Physical Therapy in Sport 33 (2018) 89–95

Contents lists available at ScienceDirect

Physical Therapy in Sport

journal homepage: www.elsevier.com/ptsp

Original Research

Implications of knee crepitus to the overall clinical presentation of women with and without patellofemoral pain

Danilo de Oliveira Silva [a, b, *], Christian Barton [b], Kay Crossley [b], Marina Waiteman [a], Bianca Taborda [a], Amanda Schenatto Ferreira [a], Fábio Mícolis de Azevedo [a]

[a] Laboratory of Biomechanics and Motor Control, School of Science and Technology, São Paulo State University (UNESP), Presidente Prudente, Brazil
[b] La Trobe Sports and Exercise Medicine Research Centre (LASEM), School of Allied Health, La Trobe University, Bundoora, Victoria, Australia

ARTICLE INFO

Article history:
Received 7 June 2018
Received in revised form 16 July 2018
Accepted 16 July 2018

keywords:
Knee pain
Kinesiophobia
Strength
Function

ABSTRACT

Objectives: Compare anthropometric characteristics, function, kinesiophobia, catastrophism and knee extensor strength between women (i) with PFP and crepitus ($PFP_{crepitus}$); (ii) with PFP and no crepitus ($PFP_{NOcrepitus}$); (iii) without PFP and crepitus ($\text{Pain-free}_{crepitus}$); and (iv) without PFP and no crepitus ($\text{Pain-free}_{NOcrepitus}$).
Design: Cross-sectional.
Setting: Laboratory study.
Participants: 65 women with PFP and 51 pain-free women.
Main outcome measures: Objective assessment of knee crepitus, forward step-down and single leg hop tests; knee extensor strength tests; and subjective ratings of function, kinesiophobia, pain catastrophising and knee stiffness.
Results: Crepitus was more common in women with PFP (50.7%) compared to those without (33.3%) ($\chi^2_{(1)} = 4.17$; $p = 0.031$). $PFP_{crepitus}$ and $PFP_{NOcrepitus}$ groups had lower self-reported function; and higher kinesiophobia, catastrophism and knee stiffness compared to $\text{Pain-free}_{crepitus}$ and $\text{Pain-free}_{NOcrepitus}$ groups ($p < 0.001$). $PFP_{crepitus}$, $PFP_{NOcrepitus}$ and $\text{Pain-free}_{crepitus}$ groups had lower functional performance compared to the $\text{Pain-free}_{NOcrepitus}$ group ($p < 0.040$). $PFP_{crepitus}$ and $PFP_{NOcrepitus}$ groups had lower isometric, concentric and eccentric knee extensor strength compared to the $\text{Pain-free}_{NOcrepitus}$ group ($p < 0.041$), but not the $\text{pain-free}_{crepitus}$ group. $PFP_{crepitus}$ presented higher BMI than other groups ($p = 0.001$).
Conclusion: Kinesiophobia, catastrophism, knee stiffness, strength and physical function are all impaired in women with PFP, regardless of crepitus. In pain-free women, crepitus was associated with poorer objective function.

1. Introduction

Patellofemoral pain (PFP) affects up to 25% of active individuals (Glaviano, Kew, Hart, & Saliba, 2015; Smith, Selfe, & Rathleff, 2018b), and is thought to be linked with development of patellofemoral osteoarthritis (OA) later in life (Crossley, 2014; Wyndow, Collins, Vicenzino, Tucker, & Crossley, 2016). Women are 2 times more likely to develop PFP than men (Boling et al., 2010). Clinically, people with PFP frequently report pain during activities that load the patellofemoral joint in a flexed knee position (Crossley et al., 2016). Research indicates lower knee strength (Toumi et al., 2013), altered movement patterns (De Oliveira Silva, Barton, Pazzinatto, Briani, & de Azevedo, 2016), kinesiophobia (Domenech, Sanchis-Alfonso, López, & Espejo, 2013), increased body mass (Hart, Barton, Khan, Riel, & Crossley, 2017) and knee crepitus (Crossley et al., 2016; De Oliveira Silva et al., 2018) are associated with PFP.

Knee crepitus is a frequent complaint for people with PFP, and its presence is reported as an inclusion criteria in some PFP studies (Kastelein et al., 2014; Nijs, Van Geel, Van Der Auwera, & Van de Velde, 2006; Patil, White, Jones, & Hui, 2010; Price, Jones, & Allum, 2000). Crepitus without pain in the general population may be an important consideration. Specifically, in a population of

* Corresponding author. La Trobe University, Kingsbury Drive, Bundoora, VIC, 3086, Australia.
E-mail address: danilo110190@hotmail.com (D. de Oliveira Silva).

https://doi.org/10.1016/j.ptsp.2018.07.007
1466-853X/

people with no preexisting frequent knee symptoms and no radiographic osteoarthritis, knee crepitus has been reported to predict symptomatic knee OA (Lo et al., 2018) up to 4 years later, possibly representing early signs of patellofemoral OA (Schiphof et al., 2014). Despite being studied and reported in knee OA literature, the relative importance of knee crepitus is poorly understood in people with PFP.

For the individual with PFP, knee crepitus creates negative emotions and beliefs leading to altered behavior (e.g. kinesiophobia and reduced physical activity) (Robertson, Hurley, & Jones, 2017). Despite this, recent reports indicate that knee crepitus is not associated with self-reported function and pain during several tasks in people with PFP (De Oliveira Silva et al., 2018). However, it is unknown if knee crepitus has an influence on other clinical features of PFP (e.g. pain catastrophism, kinesiophobia, lower physical function and strength), which might relate to poorer prognosis (Lankhorst et al., 2016). A better understanding of the relationship of crepitus with PFP and other associated clinical features could aid clinicians and research to determine the importance of developing and implementing treatment strategies to address the potential factors associated with it (Song, Park, Liang, & Kim, 2018). Additionally, investigating the potential implication of knee crepitus on function and psychological profile in pain-free people could inform future longitudinal studies.

The aim of this study was to compare anthropometric characteristics, self-reported and objective function, knee stiffness, kinesiophobia, catastrophism and knee extensor strength between women (i) with PFP and crepitus ($PFP_{crepitus}$); (ii) with PFP and no crepitus ($PFP_{NOcrepitus}$); (iii) without PFP and crepitus ($\text{Pain-free}_{crepitus}$); and (iv) without PFP and no crepitus ($\text{Pain-free}_{NOcrepitus}$).

2. Methods

2.1. Participants

Sixty-five women with PFP and fifty-one pain-free women aged 18–35 years old were recruited via advertisements at universities and posts on social media (Facebook). In order to allow blinding of measurements, one physiotherapist that did not participate in the data collection was responsible for the recruitment. This cross-sectional study was approved by the Local Ethics Committee. Each participant gave written informed consent prior to participation. Data from this paper are not a subsection of our recent study (Danilo De Oliveira Silva et al., 2018). The current data were collected in a subsequent data collection with a more comprehensive experimental design.

2.2. Eligibility criteria

The diagnosis of PFP was made by a physiotherapist (>six years of clinical experience) based on the eligibility criteria of previous studies (Crossley et al., 2016; Décary et al., 2018). The inclusion criteria were (1) reporting knee pain in at least two of the following activities: sitting for prolonged time, squatting, kneeling, running, jumping, landing, ascending or descending stairs; (2) insidious onset knee pain lasting at least 4 months; and (3) the worst pain level in the previous month corresponding to at least 30 mm in the 0–100 mm visual analogue pain scale (VAS). Participants needed to present all 3 criteria to be included in the PFP group. To be included in the pain-free group participants could not present any signs or symptoms of PFP or other musculoskeletal condition. Exclusion criteria, assessed by a physiotherapist, for both PFP and pain-free groups were as follows: (1) history of surgery in any lower limb joint, (2) history of patellar subluxation or clinical evidence of meniscal injury or ligament instability, or joint effusion, (3) symptomatic osteoarthritis in any lower limb joint assessed clinically according to OARSI criteria to diagnose patients with osteoarthritis, (4) symptomatic patellar tendon pathology, (5) referred pain coming from the lumbar spine, hips, ankles or feet, or (6) presence of medical conditions.

2.3. Procedures

A previously trained investigator explained to the participants in detail how to perform each test. Participant's symptomatic limb (unilateral symptoms) or most symptomatic limb (bilateral symptoms) was assessed (De Oliveira Silva et al., 2018). For the pain-free group, the dominant limb was evaluated (identified by asking which leg the participant would use to kick a ball as hard as possible). The investigator who performed all tests was blinded to condition (PFP or pain-free). Prior to data collection, demographic data including age, body mass and height were recorded. The data collection was separated in 2 days: Day one – Participants performed knee crepitus test, functional performance tests and completed the self-reported outcomes; Day 2 – Participants performed knee extensor strength tests.

2.4. Knee crepitus clinical test

The investigator placed the palm of the hand over the patella to detect the presence of a continuous grinding sensation during two squats as deep as the participants felt themselves comfortable, with maximum limit of 90° of knee flexion (active knee flexion-extension movement) (Souza, 1997). The test was considered positive for knee crepitus when a grinding, crackling or crunching sensation during knee extension or flexion was detected (Song et al., 2018). However, just one or two clicks or pops were not considered as crepitus (Song et al., 2018). This test was previously reported to be reliable with Kappa value (95% Confidence Interval) of 0.860 (0.727–0.993) for people with PFP and 0.906 (0.816–0.995) for pain-free (De Oliveira Silva et al., 2018).

2.5. Self-reported measures

PFP participants and pain-free controls completed the Self-reported function (Anterior Knee Pain Scale – AKPS) (Crossley, Bennell, Cowan, & Green, 2004; De Oliveira Silva et al., 2015), Kinesiophobia (Tampa Scale) (French, France, Vigneau, French, & Evans, 2007; Kori, Miller, & Todd, 1990), the Pain Catastrophizing Scale (PCS) (Sullivan, Bishop, & Pivik, 1995) and a VAS (0–100 mm) for Knee Stiffness (how severe their knee stiffness usually is later in the day).

2.6. Functional performance

Two tasks were used to assess functional performance in women with PFP and pain-free controls: forward step-down test (FSDT) and single leg hop test (SLHT) (Fig. 1). Participants performed three familiarization trials before each test.

To perform the FSDT, participants stood on a 20 cm high platform in a bipedal stance and stepped forward to tap with their non-test leg on the ground in front of the step, while keeping the tested leg on the step, before returning to starting position, with their hands on the wrist during the entire test. The number of repetitions that the participant performed in 30 s was recorded by the investigator, and for the repetition to be validated, the participant should touch the floor only with the heel, returning the position of complete extension of the knee (Loudon, Wiesner, Goist-foley, Asjes, & Loudon, 2002).

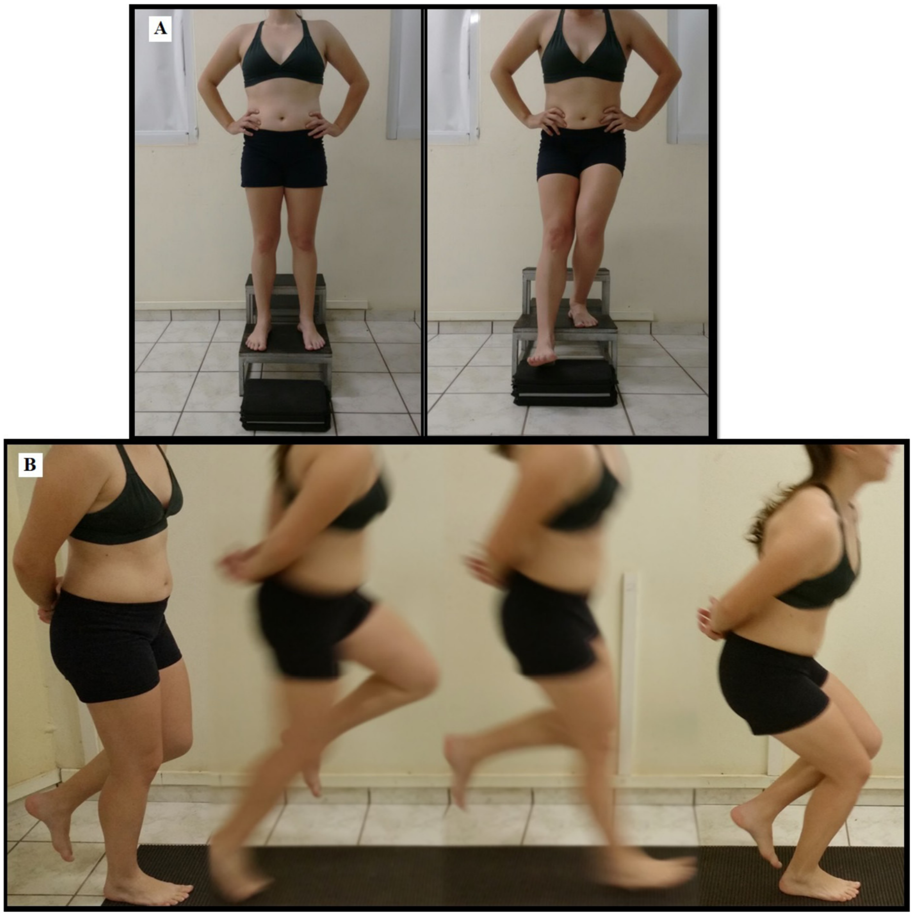

Fig. 1. Performance function tests. A) Forward step-down test. B) Single leg hop test.

To perform the SLHT, participants were positioned with the heel in a marked position on the floor and were instructed to stand in unipodal support with their arms crossed on their back. Then, the participants hopped forward with their test leg as far as possible landing on the same foot. The distance of the jump was measured in centimeters at the heel position from which the participant landed. In addition, the hop was validated only if the participant was able to maintain their balance upon landing, keeping their landing foot on the ground, without losing balance and moving the foot off the ground again, until the investigator marked where the participant landed. If the hop was not valid, participants were asked to repeat the task. The test was performed three times and the mean used for further analysis.

2.7. Knee extensor strength tests

We evaluated maximal voluntary isometric, concentric and eccentric, contractions during knee extension with an isokinetic dynamometer (*Biodex System 4 Pro,* New York, USA). Participants were assessed in the seated position with the hip and non-tested knee flexed to 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. The knee extensor muscles were evaluated at a joint angle of 60° (Nakagawa, Baldon, Muniz, & Serrão, 2011; Pua, Clark, & Bryant, 2010). The order of the contractions assessments was randomized.

Participants performed a familiarization procedure for the isometric test with 2 submaximal practice contractions of 6-s with an interval of 1-min between trials. Two maximal isometric contractions of 6-s with an interval of 1-min between each trial were performed to determine the maximum isometric strength. Participants also performed a familiarization for concentric and eccentric tests, consisting of one series of five submaximal contractions and one series of two maximal contractions, with a 1-min interval between series (Baldon et al., 2011). Concentric and eccentric strength tests were performed at an angular velocity of 30°/s (Perin, 1993). In the sequence, they performed two series of five maximal repetitions with a 3-min rest period between the series. During all contractions a standardized verbal encouragement was provided to stimulate the participants to produce their maximum strength. To correct the influence of gravity, the assessed limb was weighed before each test and the isokinetic dynamometer software (*Biodex System 4 Pro*) automatically corrected the output data. Specifically, the participants had their assessed limbs positioned in 30° of knee flexion from maximal knee extension. Then, participants were asked to let their limb relax into the isokinetic dynamometer arm, which performed the weight measurement.

The isokinetic data were analyzed using a custom code in MatLab (MATLAB; The MathWorks, Inc, Natick, MA). The variables of interest were peak isometric, concentric and eccentric knee extensor strength. The mean of the two maximum isometric contractions of each participant was used in the statistical analysis. For concentric and eccentric peak knee extensor strength we used the mean of the middle 3 repetitions for each strength test (Boling and Padua, 2009). All torque data (N.m) were normalized by body mass ([N.m/kg] x 100) (Baldon et al., 2011).

2.8. Statistical analysis

Firstly, we divided the sample in four groups based on the presence of PFP and knee crepitus: PFP and no knee crepitus ($PFP_{NOcrepitus}$), PFP and knee crepitus ($PFP_{crepitus}$), pain-free and no knee crepitus (Pain-$free_{NOcrepitus}$), pain-free and knee crepitus (Pain-$free_{crepitus}$). A Chi-square test was used to evaluate the association between the presence of crepitus and the presence of PFP.

Mean age, height, body mass, body mass index, self-reported measures, performance-based function tests, isometric, concentric and eccentric knee extensor strength were compared between-groups using a one-way between-groups analysis of variance (ANOVA). In case of significant F-values ($p < 0.05$), adjusted Tukey's *post-hoc* tests were calculated to identify which groups were different. The data reported from ANOVA are the F values (with degrees of freedom) and p-values. In order to do not draw conclusions based solely on p-values, we calculated the mean difference (95% confidence intervals [CI]) and effect sizes (95%CI) (Cohen's d) for each *post hoc* comparison with $p < 0.05$. The guidelines for interpreting the Cohen's d are: 0 to 0.40 small effect, 0.41 to 0.70 moderate effect, 0.71 or higher large effect (Cohen, 1988, p. 2). Statistical analyses were performed using the Statistical Software for Social Sciences (IBM 23.0, SPSS inc., Chicago, IL) with an *a priori* level of significance of 0.05.

3. Results

3.1. Presence of knee crepitus

Of the 65 women with PFP, 33 (50.7%) with, and 32 (49.3%) without knee crepitus were identified. Of the 51 pain-free women, 17 (33.3%) with, and 36 (66.7%) without knee crepitus were identified. Crepitus was found to be significantly associated with the presence of PFP ($\chi^2_{(1)} = 4.17$; $p = 0.031$). Demographics, self-reported outcome measures, functional performance and knee extensor strength tests for each group are presented in Table 1.

3.2. Demographics and self-reported measures

There were no significant differences between-groups for age ($p = 0.383$) and height ($p = 0.584$). However, the $PFP_{crepitus}$ group presented higher body mass ($p < 0.001$, moderate to large effect sizes) and BMI ($p = 0.001$, moderate to large effect sizes) than all three other groups (Table 2).

Both groups with PFP had lower self-reported function ($p < 0.001$, large effect size); and higher kinesiophobia ($p < 0.001$, large effect size), pain catastrophism ($p < 0.001$, large effect size) and knee stiffness ($p < 0.001$, large effect size) compared to both pain-free groups (Table 3). There were no differences between $PFP_{NOcrepitus}$ and $PFP_{crepitus}$; or Pain-$free_{NOcrepitus}$ and Pain-$free_{crepitus}$ groups for any self-reported outcome measure.

3.3. Functional performance and knee extensor strength

Both groups with PFP, and the Pain-$free_{crepitus}$ group had lower functional performance during the FSDT ($p < 0.040$, moderate effect size) and SLHT ($p < 0.039$, small to moderate effect sizes) compared with the Pain-$free_{NOcrepitus}$ group (Table 4).

Both groups with PFP also had lower knee extensor strength in isometric, concentric and eccentric contractions ($p < 0.041$, small to large effect sizes) compared to Pain-$free_{NOcrepitus}$ group (Table 5). There were no differences between $PFP_{NOcrepitus}$ and $PFP_{crepitus}$; or PFP groups and Pain-$free_{crepitus}$ group.

4. Discussion

Our findings indicate that knee crepitus is significantly more prevalent in women with PFP (50.7%) than in pain-free controls (33.3%). Our findings also indicate higher kinesiophobia and pain catastrophism in women with PFP, in those with and without crepitus. Additionally, self-reported function was lower, and knee stiffness higher in the PFP group compared to pain-free controls, regardless of whether knee crepitus was present or not.

Table 2
Mean difference 95% confidence intervals (CI's) and effect sizes of the *post hoc* comparisons with $p < 0.05$ for anthropometric measures.

Variables	Mean difference (95% CI)	Effect size (95% CI)
Body mass (kg)		
$PFP_{crepitus}$ vs $PFP_{NOcrepitus}$	4.79 (0.35–9.23)	0.41 (0.09–0.89)
$PFP_{crepitus}$ vs Pain-$free_{crepitus}$	9.02 (4.29–13.74)	1.19 (0.57–1.83)
$PFP_{crepitus}$ vs Pain-$free_{NOcrepitus}$	7.52 (3.89–11.14)	1.17 (0.65–1.67)
BMI (kg/m^2)		
$PFP_{crepitus}$ vs $PFP_{NOcrepitus}$	1.97 (0.20–3.73)	0.55 (0.55–1.04)
$PFP_{crepitus}$ vs Pain-$free_{crepitus}$	3.12 (1.31–4.93)	1.10 (0.60–1.62)
$PFP_{crepitus}$ vs Pain-$free_{NOcrepitus}$	2.72 (1.21–4.24)	0.88 (0.23–1.45)

Table 1
Characteristics of the participants.

Variables	Pain-$free_{NOcrepitus}$	Pain-$free_{crepitus}$	$PFP_{NOcrepitus}$	$PFP_{crepitus}$	F-ratio	p-value
Demographics						
Age (years)	22.06 (2.81)	22.18 (3.57)	21.53 (3.87)	22.91 (2.56)	1.02	0.383
Height (m)	1.64 (0.03)	1.62 (0.04)	1.64 (0.05)	1.63 (0.06)	0.132	0.584
Body Mass (kg)	57.82 (5.65)	56.92 (6.92)	61.94 (7.55)	64.72 (6.12)	7.89	<0.001
BMI	22.01 (2.82)	21.61 (2.15)	22.77 (3.74)	24.74 (3.36)	5.50	0.001
Self-reported measures						
Function (AKPS)	98.56 (2.31)	98.29 (3.09)	70.94 (10.58)	74.82 (9.25)	107.92	<0.001
Kinesiophobia	28.32 (4.74)	28.47 (4.41)	36.28 (6.77)	36.30 (6.84)	16.82	<0.001
Pain Catastrophism	1.29 (3.52)	3.24 (4.59)	16.06 (9.94)	12.55 (7.67)	30.07	<0.001
Knee Stiffness (VAS)	0.79 (2.50)	4.71 (9.40)	27.88 (2.68)	28.36 (1.25)	19.90	<0.001
Performance based function tests						
FSDT (repetitions)	21.26 (5.92)	18.24 (6.00)	17.53 (4.79)	17.91 (6.44)	2.86	0.040
SLHT (cm)	96.96 (19.61)	86.41 (17.95)	85.50 (14.94)	90.81 (23.13)	2.96	0.039
Knee extensor strength						
Isometric (Peak TQ/BW)	278.27 (60.82)	265.88 (56.60)	225.23 (68.37)	223.85 (72.89)	5.51	0.001
Concentric (Peak TQ/BW)	223.40 (41.71)	215.34 (41.71)	205.85 (71.52)	183.51 (63.62)	2.84	0.041
Eccentric (Peak TQ/BW)	279.55 (70.52)	265.33 (80.08)	237.66 (70.21)	230.75 (81.01)	2.98	0.034

BMI = Body mass index; AKPS = Anterior knee pain scale; VAS = Visual analogue scale; FSDT = Forward step down test; SLHT = Single leg hop test; TQ/BW = Peak torque normalized by body weight.

Table 3
Mean difference 95% confidence intervals (CI's) and effect sizes of the *post hoc* comparisons with $p < 0.05$ for self-reported measures.

Variables	Mean difference (95% CI)	Effect size (95% CI)
Anterior Knee Pain Scale (AKPS)		
$PFP_{crepitus}$ vs $Pain\text{-}free_{crepitus}$	−23.47 (−28.13 to −18.81)	3.40 (2.67–4.18)
$PFP_{crepitus}$ vs $Pain\text{-}free_{NOcrepitus}$	−23.74 (−27.00 to −20.47)	3.52 (2.19–3.90)
$PFP_{NOcrepitus}$ vs $Pain\text{-}free_{crepitus}$	−27.35 (−32.66 to −22.05)	3.50 (2.78–4.34)
$PFP_{NOcrepitus}$ vs $Pain\text{-}free_{NOcrepitus}$	−27.62 (−31.33 to −23.90)	3.60 (2.25–4.00)
Kinesiophobia		
$PFP_{crepitus}$ vs $Pain\text{-}free_{crepitus}$	7.83 (4.14–11.52)	1.36 (0.83–1.88)
$PFP_{crepitus}$ vs $Pain\text{-}free_{NOcrepitus}$	7.98 (5.11–10.84)	1.35 (0.62–1.90)
$PFP_{NOcrepitus}$ vs $Pain\text{-}free_{crepitus}$	7.81 (4.14–11.47)	1.37 (0.84–1.90)
$PFP_{NOcrepitus}$ vs $Pain\text{-}free_{NOcrepitus}$	7.95 (5.09–10.81)	1.27 (0.63–1.92)
Pain catastrophism		
$PFP_{crepitus}$ vs $Pain\text{-}free_{crepitus}$	9.31 (5.22–13.39)	1.47 (0.94–2.01)
$PFP_{crepitus}$ vs $Pain\text{-}free_{NOcrepitus}$	11.25 (8.35–14.15)	1.68 (1.00–2.36)
$PFP_{NOcrepitus}$ vs $Pain\text{-}free_{crepitus}$	12.82 (7.69–17.96)	1.67 (1.11–2.23)
$PFP_{NOcrepitus}$ vs $Pain\text{-}free_{NOcrepitus}$	14.76 (11.14–18.39)	1.74 (1.05–2.43)
Knee stiffness (0 − 100 mm VAS)		
$PFP_{crepitus}$ vs $Pain\text{-}free_{crepitus}$	23.65 (11.25–33.05)	3.52 (2.66–4.17)
$PFP_{crepitus}$ vs $Pain\text{-}free_{NOcrepitus}$	27.57 (20.23–34.90)	13.94 (12.16–18.54)
$PFP_{NOcrepitus}$ vs $Pain\text{-}free_{crepitus}$	23.16 (10.11–36.22)	3.35 (2.50–3.97)
$PFP_{NOcrepitus}$ vs $Pain\text{-}free_{NOcrepitus}$	27.08 (19.26–34.89)	10.45 (7.99–12.35)

Table 4
Mean difference 95% confidence intervals (CI's) and effect sizes of the *post hoc* comparisons with $p < 0.05$ for objective measures of function.

Variables	Mean difference (95% CI)	Effect size (95% CI)
Forward step-down test (repetitions)		
$PFP_{crepitus}$ vs $Pain\text{-}free_{NOcrepitus}$	−3.35 (−6.37 to −0.33)	0.54 (0.07–1.12)
$PFP_{NOcrepitus}$ vs $Pain\text{-}free_{NOcrepitus}$	−3.73 (−6.39 to −1.07)	0.69 (0.10–1.31)
$Pain\text{-}free_{crepitus}$ vs $Pain\text{-}free_{NOcrepitus}$	−3.02 (−6.58 to −0.52)	0.50 (0.02–1.08)
Single leg hop test (cm)		
$PFP_{crepitus}$ vs $Pain\text{-}free_{NOcrepitus}$	−6.14 (−16.59 to −0.04)	0.28 (−0.31 to 0.86)
$PFP_{NOcrepitus}$ vs $Pain\text{-}free_{NOcrepitus}$	−11.46 (−20.07 to −2.84)	0.68 (0.08–1.28)
$Pain\text{-}free_{crepitus}$ vs $Pain\text{-}free_{NOcrepitus}$	−10.52 (−21.92 to −0.86)	0.56 (0.04–1.16)

Table 5
Mean difference 95% confidence intervals (CI's) and effect sizes of the *post hoc* comparisons with $p < 0.05$ for knee extensor strength measures.

Variables	Mean difference (95% CI)	Effect size (95% CI)
Knee extensor isometric strength		
$PFP_{crepitus}$ vs $Pain\text{-}free_{NOcrepitus}$	−54.41 (−87.13 to −21.70)	0.81 (0.17–1.38)
$PFP_{NOcrepitus}$ vs $Pain\text{-}free_{NOcrepitus}$	−53.04 (−84.82 to −21.26)	0.81 (0.18–1.40)
Knee extensor concentric strength		
$PFP_{crepitus}$ vs $Pain\text{-}free_{NOcrepitus}$	−39.88 (−66.06 to −13.71)	0.74 (0.08–1.29)
$PFP_{NOcrepitus}$ vs $Pain\text{-}free_{NOcrepitus}$	−17.54 (−46.13 to −0.11)	0.29 (−0.32 to 0.87)
Knee extensor eccentric strength		
$PFP_{crepitus}$ vs $Pain\text{-}free_{NOcrepitus}$	−48.79 (−85.82 to −11.76)	0.64 (0.02–1.22)
$PFP_{NOcrepitus}$ vs $Pain\text{-}free_{NOcrepitus}$	−41.88 (−76.50 to −7.25)	0.59 (0.01–1.18)

Interestingly, women with PFP (with or without crepitus), and pain-free controls with crepitus had lower functional performance compared with pain-free controls with no crepitus. Additionally, both groups of women with PFP (with and without crepitus) had lower knee extensor strength compared to pain-free controls with no crepitus, but no difference compared with pain-free controls with crepitus.

Despite crepitus being more prevalent in women with PFP, one third of pain-free controls did present with crepitus. This rate is similar to a recent study with a larger cohort of women, which reported that 33.5% of pain-free women present knee crepitus (Danilo De Oliveira Silva et al., 2018). Additionally, in a populational study to investigate the prevalence of knee OA in people over 40 years old, crepitus was reported in 38.1% of women (Ho-Pham et al., 2014). Thus, clinically, the rate of knee crepitus in pain-free populations seems to range between 30 and 40%.

Interestingly, our findings indicate that impaired functional performance (moderate effect) in pain-free women with knee crepitus compared to pain-free women without crepitus. It is possible that evaluating the presence or absence of knee crepitus may help identify those at higher risk of PFP development. However, a large number of women with PFP did not present crepitus, which highlights that the presence of crepitus is likely to only form part of a multifactorial injury risk screening process. In addition, knee extensor strength was different only between the PFP groups and pain free no crepitus group. This finding might indicate that further case-control studies assessing knee extensor strength should be cautious with the presence of knee crepitus in the pain-free population as it is likely to impact their findings.

Knee crepitus can negatively affects patient's beliefs, and alters movement patterns in an attempt to avoid hearing the noise, and can be responsible for the lack of adherence to exercise therapy (Robertson et al., 2017). Interestingly, we found no difference in self-reported function, kinesiophobia, pain catastrophising, knee stiffness or strength between women with PFP and crepitus and women with PFP and no crepitus. This may mean that once symptoms have developed, the presence of crepitus may have minimal influence on common impairments reported in PFP. These findings add to recent reports that knee crepitus has no association with pain during squats and stair negotiation (De Oliveira Silva et al., 2018). This may be important to communicate to patients considering likely negative patients beliefs related to crepitus (Robertson et al., 2017).

Previous findings indicate that knee crepitus is common in pain-free people, and poorly related with pain in people with PFP (De Oliveira Silva et al., 2018). However, patients are unsatisfied with the lack of explanation they receive from health professionals regarding its cause (Robertson et al., 2017). As patients with PFP have stressed their interest in understanding knee crepitus, we strongly recommend that clinicians be reasonable when informing patients about the meaning of crepitus and a differentiation between physiological and pathological crepitus should be made in order to avoid nocebic information. The source of crepitus remains unclear, but previous research indicates it could be due to gas bubbles in the synovial fluid, ligaments snapping, hypermobility or discoid meniscus (Song et al., 2018).

4.1. Clinical implication

Knee crepitus is poorly understood by patients and clinicians (Robertson et al., 2017; Song et al., 2018), many individuals become fearful of the noise related to crepitus and change their daily habits (Robertson et al., 2017; Song et al., 2018). In addition, individuals with PFP report they wish to understand more about their condition (Smith et al., 2018a), but often they do not have good experience with general practitioners or physiotherapists about the cause of PFP signs and symptoms such as knee crepitus (Robertson et al., 2017). Thus, clinicians may clarify to patients with PFP that knee crepitus may not influence their strength or physical function and is also common in people without pain (30–40%). This information should be provided along with other education that crepitus is not related with self-reported pain in people with PFP (Danilo De Oliveira Silva et al., 2018) and should integrate current PFP evidence-based management (Collins et al., 2018; Lack, Neal, De Oliveira Silva, & Barton, 2018). Additionally, the association of physical inactivity (Glaviano, Baellow, & Saliba, 2017) with greater risk of developing, and progression of knee OA (Messier et al., 2013) should also be discussed with patients so that they understand the potential importance of remaining physically active and participating in exercise therapy despite knee crepitus.

4.2. Limitations and future directions

Although pain-free women with knee crepitus had impaired functional performance, the long-term implications of crepitus in a young pain-free population remains unclear. Further research is encouraged to investigate if knee crepitus triggers quadriceps muscle inhibition or if the lower function might be related to an activity avoidance behavior due to crepitus. In addition, understanding if crepitus is a risk factor for PFP development linked with impaired functional performance could allow early intervention in this population.

Due to the cross-sectional nature of this study, the longer-term influence of crepitus in women with PFP on prognosis including pain, kinesiophobia, catastrophism, and further declines in strength and functional performance is unknown. Further research in this area is encouraged. We did not look at the relationship of crepitus with imaging or joint health in this study. Considering links of crepitus with PFJ joint lesions in people with PFJ OA (Schiphof et al., 2014), and knee OA development (Lo et al., 2018), we also encourage research to explore the influence of crepitus on joint health in PFP cross-sectionally and longitudinally. Additionally, psychometric properties of participants knee stiffness using a VAS were not tested in a population with PFP, we encourage further studies to validate this outcome. Despite investigating if kinesiophobia and pain catastrophism are different in the presence of knee crepitus, a more comprehensive screening of the psychological features (coping skills, fear-avoidance beliefs, self-efficacy, etc.) of women with PFP and its relationship with crepitus is warranted. Another limitation of our study was that five participants with PFP had a dominant limb different from the pain-free participants, this difference may have influenced our findings.

5. Conclusion

Women with PFP were more likely to have crepitus than pain-free women. Women with PFP had higher kinesiophobia, catastrophism and knee stiffness compared to pain-free controls, regardless of the presence or absence of knee crepitus. In addition, women with PFP and pain-free controls with knee crepitus had lower functional performance compared to pain-free controls with no knee crepitus, indicating both pain and crepitus may detrimentally influence function.

Declaration of interest

None.

Conflicts of interest

None declared.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Ethical approval

The study was approved by the São Paulo State University Ethics Committee (number: 1.484.129).

Acknowledgments

São Paulo Research Foundation (FAPESP) for a scholarship, author: DOS (2015/11534–1).

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