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RESEARCH ARTICLE

Exploring task-specific disability on lower extremity strength and quality of life in individuals with patellofemoral pain

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ABSTRACT

Purpose: Compare frequently reported exacerbating tasks in individuals with patellofemoral pain (PFP) to the Anterior Knee Pain Scale (AKPS), Knee Injury and Osteoarthritis Outcome Score-Patellofemoral (KOOS-PF) subscale, and PFP consensus statement. Additionally, we examined differences in lower extremity strength and quality of life (QoL) based on their most exacerbating tasks.
Materials and methods: Seventy-five individuals with PFP completed open-ended questions about exacerbating tasks, AKPS, and KOOS-PF. Isometric hip abduction, hip extension, and knee extension strength were measured with a hand-held dynamometer while QoL was assessed with the KOOS-PF QoL subscale.
Results: Sixty-five percent of individuals reported squatting in their top three most painful tasks, followed by running (49.33%), stair ambulation (40.00%), sitting (36.00%), jumping (30.67%), kneeling (28.00%), and walking (17.33%). AKPS does not assess kneeling, KOOS-PF does not assess stair ambulation or walking, and consensus statement does not evaluate walking or kneeling. There were non-significant differences in strength ($p > 0.05$); however, the stair ambulation group reported significantly worse QoL compared to the squatting ($p < 0.001$) and running ($p = 0.015$) groups.
Conclusions: The AKPS, KOOS-PF, and consensus statement encapsulate most exacerbated tasks by individuals with PFP. Different exacerbating tasks may influence QoL, indicating a wide variety of functional tasks should be considered when developing tailored rehabilitation.

➤ IMPLICATIONS FOR REHABILITATION

- Frequently used patient-reported outcome measures encapsulate most, but not all, task-specific disabilities commonly reported by individuals with patellofemoral pain (PFP).
- Individuals with PFP who experience different pain provoking tasks do not present with differences in lower extremity isometric strength.
- Individuals with PFP who report stair ambulation as the most painful task have a worse quality of life compared to individuals who have pain with squatting or running.
- Rehabilitation professionals should consider identifying task-specific disabilities when developing a tailored rehabilitation program for individuals with PFP.

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Anterior knee pain; objective function; self-reported function; hip; quadriceps; patient reported outcome measures

Introduction

Patellofemoral pain (PFP) has an annual prevalence rate of 22.7% in the general adult population, with female incidence twice as common compared to males [1,2]. PFP accounts for around 7.3% of all

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orthopedic setting visits, with the incidence rate increasing over a five-year examination period [2]. PFP often does not fully resolve following treatment, with 91% of individuals reporting continued knee pain for at least 10 years following initial diagnosis [3]. Individuals with PFP have trouble performing a variety of tasks impacting their daily lives, including running, prolonged sitting, and going up or down stairs [4,5].

Due to the heterogeneous presentation of functional limitations in individuals with PFP, clinicians often use patient-reported outcome measures (PROMs) to quantify disability. The most commonly used PROMs for assessing PFP are the Anterior Knee Pain Scale (AKPS) and the Knee Injury and Osteoarthritis Outcome Score-Patellofemoral (KOOS-PF) subscale [6,7]. Both the AKPS and KOOS-PF are condition-specific, quickly completed, easily administered/scored, and quantify disability of frequently occurring tasks encountered by individuals with PFP [6–9]. The scales evaluate a range of pain-provoking tasks, which have some alignment with diagnostic criteria established from the 2016 PFP consensus [8,10]. However, there are some discrepancies between the types of functional tasks assessed in the PROMs and 2016 consensus diagnostic criteria [4,10]. One of the major challenges for individuals who experience PFP and clinicians is the wide range of pain-provocation experienced across tasks [4,10–12]. The discrepancies between PROMs and the diagnostic criteria may limit clinicians' abilities to comprehensively address pain-provoking tasks impacting patients' quality of life (QoL).

Individuals with PFP present with a wide range of self-reported limitations, as well as objective impairments such as reduced lower extremity muscle strength that may impact QoL [13–15]. In adults with PFP, isometric hip abduction, hip extension, and knee extension strength are reduced by 12–36% when compared to asymptomatic adults [13,16,17]. Individuals with PFP that had higher self-reported function were between 17% and 19% stronger in hip musculature and 32% stronger in knee extension strength compared to individuals with lower self-reported function [18]. In addition to lower extremity strength, task-specific disability may also influence the QoL experienced by individuals with PFP. Pain exacerbation during specific tasks does alter trunk and lower extremity kinematics [19], suggesting a pain management strategy to engage in functional tasks and activities. However, qualitative evidence supports that loss of activities (e.g., walking, exercise, and kneeling), can negatively impact QoL [20]. Additionally, individuals with PFP have reduced QoL compared to pain-free controls and strength-based interventions are commonly administered to improve QoL [21].

Understanding the impact of both self-reported limitations and objective strength impairments on QoL will help clinicians deliver improved care to patients with PFP. Therefore, the primary objective of this study was to examine the frequency of self-reported exacerbating tasks in individuals with PFP and compare the reported tasks to two common PROMs for PFP (AKPS and KOOS-PF) and the diagnostic criteria in the 2016 PFP consensus statement [10]. The secondary objective of this study was to categorize individuals with PFP by their top three self-reported exacerbating tasks to compare lower extremity strength and QoL. It was hypothesized that the AKPS, KOOS-PF, and 2016 consensus statement [10] do not evaluate the most frequently self-reported exacerbating tasks reported by individuals with PFP. It was also hypothesized that varying self-reported exacerbating tasks would result in differing lower extremity strength and QoL; specifically, individuals reporting more problematic tasks during common daily activities, such as stair ambulation, would have less strength and worse QoL compared to individuals reporting pain during other exacerbating tasks.

Methods

A cross-sectional study was conducted while adhering to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) and REPORTing of quantitative Patellofemoral Pain (REPORT-PFP) guideline recommendations [22,23]. All data were collected at the baseline timepoint of a larger randomized controlled clinical trial [24]. The independent variables were the three most common exacerbating tasks self-reported in a health history questionnaire. The dependent variables were lower extremity isometric strength measures for hip abduction, hip extension, knee extension, and KOOS-PF QoL. Additionally, the AKPS, KOOS-PF, and 2016 PFP consensus statement were used to evaluate the most common self-reported exacerbating tasks.

Data were collected at three sites: University of Connecticut, University of Central Florida, and University of Toledo. The lead investigator (NRG) completed in-person training of all research staff prior to participant recruitment to ensure accurate assessment of PFP and execution of testing. Inter-rater reliability (intraclass correlation coefficient) was established across the three researchers for hip abduction ($ICC_{(3,1)}$ = .85), hip extension ($ICC_{(3,1)}$ = .88), and knee extension ($ICC_{(3,1)}$ = .83) prior to data collection [24]. Intra-rater reliability was established for each of the three researchers for hip abduction (tester A [$ICC_{(3,k)}$ = .92]; tester B [$ICC_{(3,k)}$ = .80]; and tester C [$ICC_{(3,k)}$ = .87]); hip extension (tester A [$ICC_{(3,k)}$ = .98]; tester B [$ICC_{(3,k)}$ = .94]; and tester C [$ICC_{(3,k)}$ = .92]); and knee extension (tester A [$ICC_{(3,k)}$ = .89]; tester B [$ICC_{(3,k)}$ = .91]; and tester C [$ICC_{(3,k)}$ = .92]) prior to data collection [24]. Participants were recruited through flyers, social media posts, sports medicine physician referrals, and from participation in previous non-interventional PFP studies across three large universities and local communities [24]. This study was approved by the University of Connecticut Institutional Review Board, with reliance agreements with all data collection sites.

Participants

The lead researcher at each site screened participants to ensure eligibility and consent following the criteria outlined within the 2016 PFP consensus statement [10]. Each researcher had at least 10 years of experience evaluating/diagnosing PFP and conducted all measurements. Participants had to report atraumatic peri- or retro-patellar pain for greater than 3 months and pain that exceeded 3/10 on the numeric pain rating scale for at least two activities that load the patellofemoral joint during weight bearing on a flexed knee including squatting, stair ambulation, jogging/running, and hopping/jumping [10]. Participants with a history of lower extremity or low back surgery, patellar subluxation/dislocation, meniscal injury, ligamentous instability, referred pain from the lumbar spine, or other forms of anterior knee pain (Osgood-Schlatter, tendon pain, bursitis, etc.) were excluded [10].

Procedure

Participants provided informed consent via a Qualtrics survey with electronic versions of the IRB approved consent form and digital signature. Participants were told to not take pain management medication 48 h before data collection. Once participants reported for testing, demographic data were collected including sex, age, mass, height, symptom duration, and if they experience unilateral/bilateral symptoms. Participants then completed a health history questionnaire which asked participants to list their three most exacerbating tasks or activities through an open-ended question ("Please list the three tasks/activities that are most problematic due to your knee pain".). Participants then completed the AKPS and KOOS-PF [22]. Health history, AKPS, and KOOS-PF were all completed via Qualtrics in the laboratory prior to all testing.

The 13-item AKPS is used to assess self-reported knee function with possible scores ranging from 0 to 100 with a lower score showing greater disability [9]. The AKPS has shown moderate concurrent validity (r = .70), good test–retest reliability (ICC = .81), good to excellent internal consistency (α = .74–.95), and significant responsiveness in the PFP population [7,9]. Sample internal consistency for the AKPS in our dataset was α = .64.

The 11-item KOOS-PF is scored within a range 0–100, with a lower score representing greater disability [8]. The KOOS-PF has observed good test–retest reliability, $ICC_{(2.1)}$ of 0.86 and demonstrates a strong positive correlation with the AKPS (r = .74) [8]. The KOOS-PF has observed good internal consistency (α = .86), consistent with the sample internal consistency for the KOOS-PF in our dataset at α = .85. Compared to other KOOS subscales, the KOOS-PF has exhibited a larger effect size and thus may be more responsive within the PFP population [8]. The KOOS-PF has demonstrated the best content validity, reliability, and construct validity to assess pain and function of individuals with PFP [7].

Strength assessment

Isometric hip abduction, hip extension, and knee extension strength (newton meter per kilogram Nm/kg) were quantified using a hand-held dynamometer (HHD; ErgoFet HDD, Hogan Scientific, Salt Lake City, UT) (Figure 1) [24]. Participants were provided standardized instructions for all assessments. Participants completed a practice trial for each assessment followed by three recorded trials per assessment.

Participants were told to perform the contraction with maximal intensity, pushing against the strap or dynamometer as hard as possible and maintaining the contraction for at least five seconds. During each trial, participants were provided with verbal encouragement and visual feedback. The peaks of each trial were recorded. A fourth test trial was conducted if there was a coefficient of variation greater than 10% between the three trials [25]. Participants were provided with one minute of rest between trials and three minutes of rest between assessments. The order of strength testing was randomized for each participant.

Hip abduction was measured with a HHD placed on the lateral aspect of the limb; 5 cm proximal to the lateral epicondyle. Thigh length was measured from the greater trochanter to the location of the HHD. Participants performed hip abduction in a side lying position on a treatment table. The testing limb was secured with a stabilization strap at 20° of hip abduction, being neutral in the sagittal and transverse plane. The non-testing limb was placed at 45° of hip flexion and 90° of knee flexion. A second stabilization strap was placed around the participants' pelvis to minimize accessory motion. The participants' hands were placed across their body or resting on the table. Participants were instructed to raise their leg to the ceiling as hard as possible.

For hip extension, the participant was placed prone on the table with the knee and hip at 90° of flexion with the non-testing leg out straight behind them. Two stabilization straps were used, one around the participant's pelvis and the table, and the other was placed proximal to the popliteal fossa, with the HHD being placed against the leg of the table level with the stabilization strap. Prior to testing, the participants were instructed to remove the toes of their testing leg from the ground and extend their hip back as hard and fast as possible.

Knee extension was assessed with the participant in a seated position on the treatment table, with their feet off the ground. Both the hip and knee flexed to 90° and participants were instructed to place their arms across their torso. The HHD was positioned against the leg of the table with a stabilization strap attached to the anterior shank, 5 cm proximal to the ankle mortise. A second stabilization strap was used around the upper thigh to limit accessory motion. Shank length was measured from the center of the knee defined by the medial and lateral joint lines to the HHD placement.

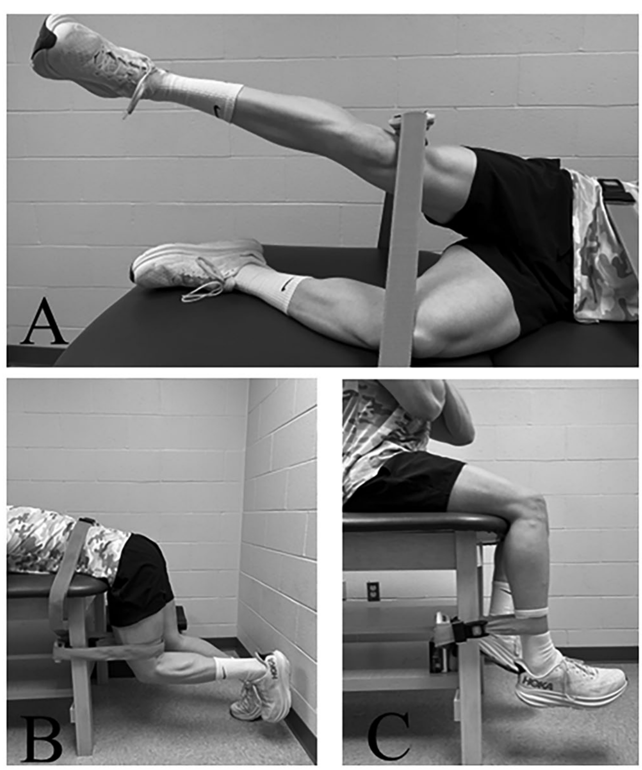

Figure 1. Lower extremity strength testing positions. (A) Hip abduction; (B) hip extension; (C) knee extension.

Data reduction

We identified functional tasks from the AKPS, KOOS-PF, and the 2016 Consensus Statement that aligned with the tasks most frequently reported by participants in our study. The participants' top seven most exacerbating tasks were extracted from the health history form, with activities grouped by task, combining variations (e.g., squat variations) and specific phases (e.g., stair movements including ascending, descending, or overall ambulation) into broader categories. Due to the wide range of exacerbating tasks, we selected the top seven tasks as this allowed for a minimum of 5% of all reported tasks across the cohort. The top seven most frequently reported exacerbating tasks were then cross-referenced to the functional tasks listed in the AKPS (questions 3–8), KOOS-PF (questions 4–9), and the inclusion criteria from the 2016 PFP consensus statement [10]. We assessed whether the self-reported tasks matched those included in the functional tasks from the PROMs and the diagnostic criteria of the 2016 consensus statement [10], categorizing them as either "Yes" (match between self-reported task and task listed in the PROM or consensus statement) or "No" (no such match was found) for agreement.

The average strength value (N) from the three trials of each muscle assessment was multiplied by the moment arm (m) of the respective segment (thigh or shank length) and divided by the participant's body mass (kg), resulting in a respective torque measurement (Nm/kg). QoL was measured using question 11 of the KOOS-PF, which asks if participants "modified your sport or recreational activities due to your knee pain". Responses were quantified as "Not at all" = 0, "Mildly" = 1, "Moderately" = 2, "Severely" = 3, and "Totally" = 4, reflecting higher values/responses denote greater disability.

Statistical analyses

Self-reported written exacerbating tasks were reported as frequencies and percentages across all participants. The self-reported exacerbating tasks were also reported as percentages compared to the functional tasks included in both the AKPS, KOOS-PF, and 2016 PFP consensus statement [10]. Frequency and percentages were calculated using Microsoft Excel 2018 (Microsoft Corp., Redmond, WA). Descriptive statistics (means ± standard deviations) were calculated for all participant demographics, and lower extremity strength.

The comparison of group differences in strength and QoL included the three most frequently reported exacerbating tasks, as those three were the only tasks with greater than 10 cases. A one-way ANOVA was used to compare differences in lower extremity strength between individuals reporting and not reporting the top three most frequently reported "problematic tasks". Post hoc testing was performed in the presence of statistical significance. Due to the QoL question resulting in ordinal data, data are reported as a median and range. A Kruskal–Wallis test was used to compare group differences for QoL responses. Alpha was set *a priori* at $p < 0.05$ for all analyses using SPSS (version 29.0; IBM Corp., New York, NY).

Results

Seventy-five participants (51 female and 24 male) were enrolled between the three sites and the data from all participants were included in analyses. Participant demographics are presented in Table 1.

Frequencies of the three most written exacerbating tasks are reported in Figure 2. Participants were grouped based on their most exacerbating task. The three most common exacerbating tasks, when considering each participant's top three tasks, were squatting (65.3%), running (49.3%), and stair ambulation (40.0%) (Table 2). When isolating just the most frequently reported painful task, 30.6% (n = 23) reported squatting, 21.3% (n = 16) reported running, and 20.0% (n = 15) reported stair ambulation. Of the 13 individuals who reported stair ambulation as their most painful task, six identified going up stairs, two identified going downstairs, and five identified stairs in general. Comparison of the exacerbating task groups on the AKPS, KOOS-PF, and 2016 consensus criteria [10] is presented in Table 3.

When comparing the differences in strength and QoL across the top three most exacerbating tasks, only 52 participants were included. The other 23 participants were excluded from the secondary analysis of this study because they did not describe squatting, running, or stair ambulation as their most exacerbating tasks, Supplementary File 1. There were no differences in lower extremity strength between the

Table 1. Participant demographics, lower extremity strength, and quality of life (n = 75).

Variable	Mean ± standard deviation
Sex, female/male	51/24
Age, years	23.87 ± 5.23
Mass, kg	73.69 ± 18.23
Height, cm	167.85 ± 9.97
Duration of symptoms, months	45.75 ± 34.17
KOOS-PF, score	58.13 ± 15.96
AKPS, score	74.34 ± 11.91
Hip abduction, Nm/kg	1.40 ± 0.50
Hip extension, Nm/kg	3.00 ± 1.18
Knee extension, Nm/kg	2.08 ± 0.73
KOOS-PF QoL, score (0–4)	1.64 (0–4)

AKPS: Anterior Knee Pain Scale; KOOS-PF: Knee Injury and Osteoarthritis Outcome Score-Patellofemoral subscale; QoL: quality of life.
Male/female values are frequency for each sex. KOOS-PF QoL was scored between 0 and 4, a higher value reflecting greater disability. The QoL data are also reported as median (range) due to data being ordinal.

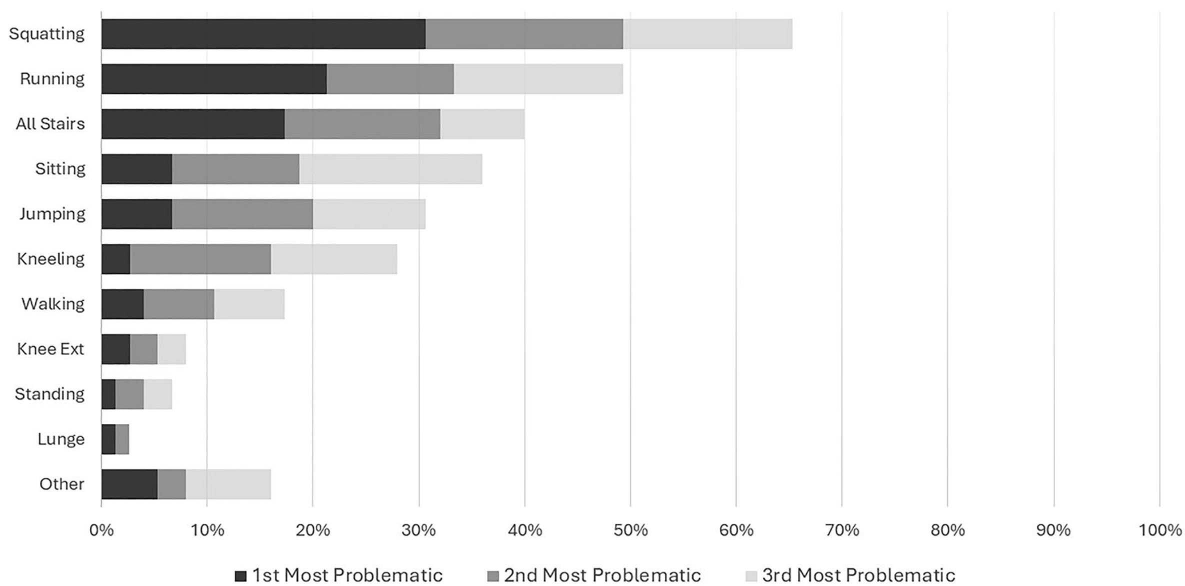

Figure 2. Frequency of three of the most common exacerbating tasks in individuals with PFP.

Table 2. Participant demographics, lower extremity strength, and quality of life based on the top three most exacerbating tasks (n = 52).

	Top three self-reported exacerbating tasks		
Variable	Squatting (1st most exacerbating task) (n = 23)	Running (2nd most exacerbating task) (n = 16)	Stair ambulation (3rd most exacerbating task) (n = 13)
Sex, female/male	13/10	12/4	10/3
Age, years	22.96 ± 4.23	25.38 ± 5.80	24.62 ± 5.95
Mass, kg	76.59 ± 13.37	76.41 ± 26.59	69.34 ± 18.13
Height, cm	172.39 ± 9.49	166.53 ± 12.03	166.69 ± 10.38
Duration, months	50.26 ± 34.31	34.69 ± 29.90	59.23 ± 36.13
KOOS-PF, score	61.36 ± 13.94	57.24 ± 19.32	52.67 ± 14.79
AKPS, score	77.69 ± 8.09	74.31 ± 9.63	70.84 ± 6.73
Hip abduction, Nm/kg	1.53 ± 0.53	1.29 ± 0.47	1.48 ± 0.49
Hip extension, Nm/kg	3.23 ± 1.40	3.05 ± 0.83	3.11 ± 0.94
Knee extension, Nm/kg	2.10 ± 0.61	2.08 ± 0.76	2.14 ± 0.77
KOOS-PF QoL, score (0–4)	1.25 [range: 0–2]	1.77 [range: 0–4]	2.64 [range: 2–4]

AKPS: Anterior Knee Pain Scale; KOOS-PF: Knee Injury and Osteoarthritis Outcome Score-Patellofemoral subscale.

squatting ($F_{3,71}$ = 1.25, p = 0.30), running ($F_{3,71}$ = .98, p = 0.41), or stair ambulation ($F_{3,71}$ = .10, p = 0.96) groups (Table 2). A significant difference was observed in QoL between the groups (χ^2 = 17.95, p < 0.001). Individuals who reported stair ambulation as the most exacerbating task had worse QoL (2.64 [range: 2–4]) compared to individuals in the squatting (1.25 [range: 0–2], p < 0.001) and running (1.77 [range: 0–4], p = 0.015) groups.

Table 3. Alignment between exacerbating tasks reported in the current study and patient-reported outcome measures and 2016 consensus statement.

Current study	AKPS	KOOS-PF	Consensus statement
Squatting	Squatting	Squatting	Squatting
Running	Running	Running	Running
Stairs	Stairs	–	Stairs
Sitting	Sitting	Sitting	Sitting[a]
Jumping	Jumping	Jumping	Jumping
Kneeling	–	Kneeling	–
Walking	Walking	–	–
–	–	Heavy household activities[b]	–

AKPS: Anterior Knee Pain Scale; KOOS-PF: Knee Injury and Osteoarthritis Outcome Score-Patellofemoral subscale.
[a]Secondary (non-essential) criteria for PFP diagnosis.
[b]0% of our study cohort reporting the task as exacerbating in the open-ended question.

Discussion

The primary aim of this study was to observe exacerbating tasks reported by individuals with PFP and compare those tasks to the AKPS, KOOS-PF, and the 2016 consensus statement [10]. Lower extremity strength and QoL were compared depending on their most self-reported exacerbating tasks. The sample reported squatting, running, stair ambulation, sitting, and jumping as the five most common tasks. Interestingly, even among the three most frequently self-reported tasks, only squatting was reported by more than half of the participants. The findings of our study indicate that most of the frequently reported tasks were encompassed within the AKPS, KOOS-PF, or the diagnostic criteria in the 2016 consensus statement [10]. However, there are certain tasks in the AKPS and KOOS-PF that are not captured (Table 3) which are commonly reported by individuals with PFP. The omission of some tasks (kneeling or walking) may underestimate the full disability of individuals with PFP. No differences in hip abduction, hip extension, or knee extension strength were observed among groups; however, there were significant differences in QoL, with the stair ambulation group having worse QoL compared to the squatting and running groups.

The AKPS is the most common, condition-specific, PROM used for individuals with PFP. The AKPS evaluates functional tasks with six out of the 13 questions including squatting, running, jumping, stair ambulation, sitting, and walking [9]. Yet, the AKPS does not evaluate kneeling, a task reported as a top three most exacerbating task by 28.0% in our study, highlighting the void in the assessment of tasks reported as exacerbating by individuals with PFP. Forty percent of participants reported stair ambulation in their top three most exacerbating tasks, with 12.0% having pain ascending stairs, 9.3% having pain descending stairs, and 18.7% listed stair ambulation in general. However, the AKPS offers only: "No difficulty", "Slight pain when descending", "Pain both when descending and ascending", and "Unable" [26]. The provided options do not allow individuals who experience pain solely during ascending.

Another concern with the AKPS is that the scoring criteria have no true references to base the numerical ratings. For example, running, stair ambulation, sitting, and jumping are evaluated out of 10 points on the AKPS; however, squatting, the most frequently reported exacerbating task in our study, is only graded out of 5 points [26]. The discrepancy in scoring weight across each question on the AKPS does influence the interpretation of self-reported disability that clinicians should consider. There are eight different scoring weights across the 13-questions of the AKPS, which questions the psychometric properties of the scale and ease of implication in clinical practice. Due to the frequency of self-reported difficulty during squatting, less weight on the AKPS may minimize the extent of disability experienced by individuals with PFP and problematic/painful squatting.

The KOOS-PF, the most responsive scale for measuring pain and function in adults with PFP, was developed using both qualitative and quantitative data from individuals with PFP [6,7]. The KOOS-PF includes six functional tasks, squatting, running, sitting, jumping, kneeling, and heavy household activities. Nevertheless, KOOS-PF does not evaluate stair ambulation or walking, which were the third or seventh most exacerbating tasks in our cohort. The KOOS-PF also includes a question regarding "heavy household activities (including carrying and lifting)", yet no participants in our study reported this as one of their painful tasks. Clinicians should be aware that common PROMs like the AKPS and KOOS-PF may not quantify all disability experienced by individuals with PFP. Including open-ended questions, in addition to common PROMs, may guide clinicians in their assessment and development of an individualized plan of care.

The 2016 PFP consensus statement provides primary diagnosis criteria as pain during squatting, running/jogging, hopping/jumping, and stair ambulation [10]. Pain while sitting, rising from sitting, and straightening the knee following sitting are listed as additional criteria, which are not essential to a diagnosis of PFP [10]. While squatting, running, and stair ambulation are the three most frequently reported tasks in our study, sitting was the fourth most frequently reported task, ahead of jumping, yet these tasks are not included as primary diagnosis criteria in the 2016 consensus statement [10]. Evidence suggests that over 80% of individuals with PFP report pain while sitting and it is one of the most commonly reported painful tasks for the PFP population [5,27]. Clinicians and researchers should include pain while sitting as an inclusion criteria for PFP. Additionally, clinicians should have some flexibility in diagnostic criteria, adhering to retro- or peri-patellar pain during weight bearing tasks that require knee flexion, as kneeling and walking, which are not included in the 2016 consensus statement [10] despite being reported by 28.0% and 17.3% of our sample, respectively.

Lower extremity isometric strength was compared among the three groups: squatting, running, and stair ambulation, which were the top three exacerbating tasks in our participants. No significant differences in strength were found among the groups. One possible explanation for this lack of differences could be the isometric strength measure. Isometric strength may not provide a complete picture of neuromuscular functions, as novel measurements like power and rate of torque development have emerged in the PFP literature [16,28,29]. Isometric strength assessments may be subject to a ceiling effect when the measure lacks adequate sensitivity, such that higher levels of strength are not distinguishable once participants approach the upper range of the scale. Isometric hip strength appears to be less sensitive to detecting muscular impairments (up to 15% deficit) than rate of torque development measures (up to 55% deficit) in individuals with PFP compared to pain-free individuals [28]. Novel methods to quantify neuromuscular function, specifically force steadiness, and its relationship to functional performance and QoL should also be examined [30]. While force steadiness has previously explained a small portion of variance for the AKPS, the underlying sensory-motor impairments may be related to functional tasks that provoke pain in PFP cohort [30]. Future research should consider assessing other neuromuscular functions rather than isometric strength, which could be more closely associated with painful tasks in the PFP population.

Another potential explanation for the lack of difference in strength between the groups could be the development of a compensatory strategy. Individuals with PFP may develop altered strategies to produce force or modify functional tasks when they experience pain, which may be an attempt to maintain a healthy level of activity or their QoL. While limited to stair ambulation and step-down tasks, pain exacerbation does alter trunk kinematics and shifts load distribution from the knee to the hip, which could be considered a strategy to reduce pain [19]. While speculative, the previous evidence [19] would support our current findings, as pain during stair ambulation did have worse QoL compared to squatting and running.

In this study, individuals who reported stair ambulation as their most painful task had worse QoL compared to individuals in the squatting and running groups. The significantly worse QoL within the stair ambulation group could be due to the nature of the task. Compared to squatting and running, stairs are relatively common and difficult to avoid in daily life which then requires individuals with PFP to regularly partake in tasks that knowingly cause them pain or discomfort. While speculative, the stair ambulation group may include individuals with more pervasive functional limitations due to the broad contextual disability in their home or public environments. On the other hand, both squatting and running are tasks that could be avoided intentionally by changing the type or demands of the activity [31]. Individuals with PFP reportedly decrease mileage or modify squatting tasks by either reducing the number of sets/repetitions or minimizing the range of motion to reduce their pain [31]. Future qualitative research should examine how specific tasks may alter QoL in individuals with PFP.

This study is not without limitations. When comparing the results of this study to the PROMs (AKPS and KOOS-PF) and the 2016 consensus statement [10], the weights placed on each of the questions could not be assessed due to a lack of data on the severity of pain elicited from each exacerbating task [12]. The PFP severity scale is one PROM that quantifies pain with a visual analog scale for 10 activities from the previous week [32]. The tasks on the PFP severity scale include six of the seven most reported tasks from our study, supporting the inclusion of common self-reported exacerbating tasks [32]. Due to the nature of open-ended questions, common tasks reported by participants were grouped, but it is unclear if subtle variations in tasks may influence the results. Considering that sex has been reported as a potential factor that may influence strength in individuals with PFP [14], the mixed-sample in our study may affect our strength results. Confounding factors were not considered by the authors, such as the participant's physical activity levels, which may affect the reported exacerbating tasks and QoL.

Conclusions

While PFP presents with a heterogeneous nature of functional limitations, self-reported exacerbating tasks are commonly assessed in current PROMs or presented in established diagnostic criteria commonly used in the PFP literature. While some tasks may not be included in the PROMs, clinicians and researchers may want to consider including open-ended questions in addition to common standardized PROMs. Our findings suggest that different exacerbating tasks influenced the QoL in individuals with PFP suggesting the need for more personalized rehabilitation programs based on the specific exacerbating tasks reported by each individual.

Author contributions

CRediT: **Cole Bhella**: Conceptualization, Visualization, Writing – original draft, Writing – review & editing; **Sungwan Kim**: Conceptualization, Writing – review & editing; **L. Colby Mangum**: Conceptualization, Investigation, Methodology, Writing – review & editing; **David M. Bazett-Jones**: Conceptualization, Investigation, Methodology, Writing – review & editing; **Michelle C. Boling**: Conceptualization, Writing – review & editing; **Michael D. Toland**: Conceptualization, Formal analysis, Visualization, Writing – review & editing; **Lindsay J. DiStefano**: Conceptualization, Writing – review & editing; **Neal R. Glaviano**: Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Visualization, Writing – review & editing.

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Data availability statement

The data that support the findings of this study are available from the corresponding author [NRG], upon reasonable request.

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