such as rate of force development or muscle power, along with function of other key muscle groups (e.g. hip musculature) may have a more important influence on the ability of someone with PFP when descending stairs. Further research is needed to explore these possibilities.

The absence of relationship between strength and kinesiophobia in this study was also surprising. Avoidance of quadriceps contraction due to pain inhibition is thought to be common in people with experimentally induced anterior knee pain [25], potentially forming a relationship with kinesiophobia. Theoretically, someone with high levels of kinesiophobia would have greater avoidance of knee joint loading and quadriceps activation, leading to disuse and muscle atrophy. However, our findings indicate that there is no relationship between kinesiophobia and knee extensor strength in women with PFP. Thus, other factors than kinesiophobia seem to contribute to lower knee extensor strength found in people with PFP. Possibilities warranting further investigation include lower H-reflex excitability [26] and pain inhibition [27], which may impair power produced during strength testing.

4.1. Clinical implications

Exercise therapy, including strength training of the knee extensors, has the strongest supporting evidence for treating people with PFP, and is recommended as the cornerstone treatment in the most recent consensus statement [28,29]. However, our findings highlight a potential need to provide additional interventions to address non-physical impairments such as kinesiophobia. This is further emphasized by recently reported links of improvement in pain and disability with a reduction in kinesiophobia [14]. Importantly, interventions able to successfully address kinesiophobia may contribute to optimizing outcomes in people with PFP, a population with a typically high rate of unfavorable outcomes when receiving traditional rehabilitation [7]. Regardless, the lack of relationship of knee extensor strength with movement patterns or kinesiophobia, indicates that targeting strengthening alone may be sub-optimal care, and it does not address all impairments in people with PFP. Thus, further high-quality randomised controlled trials (RCTs) are warranted to test if targeting kinesiophobia through education and targeted exercise therapy may add value to PFP management.

To date, no trials with specific interventions targeting kinesiophobia have been reported in people with PFP [30]. Therefore, development and evaluation of such interventions is needed, perhaps involving education and graded exposure. Considering the strong relationship of reduced peak knee flexion and cadence with kinesiophobia, movement pattern retraining to facilitate increases in knee flexion and cadence may also warrant consideration to address kinesiophobia in people with PFP.

4.2. Limitations

Despite providing some insights about which interventions could be beneficial to people with PFP, the design of this study does not allow direct recommendations for clinical practice related to intervention. However, it does highlight a need to consider conducting RCTs evaluating the effect of interventions targeting kinesiophobia in addition to currently evidence-based interventions such as exercise therapy which typically target strength and muscle function. The only task assessed in our study was stair descent, which limits extrapolation of our findings to other tasks such as squatting, running and jumping. There are more than 300 biomechanical parameters previously reported in people with PFP [2]. Some of these, if evaluated, may help explain the potential influence of reduced knee flexion and cadence on joint health. However, such analysis was beyond the scope of this study, which aimed to

understand how clinically applicable measurements of strength and kinesiophobia might influence these gait adaptations.

5. Conclusion

Kinesiophobia, but not knee extensor strength is highly related with altered movement during stair descent in women with PFP. Additionally, kinesiophobia and knee extensor strength are not related to each other, indicating more traditional exercise therapy programs targeting strength may not improve kinesiophobia or movement pattern impairments. Put together, this suggests that further value may be added if traditional exercise therapy for PFP is combined with education and/or graded exposure to address altered movement patterns and kinesiophobia. Further high-quality RCTs are required to test this hypothesis.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.gaitpost.2018.10.033.

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