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Complete List of Authors:	Ophey, Martin; Amsterdam UMC Locatie Meibergdreef, Orthopedie en Sportgeneeskunde Frieling, Sophie; HAN University of Applied Sciences - Nijmegen Campus, Physical Therapy Kerkhoffs, Gino; Amsterdam UMC Locatie AMC, Orthopaedic surgery, Amsterdam movement sciences; Amsterdam Collaboration on Health & Safety in Sports , Amsterdam UMC IOC Research Center of Excellence Tak, Igor; Physiotherapy Utrecht Oost – Sports Rehabilitation and Manual Therapy, ; Amsterdam Collaboration on Health and Safety in Sports (ACHSS) / IOC Research Center of Excellence,
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Pain during prolonged sitting in patients with patellofemoral pain: an online questionnaire-based analysis

Martin J. Ophey, MSc, PT_{sport},[a,b,c] Sophie M. W. Frieling, MSc, PT,[d] Gino M. M. J. Kerkhoffs, Prof. Dr., MD,[b,f,g] Igor J. R. Tak, PhD, PT_{sport},[b,c,e,f,g]

[a] IJsveldFysio – Private Physical Therapy Clinic, Nijmegen, The Netherlands; email: m.j.ophey@amsterdamumc.nl

[b] Amsterdam UMC location University of Amsterdam, Department of Orthopaedic Surgery and Sports Medicine, Amsterdam, The Netherlands; email: g.m.kerkhoffs@amsterdamumc.nl

[c] ESP Science and Education, Vienna, Austria. email: igor.tak@gmail.com

[d] HAN – University of Applied Sciences, Physical Therapy Department, Nijmegen, The Netherlands; email: sophie.frieling1995@gmail.com

[e] Physiotherapy Utrecht Oost – Sports Rehabilitation and Manual Therapy, Utrecht, The Netherlands.

[f] Amsterdam Collaboration on Health and Safety in Sports (ACHSS) / IOC Research Center of Excellence, Amsterdam, The Netherlands

[g] Center for Evidence Based Sports Medicine (ACES), Amsterdam, The Netherlands.

Corresponding author: Martin Ophey, Amsterdam UMC, Meibergdreef 9, 1105 AZ Amsterdam, The Netherlands, phone: +31-650616509, email: m.j.ophey@amsterdamumc.nl

ORCID iD: https://orcid.org/0000-0002-8674-0477

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ABSTRACT

Objectives A significant proportion of patients with patellofemoral pain (PFP) report pain during prolonged sitting (PDPS); however, detailed characteristics of PDPS are lacking. This study aimed to describe 1) differences between PFP patients with and without PDPS, 2) minimum knee flexion angle and time to onset/disappearance of PDPS, and 3) differences between those with PDPS at smaller/greater flexion angles, with faster/slower onset, and faster/slower disappearance of PDPS, respectively.

Design Online questionnaire.

Setting Private physical therapy clinics in the Netherlands.

Participants 87 patients (61 [70%] females, mean age 22.0 years [IQR 4.0], BMI 23.1 [IQR 4.7]).

Primary and secondary outcome measures VAS for worst pain (VAS-W) and worst sitting pain (VAS-W sitting) in the past seven days and the Anterior Knee Pain Scale (AKPS).

Results Sixty-three of 87 (72%) patients reported PDPS. Patients with PDPS more often experienced bilateral symptoms of PFP ($p = .044$), and exhibited a 12-point lower AKPS score ($p < .001$). The reported median time to PDPS onset was 16–20 min, with 6–10 min for disappearance. Patients with PDPS experiencing symptoms at smaller flexion angles and with faster onset exhibited higher VAS-W ($p = .002$, $p < .001$) and VAS-W sitting ($p = .001$, $p = .025$) scores.

Conclusions Patients with PDPS reported higher levels of disability, and a delayed onset of PDPS, compared to the time for disappearance. Suggestions for future research are

offered to enhance the understanding of the underlying mechanisms of PDPS, in conjunction with suggestions for the development of targeted interventions aimed at improving long-term outcomes.

Keywords: patellofemoral pain syndrome, knee, orthopaedics

Strengths and limitations of this study

- Pain during prolonged sitting occurred with the knees flexed ≥ 90 degrees.
- PFP patients with PDPS experienced higher levels of disability, compared to those without.
- Patients with PDPS at smaller flexion angles and with a faster onset experienced higher levels of pain.
- PFP patients reported onset of PDPS after 16-20 minutes, while time for disappearance was shorter.
- The final sample size was slightly smaller than the commonly accepted guideline for an appropriate sample size for online questionnaires, which may lead to a lower external validity of the current study.

INTRODUCTION

Patellofemoral pain (PFP) is a common musculoskeletal condition that has an annual prevalence of up to 36% [1]. A significant proportion of patients with PFP experience 'pain during prolonged sitting' (PDPS), which is also referred to as the "movie goers' sign" due to the extended periods of sitting with flexed knees in a seat with little leg space during a cinema visit [2]. A large study of 458 patients with PFP reported a prevalence of PDPS in 80% within the sample population [3].

The mechanisms underlying PDPS in patients with PFP are unelucidated. For instance, prolonged sitting with knees flexed does not expose the patellofemoral joint (PFJ) to biomechanical loading. Additionally, a recent study employing magnetic resonance imaging (MRI) found no association of any morphological parameters, such as alignment or structural characteristics of the PFJ, with PDPS in patients with PFP [4].

Collins et al. reported that patients with PFP and PDPS were younger, more likely to be female, had a lower body mass index (BMI), higher pain severity, lower Anterior Knee Pain Scale (AKPS) scores, and more problems with squatting compared to patients without PDPS [3]. The existing literature lacks specific details such as the degree of knee flexion required to elicit PDPS, and the duration between seating and the onset of PDPS. A delayed onset of symptoms, for instance, may indicate disturbed homeostasis of structures of the anterior knee due to increased intraosseous pressure of the patella, as previously described [5,6]. Moreover, patients with PDPS at smaller flexion angles may exhibit demographic or symptom characteristics distinct from those with PDPS at greater flexion angles.

Therefore, in this study, we aimed to describe 1) differences between PFP patients with and without PDPS, 2) minimum knee flexion angles to provoke symptoms of PDPS, and time to onset and for disappearance in those with PDPS, and 3) differences between those with PDPS at smaller flexion angles, with fast-onset and fast-disappearance of PDPS compared to those with PDPS at greater flexion angles, with slow-onset, and slow-disappearance, respectively.

METHODS

Ethical approval was obtained from the Ethical Scientific Advisory Board of the Ethical of the HAN – University of Applied Sciences (EACO 147.04/19), Nijmegen, the Netherlands.

Patient involvement

Patients with PFP and PDPS actively participated in the identification of criteria for assessing PDPS characteristics. Then they reviewed the developed preliminary questionnaire and assessed it for readability and item clarity. Following publication, enrolled participants will receive a comprehensive manuscript encompassing the full text.

Patients

Patients were recruited by nine physical therapists (PT) working in private clinics in The Netherlands with a special interest in the rehabilitation of knee injuries and PFP. These PTs were informed about the inclusion and exclusion criteria (TABLE 1), and asked to

screen and invite patients with PFP to participate in this study. The invitation was sent between May 2021 and March 2023. Informed consent was obtained online as the first item of the survey questionnaire.

TABLE 1. Criteria for the inclusion and exclusion of potential participants

Inclusion	Exclusion

• Age: 18–40 years.
• Pain:
  ○ experienced around and/or behind the patella.
  ○ aggravated by one or more of the following activities: squatting, stair ambulation, jogging/running, hopping/jumping.
  ○ lasting for ≥ 3 months.
  ○ that did not arise from trauma.
• Worst pain levels ≥ 3/10 on a VAS (VAS-W) during the past 7 days.
• Electronic informed consent.
	• Previous or current clinical diagnosis of serious pathology (e.g., malignancy).
	• Previous or current other clinical diagnosis of specific knee conditions (e.g., Osgood–Schlatter, Sinding–Larsson, patellar instability or dislocation, jumper's knee, meniscal tears, or ligament injury).
	• History of surgery (e.g., ankle, knee, hip, or lower back).

Abbreviations: VAS-W, Visual Analogue Scale for Worst pain.

Questionnaire

The online questionnaire comprised three parts. The first part contained eight items and evaluated general patient characteristics (e.g., sex, age, body weight and length, and hours of sport participation per week). The activity level was rated according to the Tegner Score [7–9], which contains 11 response options ranging from 0 to 10. Higher scores indicated higher activity levels. The Dutch version of the Tegner Score is reliable (*ICC* = .97) with moderate correlations with other knee- and quality-of-life related questionnaires (r = .42 – .48) [10].

The second part of the questionnaire contained seven items and evaluated specific PFP characteristics, such as symptom duration, history of other knee injuries, and worst pain in the past seven days on a visual analogue scale (VAS-W), which is a continuous 10 cm-line to indicate the intensity of pain perception when at its worst (score from '0 cm' [no pain] to '10 cm' [maximal pain]) [11].

Additionally, the Anterior Knee Pain Scale (AKPS) and Tampa Scale for Kinesiophobia (TSK) were followed. The AKPS measures pain and disability, and contains 13 items with 3 to 5 response options [11]. Scores between '0' and '10' were allocated to each response option. The overall score was normalised on a 0–100 scale, where '100' indicated no problems at all and '0' indicated the maximum number of knee problems experienced [12]. The Dutch Version of the AKPS is reliable (*ICC* = .98) with good internal consistency (r = .78 – .80) [13]. Item 8 of the AKPS refers to 'prolonged sitting' and contains five response options. Two groups were formed based on these response options: (1) presence of PDPS ('pain after exercise', 'constant pain', 'pain forces to extend knees temporarily', and 'unable') and (2) absence of PDPS ('no difficulty').

A previous study found no PFJ loading variables (e.g., peak PFJ contact force), but kinesiophobia being associated with self-reported pain and disability in patients with PFP [14]. Since prolonged sitting lacks PFJ loading, evaluation of kinesiophobia in patients with PDPS may be relevant. Therefore, the Tampa Scale for Kinesiophobia (TSK) was also administered. The TSK is a 17-item questionnaire for evaluating pain-related fear and avoidance behaviour [15]. Patients were asked to rate their level of agreement with statements regarding fear of movement behaviour on a 4-point Likert scale from 'strongly disagree' to 'strongly agree'. Higher scores indicate higher levels of kinesiophobia.

The third section contained four items and specifically evaluated the characteristics of PDPS. Patients were asked to rate their worst sitting pain in the past seven days (VAS-W sitting) on a 10 cm-line with a continuous score from '0 cm' (no pain) to '10 cm' (maximal pain) [11]. The minimum degree of knee flexion required to provoke PDPS was evaluated by presenting four pictures with the knees flexed at 0°, 45°, 90°, or beyond 90°. The minimum time to onset of PDPS with the knees in 90° was evaluated in seven response options ('0–5 min', '6–10 min', '11–15 min', '16–20 min', '20–30 min', '30–40 min', and '> 40 minutes'). The minimum time required for disappearance of PDPS after extending the knees from 90° flexion was evaluated using the same response options. Items of this category were dichotomised by defining a 'smaller flexion angle' group (< 90°) and a 'greater flexion angle' group (≥ 90°); a 'fast-onset' group (≤ 10 minutes) and a 'slow-onset' group (> 10 minutes); and a 'fast-disappearance' group (≤ 10 minutes) and a 'slow-disappearance' group (> 10 minutes).

The draft version of the third part of the questionnaire was checked by four patients with PFP and two PTs. Minor changes were made to two items to ensure their readability and feasibility. The final questionnaire was administered online via Castor (Castor EDC, Amsterdam, The Netherlands).

Sample size

A commonly accepted guideline for an appropriate sample size for online questionnaires is a minimum of $n = 100$ participants [16]. Given that patients are invited by their treating PTs, it was hypothesized that this would foster commitment to promptly complete the questionnaire. We projected a potential dropout rate up to 20%. Consequently, we aimed

to recruit a sample size of $n = 125$ participants. Considering that this online questionnaire would be conducted concurrently with multiple other PFP studies over a 2-year period, we anticipated the enrolment of 100 participants.

Statistical analysis

The normality of the data distribution was evaluated using the Shapiro–Wilk test. Normally distributed data ($p > .05$) were analysed parametrically and presented as mean (± standard deviation). When data were not normally distributed, they were analysed non-parametrically and presented as the median (interquartile range [*IQR*], 25–75%). Differences between groups (with and without PDPS, smaller and greater flexion angles, fast and slow onset, fast and slow disappearance) in continuous characteristics were analysed using Student's *t*-test (normally distributed data) or the Mann–Whitney *U*-test (non-normally distributed data). Differences in dichotomous characteristics were analysed using the Fisher's exact test. A critical level of $p < .05$ was considered statistically significant. The effect sizes (*ES*) for normally distributed data were calculated using Cohen's *d* to determine the magnitude of the differences. For non-normally distributed data, *ES r* using the formula $r = Z/\sqrt{(n_a + n_b)}$, with *Z* being the Z-score from the Mann-Whitney *U* test and n_a and n_b being sample sizes of both groups, has been determined [17]. For dichotomous variables *Phi* has been calculated based on the chi-square statistic χ^2 [17]. An *ES* of 0.2, 0.5, and ≥ 0.8 is considered small, medium, and large, respectively [18]. Statistical analyses were performed using SPSS version 25.0 (SPSS Inc., Chicago, IL, USA).

RESULTS

A total of 107 patients with PFP were invited to participate, of whom 20 were excluded (SUPPLEMENTARY FIGURE 1). The remaining 87 (81%) patients were eligible for inclusion (61 [70%] females, mean age 22.0 years [IQR 4.0], BMI 23.1 [IQR 4.7]).

Sixty-three (72%) patients with PFP reported PDPS (TABLE 2). More patients with PDPS had bilateral symptoms (71%), compared to those without PDPS (46%) ($p = .044$). Participants with PDPS exhibited a 12-point lower total score on the AKPS ($U = 355.50$, $p < .001$, $r = 0.41$), and lower scores on items 3 'walking' ($U = 474.00$, $p = .004$, $r = 0.31$), 5 'squatting' ($U = 505.50$, $p = .009$, $r = 0.28$), 8 'prolonged sitting' ($U = 0.00$, $p < .001$, $r = 0.51$), and 9 'pain' ($U = 555.00$, $p < .025$, $r = 0.24$). Most patients with PFP and PDPS ($n = 52$ [85%]) reported symptoms that occurred when the knees were flexed to 90° or more. Only a small proportion (n = 9 [15%]) of the patients with PFP and PDPS experienced symptoms in smaller knee flexion positions (0° or 45°). Two patients with PDPS omitted this item.

TABLE 2. Baseline characteristics of the participants

Characteristics	PFP patients with PDPS	PFP patients without PDPS	*P*-value	*ES*
Participants, *n* (%)	63 (72)	24 (28)	n/a	n/a
Female, *n* (%)	46 (73)	15 (63)	.433	*Phi* = .10
Age (years)	22.0 (*IQR* 6.0)	23.0 (*IQR* 9.3)	.242	*r* = .13
BMI (kg/m²)	23.5 (*IQR* 4.9)	21.7 (*IQR* 4.0)	.207	*r* = .14
Sport participation (h/week)	3.0 (*IQR* 3.0)	3.5 (*IQR* 1.9)	.466	*r* = .08
Tegner Score (0–10)	4.0 (*IQR* 3.0)	5.0 (*IQR* 2.0)	.138	*r* = .16
VAS-W (0–10)	6.0 (*IQR* 3.0)	5.0 (*IQR* 2.0)	.212	*r* = .13
Bilateral PFP, *n* (%)	45 (71)*	11 (46)*	.044	*Phi* = .24
Symptom duration (months)	40.0 (*IQR* 64.0)	20.0 (*IQR* 45.0)	.337	*r* = .07
AKPS (0–100)	74.0*** (*IQR* 14.0)	86.0*** (*IQR* 11.5)	< .001	*r* = .41
Item 1 ‘limp’ (0–5)	5.0 (*IQR* 2.0)	5.0 (*IQR* 2.0)	.197	*r* = .14
Item 2 ‘support’ (0–5)	5.0 (*IQR* 2.0)	5.0 (*IQR* 0.0)	.207	*r* = .14
Item 3 ‘walking’ (0–5)	3.0** (*IQR* 2.0)	5.0** (*IQR* 2.0)	.004	*r* = .31
Item 4 ‘stairs’ (0–10)	8.0 (*IQR* 3.0)	8.0 (*IQR* 5.0)	.992	*r* = .00
Item 5 ‘squatting’ (0–5)	4.0** (*IQR* 1.0)	4.0** (*IQR* 1.0)	.009	*r* = .28
Item 6 ‘running’ (0–10)	6.0 (*IQR* 2.0)	7.0 (*IQR* 2.0)	.286	*r* = .11
Item 7 ‘jumping’ (0–10)	7.0 (*IQR* 3.0)	7.0 (*IQR* 3.0)	.090	*r* = .18
Item 8 ‘prolonged sitting’ (0–10)	6.0*** (*IQR* 4.0)	10.0*** (*IQR* 0.0)	< .001	*r* = .51
Item 9 ‘pain’ (0–10)	8.0* (*IQR* 5.0)	8.0* (*IQR* 0.0)	.025	*r* = .24
Item 10 ‘swelling’ (0–10)	10.0 (*IQR* 2.0)	10.0 (*IQR* 0.0)	.077	*r* = .19
Item 11 ‘subluxations’ (0–10)	10.0 (*IQR* 4.0)	10.0 (*IQR* 0.0)	.128	*r* = .16
Item 12 ‘atrophy’ (0–5)	5.0 (*IQR* 0.0)	5.0 (*IQR* 2.0)	.337	*r* = .10
Item 13 ‘flexion deficiency’ (0–5)	5.0 (*IQR* 0.0)	5.0 (*IQR* 0.0)	.357	*r* = .10
TSK (17–68)	33.0 (*IQR* 8.0)	33.0 (*IQR* 10.0)	.853	*r* = .20

Abbreviations: n, number; BMI, Body Mass Index in kilograms of body weight per m^2; h/week, hours per week; VAS-W, Visual Analogue Scale for Worst pain; AKPS, Anterior Knee Pain Scale; TSK, Tampa Scale for Kinesiophobia; ES, Effect Size as Cohen's *d*, *r* or *Phi*; n/a, not applicable.

Data are presented as numbers (percentages), and median (interquartile range 25%–75%). *, ** and *** indicate *p*-value < .05, < .01, and < .001, respectively.

Among those with PDPS, 44 (70%) patients experienced sitting-related pain in 90 degrees or less knee flexion, and thus were capable to answer questions regarding time to onset and disappearance with the knees at 90 degrees of flexion. These participants reported a median time to PDPS onset of 16 to 20 minutes, and a median time for disappearance of 6 to 10 minutes.

Patients with PFP and PDPS at smaller flexion angles were two years younger, scored two points higher scores on the VAS-W, had an 11-points lower total score on the AKPS, higher scores on the TSK, and almost two points higher VAS-W sitting score, compared to those with PDPS at greater flexion angles (TABLE 3).

TABLE 3. Characteristics of groups of patients with PDPS in smaller and greater knee flexion angles

Characteristics	Smaller flexion angle (< 90°)	Greater flexion angle (≥ 90°)	*P*-value	*ES*
Participants, n (%)	9 (15)	52 (85)	n/a	n/a
Female, *n* (%)	7 (78)	37 (71)	.515	*Phi* = .05
Age (years)	20.0* (*IQR* 4.0)	22.0* (*IQR* 5.8)	.018	*r* = .30
BMI (kg/m²)	23.2 (*IQR* 4.8)	23.8 (*IQR* 5.2)	.190	*r* = .17
Sport participation (h/week)	3.0 (*SD* ± 2.1)	3.6 (*SD* ± 2.2)	.400	*d* = .11
Tegner Score (0–10)	4.0 (*IQR* 5.0)	4.0 (*IQR* 3.0)	.452	*r* = .10
VAS-W (0–10)	7.0** (*IQR* 1.0)	5.0** (*IQR* 3.0)	.002	*r* = .39
Bilateral PFP, *n* (%)	9 (100)	36 (69)	.096	*Phi* = .25
Symptom duration (months)	48.0 (*IQR* 74.5)	38.0 (*IQR* 64.0)	.445	*r* = .10
AKPS (0–100)	66.0** (*IQR* 13.5)	77.0** (*IQR* 13.0)	.005	*r* = .36
TSK (17–68)	36.0* (*IQR* 14.5)	32.0* (*IQR* 8.0)	.029	*r* = .28
VAS-W sitting (0–10)	6.8** (*IQR* 1.1)	5.0** (*IQR* 3.0)	.001	*r* = .41

Abbreviations: n, number; BMI, Body Mass Index in kilograms of body weight per m²; h/week, hours per week; VAS-W, Visual Analogue Scale for Worst pain; AKPS, Anterior Knee Pain Scale; TSK, Tampa Scale for Kinesiophobia; VAS-W sitting, Visual Analogue Scale for Worst sitting pain; *ES*, Effect Size as Cohen's *d*, *r* or *Phi*; n/a, not applicable.

Data are presented as numbers (percentages), mean (± standard deviation), or median (interquartile range 25%-75%). *, ** and *** indicate *p*-value < .05, < .01, and < .001, respectively.

Patients with PFP with fast-onset PDPS exhibited VAS-W and VAS-W sitting scores that were two points and one point higher, respectively, compared to those with slow-onset PDPS (TABLE 4). Patients with PFP with fast-disappearance PDPS reported an additional 1.3 hours of weekly sports participation, and an 8-points higher total score on the AKPS, compared to those with slow-disappearance (TABLE 5).

TABLE 4. Characteristics of groups of patients with PDPS with faster and slower onset of symptoms

Characteristics	Fast-onset (≤ 10 min)	Slow-onset (> 10 min)	*P*-value	*ES*
Participants, *n* (%)	14 (32)	30 (68)	n/a	n/a
Female, *n* (%)	8 (57)	22 (73)	.316	*Phi* = .16
Age (years)	21.5 (*IQR* 7.0)	22.0 (*IQR* 6.3)	.577	*r* = .08
BMI (kg/m²)	24.0 (*IQR* 3.0)	24.0 (*IQR* 5.9)	.821	*r* = .03
Sport participation (h/week)	3.1 (*SD* ± 2.1)	3.0 (*SD* ± 2.0)	.934	*d* = .03
Tegner Score (0–10)	4.0 (*IQR* 2.3)	3.0 (*IQR* 4.0)	.096	*r* = .25
VAS-W (0–10)	7.0*** (*IQR* 2.0)	5.0*** (*IQR* 3.0)	< .001	*r* = .50
Bilateral PFP, *n* (%)	10 (71)	24 (80)	.701	*Phi* = .10
Symptom duration (months)	42.0 (*IQR* 87.0)	40.0 (*IQR* 48.0)	.696	*r* = .06
AKPS (0–100)	68.0 (*IQR* 10.0)	74.0 (*IQR* 16.3)	.109	*r* = .24
TSK (17–68)	32.5 (*IQR* 8.0)	32.5 (*IQR* 10.5)	.940	*r* = .01
VAS-W sitting (0-10)	6.0* (*IQR* 2.0)	5.0* (*IQR* 4.0)	.038	*r* = .31

Abbreviations: n, number; BMI, Body Mass Index in kilograms of body weight per m²; h/week, hours per week; VAS-W, Visual Analogue Scale for Worst pain; AKPS, Anterior Knee Pain Scale; TSK, Tampa Scale for Kinesiophobia; VAS-W sitting, Visual Analogue Scale for Worst sitting pain; *ES*, Effect Size as Cohen's *d*, *r* or *Phi*; n/a, not applicable.

Data are presented as numbers (percentages), mean (± standard deviation), or median (interquartile range 25%–75%). *, ** and *** indicate *p*-value < .05, < .01, and < .001, respectively.

TABLE 5. Characteristics of groups of patients with PDPS with faster and slower disappearance of symptoms

Characteristics	Fast-disappearance (≤ 10 min)	Slow-disappearance (> 10 min)	*P*-value	*ES*
Participants, *n* (%)	25 (57)	19 (43)	n/a	n/a
Female, *n* (%)	16 (64)	14 (74)	.534	*Phi* = .10
Age (years)	22.0 (*IQR* 6.0)	20.0 (*IQR* 5.0)	.229	*r* = .18
BMI (kg/m²)	24.1 (*IQR* 4.1)	22.4 (*IQR* 5.0)	.112	*r* = .24
Sport participation (h/week)	3.6* (*SD* ± 2.0)	2.3* (*SD* ± 1.9)	.036	*d* = .66
Tegner Score (0–10)	4.0 (*IQR* 3.0)	3.0 *IQR* (2.0)	.197	*r* = .19
VAS-W (0–10)	5.0 (*IQR* 3.0)	6.0 (*IQR* 2.0)	.379	*r* = .13
Bilateral PFP, *n* (%)	17 (68)	17 (90)	.148	*Phi* = .25
Symptom duration (months)	36.0 (*IQR* 54.5)	42.0 (*IQR* 60.0)	.406	*r* = .13
AKPS (0–100)	74.0** (*IQR* 16.0)	67.0** (*IQR* 12.0)	.005	*r* = .43
TSK (17–68)	32.0 (*IQR* 8.0)	33.0 (*IQR* 14.0)	.374	*r* = .13
VAS-W sitting (0–10)	5.0 (*IQR* 4.0)	6.0 (*IQR* 2.0)	.156	*r* = .21

Abbreviations: n, number; BMI, Body Mass Index in kilograms of body weight per m²; h/week, hours per week; VAS-W, Visual Analogue Scale for Worst pain; AKPS, Anterior Knee Pain Scale; TSK, Tampa Scale for Kinesiophobia; VAS-W sitting, Visual Analogue Scale for Worst sitting pain; *ES*, Effect Size as Cohen's *d*, *r* or *Phi*; n/a, not applicable.

Data are presented as numbers (percentages), mean (± standard deviation), or median (interquartile range 25%–75%). *, ** and *** indicate *p*-value < .05, < .01, and < .001, respectively.

DISCUSSION

Patients with PDPS more often reported bilateral PFP and higher levels of disability, compared to those without PDPS. Pain during prolonged sitting was typically induced when the knees were flexed to 90° or more. The median time to reported onset of PDPS was 16 to 20 minutes, and the time for disappearance of PDPS was generally 6 to 10 minutes. Patients with PDPS at smaller knee flexion angles were younger and had higher levels of pain, disability, and kinesiophobia, compared to patients with PDPS at greater flexion angles. Patients with PDPS with faster onset had higher levels of pain, compared

to those with slower onset. Patients with PDPS with slower disappearance of PDPS were less physically active and had higher levels of disability, compared to patients with faster disappearance of PDPS.

In the present study, the prevalence of PDPS in patients with PFP was 72%. This is in line with the previously reported prevalence of 77%–80% [3,19]. Bilateral symptoms occurred more frequently in patients with PDPS than in those without. As bilateral PFP is a prognostic factor for an unfavourable course [20], PDPS may similarly exert prognostic influence. Nonetheless, definitive establishment necessitates a prospective study design.

Furthermore, patients with PFP and PDPS had 12-point lower AKPS score, compared to those patients without PDPS. This is in line with the findings of Collins et al. [3]. The lower AKPS score holds clinical significance, as the smallest clinically important difference in the AKPS has been established to be at least 10 points [21]. Since this group comparison is based on item 8 ‘prolonged sitting’ of the AKPS a lower AKPS total score of patients with PFP and PDPS is inevitable. But the difference on item 8 ‘prolonged sitting’ between both groups was only four points. Patients with PDPS scored also lower on item 3 ‘walking’ and 5 ‘squatting’. Higher levels of problems with squatting were also identified in the PDPS group by Collins et al. [3], while they did not evaluate differences on item 3 ‘walking’.

Additionally, Collins et al. noted that patients with PDPS were younger, predominantly female, had lower BMI, and worse levels of knee pain, compared to PFP patients without PDPS [3]. The reasons for the current study’s inability to confirm these findings may stem from the slightly different categorisation of AKPS item 8 ’prolonged sitting’. In the

current study, patients experiencing PDPS only after exercise were not treated and analysed as a distinct category. In contrast, Collins et al. considered this subgroup as a distinct category in their study [3].

A smaller proportion of patients with PFP and PDPS reported experiencing knee pain at smaller flexion angles, and with faster onset of PDPS. They also reported higher pain levels (VAS-W and VAS-W sitting). Different theories have been proposed regarding the origin of PDPS in patients with PFP. Especially in patients with PDPS at smaller flexion angles and with faster onset of PDPS, biomechanical models seem implausible explanations for PFP due to the absence of PFJ reaction forces. The homeostasis model [22] may be a more suitable construct because it proposes disturbed homeostasis of osseous and soft tissues in the anterior knee after supraphysiologic loading. Homeostatic disturbance is then induced by vascular stress and stretching of the peripatellar anastomotic ring, resulting in increased intraosseous water content and pressure of the patella, and triggering a cascade of ischaemic nociceptive responses [5,6,23–28]. This would not only explain the delayed onset of PDPS but also the shorter time for disappearance of PDPS after prolonged sitting.

Research and clinical implications

Previous studies on patellar bone blood flow evaluated rather short episodes (seconds to minutes) [24,29,30] and/or with the knee in extension [29,30], future studies should focus on evaluating patellar blood flow beyond 20 min of prolonged sitting with the knee in 90 degrees of flexion.

According to the 2017 Gold Coast Consensus Statement on Treating PFP, hip- and knee-focused exercise therapy is a key component in the management of all patients with PFP [31]. In a subgroup of patients with PFP and PDPS at smaller flexion angles and with faster onset, knee-focused exercise therapy to reduce PFJ reaction forces may increase ischaemia, thereby provoking homeostatic pain. Since intermittent training (two seconds of rest between repetitions) reduces patellar bone blood flow in healthy participants [32], this could be a valuable alternative for patients with PFP and PDPS at smaller flexion angles and with faster onset, and may even be valuable in patients with PFP and PDPS. However, this aspect should be further investigated.

Additionally, health care professionals should advise patients with PDPS at smaller flexion angles and with faster onset to avoid these provocative postures altogether, or at the very least, to minimize the duration spent in such positions.

Strengths and limitations

The current study marks the first attempt to evaluate key characteristics of PDPS in patients with PFP, thereby offering more detailed insights into this clinical phenomenon. The study also acknowledges certain limitations. Firstly, in the available study period we did not manage to invite 125 participants as anticipated, but only 107 participants. With 20 out of 107 participants (19%), the dropout rate in the current study was as estimated. Thus, the final sample size (n = 87) is slightly smaller than the commonly accepted guideline for an appropriate sample size for online questionnaires (n = 100), which may lead to a lower external validity of the current study.

Furthermore, eight (7%) invited patients with PFP were excluded because their worst pain levels were too low at the moment of completion of the questionnaire. Though the time between invitation and study participation was usually one week, the worst pain level at the time of invitation may have been higher than that at the time of completion of the questionnaire. We underestimated, this change in worst pain level as being a factor for successful recruitment. Future studies should take this into account when determining sample size. Only four (4%) patients with PFP were excluded due to the presence of other knee problems or too short symptom duration, indicating a generally accurate procedure of recruitment by experienced PTs.

Secondly, subgroups of patients with PFP and PDPS (smaller/greater flexion angle, fast/slow onset, and fast/slow disappearance) were created by dichotomising the response options. This approach was based on our clinical experience with a large number of patients in our clinics. The choice to aggregate response options into one or more subgroup categories may be arbitrary and subject to debate.

Thirdly, though the PTs responsible for inviting patients with PFP were allocated to several regions of the Netherlands, the sampling method applied in the current study was a non-probability (convenience) sampling method. Therefore, generalisations based on the results of this study should be made cautiously.

CONCLUSION

Patients with PDPS more often reported bilateral PFP and higher levels of disability. PDPS typically occurred when the knees are flexed 90 degrees or more. Patients reported delayed onset of PDPS, whereas the time for disappearance of PDPS after prolonged

sitting was shorter. This study provides a detailed description of the characteristics of PDPS in patients with PFP. Suggestions for future research are offered to enhance the understanding of the underlying mechanisms of PDPS, in conjunction with suggestions for the development of targeted interventions aimed at improving long-term outcomes in patients with PFP.

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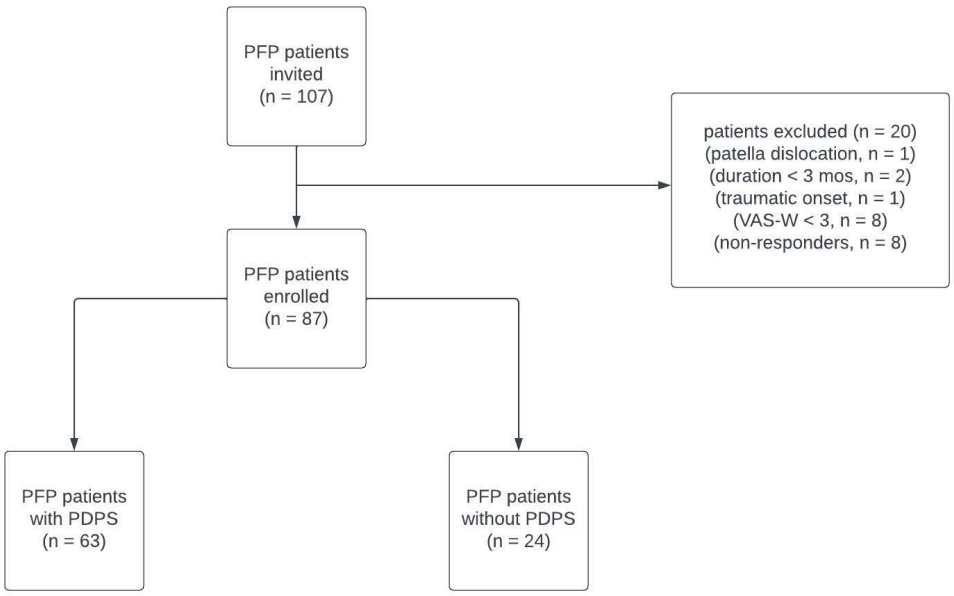
Captions of illustrations

SUPPLEMENTARY FIGURE 1. Flowchart of the inclusion process.



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Pain during prolonged sitting in subjects with patellofemoral pain in Dutch physical therapy clinics: an online questionnaire-based analysis

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Pain during prolonged sitting in subjects with patellofemoral pain in Dutch physical therapy clinics: an online questionnaire-based analysis

Martin J. Ophey, MSc, PT_{sport},[a,b,c] Sophie M. W. Frieling, MSc, PT,[d] Gino M. M. J. Kerkhoffs, Prof. Dr., MD,[b,f,g] Igor J. R. Tak, PhD, PT_{sport},[b,c,e,f,g]

[a] YsveldFysio – Private Physical Therapy Clinic, Nijmegen, The Netherlands; email: m.j.ophey@amsterdamumc.nl

[b] Amsterdam UMC location University of Amsterdam, Department of Orthopaedic Surgery and Sports Medicine, Amsterdam, The Netherlands; email: g.m.kerkhoffs@amsterdamumc.nl

[c] ESP Science and Education, Vienna, Austria. email: igor.tak@gmail.com

[d] HAN – University of Applied Sciences, Physical Therapy Department, Nijmegen, The Netherlands; email: sophie.frieling1995@gmail.com

[e] Physiotherapy Utrecht Oost – Sports Rehabilitation and Manual Therapy, Utrecht, The Netherlands.

[f] Amsterdam Collaboration on Health and Safety in Sports (ACHSS) / IOC Research Center of Excellence, Amsterdam, The Netherlands

[g] Center for Evidence Based Sports Medicine (ACES), Amsterdam, The Netherlands.

Corresponding author: Martin Ophey, Amsterdam UMC, Meibergdreef 9, 1105 AZ Amsterdam, The Netherlands, phone: +31-650616509, email: m.j.ophey@amsterdamumc.nl

ORCID iD: https://orcid.org/0000-0002-8674-0477

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ABSTRACT

Objectives A significant proportion of subjects with patellofemoral pain (PFP) report pain during prolonged sitting (PDPS); however, detailed characteristics of PDPS are lacking. This patient-reported questionnaire study aimed to describe 1) differences in characteristics between subjects with and without PDPS, 2) minimum knee flexion angle and time to onset/disappearance of PDPS, and 3) differences between those with PDPS at smaller/greater flexion angles, with faster/slower onset, and faster/slower disappearance of PDPS, respectively.

Design Online questionnaire.

Setting Private physical therapy clinics in the Netherlands.

Participants 87 participants (61 [70%] females, mean age 22.0 years [IQR 4.0], BMI 23.1 [IQR 4.7]).

Primary and secondary outcome measures VAS for worst pain (VAS-W) and worst sitting pain (VAS-W sitting) in the past seven days and the Anterior Knee Pain Scale (AKPS), Tampa Scale for Kinesiophobia (TSK), degree of knee flexion required to provoke PDPS, and time to onset and disappearance of PDPS.

Results Sixty-three of 87 (72%) participants reported PDPS. Participants with PDPS more often experienced bilateral symptoms of PFP ($p = .044$), and exhibited a 12-point lower AKPS score ($p < .001$). The reported median time to PDPS onset was 16–20 min, with 6–10 min for disappearance. Participants experiencing PDPS at smaller flexion angles exhibited higher VAS-W and VAS-W sitting scores compared to participants with PDPS at greater flexion angles ($p = .002$, $p = .001$). Additionally, higher VAS-W

and VAS-W sitting scores ($p < .001$, $p = .025$) were reported by participants with fast-onset compared to participants with slow-onset of PDPS.

Conclusions Subjects with PDPS reported higher levels of disability, and a delayed onset of PDPS, compared to the time for disappearance. Future research should focus on understanding the underlying mechanisms of PDPS and developing targeted interventions to improve long-term outcomes in subjects with PFP.

Keywords: patellofemoral pain syndrome, knee, orthopaedics

Strengths and limitations of this study

- Characteristics of pain during prolonged sitting were evaluated using an online patient-reported questionnaire rather than clinician-based measures.
- Subgroups of participants with pain during prolonged sitting were created by dichotomizing item response options, based on clinical experience, which may be arbitrary and subject to debate.
- The final sample size was slightly smaller than the commonly accepted guideline for an appropriate sample size for online questionnaires, which may lead to a lower external validity of the current study.
- Subjects were recruited from Dutch private physical therapy clinics, which may explain why participants were slightly younger compared to those in other studies.
- The reliability and validity of self-reported items evaluating the characteristics of pain during prolonged sitting are not yet known.

INTRODUCTION

Patellofemoral pain (PFP) is a common musculoskeletal condition that has an annual prevalence of up to 36% [1]. A significant proportion of subjects with PFP experience 'pain during prolonged sitting' (PDPS), which is also referred to as the "movie goers' sign" due to the extended periods of sitting with flexed knees in a seat with little leg space during a cinema visit [2]. A large study of 458 subjects with PFP reported a prevalence of PDPS in 80% within the sample population [3].

The mechanisms underlying PDPS in subjects with PFP are unelucidated. For instance, prolonged sitting with knees flexed does not expose the patellofemoral joint (PFJ) to biomechanical loading. Additionally, a recent study employing magnetic resonance imaging (MRI) found no association of any morphological parameters, such as alignment or structural characteristics of the PFJ, with PDPS in subjects with PFP [4].

Previously, only one study evaluated differences in characteristics between subjects with and without PDPS. It reported that subjects with PFP and PDPS were younger, more likely to be female, had a lower body mass index (BMI), higher pain severity, lower Anterior Knee Pain Scale (AKPS) scores, and more problems with squatting compared to subjects without PDPS [3]. Replicating and evaluating this in a different cohort may be valuable. Furthermore, the existing literature lacks specific details such as the degree of knee flexion required to elicit PDPS, and the duration between seating and the onset of PDPS. A delayed onset of symptoms, for instance, may indicate disturbed homeostasis of structures of the anterior knee due to increased intraosseous pressure of the patella, as previously described [5,6]. Moreover, subjects with PDPS at smaller flexion angles may exhibit demographic or symptom characteristics distinct

from those with PDPS at greater flexion angles. These differences could have prognostic value and clinical implications.

Therefore, in this patient-reported questionnaire study, we aimed to describe 1) differences in characteristics between subjects with PFP with and without PDPS, 2) minimum knee flexion angles to provoke symptoms of PDPS, and time to onset and for disappearance of PDPS, and 3) differences between those with PDPS at smaller versus greater flexion angles, with fast-onset versus slow-onset, and fast-disappearance versus slow-disappearance, respectively.

METHODS

Ethical approval was obtained from the Ethical Scientific Advisory Board of the Ethical of the HAN – University of Applied Sciences (EACO 147.04/19), Nijmegen, the Netherlands.

Patient involvement

Four subjects with PFP and PDPS (mean age 23 years; three females and one male) who met the inclusion and exclusion criteria were interviewed to identify criteria for assessing PDPS characteristics. Then they reviewed the developed preliminary questionnaire and assessed it for readability and item clarity. Minor changes were made to two items to ensure their readability and feasibility. Following publication, enrolled participants will receive a comprehensive manuscript encompassing the full text.

Participants

Subjects were recruited by nine physical therapists (PT) working in private clinics in The Netherlands with a special interest in the rehabilitation of knee injuries and PFP. These PTs were informed about the inclusion and exclusion criteria (TABLE 1), and asked to carefully evaluate history of knee pain, perform clinical examination (hip, and knee including exact site of pain), and invite subjects with PFP to participate in the current study. The inclusion and exclusion criteria are based on the Manchester consensus statement (definition of PFP, exclusion of other pathologies) [7], and standard practices in PFP research, which consider minimum symptom duration and pain levels (e.g., [3]) to ensure a homogeneous study population. The invitation was sent between May 2021 and March 2023. Informed consent was obtained online as the first item of the survey questionnaire.

TABLE 1. Criteria for the inclusion and exclusion of potential participants

Inclusion	Exclusion

• Age: 18–40 years.
• Pain:
  ○ experienced around and/or behind the patella.
  ○ aggravated by one or more of the following activities: squatting, stair ambulation, jogging/running, hopping/jumping.
  ○ lasting for ≥ 3 months.
  ○ that did not arise from trauma.
• Worst pain levels ≥ 3/10 on a VAS (VAS-W) during the past seven days.
• Electronic informed consent.
	• Previous or current clinical diagnosis of serious pathology (e.g., malignancy).
	• Previous or current other clinical diagnosis of specific knee conditions (e.g., Osgood–Schlatter, Sinding–Larsson, patellar instability or dislocation, jumper's knee, meniscal tears, or ligament injury).
	• History of surgery (e.g., ankle, knee, hip, or lower back).

Abbreviations: VAS-W, Visual Analogue Scale for Worst pain.

Questionnaire

The online questionnaire comprised three parts. The first part contained eight items and evaluated general patient characteristics (e.g., sex, age, body weight and length, and hours of sport participation per week). The activity level was rated according to the Tegner Score [8–10], which contains 11 response options ranging from 0 to 10. Higher scores indicated higher activity levels. The Dutch version of the Tegner Score is reliable (*ICC* = .97) with moderate correlations with other knee- and quality-of-life related questionnaires (*r* = .42 – .48) [11].

The second part of the questionnaire contained seven items and evaluated specific PFP characteristics, such as symptom duration, history of other knee injuries, and worst pain in the past seven days on a visual analogue scale (VAS-W), which is a continuous 10 cm-line to indicate the intensity of pain perception when at its worst (score from '0 cm' [no pain] to '10 cm' [maximal pain]) [12].

Additionally, the Anterior Knee Pain Scale (AKPS) and Tampa Scale for Kinesiophobia (TSK) were followed. The AKPS measures pain and disability, and contains 13 items with 3 to 5 response options [12]. Scores between '0' and '10' were allocated to each response option. The overall score was normalised on a 0–100 scale, where '100' indicated no problems at all and '0' indicated the maximum number of knee problems experienced [13]. The Dutch Version of the AKPS is reliable (*ICC* = .98) with good internal consistency (*r* = .78 – .80) [14]. Item 8 of the AKPS refers to 'prolonged sitting' and contains five response options. Two groups were formed based on these response options: (1) presence of PDPS ('pain after exercise', 'constant pain', 'pain forces to extend knees temporarily', and 'unable') and (2) absence of PDPS ('no difficulty').

A previous study found no PFJ loading variables (e.g., peak PFJ contact force), but kinesiophobia being associated with self-reported pain and disability in subjects with PFP [15]. Since prolonged sitting lacks PFJ loading, evaluation of kinesiophobia in subjects with PDPS may be relevant. Therefore, the Tampa Scale for Kinesiophobia (TSK) was also administered. The TSK is a 17-item questionnaire for evaluating pain-related fear and avoidance behaviour [16]. Participants were asked to rate their level of agreement with statements regarding fear of movement behaviour on a 4-point Likert scale from 'strongly disagree' to 'strongly agree'. Scores range from 17 to 68 points, with higher scores indicating greater levels of kinesiophobia [16].

The third section contained four items and specifically evaluated the characteristics of PDPS (SUPPLEMENTARY FILE 1). Participants were asked to rate their worst sitting pain in the past seven days (VAS-W sitting) on a 10 cm-line with a continuous score from '0 cm' (no pain) to '10 cm' (maximal pain) [12]. The minimum degree of knee flexion required to provoke PDPS was evaluated by presenting four pictures with the knees flexed at 0°, 45°, 90°, or beyond 90°. The minimum time to onset of PDPS with the knees in 90° was evaluated in seven response options ('0–5 min', '6–10 min', '11–15 min', '16–20 min', '21–30 min', '31–40 min', and '> 40 minutes'). The minimum time required for disappearance of PDPS after extending the knees from 90° flexion was evaluated using the same response options. Items of this category were dichotomised by defining a 'smaller flexion angle' group (< 90°) and a 'greater flexion angle' group (≥ 90°); a 'fast-onset' group (≤ 10 minutes) and a 'slow-onset' group (> 10 minutes); and a 'fast-disappearance' group (≤ 10 minutes) and a 'slow-disappearance' group (> 10 minutes).

The questionnaire was administered online via Castor (Castor EDC, Amsterdam, The Netherlands).

Sample size

A commonly accepted guideline for an appropriate sample size for online questionnaires is a minimum of $n = 100$ participants [17]. Given that subjects are invited by their treating PTs, it was hypothesized that this would foster commitment to promptly complete the questionnaire. Nonetheless, we projected that 20% of invited subjects would either not complete the questionnaire or only partially complete it. Consequently, we aimed to recruit a sample size of $n = 125$ participants. Considering that this online questionnaire would be conducted concurrently with multiple other PFP studies over a 2-year period, we anticipated the enrolment of 100 participants.

Statistical analysis

Only data from subjects who completed the questionnaire were analysed. The normality of the data distribution was evaluated using the Shapiro–Wilk test. Normally distributed data ($p > .05$) were analysed parametrically and presented as mean (± standard deviation [*SD*] and range [*R*]). When data were not normally distributed, they were analysed non-parametrically and presented as the median (interquartile range [*IQR*], 25–75%). Differences between groups (with and without PDPS, smaller and greater flexion angles, fast and slow onset, fast and slow disappearance) in continuous characteristics were analysed using Student's *t*-test (normally distributed data) or the Mann–Whitney *U*-test (non-normally distributed data). Differences in dichotomous characteristics were

analysed using the Fisher's exact test. A priori, a significance level of $p < .05$ was established as the criterion for statistical significance. The effect sizes (*ES*) for normally distributed data were calculated using Cohen's *d* to determine the magnitude of the differences. For non-normally distributed data, *ES r* using the formula $r = Z/\sqrt{(n_a + n_b}$), with *Z* being the Z-score from the Mann-Whitney *U* test and n_a and n_b being sample sizes of both groups, has been determined [18]. For dichotomous variables *Phi* has been calculated based on the chi-square statistic χ^2 [18]. An *ES* of 0.2, 0.5, and ≥ 0.8 was considered small, medium, and large, respectively [19]. Statistical analyses were performed using SPSS version 25.0 (SPSS Inc., Chicago, IL, USA).

RESULTS

A total of 107 subjects with PFP were invited to participate, of whom 20 were excluded (patella dislocation [*n* = 1], symptom duration <3 months [*n* = 2], traumatic origin [*n* = 1], VAS-W <3 [*n* = 8], and non/partial respondents [*n* = 8]). (SUPPLEMENTARY FIGURE 1). The remaining 87 (81%) subjects were eligible for inclusion (61 [70%] females, mean age 22.0 years [*IQR* 4.0], BMI 23.1 [*IQR* 4.7]).

Sixty-three (72%) participants reported PDPS (TABLE 2). More participants with PDPS had bilateral symptoms (71%), compared to those without PDPS (46%) (*p* = .044). Participants with PDPS demonstrated a median total score on the AKPS that was 12 points lower when compared to participants without PDPS (small to medium *ES*), including lower scores on items 3 'walking' (small *ES*), 5 'squatting' (small *ES*), 8 'prolonged sitting' (medium *ES*), and 9 'pain' (small *ES*). Most participants with PDPS (*n* = 52 [85%]) reported symptoms that occurred when the knees were flexed to 90° or

beyond. Only a small proportion (n = 9 [15%]) of participants with PDPS experienced symptoms in smaller knee flexion positions (0° or 45°). Two participants with PDPS omitted this item.

TABLE 2. Baseline characteristics of the participants

Characteristics	Participants with PDPS	Participants without PDPS	*P*-value	*ES*
Participants, *n* (%)	63 (72)	24 (28)	n/a	n/a
Female, *n* (%)	46 (73)	15 (63)	.433	*Phi* = 0.10
Age (years)	22.0 (*IQR* 6.0)	23.0 (*IQR* 9.3)	.242	*r* = 0.13
BMI (kg/m²)	23.5 (*IQR* 4.9)	21.7 (*IQR* 4.0)	.207	*r* = 0.14
Sport participation (h/week)	3.0 (*IQR* 3.0)	3.5 (*IQR* 1.9)	.466	*r* = 0.08
Tegner Score (0–10)	4.0 (*IQR* 3.0)	5.0 (*IQR* 2.0)	.138	*r* = 0.16
VAS-W (0–10)	6.0 (*IQR* 3.0)	5.0 (*IQR* 2.0)	.212	*r* = 0.13
Bilateral PFP, *n* (%)	45 (71)	11 (46)	.044	*Phi* = 0.24
Symptom duration (months)	40.0 (*IQR* 64.0)	20.0 (*IQR* 45.0)	.337	*r* = 0.07
AKPS (0–100)	74.0 (*IQR* 14.0)	86.0 (*IQR* 11.5)	< .001	*r* = 0.41
Item 1 ‘limp’ (0–5)	5.0 (*IQR* 2.0)	5.0 (*IQR* 2.0)	.197	*r* = 0.14
Item 2 ‘support’ (0–5)	5.0 (*IQR* 2.0)	5.0 (*IQR* 0.0)	.207	*r* = .014
Item 3 ‘walking’ (0–5)	3.0 (*IQR* 2.0)	5.0 (*IQR* 2.0)	.004	*r* = 0.31
Item 4 ‘stairs’ (0–10)	8.0 (*IQR* 3.0)	8.0 (*IQR* 5.0)	.992	*r* = 0.00
Item 5 ‘squatting’ (0–5)	4.0 (*IQR* 1.0)	4.0 (*IQR* 1.0)	.009	*r* = 0.28
Item 6 ‘running’ (0–10)	6.0 (*IQR* 2.0)	7.0 (*IQR* 2.0)	.286	*r* = 0.11
Item 7 ‘jumping’ (0–10)	7.0 (*IQR* 3.0)	7.0 (*IQR* 3.0)	.090	*r* = 0.18
Item 8 ‘prolonged sitting’ (0–10)	6.0 (*IQR* 4.0)	10.0 (*IQR* 0.0)	< .001	*r* = 0.51
Item 9 ‘pain’ (0–10)	8.0 (*IQR* 5.0)	8.0 (*IQR* 0.0)	.025	*r* = 0.24
Item 10 ‘swelling’ (0–10)	10.0	10.0	.077	*r* = 0.19

	(*IQR* 2.0)	(*IQR* 0.0)		
Item 11 'subluxations' (0–10)	10.0 (*IQR* 4.0)	10.0 (*IQR* 0.0)	.128	$r = 0.16$
Item 12 'atrophy' (0–5)	5.0 (*IQR* 0.0)	5.0 (*IQR* 2.0)	.337	$r = 0.10$
Item 13 'flexion deficiency' (0–5)	5.0 (*IQR* 0.0)	5.0 (*IQR* 0.0)	.357	$r = 0.10$
TSK (17–68)	33.0 (*IQR* 8.0)	33.0 (*IQR* 10.0)	.853	$r = 0.20$

Abbreviations: n, number; BMI, Body Mass Index in kilograms of body weight per m²; h/week, hours per week; VAS-W, Visual Analogue Scale for Worst pain; AKPS, Anterior Knee Pain Scale; TSK, Tampa Scale for Kinesiophobia; ES, Effect Size as Cohen's *d*, *r* or *Phi*; n/a, not applicable.

Data are presented as numbers (percentages), and median (interquartile range 25%–75% [*IQR*]).

Among those with PDPS, 44 (70%) participants experienced sitting-related pain in 90 degrees or less knee flexion, and thus were capable to answer questions regarding time to onset and disappearance with the knees at 90 degrees of flexion. These participants reported a median time to PDPS onset of 16 to 20 minutes, and a median time for disappearance of 6 to 10 minutes.

Participants with PDPS at smaller flexion angles were two years younger (small *ES*), scored two points higher scores on the VAS-W (small to medium *ES*), had an 11-points lower total score on the AKPS (small to medium *ES*), higher scores on the TSK (small *ES*), and almost two points higher VAS-W sitting score (small to medium *ES*), compared to those with PDPS at greater flexion angles (TABLE 3).

TABLE 3. Characteristics of participants with PDPS in smaller and greater knee flexion angles

Characteristics	Smaller flexion angle (< 90°)	Greater flexion angle (≥ 90°)	*P*-value	*ES*
Participants, n (%)	9 (15)	52 (85)	n/a	n/a
Female, *n* (%)	7 (78)	37 (71)	.515	*Phi* = 0.05
Age (years)	20.0 (*IQR* 4.0)	22.0 (*IQR* 5.8)	.018	*r* = 0.30
BMI (kg/m²)	23.2 (*IQR* 4.8)	23.8 (*IQR* 5.2)	.190	*r* = 0.17
Sport participation (h/week)	3.0 (*SD* ± 2.1, *R* 6.0)	3.6 (*SD* ± 2.2, *R* 10.0)	.400	*d* = 0.11
Tegner Score (0–10)	4.0 (*IQR* 5.0)	4.0 (*IQR* 3.0)	.452	*r* = 0.10
VAS-W (0–10)	7.0 (*IQR* 1.0)	5.0 (*IQR* 3.0)	.002	*r* = 0.39
Bilateral PFP, *n* (%)	9 (100)	36 (69)	.096	*Phi* = 0.25
Symptom duration (months)	48.0 (*IQR* 74.5)	38.0 (*IQR* 64.0)	.445	*r* = 0.10
AKPS (0–100)	66.0 (*IQR* 13.5)	77.0 (*IQR* 13.0)	.005	*r* = 0.36
TSK (17–68)	36.0 (*IQR* 14.5)	32.0 (*IQR* 8.0)	.029	*r* = 0.28
VAS-W sitting (0–10)	6.8 (*IQR* 1.1)	5.0 (*IQR* 3.0)	.001	*r* = 0.41

Abbreviations: n, number; BMI, Body Mass Index in kilograms of body weight per m²; h/week, hours per week; VAS-W, Visual Analogue Scale for Worst pain; AKPS, Anterior Knee Pain Scale; TSK, Tampa Scale for Kinesiophobia; VAS-W sitting, Visual Analogue Scale for Worst sitting pain; *ES*, Effect Size as Cohen's *d*, *r* or *Phi*; n/a, not applicable.

Data are presented as numbers (percentages), mean (± standard deviation [*SD*] and range [*R*]), or median (interquartile range 25%-75% [*IQR*]).

Participants with fast-onset PDPS exhibited VAS-W and VAS-W sitting scores that were two points and one point higher (small to medium *ES*), respectively, compared to those with slow-onset PDPS (TABLE 4). Participants with fast-disappearance PDPS reported an additional 1.3 (*95% CI* 0.01 – 2.44) hours of weekly sports participation (medium to large *ES*), and an 8-points higher total score on the AKPS (small to medium *ES*), compared to those with slow-disappearance (TABLE 5).

TABLE 4. Characteristics of participants with PDPS with faster and slower onset of symptoms

Characteristics	Fast-onset (≤ 10 min)	Slow-onset (> 10 min)	*P*-value	*ES*
Participants, *n* (%)	14 (32)	30 (68)	n/a	n/a

Female, *n* (%)	8 (57)	22 (73)	.316	*Phi* = 0.16
Age (years)	21.5 (*IQR* 7.0)	22.0 (*IQR* 6.3)	.577	*r* = 0.08
BMI (kg/m²)	24.0 (*IQR* 3.0)	24.0 (*IQR* 5.9)	.821	*r* = 0.03
Sport participation (h/week)	3.1 (*SD* ± 2.1, *R* 6.0)	3.0 (*SD* ± 2.0, *R* 7.0)	.934	*d* = 0.03
Tegner Score (0–10)	4.0 (*IQR* 2.3)	3.0 (*IQR* 4.0)	.096	*r* = 0.25
VAS-W (0–10)	7.0 (*IQR* 2.0)	5.0 (*IQR* 3.0)	< .001	*r* = 0.50
Bilateral PFP, *n* (%)	10 (71)	24 (80)	.701	*Phi* = 0.10
Symptom duration (months)	42.0 (*IQR* 87.0)	40.0 (*IQR* 48.0)	.696	*r* = 0.06
AKPS (0–100)	68.0 (*IQR* 10.0)	74.0 (*IQR* 16.3)	.109	*r* = 0.24
TSK (17–68)	32.5 (*IQR* 8.0)	32.5 (*IQR* 10.5)	.940	*r* = 0.01
VAS-W sitting (0-10)	6.0 (*IQR* 2.0)	5.0 (*IQR* 4.0)	.038	*r* = 0.31

Abbreviations: n, number; BMI, Body Mass Index in kilograms of body weight per m²; h/week, hours per week; VAS-W, Visual Analogue Scale for Worst pain; AKPS, Anterior Knee Pain Scale; TSK, Tampa Scale for Kinesiophobia; VAS-W sitting, Visual Analogue Scale for Worst sitting pain; *ES*, Effect Size as Cohen's *d*, *r* or *Phi*; n/a, not applicable.

Data are presented as numbers (percentages), mean (± standard deviation [*SD*] and range [*R*]), or median (interquartile range 25%-75% [*IQR*]).

TABLE 5. Characteristics of participants with PDPS with faster and slower disappearance of symptoms

Characteristics	Fast-disappearance (≤ 10 min)	Slow-disappearance (> 10 min)	*P*-value	*ES*
Participants, *n* (%)	25 (57)	19 (43)	n/a	n/a
Female, *n* (%)	16 (64)	14 (74)	.534	*Phi* = 0.10
Age (years)	22.0 (*IQR* 6.0)	20.0 (*IQR* 5.0)	.229	*r* = 0.18
BMI (kg/m²)	24.1 (*IQR* 4.1)	22.4 (*IQR* 5.0)	.112	*r* = 0.24
Sport participation (h/week)	3.6 (*SD* ± 2.0, *R* 7.0)	2.3 (*SD* ± 1.9, *R* 6.0)	.036	*d* = 0.66
Tegner Score (0–10)	4.0 (*IQR* 3.0)	3.0 *IQR* (2.0)	.197	*r* = 0.19
VAS-W (0–10)	5.0 (*IQR* 3.0)	6.0 (*IQR* 2.0)	.379	*r* = 0.13
Bilateral PFP, *n* (%)	17 (68)	17 (90)	.148	*Phi* = 0.25
Symptom duration (months)	36.0 (*IQR* 54.5)	42.0 (*IQR* 60.0)	.406	*r* = 0.13
AKPS (0–100)	74.0 (*IQR* 16.0)	67.0 (*IQR* 12.0)	.005	*r* = 0.43
TSK (17–68)	32.0 (*IQR* 8.0)	33.0 (*IQR* 14.0)	.374	*r* = 0.13

VAS-W sitting (0–10)	5.0 (*IQR* 4.0)	6.0 (*IQR* 2.0)	.156	$r = 0.21$

Abbreviations: n, number; BMI, Body Mass Index in kilograms of body weight per m^2; h/week, hours per week; VAS-W, Visual Analogue Scale for Worst pain; AKPS, Anterior Knee Pain Scale; TSK, Tampa Scale for Kinesiophobia; VAS-W sitting, Visual Analogue Scale for Worst sitting pain; *ES*, Effect Size as Cohen's *d*, *r* or *Phi*; n/a, not applicable.

Data are presented as numbers (percentages), mean (± standard deviation [*SD*] and range [*R*]), or median (interquartile range 25%-75% [*IQR*]).

DISCUSSION

Subjects with PDPS more often reported bilateral PFP and higher levels of disability, compared to those without PDPS. Subjects typically described PDPS to be induced when the knees were flexed to 90° or beyond. The median time to reported onset of PDPS was 16 to 20 minutes, and the time for disappearance of PDPS was generally 6 to 10 minutes. Subjects with PDPS at smaller knee flexion angles were younger and had higher levels of pain, disability, and kinesiophobia, compared to subjects with PDPS at greater flexion angles. Subjects with PDPS with faster onset experienced higher levels of pain, compared to those with slower onset. Subjects with PDPS with slower disappearance of PDPS reported to be less physically active and had higher levels of disability, compared to subjects with faster disappearance of PDPS.

In the present study, the prevalence of PDPS in subjects with PFP was 72%. This is in line with the previously reported prevalence of 77%–80% [3,20]. Bilateral symptoms occurred more frequently in subjects with PDPS than in those without. As bilateral PFP is a prognostic factor for an unfavourable course [21], PDPS may similarly exert prognostic influence. Nonetheless, definitive establishment necessitates a prospective study design.

Furthermore, subjects with PDPS exhibited a median total score on the AKPS that was 12 points lower, compared to those subjects without PDPS. This is in line with the

findings of Collins et al. [3]. The lower AKPS score holds clinical significance, as the smallest clinically important difference in the AKPS has been established to be at least 10 points [22]. Since this group comparison is based on item 8 'prolonged sitting' of the AKPS a lower AKPS total score of subjects with PFP and PDPS is inevitable. But the difference on item 8 'prolonged sitting' between both groups was only four points. Subjects with PDPS scored also lower on item 3 'walking' and 5 'squatting'. Higher levels of problems with squatting were also identified in the PDPS group by Collins et al. [3], while they did not evaluate differences on item 3 'walking'.

Additionally, Collins et al. noted that subjects with PDPS were younger, predominantly female, had lower BMI, and worse levels of knee pain, compared to subjects without PDPS [3]. The reasons for the current study's inability to confirm these findings may stem from the slightly different categorisation of AKPS item 8 'prolonged sitting'. In the current study, subjects experiencing PDPS only after exercise were not treated and analysed as a distinct category. In contrast, Collins et al. considered this subgroup as a distinct category in their study [3]. Another reason for not confirming these findings could be the smaller sample size in the current study (n = 87) compared to that in the study by Collins et al. (n = 458) [3].

A smaller proportion of subjects with PDPS reported experiencing knee pain at smaller flexion angles, and with faster onset of PDPS. They also reported higher pain levels (VAS-W and VAS-W sitting). Different theories have been proposed regarding the origin of PDPS in subjects with PFP. During prolonged sitting, PFJ reaction forces are absent, and only the compressive forces of the PFJ at greater flexion angles may explain the onset of PDPS. In subjects with PDPS at smaller flexion angles and with faster onset, the compressive forces of the PFJ seem less plausible as an explanation. The

homeostasis model [23] may be a more suitable construct because it proposes disturbed homeostasis of osseous and soft tissues in the anterior knee after supraphysiologic loading. Homeostatic disturbance is then induced by vascular stress and stretching of the peripatellar anastomotic ring, resulting in increased intraosseous water content and pressure of the patella, and triggering a cascade of ischaemic nociceptive responses [5,6,24–29]. This would not only explain the delayed onset of PDPS but also the shorter time for disappearance of PDPS after prolonged sitting.

Research and clinical implications

The results of the current study have significant implications for both research and clinical practice. Previous experiments assessing disturbance of the patellar bone blood flow evaluated rather short episodes (seconds to minutes) [25,30,31] and/or with the knee in extension [30,31], future studies should focus on evaluating patellar blood flow beyond 20 min of prolonged sitting with the knee in 90 degrees of flexion.

According to the 2017 Gold Coast Consensus Statement on Treating PFP, hip- and knee-focused exercise therapy is a key component in the management of all subjects with PFP [32]. In a subgroup of subjects with PDPS at smaller flexion angles and with faster onset, knee-focused exercise therapy to improve quadriceps muscle function may exacerbate knee pain. This is because continuous quadriceps muscle training increases the hemodynamic load on the patellar bone [33], thereby provoking homeostatic pain [34]. Since intermittent quadriceps muscle training (two seconds of rest between repetitions) reduces patellar bone blood flow in healthy participants [33], this could be a valuable alternative for subjects with PFP and PDPS at smaller flexion angles and with

faster onset. This approach may even be valuable in subjects with PFP and PDPS in general. However, this aspect should be further investigated.

Additionally, health care professionals should advise subjects with PDPS at smaller flexion angles and with faster onset to avoid these provocative postures altogether, or at the very least, to minimize the duration spent in such positions. Even if patients cannot avoid these positions, this may provide a plausible explanation for why an otherwise well-designed multimodal treatment program may fail to result in improvements in pain and disability. Offering explanations for failure often serves as a starting point for changes in treatment strategies.

Strengths and limitations

The current study marks the first attempt to evaluate key characteristics of PDPS in subjects with PFP, thereby offering more detailed insights into this clinical phenomenon. The study also acknowledges certain limitations. Firstly, in the available study period we did not manage to invite 125 subjects as anticipated, but only 107 subjects. With 20 out of 107 subjects (19%) being excluded, the exclusion rate in the current study was as estimated. Thus, the final sample size (n = 87) is slightly smaller than the commonly accepted guideline for an appropriate sample size for online questionnaires (n = 100), which may lead to a lower external validity of the current study.

Furthermore, eight (7%) invited subjects with PFP were excluded because their worst pain levels were too low at the moment of completion of the questionnaire. Though the time between invitation and study participation was usually one week, the worst pain

level at the time of invitation may have been higher than that at the time of completion of the questionnaire. We underestimated, this change in worst pain level as being a factor for successful recruitment. Future studies should take this into account when determining sample size. Only four (4%) subjects with PFP were excluded due to the presence of other knee problems or too short symptom duration, indicating a generally accurate procedure of recruitment by experienced PTs.

Secondly, subgroups of subjects with PFP and PDPS (smaller/greater flexion angle, fast/slow onset, and fast/slow disappearance) were created by dichotomising the response options. This approach was based on our clinical experience with a large number of subjects in our clinics. The choice to aggregate response options into one or more subgroup categories may be arbitrary and subject to debate.

Thirdly, though the PTs responsible for inviting subjects with PFP were allocated to several regions of the Netherlands, the sampling method applied in the current study was a non-probability (convenience) sampling method. Additionally, subjects were recruited in private physical therapy clinics. In the Netherlands, the majority of patients utilize the direct access option to see their physical therapist, bypassing the general practitioner or sports medicine physician [35]. This option is more frequently used by younger adults compared to older adults [35]. In the sitting pain study conducted by Collins et al., participants from several different cohorts were analysed [3]. The included Dutch cohorts from van Linschoten et al. (n = 131) and van der Heijden et al. (n = 64) were recruited through general practitioners and sports medicine physicians [36,37]. This difference in recruitment setting may explain why participants with and without PDPS in the current study were younger (median age 22.0 years, *IQR* 6.0, and median age 23 years, *IQR* 9.3, respectively) compared to the participants from the

Collins study (mean age 27.5, *SD* 8,1, and mean age 30.0 years, *SD* 8.6, respectively). Therefore, generalisations based on the results of the current study should be made cautiously.

Lastly, although subjects with PFP were involved in the construction of the four items assessing PDPS characteristics, the reliability and validity of these items remain unknown. This may have led, for instance, to the overestimation or underestimation of both minimum knee flexion angles and the time to reported onset of PDPS, indicating the need for further research.

CONCLUSION

Subjects with PDPS more often reported bilateral PFP and higher levels of disability. PDPS typically occurred when the knees are flexed 90 degrees or beyond. Subjects identified a delayed onset of PDPS occurring after 16 to 20 minutes, whereas the time for its disappearance was shorter, between 6 to 10 minutes. Younger subjects with PDPS at smaller knee flexion angles reported higher pain, disability, and kinesiophobia than those with PDPS at greater flexion angles. Additionally, subjects with faster onset of PDPS experienced higher pain levels, while those with slower PDPS disappearance were less physically active and had greater disability than those with faster disappearance. This study provides a detailed description of the characteristics of PDPS as experienced by subjects with PFP. Future research should focus on understanding the underlying mechanisms of PDPS and developing targeted interventions to improve long-term outcomes in subjects with PFP.

STATEMENTS

Conflicts of interest: None. The authors declare that they have no affiliations with or financial involvement in any organisation or entity with direct financial interest in the subject matter or materials discussed in this article.

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Authorship: MO and IT designed the study, established the methods and wrote the study protocol. GK contributed to development of the study protocol. MO, SF, and IT collected the data. MO and SF managed the data entry and preparation of the database. Statistical analyses were performed by MO, SF, GK, and IT. MO wrote the first draft of the manuscript, supported by SF and IT. GK provided comments on the draft, and all authors read and approved the final version of the manuscript prior to submission.

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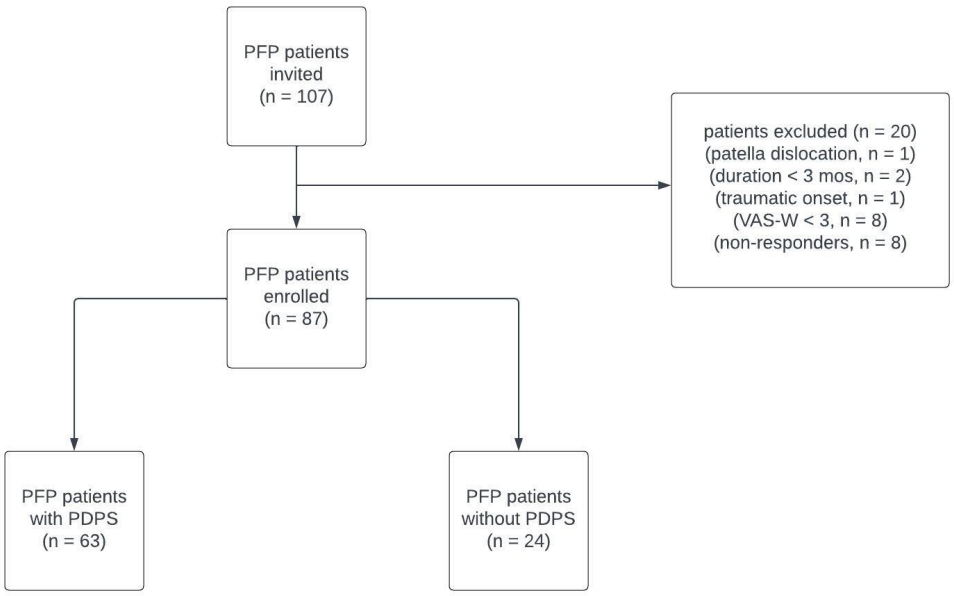
Captions of illustrations

SUPPLEMENTARY FIGURE 1. Flowchart of the inclusion process.

Abbreviations: mos, months; VAS-W, visual analogue scale for worst pain; PDPS, pain during prolonged sitting.



228x146mm (160 x 160 DPI)

ONLINE SUPPLEMENTARY FILE 1

PDPS QUESTIONNAIRE (Part 3 'Characteristics of PDPS')

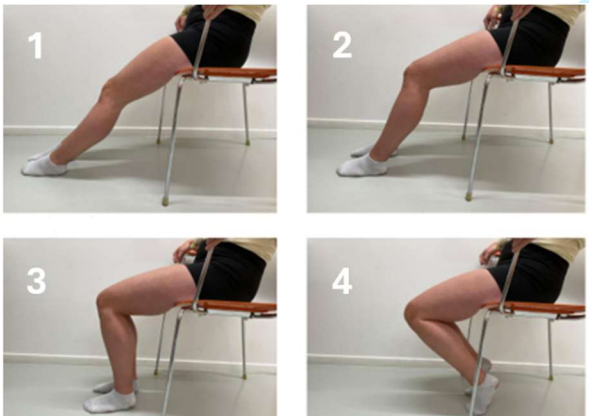
Item 1: What was the worst sitting pain in the past 7 days? Please mark between 0 cm (indicating no pain) and 10 cm (indicating maximum pain)?

No pain |----------| Maximum pain

(0 cm) (10 cm)

Item 2: How bent must your knees be to develop knee pain during prolonged sitting?

- I experience knee pain if my knee is in a 0° bent position (picture 1).
- I experience knee pain if my knee is in a 45° bent position (picture 2).
- I experience knee pain if my knee is in a 90° bent position (picture 3).
- I experience knee pain if my knee is in a more than 90° bent position (picture 4).



Item 3: If you bend your knee to 90° (as shown in the picture), how many minutes does it take before you start experiencing knee pain during sitting?

- 0-5 minutes.
- 6-10 minutes.
- 11-15 minutes.
- 16-20 minutes.
- 21-30 minutes.
- 31-40 minutes.

- > 40 minutes.

Item 4: If you extend your knee again after prolonged sitting with bent knees, how many minutes does it take for the pain to go away completely?

- 0-5 minutes.
- 6-10 minutes.
- 11-15 minutes.
- 16-20 minutes.
- 21-30 minutes.
- 31-40 minutes.
- > 40 minutes.

From: "Pain during prolonged sitting in subjects with patellofemoral pain in Dutch physical therapy clinics: an online questionnaire-based analysis", by Ophey M., Frieling S., Kerkhoffs G., and Tak I.

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Pain during prolonged sitting in subjects with patellofemoral pain in Dutch physical therapy clinics: an online questionnaire-based analysis

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Pain during prolonged sitting in subjects with patellofemoral pain in Dutch physical therapy clinics: an online questionnaire-based analysis

Martin J. Ophey, MSc, PT_{sport},[a,-d] Sophie M. W. Frieling, MSc, PT,[e] Gino M. M. J. Kerkhoffs, Prof. Dr., MD,[a,b,g,h] Igor J. R. Tak, PhD, PT_{sport},[a,b,f,g,h]

[a] Amsterdam UMC location University of Amsterdam, Orthopaedic Surgery and Sports Medicine, Amsterdam, Netherlands;

[b] Amsterdam Movement Sciences, Sports, Ageing & Vitality, Amsterdam, Netherlands;

[c] YsveldFysio – Private Physical Therapy Clinic, Nijmegen, Netherlands;

[d] ESP Science and Education, Vienna, Austria;

[e] HAN – University of Applied Sciences, Physical Therapy Department, Nijmegen, Netherlands;

[f] Physiotherapy Utrecht Oost – Sports Rehabilitation and Manual Therapy, Utrecht, Netherlands;

[g] Amsterdam Collaboration on Health and Safety in Sports (ACHSS), AMC/VUmc IOC Research Center, Amsterdam, Netherlands;

[h] Academic Center for Evidence-based Sports medicine (ACES), Amsterdam, Netherlands.

Corresponding author: Martin Ophey, Amsterdam UMC, Meibergdreef 9, 1105 AZ Amsterdam, Netherlands, phone: +31-650616509, email: m.j.ophey@amsterdamumc.nl

ORCID iD: https://orcid.org/0000-0002-8674-0477

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ABSTRACT

Objectives: This study aimed to describe 1) differences between subjects with patellofemoral pain (PFP) with and without pain during prolonged sitting (PDPS), 2) minimum knee flexion angle and time to onset/disappearance of PDPS, and 3) differences between those with PDPS at smaller/greater flexion angles, and with fast/slow onset and disappearance of PDPS.

Design: Patient-reported online questionnaire.

Setting: Private physical therapy clinics in the Netherlands between May 2021 and March 2023.

Participants: 87 participants (61 [70%] females, mean age 22.0 years [*IQR* 4.0], BMI 23.1 [4.7]).

Outcome measures: VAS for worst pain (VAS-W) and sitting pain (VAS-W sitting), the Anterior Knee Pain Scale (AKPS), knee flexion angle to provoke PDPS, and time to onset/disappearance of PDPS.

Results: Sixty-three of 87 (72%) participants reported PDPS. Participants with PDPS experienced bilateral symptoms of PFP more frequently (71% vs. 46%, $p = .44$) and scored 12 points lower on the AKPS ($p < .001$). Most participants (85%) reported a minimum knee flexion angle of ≥90°, median time to PDPS onset of 16–20 minutes, and 6–10 minutes for disappearance. Participants experiencing PDPS at smaller flexion angles exhibited higher VAS-W and VAS-W sitting scores (7.0 [1.0], 6.8 [1.1]) than those at greater flexion angles (5.0 [3.0], for both) ($p = .002$, $p = .001$). Participants with fast-onset of PDPS reported higher VAS-W and VAS-W sitting scores (7.0 [2.0], 6.0 [2.0]) than those with slow-onset (5.0 [3.0], 5.0 [4.0]) ($p < .001$, $p = .025$).

Conclusions: Participants with PDPS reported higher levels of disability than those without. PDPS was typically induced at knee flexion of ≥90°, with delayed onset/disappearance. Higher pain levels were reported by those experiencing PDPS at smaller knee flexion angles or with faster onset. Future research should explore the mechanisms of PDPS and develop targeted interventions to improve long-term outcomes.

Keywords: patellofemoral pain syndrome, knee, orthopaedics

Strengths and limitations of this study

- Characteristics of pain during prolonged sitting were evaluated using an online patient-reported questionnaire rather than clinician-based measures.
- Subgroups of participants with pain during prolonged sitting were created by dichotomizing item response options, based on clinical experience, which may be arbitrary and subject to debate.
- The final sample size was slightly smaller than the commonly accepted guideline for an appropriate sample size for online questionnaires, which may lead to a lower external validity of the current study.
- Subjects were recruited from Dutch private physical therapy clinics, which may explain why participants were slightly younger compared to those in other studies.
- The reliability and validity of self-reported items evaluating the characteristics of pain during prolonged sitting are not yet known.

INTRODUCTION

Patellofemoral pain (PFP) is a common musculoskeletal condition that has an annual prevalence of up to 36% [1]. A significant proportion of subjects with PFP experience 'pain during prolonged sitting' (PDPS), which is also referred to as the "movie goers' sign" due to the extended periods of sitting with flexed knees in a seat with little leg space during a cinema visit [2]. A large study of 458 subjects with PFP reported a prevalence of PDPS in 80% within the sample population [3].

The mechanisms underlying PDPS in subjects with PFP are unelucidated. No data were found regarding patellofemoral joint reaction forces (PFJRF) during sitting. It is well established that PFJRF increase with greater knee flexion angles and higher quadriceps muscle forces [4]. For example, PFJRF in subjects with PFP are higher during stair ascent (3.2 [SD ±0.7] times body weight [BW]) compared to walking (0.9 [SD ±0.4] BW) [4]. Given that quadriceps muscle forces decrease during sitting relative to walking, and that patellofemoral contact area increases with greater knee flexion [4], PFJRF during sitting are expected to be lower than during walking. Although PFJRF are not entirely absent during sitting, their small magnitude calls into question whether they sufficiently reflect the underlying mechanism of PDPS. Additionally, a recent study employing magnetic resonance imaging (MRI) found no association of any morphological parameters, such as alignment or structural characteristics of the PFJ, with PDPS in subjects with PFP [5].

Previously, only one study evaluated differences in characteristics between subjects with and without PDPS [3]. It reported that subjects with PFP and PDPS were younger, more likely to be female, had a lower body mass index (BMI), higher pain severity,

lower Anterior Knee Pain Scale (AKPS) scores, and more problems with squatting compared to subjects without PDPS [3]. Given that this study analysed participants from four distinct cohorts, each recruited in different settings, replicating and evaluating the findings in a more homogeneous cohort could yield valuable insights. Furthermore, the existing literature lacks specific details such as the degree of knee flexion required to elicit PDPS, and the duration between seating and the onset of PDPS. A delayed onset of symptoms, for instance, may indicate disturbed homeostasis of structures of the anterior knee due to increased intraosseous pressure of the patella, as previously described [6,7]. Moreover, subjects with PDPS at smaller knee flexion angles may exhibit demographic or symptom characteristics distinct from those with PDPS at greater flexion angles. These differences could have prognostic value and clinical implications.

Therefore, in this patient-reported questionnaire study, we aimed to describe 1) differences in characteristics between subjects with PFP with and without PDPS, 2) minimum knee flexion angles to provoke symptoms of PDPS, and time to onset and for disappearance of PDPS, and 3) differences between those with PDPS at smaller versus greater flexion angles, with fast-onset versus slow-onset, and fast-disappearance versus slow-disappearance, respectively.

METHODS

Ethical approval was obtained from the Ethical Scientific Advisory Board of the Ethical of the HAN – University of Applied Sciences (EACO 147.04/19), Nijmegen, the Netherlands.

Patient and public involvement

Four subjects with PFP and PDPS (median age 22.5 years [interquartile range, *IQR* 1.5]; three females and one male) who met the inclusion and exclusion criteria were interviewed to identify criteria for assessing PDPS characteristics. Then they reviewed the developed preliminary questionnaire and assessed it for readability and item clarity. Minor changes were made to two items to ensure their readability and feasibility. Following publication, enrolled participants will receive a comprehensive manuscript encompassing the full text, as part of our commitment to patient involvement.

Participants

Subjects were recruited by nine physical therapists (PT) working in private clinics in the Netherlands with a special interest in the rehabilitation of knee injuries and PFP. These PTs were informed about the inclusion and exclusion criteria (Table 1), and asked to carefully evaluate history of knee pain, perform clinical examination (hip, and knee including exact site of pain), and consecutively invite subjects with PFP to participate in the current study as they became available (using convenience sampling). The inclusion and exclusion criteria are based on the Manchester consensus statement (definition of PFP, exclusion of other pathologies) [8]. A minimum pain level was established as an inclusion criterion to prevent the enrollment of participants with symptoms of PDPS that are too mild to be effectively evaluated. The invitation was sent between May 2021 and March 2023. Informed consent was obtained online as the first item of the survey questionnaire.

Table 1. Criteria for the inclusion and exclusion of potential participants

Inclusion	Exclusion

• Age: 18–40 years.
• Pain:
  ○ experienced around and/or behind the patella.
  ○ aggravated by one or more of the following activities: squatting, stair ambulation, jogging/running, hopping/jumping.
  ○ lasting for ≥ 3 months.
  ○ that did not arise from trauma.
• Worst pain levels ≥ 3/10 on a VAS (VAS-W) during the past seven days.
• Electronic informed consent.
	• Previous or current clinical diagnosis of serious pathology (e.g., malignancy).
	• Previous or current other clinical diagnosis of specific knee conditions (e.g., Osgood–Schlatter, Sinding–Larsson, patellar instability or dislocation, jumper's knee, meniscal tears, or ligament injury).
	• History of surgery (e.g., ankle, knee, hip, or lower back).

Abbreviations: VAS-W, Visual Analogue Scale for Worst pain.

Questionnaire

The online questionnaire comprised three parts. The first part contained eight items and evaluated general patient characteristics (e.g., sex, age, body weight and length, and hours of sport participation per week). The activity level was rated according to the Tegner Score [9–11], which contains 11 response options ranging from 0 to 10. Higher scores indicated higher activity levels. The Dutch version of the Tegner Score is reliable (*ICC* = .97) with moderate correlations with other knee- and quality-of-life related questionnaires (r = .42 – .48) [12].

The second part of the questionnaire contained seven items and evaluated specific PFP characteristics, such as symptom duration, history of other knee injuries, and worst pain in the past seven days on a visual analogue scale (VAS-W), which is a continuous 10 cm-line to indicate the intensity of pain perception when at its worst (score from '0 cm' [no pain] to '10 cm' [maximal pain]) [13].

Additionally, the Anterior Knee Pain Scale (AKPS) and Tampa Scale for Kinesiophobia (TSK) were followed. The AKPS measures pain and disability, and contains 13 items with 3 to 5 response options [14]. Scores between '0' and '10' were allocated to each response option. The overall score was normalised on a 0–100 scale, where '100' indicated no problems at all and '0' indicated the maximum number of knee problems experienced [13]. The Dutch Version of the AKPS is reliable (*ICC* = .98) with good internal consistency (r = .78 – .80) [15]. Item 8 of the AKPS refers to 'prolonged sitting' and contains five response options. Two groups were formed based on these response options: (1) presence of PDPS ('pain after exercise', 'constant pain', 'pain forces to extend knees temporarily', and 'unable') and (2) absence of PDPS ('no difficulty').

A previous study found no PFJ loading variables (e.g., peak PFJ contact force), but kinesiophobia being associated with self-reported pain and disability in subjects with PFP [16]. Since prolonged sitting lacks PFJ loading, evaluation of kinesiophobia in subjects with PDPS may be relevant. Therefore, the Tampa Scale for Kinesiophobia (TSK) was also administered. The TSK is a 17-item questionnaire for evaluating pain-related fear and avoidance behaviour [17]. Participants were asked to rate their level of agreement with statements regarding fear of movement behaviour on a 4-point Likert scale from 'strongly disagree' to 'strongly agree'. Scores range from 17 to 68 points, with higher scores indicating greater levels of kinesiophobia [17].

The third section contained four items and specifically evaluated the characteristics of PDPS (Supplementary File 1). Participants were asked to rate their worst sitting pain in the past seven days (VAS-W sitting) on a 10 cm-line with a continuous score from '0 cm' (no pain) to '10 cm' (maximal pain) [13]. The minimum degree of knee flexion

required to provoke PDPS was evaluated by presenting four pictures with the knees flexed at 0°, 45°, 90°, or beyond 90°. The minimum time to onset of PDPS with the knees in 90° was evaluated in seven response options ('0–5 min', '6–10 min', '11–15 min', '16–20 min', '21–30 min', '31–40 min', and '> 40 min'). The minimum time required for disappearance of PDPS after extending the knees from 90° flexion was evaluated using the same response options. Items of this category were dichotomised by defining a 'smaller flexion angle' group (< 90°) and a 'greater flexion angle' group (≥ 90°); a 'fast-onset' group (≤ 10 minutes) and a 'slow-onset' group (> 10 minutes); and a 'fast-disappearance' group (≤ 10 minutes) and a 'slow-disappearance' group (> 10 minutes).

The questionnaire was administered online via Castor (Castor EDC, Amsterdam, Netherlands).

Sample size

A commonly accepted guideline for an appropriate sample size for online questionnaires is a minimum of n = 100 participants [18]. Given that subjects are invited by their treating PTs, it was hypothesized that this would foster commitment to promptly complete the questionnaire. Nonetheless, we projected that 20% of invited subjects would either not complete the questionnaire or only partially complete it. Consequently, we aimed to recruit a sample size of n = 125 participants. Considering that this online questionnaire would be conducted concurrently with multiple other PFP studies over a 2-year period, we anticipated the enrolment of 100 participants.

Statistical analysis

Only data from participants who completed the questionnaire were analysed. The normality of the data distribution was evaluated using the Shapiro–Wilk test. Normally distributed data ($p > .05$) were analysed parametrically and presented as mean (± standard deviation [*SD*] and range [*R*]). When data were not normally distributed, they were analysed non-parametrically and presented as the median (interquartile range [*IQR*], 25–75%). Differences between groups (with and without PDPS, smaller and greater flexion angles, fast and slow onset, fast and slow disappearance) in continuous characteristics were analysed using Student's *t*-test (normally distributed data) or the Mann–Whitney *U*-test (non-normally distributed data). Differences in dichotomous characteristics were analysed using the Fisher's exact test. A priori, a significance level of $p < .05$ was established as the criterion for statistical significance. The effect sizes (*ES*) for normally distributed data were calculated using Cohen's *d* to determine the magnitude of the differences. For non-normally distributed data, *ES r* using the formula $r = Z/\sqrt{(n_a + n_b)}$, with *Z* being the Z-score from the Mann-Whitney *U* test and n_a and n_b being sample sizes of both groups, has been determined [19]. For dichotomous variables *Phi* has been calculated based on the chi-square statistic χ^2 [19]. An *ES* of 0.2, 0.5, and ≥ 0.8 was considered small, medium, and large, respectively [20]. Statistical analyses were performed using SPSS version 25.0 (SPSS Inc., Chicago, IL, USA).

RESULTS

A total of 107 subjects with PFP were invited to participate, of whom 20 were excluded (patella dislocation [$n = 1$], symptom duration <3 months [$n = 2$], traumatic origin [$n =$

1], VAS-W <3 [n = 8], and non/partial respondents [n = 8]) (Supplementary Figure 1). The remaining 87 (81%) subjects were eligible for inclusion (61 [70%] females, mean age 22.0 years [*IQR* 4.0], BMI 23.1 [*IQR* 4.7]).

Based on the responses to item 8 of the AKPS, 63 (72%) participants reported PDPS (Table 2). More participants with PDPS had bilateral symptoms (71%), compared to those without PDPS (46%) (p = .044). Participants with PDPS demonstrated a median total score on the AKPS that was 12 points lower when compared to participants without PDPS, a difference that was statistically significant (small to medium *ES* [0.41]). This included statistically significant lower scores on items 3 'walking' (small *ES* [0.31]), 5 'squatting' (small *ES* [0.28]), 8 'prolonged sitting' (medium *ES* [0.51]), and 9 'pain' (small *ES* [0.24]). Most participants with PDPS (n = 52 [85%]) reported symptoms that occurred when the knees were flexed to 90° or beyond. Only a small proportion (n = 9 [15%]) of participants with PDPS experienced symptoms in smaller knee flexion positions (0° or 45°). Two participants with PDPS omitted this item.

Table 2. Baseline characteristics of the participants

Characteristics	Participants with PDPS	Participants without PDPS	*P*-value	*ES*
Participants, *n* (%)	63 (72)	24 (28)	n/a	n/a
Female, *n* (%)	46 (73)	15 (63)	.433	*Phi* = 0.10
Age (years)	22.0 (*IQR* 6.0)	23.0 (*IQR* 9.3)	.242	r = 0.13
BMI (kg/m²)	23.5 (*IQR* 4.9)	21.7 (*IQR* 4.0)	.207	r = 0.14
Sport participation (h/week)	3.0 (*IQR* 3.0)	3.5 (*IQR* 1.9)	.466	r = 0.08
Tegner Score (0–10)	4.0 (*IQR* 3.0)	5.0 (*IQR* 2.0)	.138	r = 0.16
VAS-W (0–10)	6.0 (*IQR* 3.0)	5.0 (*IQR* 2.0)	.212	r = 0.13

Bilateral PFP, *n* (%)	45 (71)	11 (46)	.044	*Phi* = 0.24
Symptom duration (months)	40.0 (*IQR* 64.0)	20.0 (*IQR* 45.0)	.337	*r* = 0.07
AKPS (0–100)	74.0 (*IQR* 14.0)	86.0 (*IQR* 11.5)	< .001	*r* = 0.41
Item 1 'limp' (0–5)	5.0 (*IQR* 2.0)	5.0 (*IQR* 2.0)	.197	*r* = 0.14
Item 2 'support' (0–5)	5.0 (*IQR* 2.0)	5.0 (*IQR* 0.0)	.207	*r* = .014
Item 3 'walking' (0–5)	3.0 (*IQR* 2.0)	5.0 (*IQR* 2.0)	.004	*r* = 0.31
Item 4 'stairs' (0–10)	8.0 (*IQR* 3.0)	8.0 (*IQR* 5.0)	.992	*r* = 0.00
Item 5 'squatting' (0–5)	4.0 (*IQR* 1.0)	4.0 (*IQR* 1.0)	.009	*r* = 0.28
Item 6 'running' (0–10)	6.0 (*IQR* 2.0)	7.0 (*IQR* 2.0)	.286	*r* = 0.11
Item 7 'jumping' (0–10)	7.0 (*IQR* 3.0)	7.0 (*IQR* 3.0)	.090	*r* = 0.18
Item 8 'prolonged sitting' (0–10)	6.0 (*IQR* 4.0)	10.0 (*IQR* 0.0)	< .001	*r* = 0.51
Item 9 'pain' (0–10)	8.0 (*IQR* 5.0)	8.0 (*IQR* 0.0)	.025	*r* = 0.24
Item 10 'swelling' (0–10)	10.0 (*IQR* 2.0)	10.0 (*IQR* 0.0)	.077	*r* = 0.19
Item 11 'subluxations' (0–10)	10.0 (*IQR* 4.0)	10.0 (*IQR* 0.0)	.128	*r* = 0.16
Item 12 'atrophy' (0–5)	5.0 (*IQR* 0.0)	5.0 (*IQR* 2.0)	.337	*r* = 0.10
Item 13 'flexion deficiency' (0–5)	5.0 (*IQR* 0.0)	5.0 (*IQR* 0.0)	.357	*r* = 0.10
TSK (17–68)	33.0 (*IQR* 8.0)	33.0 (*IQR* 10.0)	.853	*r* = 0.20

Abbreviations: n, number; BMI, Body Mass Index in kilograms of body weight per m^2; h/week, hours per week; VAS-W, Visual Analogue Scale for Worst pain; AKPS, Anterior Knee Pain Scale; TSK, Tampa Scale for Kinesiophobia; ES, Effect Size as Cohen's *d*, *r* or *Phi*; n/a, not applicable.

Data are presented as numbers (percentages), and median (interquartile range 25%–75% [*IQR*]).

Among those with PDPS, 44 (70%) participants experienced sitting-related pain in 90 degrees or more knee flexion, and thus were capable to answer questions regarding time to onset and disappearance with the knees at 90 degrees of flexion. These participants reported a median time to PDPS onset of 16 to 20 minutes, and a median time for disappearance of 6 to 10 minutes.

Participants with PDPS at smaller flexion angles were two years younger (small *ES* [0.30]), scored two points higher scores on the VAS-W (small to medium *ES* [0.39]), had an 11-points lower total score on the AKPS (small to medium *ES* [0.36]), higher scores on the TSK (small *ES* [0.28]), and almost two points higher VAS-W sitting score (small to medium *ES* [0.41]), compared to those with PDPS at greater flexion angles (Table 3).

Table 3. Characteristics of participants with PDPS in smaller and greater knee flexion angles

Characteristics	Smaller flexion angle (< 90°)	Greater flexion angle (≥ 90°)	*P*-value	*ES*
Participants, n (%)	9 (15)	52 (85)	n/a	n/a
Female, *n* (%)	7 (78)	37 (71)	.515	*Phi* = 0.05
Age (years)	20.0 (*IQR* 4.0)	22.0 (*IQR* 5.8)	.018	*r* = 0.30
BMI (kg/m²)	23.2 (*IQR* 4.8)	23.8 (*IQR* 5.2)	.190	*r* = 0.17
Sport participation (h/week)	3.0 (*SD* ± 2.1, *R* 6.0)	3.6 (*SD* ± 2.2, *R* 10.0)	.400	*d* = 0.11
Tegner Score (0–10)	4.0 (*IQR* 5.0)	4.0 (*IQR* 3.0)	.452	*r* = 0.10
VAS-W (0–10)	7.0 (*IQR* 1.0)	5.0 (*IQR* 3.0)	.002	*r* = 0.39
Bilateral PFP, *n* (%)	9 (100)	36 (69)	.096	*Phi* = 0.25
Symptom duration (months)	48.0 (*IQR* 74.5)	38.0 (*IQR* 64.0)	.445	*r* = 0.10
AKPS (0–100)	66.0 (*IQR* 13.5)	77.0 (*IQR* 13.0)	.005	*r* = 0.36
TSK (17–68)	36.0 (*IQR* 14.5)	32.0 (*IQR* 8.0)	.029	*r* = 0.28
VAS-W sitting (0–10)	6.8 (*IQR* 1.1)	5.0 (*IQR* 3.0)	.001	*r* = 0.41

Abbreviations: n, number; BMI, Body Mass Index in kilograms of body weight per m²; h/week, hours per week; VAS-W, Visual Analogue Scale for Worst pain; AKPS, Anterior Knee Pain Scale; TSK, Tampa Scale for Kinesiophobia; VAS-W sitting, Visual Analogue Scale for Worst sitting pain; *ES*, Effect Size as Cohen's *d*, *r* or *Phi*; n/a, not applicable.

Data are presented as numbers (percentages), mean (± standard deviation [*SD*] and range [*R*]), or median (interquartile range 25%-75% [*IQR*]).

Participants with fast-onset PDPS exhibited VAS-W and VAS-W sitting scores that were two points and one point higher (medium *ES* [0.50], small *ES* [0.31]), respectively,

compared to those with slow-onset PDPS (Table 4). Participants with fast-disappearance PDPS reported an additional 1.3 (*95% CI* 0.01 – 2.44) hours of weekly sports participation (medium to large *ES* [0.66]), and an 8-points higher total score on the AKPS (small to medium *ES* [0.43]), compared to those with slow-disappearance (Table 5).

Table 4. Characteristics of participants with PDPS with faster and slower onset of symptoms

Characteristics	Fast-onset (≤ 10 min)	Slow-onset (> 10 min)	*P*-value	*ES*
Participants, *n* (%)	14 (32)	30 (68)	n/a	n/a
Female, *n* (%)	8 (57)	22 (73)	.316	*Phi* = 0.16
Age (years)	21.5 (*IQR* 7.0)	22.0 (*IQR* 6.3)	.577	*r* = 0.08
BMI (kg/m²)	24.0 (*IQR* 3.0)	24.0 (*IQR* 5.9)	.821	*r* = 0.03
Sport participation (h/week)	3.1 (*SD* ± 2.1, *R* 6.0)	3.0 (*SD* ± 2.0, *R* 7.0)	.934	*d* = 0.03
Tegner Score (0–10)	4.0 (*IQR* 2.3)	3.0 (*IQR* 4.0)	.096	*r* = 0.25
VAS-W (0–10)	7.0 (*IQR* 2.0)	5.0 (*IQR* 3.0)	< .001	*r* = 0.50
Bilateral PFP, *n* (%)	10 (71)	24 (80)	.701	*Phi* = 0.10
Symptom duration (months)	42.0 (*IQR* 87.0)	40.0 (*IQR* 48.0)	.696	*r* = 0.06
AKPS (0–100)	68.0 (*IQR* 10.0)	74.0 (*IQR* 16.3)	.109	*r* = 0.24
TSK (17–68)	32.5 (*IQR* 8.0)	32.5 (*IQR* 10.5)	.940	*r* = 0.01
VAS-W sitting (0-10)	6.0 (*IQR* 2.0)	5.0 (*IQR* 4.0)	.038	*r* = 0.31

Abbreviations: n, number; BMI, Body Mass Index in kilograms of body weight per m²; h/week, hours per week; VAS-W, Visual Analogue Scale for Worst pain; AKPS, Anterior Knee Pain Scale; TSK, Tampa Scale for Kinesiophobia; VAS-W sitting, Visual Analogue Scale for Worst sitting pain; *ES*, Effect Size as Cohen's *d*, *r* or *Phi*; n/a, not applicable.

Data are presented as numbers (percentages), mean (± standard deviation [*SD*] and range [*R*]), or median (interquartile range 25%-75% [*IQR*]).

Table 5. Characteristics of participants with PDPS with faster and slower disappearance of symptoms

Characteristics	Fast-disappearance (≤ 10 min)	Slow-disappearance (> 10 min)	*P*-value	*ES*

Participants, *n* (%)	25 (57)	19 (43)	n/a	n/a
Female, *n* (%)	16 (64)	14 (74)	.534	*Phi* = 0.10
Age (years)	22.0 (*IQR* 6.0)	20.0 (*IQR* 5.0)	.229	*r* = 0.18
BMI (kg/m²)	24.1 (*IQR* 4.1)	22.4 (*IQR* 5.0)	.112	*r* = 0.24
Sport participation (h/week)	3.6 (*SD* ± 2.0, *R* 7.0)	2.3 (*SD* ± 1.9, *R* 6.0)	.036	*d* = 0.66
Tegner Score (0–10)	4.0 (*IQR* 3.0)	3.0 *IQR* (2.0)	.197	*r* = 0.19
VAS-W (0–10)	5.0 (*IQR* 3.0)	6.0 (*IQR* 2.0)	.379	*r* = 0.13
Bilateral PFP, *n* (%)	17 (68)	17 (90)	.148	*Phi* = 0.25
Symptom duration (months)	36.0 (*IQR* 54.5)	42.0 (*IQR* 60.0)	.406	*r* = 0.13
AKPS (0–100)	74.0 (*IQR* 16.0)	67.0 (*IQR* 12.0)	.005	*r* = 0.43
TSK (17–68)	32.0 (*IQR* 8.0)	33.0 (*IQR* 14.0)	.374	*r* = 0.13
VAS-W sitting (0–10)	5.0 (*IQR* 4.0)	6.0 (*IQR* 2.0)	.156	*r* = 0.21

Abbreviations: n, number; BMI, Body Mass Index in kilograms of body weight per m²; h/week, hours per week; VAS-W, Visual Analogue Scale for Worst pain; AKPS, Anterior Knee Pain Scale; TSK, Tampa Scale for Kinesiophobia; VAS-W sitting, Visual Analogue Scale for Worst sitting pain; *ES*, Effect Size as Cohen's *d*, *r* or *Phi*; n/a, not applicable.

Data are presented as numbers (percentages), mean (± standard deviation [*SD*] and range [*R*]), or median (interquartile range 25%-75% [*IQR*]).

DISCUSSION

Participants with PDPS more often reported bilateral PFP and higher levels of disability, compared to those without PDPS. Participants typically described PDPS to be induced when the knees were flexed to 90° or beyond. The median time to reported onset of PDPS was 16 to 20 minutes, and the time for disappearance of PDPS was generally 6 to 10 minutes. Participants with PDPS at smaller knee flexion angles were younger and had higher levels of pain, disability, and kinesiophobia, compared to participants with PDPS at greater flexion angles. Participants with PDPS with faster onset experienced higher levels of pain, compared to those with slower onset. Participants with PDPS with

slower disappearance of PDPS reported to be less physically active and had higher levels of disability, compared to participants with faster disappearance of PDPS.

In the present study, the prevalence of PDPS in subjects with PFP was 72%. This is in line with the previously reported prevalence of 77%–80% [3,21]. Bilateral symptoms occurred more frequently in participants with PDPS than in those without. As bilateral PFP is a prognostic factor for an unfavourable course [22], PDPS may similarly exert prognostic influence. Nonetheless, definitive establishment necessitates a prospective study design.

Furthermore, participants with PDPS exhibited a median total score on the AKPS that was 12 points lower, compared to those participants without PDPS. This is in line with the findings of Collins et al. [3]. The lower AKPS score holds clinical significance, as the smallest clinically important difference in the AKPS has been established to be at least 10 points [23]. Since this group comparison is based on item 8 ‘prolonged sitting’ of the AKPS a lower AKPS total score of participants with PFP and PDPS is inevitable. But the difference on item 8 ‘prolonged sitting’ between both groups was only four points. Participants with PDPS scored also lower on item 3 ‘walking’ and 5 ‘squatting’. Higher levels of problems with squatting were also identified in the PDPS group by Collins et al. [3], while they did not evaluate differences on item 3 ‘walking’.

Additionally, Collins et al. noted that subjects with PDPS were younger, predominantly female, had lower BMI, and worse levels of knee pain, compared to subjects without PDPS [3]. The reasons for the current study’s inability to confirm these findings may stem from the slightly different categorisation of AKPS item 8 ’prolonged sitting’. In the current study, participants experiencing PDPS only after exercise were not treated

and analysed as a distinct category. In contrast, Collins et al. considered this subgroup as a distinct category in their study [3]. Another reason for not confirming these findings could be the smaller sample size in the current study (n = 87) compared to that in the study by Collins et al. (n = 458) [3].

A smaller proportion of participants with PDPS reported experiencing knee pain at smaller flexion angles, and with faster onset of PDPS. They also reported higher pain levels (VAS-W and VAS-W sitting). Various theories have been proposed to explain the underlying mechanisms of PDPS in subjects with PFP. Biomechanical theories often attribute PFP to increased PFJRF. While PFJRF are not entirely absent during sitting, they are expected to be lower than 0.9 times bodyweight [4], with an even greater reduction likely in subjects with PDPS at smaller knee flexion angles. Although the patellofemoral contact area decreases in smaller flexion angles, overall, increased PFJRF seems to be a less satisfactory explanation for PDPS. The homeostasis model [24] may be a more suitable construct because it proposes disturbed homeostasis of osseous and soft tissues in the anterior knee after supraphysiologic loading. Homeostatic disturbance is then induced by vascular stress and stretching of the peripatellar anastomotic ring, resulting in increased intraosseous water content and pressure of the patella, and triggering a cascade of ischaemic nociceptive responses [6,7,25–30]. This would not only explain the delayed onset of PDPS but also the shorter time for disappearance of PDPS after prolonged sitting.

Research and clinical implications

The results of the current study have significant implications for both research and clinical practice. Previous experiments assessing disturbance of the patellar bone blood

flow evaluated rather short episodes (seconds to minutes) [26,31,32] and/or with the knee in extension [31,32], future studies should focus on evaluating patellar blood flow beyond 20 minutes of prolonged sitting with the knee in 90 degrees of flexion.

According to the 2017 Gold Coast Consensus Statement on Treating PFP, hip- and knee-focused exercise therapy is a key component in the management of all subjects with PFP [33]. In a subgroup of subjects with PDPS at smaller flexion angles and with faster onset, knee-focused exercise therapy to improve quadriceps muscle function may exacerbate knee pain. This is because continuous quadriceps muscle training increases the hemodynamic load on the patellar bone [34], thereby provoking homeostatic pain [35]. Since intermittent quadriceps muscle training (two seconds of rest between repetitions) reduces patellar bone blood flow in healthy participants [34], this could be a valuable alternative for subjects with PFP and PDPS at smaller flexion angles and with faster onset. This approach may even be valuable in subjects with PFP and PDPS in general. However, this aspect should be further investigated.

Additionally, health care professionals should advise subjects with PDPS at smaller flexion angles and with faster onset to avoid these provocative postures altogether, or at the very least, to minimize the duration spent in such positions. Even if patients cannot avoid these positions, this may provide a plausible explanation for why an otherwise well-designed multimodal treatment program may fail to result in improvements in pain and disability. Offering explanations for failure often serves as a starting point for changes in treatment strategies.

Strengths and limitations

The current study marks the first attempt to evaluate key characteristics of PDPS in subjects with PFP, thereby offering more detailed insights into this clinical phenomenon. The study also acknowledges certain limitations. Firstly, we do not have information on which subjects were eligible for invitation but were not approached by the participating PTs. This may introduce selection bias, potentially impacting the internal validity of the current study's results. Additionally, in the available study period we did not manage to invite 125 subjects as anticipated, but only 107 subjects. With 20 out of 107 subjects (19%) being excluded, the exclusion rate in the current study was as estimated. Thus, the final sample size (n = 87) is slightly smaller than the commonly accepted guideline for an appropriate sample size for online questionnaires (n = 100), which may lead to a lower external validity of the current study.

Furthermore, eight (7%) invited subjects with PFP were excluded because their worst pain levels were too low at the moment of completion of the questionnaire. Though the time between invitation and study participation was usually one week, the worst pain level at the time of invitation may have been higher than that at the time of completion of the questionnaire. We underestimated, this change in worst pain level as being a factor for successful recruitment. Future studies should take this into account when determining sample size. Only four (4%) subjects with PFP were excluded due to the presence of other knee problems or too short symptom duration, indicating a generally accurate procedure of recruitment by experienced PTs.

Secondly, subgroups of participants with PFP and PDPS (smaller/greater flexion angle, fast/slow onset, and fast/slow disappearance) were created by dichotomising the response options. This approach was based on our clinical experience with a large

number of subjects in our clinics. The choice to aggregate response options into one or more subgroup categories may be arbitrary and subject to debate.

Thirdly, though the PTs responsible for inviting subjects with PFP were allocated to several regions of the Netherlands, the sampling method applied in the current study was a non-probability (convenience) sampling method. This sampling method have introduced bias into the study's results, affecting Additionally, subjects were recruited in private physical therapy clinics. In the Netherlands, the majority of patients utilize the direct access option to see their physical therapist, bypassing the general practitioner or sports medicine physician [36]. This option is more frequently used by younger adults compared to older adults [36]. In the sitting pain study conducted by Collins et al., participants from several different cohorts were analysed [3]. The included Dutch cohorts from van Linschoten et al. (n = 131) and van der Heijden et al. (n = 64) were recruited through general practitioners and sports medicine physicians [37,38]. This difference in recruitment setting may explain why participants with and without PDPS in the current study were younger (median age 22.0 years, *IQR* 6.0, and median age 23 years, *IQR* 9.3, respectively) compared to the participants from the Collins study (mean age 27.5, *SD* 8,1, and mean age 30.0 years, *SD* 8.6, respectively). Therefore, due to the convenience sampling method and the differences in recruitment settings, generalizations based on the results of the current study should be made with caution.

Lastly, although subjects with PFP were involved in the construction of the four items assessing PDPS characteristics, the reliability and validity of these items remain unknown. This may have led, for instance, to the overestimation or underestimation of both minimum knee flexion angles and the time to reported onset of PDPS, indicating the need for further research.

CONCLUSION

Participants with PDPS more often reported bilateral PFP and higher levels of disability. PDPS typically occurred when the knees are flexed 90 degrees or beyond. Participants identified a delayed onset of PDPS occurring after 16 to 20 minutes, whereas the time for its disappearance was shorter, between 6 to 10 minutes. Younger participants with PDPS at smaller knee flexion angles reported higher pain, disability, and kinesiophobia than those with PDPS at greater flexion angles. Additionally, participants with faster onset of PDPS experienced higher pain levels, while those with slower PDPS disappearance were less physically active and had greater disability than those with faster disappearance. This study provides a detailed description of the characteristics of PDPS as experienced by subjects with PFP. Future research should focus on understanding the underlying mechanisms of PDPS and developing targeted interventions to improve long-term outcomes in subjects with PFP.

STATEMENTS

Competing interests: None. The authors declare that they have no affiliations with or financial involvement in any organisation or entity with direct financial interest in the subject matter or materials discussed in this article.

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Data availability statement: Research data will be available upon reasonable request.

Contributors: MO and IT designed the study, established the methods and wrote the study protocol. GK contributed to development of the study protocol. MO, SF, and IT collected the data. MO and SF managed the data entry and preparation of the database. Statistical analyses were performed by MO, SF, GK, and IT. MO wrote the first draft of the manuscript, supported by SF and IT. GK provided comments on the draft, and all authors read and approved the final version of the manuscript prior to submission. MO is the guarantor and accepts full responsibility for this study.

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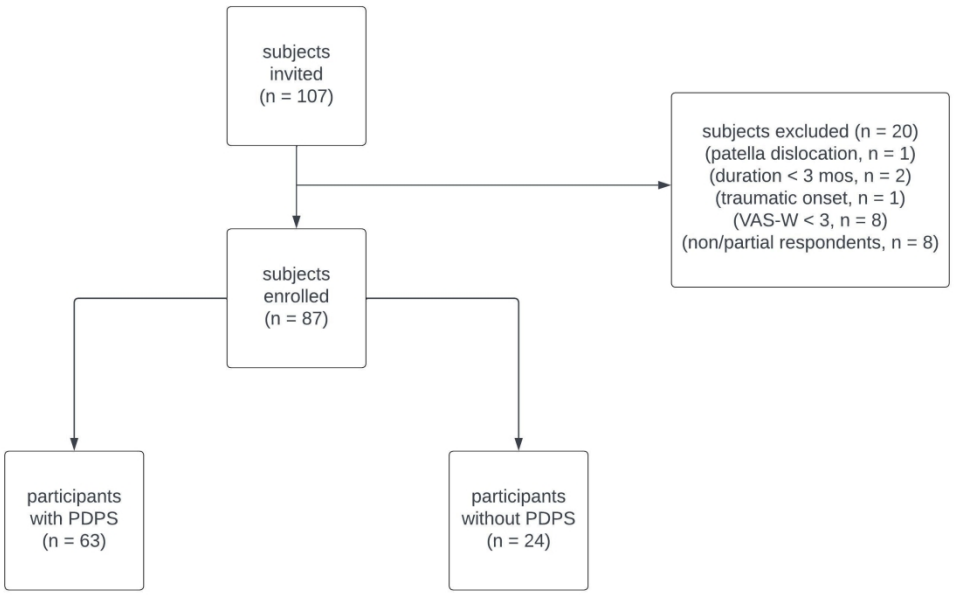
Captions of illustrations

Supplementary Figure 1. Flowchart of the inclusion process.

Abbreviations: mos, months; VAS-W, visual analogue scale for worst pain; PDPS, pain during prolonged sitting.



228x146mm (300 x 300 DPI)

ONLINE SUPPLEMENTARY FILE 1

PDPS QUESTIONNAIRE (Part 3 'Characteristics of PDPS')

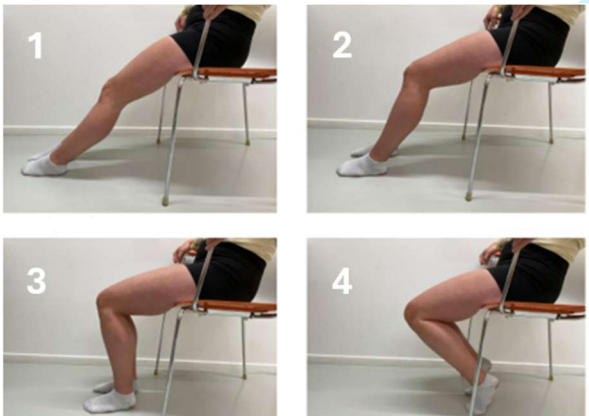
Item 1: What was the worst sitting pain in the past 7 days? Please mark between 0 cm (indicating no pain) and 10 cm (indicating maximum pain)?

No pain |----------| Maximum pain

(0 cm) (10 cm)

Item 2: How bent must your knees be to develop knee pain during prolonged sitting?

- I experience knee pain if my knee is in a 0° bent position (picture 1).
- I experience knee pain if my knee is in a 45° bent position (picture 2).
- I experience knee pain if my knee is in a 90° bent position (picture 3).
- I experience knee pain if my knee is in a more than 90° bent position (picture 4).



Item 3: If you bend your knee to 90° (as shown in the picture), how many minutes does it take before you start experiencing knee pain during sitting?

- 0-5 minutes.
- 6-10 minutes.
- 11-15 minutes.
- 16-20 minutes.
- 21-30 minutes.
- 31-40 minutes.

- > 40 minutes.

Item 4: If you extend your knee again after prolonged sitting with bent knees, how many minutes does it take for the pain to go away completely?

- 0-5 minutes.
- 6-10 minutes.
- 11-15 minutes.
- 16-20 minutes.
- 21-30 minutes.
- 31-40 minutes.
- > 40 minutes.

From: "Pain during prolonged sitting in subjects with patellofemoral pain in Dutch physical therapy clinics: an online questionnaire-based analysis", by Ophey M., Frieling S., Kerkhoffs G., and Tak I.