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Pain and disability in women with patellofemoral pain relates to kinesiophobia, but not to patellofemoral joint loading variables

Running head: Kinesiophobia relates to patellofemoral pain

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ABSTRACT

Background: Altered patellofemoral joint (PFJ) loading and elevated kinesiophobia are commonly reported in people with patellofemoral pain (PFP). However, the relative relationship of these physical-psychological variables with pain and disability in people with PFP is unknown.

Aim: To explore the relationship of PFJ loading during stair ascent and kinesiophobia, with self-reported pain and disability in women with PFP.

Methods: Fifty-seven women with PFP completed the Tampa Scale for Kinesiophobia, a Visual Analog Scale (0-100mm) for pain during stair ascent, and the Anterior Knee Pain Scale (disability). Stair ascent mechanics were assessed via three-dimensional motion analysis while participants ascended an instrumented seven-step staircase. Peak PFJ contact force and stress, and PFJ contact force and stress loading rates were estimated using a musculoskeletal model. The relationships of PFJ kinetics during stair ascent and kinesiophobia, with the Anterior Knee Pain Scale (disability) and pain during stair ascent were evaluated with Spearman rank correlation. Variables (kinetics, kinesiophobia) significantly correlating with the dependent variables (pain, disability) were inserted in linear regression models.

Results: Kinesiophobia was moderately associated with self-reported pain ($\rho = 0.37$) and disability ($\rho = -0.58$) in women with PFP. No PFJ loading variables were found to be associated with self-reported pain or disability ($p > 0.05$). Kinesiophobia explained 14% of the variance of participants' pain while ascending stairs, and 33% of the variance of participant's self-reported disability.

Conclusion: Addressing kinesiophobia during treatment of women with PFP may be important to reduce self-reported pain and disability.

Keywords: anterior knee pain; rehabilitation; biomechanics; psychology.

INTRODUCTION

Patellofemoral pain (PFP) affects one in four people of the general population and is characterized by peripatellar pain exacerbated by activities that load the patellofemoral joint (PFJ)^{1,2}. Research, and the treatment of people with PFP has historically focussed on mechanical factors that increase or alter patellofemoral joint loading³, with elevated PFJ loading reported during numerous activities in people with PFP^{4,5}. Yet, a growing body of research suggests psychological factors may influence pain and function in people with PFP^{6,7}.

Increased PFJ loading, particularly during repetitive tasks, is thought to influence the development and persistence of PFP^{3,4}. While the exact mechanism by which elevated PFJ loading may contribute to PFP is presently unclear³, increased subchondral bone metabolic activity in the PFJ⁸ and greater patellar cartilage water content⁹ has been reported in people with PFP. Additionally, subchondral bone water content of the PFJ increases with acute loading in people with PFP, with this increase reported to be proportional to increases in PFP symptoms⁹.

Both peak and loading rates of joint forces are proposed to influence PFP⁵. Interestingly, during stair ascent, peak PFJ contact force is reduced in people with PFP compared with pain-free controls, and peak PFJ stress does not differ between groups¹⁰. These findings may reflect compensatory movement strategy to reduce PFJ forces in the presence of pain¹¹. Despite not being increased people with PFP, peak PFJ contact force and PFJ stress occur earlier in people with PFP compared with pain-free controls during stair ascent¹⁰, suggesting a higher PFJ loading rate. Since the peak values and loading rates of the PFJ contact force and stress may represent different domains of PFJ loading, it is important to consider the potential for both to influence PFP. What is unclear from current evidence, is what potential relationships PFJ loading has with pain and disability in people with PFP, and thus how important it might be when developing interventions.

Psychological features of PFP, including kinesiophobia has received increasing attention in the PFP literature^{6,7,11}, and is proposed to be a key driver in the persistence of several musculoskeletal complaints^{12–14}. In people with PFP, higher kinesiophobia is associated with higher pain and disability^{7,15} and, reduced kinesiophobia is reported to be associated with symptomatic improvement following intervention¹⁶.

To date, no study has concurrently investigated the relationship of both physical and psychological features of PFP with pain and disability in the same cohort. We sought to determine the relationship of (i) PFJ loading during stair ascent and (ii) fear of movement, with self-reported pain and disability in women with PFP. Our hypotheses were that both PFJ loading and fear of movement would present a moderate association with pain and disability.

METHODS

Study design

This cross-sectional study was reported according to STROBE guideline recommendations¹⁷. Fifty-seven women with PFP were recruited via advertisements at universities, public parks and posts on social media. The study was approved by the Sao Paulo State University Ethics Committee (process number: 1.484.129). Each participant gave written and verbal informed consent prior to participation.

Eligibility criteria

The adopted eligibility criteria were based on previous studies and a recent PFP consensus statement¹. Volunteers were screened by a licensed physiotherapist with more than five years of clinical experience assessing patients with knee pain. The inclusion criteria were: unilateral anterior knee pain higher than 30mm in a 0-100mm visual analogue scale (VAS) when performing at least two of the following: sitting for prolonged time, squatting, kneeling, running, climbing and descending stairs, jumping or landing; insidious onset of symptoms with a duration of at least the 3 months prior to study enrollment; the worst knee pain level in the previous week higher than 30mm in a VAS; and score lower than 83 in the Anterior Knee Pain Scale (AKPS)¹⁸. The exclusion criteria were history of surgery on any lower limb joint; history of patellar subluxation; clinical evidence of meniscal injury or ligament instability; presence of neurological disease; recent or current physiotherapy treatment for PFP (at least 6 months prior to data collection). Participants were asked to refrain from any pain-relieving medications and avoid unaccustomed types of physical activity in the 7 days prior to data collection. Aiming to control for confounders, we only included women in this study as there are previously reported biomechanical differences between males and females with PFP¹⁹. Moreover, women are one of the most affected population being two times more likely to develop PFP than men²⁰.

Demographics and self-reported outcomes

Demographic and self-reported data were obtained prior to biomechanical testing, including age (years), body mass (kg) and height (m). All participants were asked to rate their worst knee pain intensity in the last week on a 0–100mm VAS as well as the duration of their knee-related symptoms (months).

Participants also completed the (i) Tampa Scale of Kinesiophobia (Tampa), a 17-item questionnaire that quantifies 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. Tampa is reported to have acceptable internal consistency (Cronbach's $\alpha = 0.68\text{--}0.91$) and moderate to high test-retest reliability (ICC = 0.64–0.91) for musculoskeletal conditions²¹; (ii) AKPS, a 13-item questionnaire that evaluates subjective symptoms and functional limitations associated with PFP. The questionnaire score ranges from 0 to 100, with the maximum total score of 100 indicating no disability. This tool has been validated for people with PFP and has been reported to demonstrate high test-retest reliability²².

Biomechanical assessment

The kinematic and kinetic assessment was performed during a stair ascent task. Thirty-two retroreflective markers (Oxford Foot Model (OFM) combined with plug-in gait model [PiG to lower limbs]²³) were applied to each participant to define joint centers, segmental coordinate systems and to serve as tracking markers. Marker trajectories were sampled via a 9-camera three-dimensional motion capture system (Vicon Motion Systems Inc.; Denver EUA) Marker trajectories were sampled at 100 Hz and ground reaction forces were sampled at 4000 Hz with a force plate (Bertec Corporation, Columbus, OH, model FP4060). The force plate was embedded in the fourth step of a seven-step staircase, each step being 18 cm high and 28 cm deep, with a two-meter walkway in front of and behind the staircase. The force plate was mechanically coupled to the ground (i.e. independent and uncoupled from the stair structure)²³. The force plate and motion system were synchronized by the Vicon Lock[®] device.

Participants performed three practice stair ascent trials to allow familiarization with the instrumentation and laboratory environment. Each participant was asked to ascend a seven-

step staircase at a self-selected pace so that stair ascent pace was not artificially constrained. Five successful trials were collected for each participant and the average value of the five trials was used for data analyses. A trial was considered successful when the tested limb made full contact with the instrumented fourth step. In the instance of a non-valid trial, an additional trial was performed. Only the stance phases on the fourth step were used for the biomechanical analysis. All participants were asked to report their level of knee pain on a 0–100mm VAS after the last stair ascent trial.

Data analysis

Kinematic and ground reaction force data were used to calculate three-dimensional hip, knee, and ankle joint kinematics and internal joint moments (The MotionMonitor; Innovative Sports Training, Inc, Chicago, IL). Kinematic data and ground reaction force data used in inverse dynamics calculations were digitally filtered using a low pass, fourth order Butterworth recursive filter with matched cut off frequencies (15 Hz)²⁴. Ground reaction force data used to identify initial contact were digitally filtered at 50 Hz using a low pass, fourth order Butterworth filter. Events of the foot-strike and foot-off during the stair ascent trials were identified using a threshold of 10N. Internal joint moments were then calculated using an inverse dynamics approach, using published segmental inertial properties²⁵.

A previously described biomechanical model^{26,27} was used to estimate PFJ contact force and stress during stair ascent. Briefly, this model uses sagittal plane hip, knee and ankle joint angles, net moments, estimated muscle moment arms and cross-sectional areas to derive hamstrings, quadriceps, gastrocnemius, and soleus muscle forces. After accounting for co-contraction of the knee flexors, PFJ contact force was then calculated using the quadriceps force as a function of knee flexion angle^{28–30} and expressed in body weights (BW). PFJ stress throughout the stance phase was estimated as the quotient of PFJ contact force and PFJ contact area²⁶ and expressed as megaPascals (MPa).

The dependent variables of interest using this model were peak PFJ contact force, peak PFJ stress, peak PFJ contact force loading rate and peak PFJ stress loading rate. A custom program (National Instruments Corporation, Austin, TX) was used to extract discrete variables from the PFJ contact force and PFJ stress curves of the individual step ascent trials. First, the peak values of PFJ contact force and PFJ stress were extracted. Loading rates of PFJ contact force and PFJ

stress were then determined at the steepest portion of the ascending portion of the respective curves via the first central difference method³¹ and expressed as BW/s and MPa/s, respectively.

Statistical analysis

Sample size was determined based on 80% predicted power and alpha of 0.05 with an expected correlation coefficient of 0.53 reported by Domenech et al.¹⁵ on the correlation of kinesiophobia with self-reported disability. Based on calculations described by Hulley et al.³², a minimum sample size of 26 participants was indicated. We aimed to recruit more participants in order to avoid type II error related to PFJ loading variables which sample size could not be calculated *a priori* due to the originality of our proposal. Therefore, 57 women with PFP were included.

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). As most of the variables included in our study are ordinal scales (VAS, AKPS and Tampa) we used Spearman rank correlation to quantify the relationship between kinesiophobia and PFJ loading variables with pain and disability. The classification of correlation was defined as $\rho < 0.19$ very low; 0.20–0.39 low; 0.40–0.59 moderate; 0.6–0.79 high; 0.8–1 very high³³.

All variables found to be significantly correlated with the dependent variables were inserted in a linear regression model. The assumption of homogeneity of variance and linearity was verified by qualitative inspection of the regression of standardized residual versus regression of standardized predicted value plot. Overall performance of the final models (parameters with significant Pearson correlation) was evaluated using the coefficient of determination (r^2), which estimates explained variation of the model³⁴.

RESULTS

Descriptive characteristics of the participants including demographics, self-reported measures and PFJ loading variables while ascending stairs are reported in Table 1.

PLEASE INSERT TABLE 1 HERE

Kinesiophobia was moderately associated with self-reported pain ($\rho = 0.37$) and disability ($\rho = -0.58$) in women with PFP. No significant relationships were found between any PFJ loading variables and self-reported pain or disability (Table 2).

PLEASE INSERT TABLE 2 HERE

Kinesiophobia explained 14% of the variance of participants' pain while ascending stairs ($r^2 = 0.14$; F-value = 9.25; $p = 0.004$) and 33% of the variance of participant's self-reported disability ($r^2 = 0.33$; F-value = 19.99; $p < 0.001$).

DISCUSSION

This study concurrently investigated the relationship of both physical and psychological features of PFP with pain and disability in the same cohort. Our hypotheses were only partially confirmed. Specifically, a moderate relationship of kinesiophobia with self-reported pain and disability was identified, explaining 14% and 33% of its variance respectively. However, PFJ loading variables were not found to be related with self-reported pain or disability in our cohort.

The moderate relationship of kinesiophobia with self-reported pain and disability identified in this study adds to the growing body of evidence indicating the potential importance of psychological factors for PFP^{6,7,15}. The magnitude of kinesiophobia in our cohort (TSK = 36.6) is consistent with previously published PFP cohorts (average range = 36.3 – 39.3)^{6,11}, and substantially higher than published pain-free cohorts (average range = 27.30 – 28.4)⁷. Adolescents with PFP have also reported high levels of kinesiophobia³⁵. To date, only one randomized controlled trial has specifically targeted reducing kinesiophobia of people with PFP³⁶, reporting a large reduction in kinesiophobia following wearing a knee brace for 2-weeks compared to minimal intervention. Previous studies have also reported a link between reduction in kinesiophobia and improvements in clinical outcomes following intervention in people with PFP¹⁶, further highlighting its potential importance. However, determining if reducing kinesiophobia mediates improvements in key outcomes (i.e. pain and disability) requires further well-designed clinical trials. Nonetheless, our findings linking kinesiophobia with pain and disability indicate that developing interventions that expand beyond solely biomechanical

factors³⁷ may help improve clinical outcomes for a condition with often poor long-term prognosis.

The absence of a significant relationship for PFJ loading variables during stair ascent with pain and disability is interesting considering these variables are frequently proposed to be key treatment targets within a theoretical pathoanatomical model³. This finding highlights the complexity of PFP, where direct links between biomechanical impairments and clinical outcomes have not been established. The absence of association for PFJ loading variables with self-reported pain and disability in our findings raises several key considerations. Firstly, previous reports exploring PFJ loading during tasks demanding high knee flexion angles (e.g. deep squat, running) have reported no differences between people with and without PFP³⁸, a finding contrary to previous theoretical pathoanatomical assumptions³. Secondly, biomechanical impairments are not homogenous across the PFP population, with impairments distributed inconsistently through proximal (trunk and hip), local (knee), and distal (ankle and foot) factors^{3,39}. Finally, kinesiophobia, which was found to be related to pain and disability in our cohort, may have translated to adoption of protective movement patterns to reduce loading of an irritable PFJ while ascending stairs¹¹. For instance, previous findings from our group suggested there is a strong relationship of higher levels of kinesiophobia with lower peak knee flexion and cadence during stair ambulation in women with PFP¹¹.

There are few previously published reports of PFJ contact force and stress during step ascent and these investigations used the same experimental setup and musculoskeletal model^{10,40}. The PFJ contact force and PFJ stress values in the aforementioned reports are greater than the values found in the present investigation. However, the prior reports used the first step of a two-step stair configuration whereas our investigation used the fourth step of a seven-step configuration. Further, our musculoskeletal model accounted for co-contraction of the knee musculature to determine PFJ kinetics whereas the previous investigations used a musculoskeletal model that relied solely on the knee extensor moment to determine quadriceps force¹⁰. Thus, we are unable to compare values of PFJ kinetics from the current investigation with prior studies.

Limitations

The design of our study (cross-sectional) does not allow direct recommendations for clinical practice related to interventions. The only task assessed in our study was stair ascent, which

limits extrapolation of our findings to other tasks such as walking, squatting, running and jumping. Further studies exploring the interaction among physical and psychological variables may produce different outcomes depending on the task. Additionally, future research could explore the associations between PFJ loading and the fear of performing stair ambulation or other pain-provoking tasks. The musculoskeletal model used in our study was not entirely subject-specific and did not account for joint motions and forces in the frontal and transverse planes to estimate PFJ loading variables, which may have influenced our outcomes. Only women with PFP were included in our study, meaning further research using similar methodology in men and adolescents with PFP is required before findings can be applied to these populations.

Perspective

PFP has been historically seen as purely mechanical condition^{1,3}. However, our findings provide insight that kinesiophobia may be a potential psychological mediator of pain and disability outcomes in people with PFP. Future research should seek to understand if interventions targeting reductions in kinesiophobia can effectively optimize rehabilitation and reduce high rates of people with PFP reporting unfavourable outcomes in the long-term. Our findings suggest a paradigm change in the field. Future research exploring mediating factors thought to contribute to recovery from PFP should not be limited to biomechanics, but should also include psychological factors such as kinesiophobia.

CONCLUSION

The moderate relationship of kinesiophobia with self-reported pain and disability indicates addressing kinesiophobia during the treatment of women with PFP may be important to improve clinical outcomes. Our findings suggest that PFJ loading during stair ambulation may have questionable importance in those with symptomatic PFP and that kinesiophobia may play a more important role in their self-reported pain and disability.

CONFLICT OF INTEREST

The authors wish to declare there is no conflict of interest associated with this publication.

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Table 1 – Characteristics of the participants with PFP.

Variables	Mean (SD)
<i>Demographics</i>	
Age (years)	22.00 (3.00)
Body Mass (kg)	61.95 (9.42)

Height (m)	1.62 (0.05)
Body Mass Index (BMI)	23.62 (3.76)
<i>Self-reported measures</i>	
Worst pain in the last week (VAS)	52.07 (16.24)
Pain ascending stairs (VAS)	38.87 (10.14)
Symptoms duration (months)	53.46 (47.08)
Anterior Knee Pain Scale (AKPS)	72.56 (10.70)
Kinesiophobia (TAMPA)	36.66 (7.34)
<i>PFJ loading variables – Stair ascent</i>	
Peak PFJ contact force (BW)	2.09 (0.55)
PFJ contact force loading rate (BW/s)	18.65 (11.80)
Peak PFJ stress (MPa)	2.65 (0.61)
PFJ stress loading rate (MPa/s)	22.41 (12.54)

Abbreviations: BW = Body weight; MPa = megaPascals

Table 2 – Correlations of PFJ loading variables and kinesiophobia with self-reported pain ascending stairs and disability of women with PFP.

Variables	Pain Ascending Stairs		Disability	
	rho	p-value	rho	p-value
Peak PFJ contact force	0.05	0.669	0.01	0.902
Peak PFJ stress	0.10	0.455	-0.03	0.827
PFJ contact force loading rate	-0.04	0.731	-0.04	0.762
PFJ stress loading rate	-0.04	0.756	-0.01	0.950
Kinesiophobia	0.37	0.005	-0.58	< 0.001

PFJ = Patellofemoral joint

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