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Pain during prolonged sitting in patients with patellofemoral pain: an online questionnaire-based analysis

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2	questionnaire-based analysis
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40 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.

48 Setting Private physical therapy clinics in the Netherlands.

49 Participants 87 patients (61 [70%] females, mean age 22.0 years [IQR 4.0], BMI 23.1
50 [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.

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

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3 4 5	62	offered to enhance the understanding of the underlying mechanisms of PDPS, in
6 7	63	conjunction with suggestions for the development of targeted interventions aimed at
8 9 10	64	improving long-term outcomes.
11 12	65	
13 14	66	Keywords: patellofemoral pain syndrome, knee, orthopaedics
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90	Stre	engths and limitations of this study
91	•	Pain during prolonged sitting occurred with the knees flexed \geq 90 degrees.
92	•	PFP patients with PDPS experienced higher levels of disability, compared to those
93	,	without.
94	•	Patients with PDPS at smaller flexion angles and with a faster onset experienced
95]	higher levels of pain.
96	•	PFP patients reported onset of PDPS after 16-20 minutes, while time for
97		disappearance was shorter.
98	•	The final sample size was slightly smaller than the commonly accepted guideline for
99	i	an appropriate sample size for online questionnaires, which may lead to a lower
100		external validity of the current study.
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111 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.

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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. e.e.

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

157 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 or 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).
bbreviations: VAS-W, Visual Analogue Scale for Worst pair	n.

162 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]. Enseignement Superieur (ABES) Protected by copyright, including for uses related to text and data mining, AI training, and similar technologies.

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> 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 cmline 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.

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193	The third section contained four items and specifically evaluated the characteristics of
194	PDPS. Patients were asked to rate their worst sitting pain in the past seven days (VAS-W
195	sitting) on a 10 cm-line with a continuous score from '0 cm' (no pain) to '10 cm'
196	(maximal pain) [11]. The minimum degree of knee flexion required to provoke PDPS
197	was evaluated by presenting four pictures with the knees flexed at 0°, 45°, 90°, or beyond
198	90°. The minimum time to onset of PDPS with the knees in 90° was evaluated in seven
199	response options ('0-5 min', '6-10 min', '11-15 min', '16-20 min', '20-30 min', '30-
200	40 min', and '> 40 minutes'). The minimum time required for disappearance of PDPS
201	after extending the knees from 90° flexion was evaluated using the same response options.
202	Items of this category were dichotomised by defining a 'smaller flexion angle' group (<
203	90°) and a 'greater flexion angle' group (\geq 90°); a 'fast-onset' group (\leq 10 minutes) and
204	a 'slow-onset' group (> 10 minutes); and a 'fast-disappearance' group (\leq 10 minutes) and
205	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).

211 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 Enseignement Superieur (ABES) Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.

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.

220 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 chisquare 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

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240	A total of 107 patients with PFP were invited to participate, of whom 20 were excluded
241	(SUPPLEMENTARY FIGURE 1). The remaining 87 (81%) patients were eligible for
242	inclusion (61 [70%] females, mean age 22.0 years [IQR 4.0], BMI 23.1 [IQR 4.7]).
243	Sixty-three (72%) patients with PFP reported PDPS (TABLE 2). More patients with
244	PDPS had bilateral symptoms (71%), compared to those without PDPS (46%) ($p = .044$).
245	Participants with PDPS exhibited a 12-point lower total score on the AKPS ($U = 355.50$,
246	p < .001, $r = 0.41$), and lower scores on items 3 'walking' ($U = 474.00$, $p = .004$, $r =$
247	0.31), 5 'squatting' ($U = 505.50$, $p = .009$, $r = 0.28$), 8 'prolonged sitting' ($U = 0.00$, $p < 0.00$
248	.001, $r = 0.51$), and 9 'pain' ($U = 555.00$, $p < .025$, $r = 0.24$). Most patients with PFP and
249	PDPS ($n = 52$ [85%]) reported symptoms that occurred when the knees were flexed to
250	90° or more. Only a small proportion (n = 9 [15%]) of the patients with PFP and PDPS
251	experienced symptoms in smaller knee flexion positions (0° or 45°). Two patients with
252	PDPS omitted this item.
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TABLE 2. Baseline characteristics of the participants

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

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

290 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, <i>n</i> (%)	7 (78)	37 (71)	.515	Phi = .05
Age (years)	20.0*	22.0*	.018	r = .30
	(<i>IQR</i> 4.0)	(<i>IQR</i> 5.8)		
BMI (kg/m ²)	23.2	23.8	.190	r = .17
	(<i>IQR</i> 4.8)	(IQR 5.2)		
Sport participation (h/week)	3.0	3.6	.400	<i>d</i> = .11
	$(SD \pm 2.1)$	$(SD \pm 2.2)$		
Tegner Score (0–10)	4.0	4.0	.452	<i>r</i> = .10
	(<i>IQR</i> 5.0)	(<i>IQR</i> 3.0)		
VAS-W (0–10)	7.0**	5.0**	.002	<i>r</i> = .39
	(IQR 1.0)	(<i>IQR</i> 3.0)		
Bilateral PFP, n (%)	9 (100)	36 (69)	.096	<i>Phi</i> = .25
Symptom duration (months)	48.0	38.0	.445	<i>r</i> = .10
	(IQR 74.5)	(IQR 64.0)		
AKPS (0-100)	66.0**	77.0**	.005	<i>r</i> = .36
	(IQR 13.5)	(IQR 13.0)		
TSK (17–68)	36.0*	32.0*	.029	<i>r</i> = .28
	(IQR 14.5)	(IQR 8.0)		
VAS-W sitting (0–10)	6.8**	5.0**	.001	<i>r</i> = .41
	(<i>IQR</i> 1.1)	(IQR 3.0)		

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.

294 Data are presented as numbers (percentages), mean (\pm 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).

305	TABLE 4 . Characteristics of groups of patients with PDPS with faster and slower onset
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306 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, <i>n</i> (%)	8 (57)	22 (73)	.316	<i>Phi</i> = .16
Age (years)	21.5	22.0	.577	r = .08
	(IQR 7.0)	(<i>IQR</i> 6.3)		
BMI (kg/m ²)	24.0	24.0	.821	<i>r</i> = .03
	(<i>IQR</i> 3.0)	(<i>IQR</i> 5.9)		
Sport participation (h/week)	3.1	3.0	.934	<i>d</i> = .03
	$(SD \pm 2.1)$	$(SD \pm 2.0)$		
Tegner Score (0–10)	4.0	3.0	.096	<i>r</i> = .25
	(<i>IQR</i> 2.3)	(IQR 4.0)		
VAS-W (0-10)	7.0***	5.0***	< .001	r = .50
	(IQR 2.0)	(<i>IQR</i> 3.0)		
Bilateral PFP, n (%)	10 (71)	24 (80)	.701	Phi = .10
Symptom duration (months)	42.0	40.0	.696	r = .06
	(IQR 87.0)	(IQR 48.0)		
AKPS (0-100)	68.0	74.0	.109	r = .24
	(IQR 10.0)	(IQR 16.3)		
TSK (17–68)	32.5	32.5	.940	<i>r</i> = .01
	(IQR 8.0)	(IQR 10.5)		
VAS-W sitting (0-10)	6.0*	5.0*	.038	<i>r</i> = .31
	(IQR 2.0)	(IQR 4.0)		

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.

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

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Characteristics	Fast-	Slow-	P -value	ES
	disappearance	disappearance		
	(≤ 10 min)	(> 10 min)		
Participants, n (%)	25 (57)	19 (43)	n/a	n/a
Female, <i>n</i> (%)	16 (64)	14 (74)	.534	Phi = .10
Age (years)	22.0	20.0	.229	<i>r</i> = .18
	(<i>IQR</i> 6.0)	(IQR 5.0)		
BMI (kg/m ²)	24.1	22.4	.112	<i>r</i> = .24
	(<i>IQR</i> 4.1)	(<i>IQR</i> 5.0)		
Sport participation (h/week)	3.6*	2.3*	.036	<i>d</i> = .66
	$(SD \pm 2.0)$	$(SD \pm 1.9)$		
Tegner Score (0–10)	4.0	3.0	.197	<i>r</i> = .19
	(<i>IQR</i> 3.0)	<i>IQR</i> (2.0)		
VAS-W (0-10)	5.0	6.0	.379	<i>r</i> = .13
	(<i>IQR</i> 3.0)	(<i>IQR</i> 2.0)		
Bilateral PFP, n (%)	17 (68)	17 (90)	.148	Phi = .25
Symptom duration (months)	36.0	42.0	.406	<i>r</i> = .13
	(IQR 54.5)	(IQR 60.0)		
AKPS (0-100)	74.0**	67.0**	.005	<i>r</i> = .43
	(IQR 16.0)	(IQR 12.0)		
TSK (17–68)	32.0	33.0	.374	<i>r</i> = .13
	(IQR 8.0)	(IQR 14.0)		
VAS-W sitting (0–10)	5.0	6.0	.156	<i>r</i> = .21
	(<i>IQR</i> 4.0)	(IQR 2.0)		

328 329 330 *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. 331 332 Data are presented as numbers (percentages), mean (± standard deviation), or median (interquartile range 25%-75%). *, ** and ***

indicate p-value < .05, < .01, and < .001, respectively.

334 DISCUSSION

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Patients with PDPS more often reported bilateral PFP and higher levels of disability, 335 compared to those without PDPS. Pain during prolonged sitting was typically induced 336 when the knees were flexed to 90° or more. The median time to reported onset of PDPS 337 was 16 to 20 minutes, and the time for disappearance of PDPS was generally 6 to 10 338 339 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 340 flexion angles. Patients with PDPS with faster onset had higher levels of pain, compared 341

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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 Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.

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.

382 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.

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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.

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400 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.

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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.

428 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.

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. Ethical Approval: By the Ethical Scientific Advisory Board of the HAN – University of Applied Sciences (EACO 278.06/21), Nijmegen, The Netherlands. Funding: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. Data statement: Research data will be available upon reasonable request. 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. Contributors: We thank Dide Bennink (PT), Iris Blazevic (PT), Lucie van den Akker (PT), Demi Beumer (PT), Maud Duijzings (PT) and Job van Knippenberg (PT) for their contributions to the first draft of the online questionnaire.

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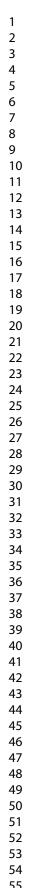
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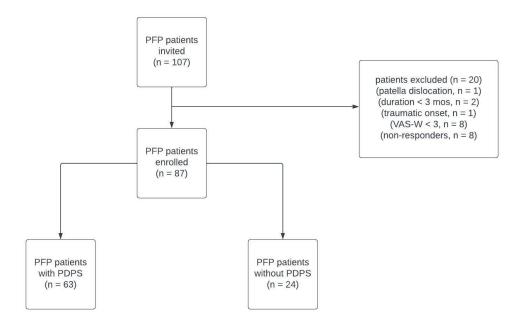
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Pain during prolonged sitting in subjects with patellofemoral pain in Dutch physical therapy clinics: an online questionnaire-based analysis

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Secondary Subject Heading:	Rehabilitation medicine, General practice / Family practice
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1	Pain during prolonged sitting in subjects with patellofemoral pain in Dutch
2	physical therapy clinics: an online questionnaire-based analysis
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40	ABSTRACT
41	Objectives A significant proportion of subjects with patellofemoral pain (PFP) report
42	pain during prolonged sitting (PDPS); however, detailed characteristics of PDPS are
43	lacking. This patient-reported questionnaire study aimed to describe 1) differences in
44	characteristics between subjects with and without PDPS, 2) minimum knee flexion
45	angle and time to onset/disappearance of PDPS, and 3) differences between those with
46	PDPS at smaller/greater flexion angles, with faster/slower onset, and faster/slower
47	disappearance of PDPS, respectively.
48	Design Online questionnaire.
49	Setting Private physical therapy clinics in the Netherlands.
50	Participants 87 participants (61 [70%] females, mean age 22.0 years [IQR 4.0], BMI
51	23.1 [IQR 4.7]).
52	Primary and secondary outcome measures VAS for worst pain (VAS-W) and worst
53	sitting pain (VAS-W sitting) in the past seven days and the Anterior Knee Pain Scale
54	(AKPS), Tampa Scale for Kinesiophobia (TSK), degree of knee flexion required to
55	provoke PDPS, and time to onset and disappearance of PDPS.
56	Results Sixty-three of 87 (72%) participants reported PDPS. Participants with PDPS
57	more often experienced bilateral symptoms of PFP ($p = .044$), and exhibited a 12-point
58	lower AKPS score ($p < .001$). The reported median time to PDPS onset was 16–20 min,
59	with 6-10 min for disappearance. Participants experiencing PDPS at smaller flexion
60	angles exhibited higher VAS-W and VAS-W sitting scores compared to participants
61	with PDPS at greater flexion angles ($p = .002$, $p = .001$). Additionally, higher VAS-W

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62	and VAS-W sitting scores ($p < .001$, $p = .025$) were reported by participants with fast-
63	onset compared to participants with slow-onset of PDPS.
64	Conclusions Subjects with PDPS reported higher levels of disability, and a delayed
65	onset of PDPS, compared to the time for disappearance. Future research should focus on
66	understanding the underlying mechanisms of PDPS and developing targeted
67	interventions to improve long-term outcomes in subjects with PFP.
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69	Keywords: patellofemoral pain syndrome, knee, orthopaedics
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89	Strengths and limitations of this study
90	• Characteristics of pain during prolonged sitting were evaluated using an online
91	patient-reported questionnaire rather than clinician-based measures.
92	• Subgroups of participants with pain during prolonged sitting were created by
93	dichotomizing item response options, based on clinical experience, which may be
94	arbitrary and subject to debate.
95	• The final sample size was slightly smaller than the commonly accepted guideline for
96	an appropriate sample size for online questionnaires, which may lead to a lower
97	external validity of the current study.
98	• Subjects were recruited from Dutch private physical therapy clinics, which may
99	explain why participants were slightly younger compared to those in other studies.
100	• The reliability and validity of self-reported items evaluating the characteristics of
101	pain during prolonged sitting are not yet known.
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111	INTRODUCTION
112	Patellofemoral pain (PFP) is a common musculoskeletal condition that has an annual
113	prevalence of up to 36% [1]. A significant proportion of subjects with PFP experience
114	'pain during prolonged sitting' (PDPS), which is also referred to as the "movie goers'
115	sign" due to the extended periods of sitting with flexed knees in a seat with little leg
116	space during a cinema visit [2]. A large study of 458 subjects with PFP reported a
117	prevalence of PDPS in 80% within the sample population [3].
118	The mechanisms underlying PDPS in subjects with PFP are unelucidated. For instance,
119	prolonged sitting with knees flexed does not expose the patellofemoral joint (PFJ) to
120	biomechanical loading. Additionally, a recent study employing magnetic resonance
121	imaging (MRI) found no association of any morphological parameters, such as
122	alignment or structural characteristics of the PFJ, with PDPS in subjects with PFP [4].
123	Previously, only one study evaluated differences in characteristics between subjects
124	with and without PDPS. It reported that subjects with PFP and PDPS were younger,
125	more likely to be female, had a lower body mass index (BMI), higher pain severity,
126	lower Anterior Knee Pain Scale (AKPS) scores, and more problems with squatting
127	compared to subjects without PDPS [3]. Replicating and evaluating this in a different
128	cohort may be valuable. Furthermore, the existing literature lacks specific details such
129	as the degree of knee flexion required to elicit PDPS, and the duration between seating
130	and the onset of PDPS. A delayed onset of symptoms, for instance, may indicate
131	disturbed homeostasis of structures of the anterior knee due to increased intraosseous
132	pressure of the patella, as previously described [5,6]. Moreover, subjects with PDPS at
133	smaller flexion angles may exhibit demographic or symptom characteristics distinct

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> 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 or serious pathology (e.g., malignancy). Previous or current other clinical diagnosis of specific knee conditions (e.g., Osgood-Schlatter, Sinding–Larsson, patella instability or dislocation, jumper's knee meniscal tears, or ligament injury). History of surgery (e.g., ankle, knee, hip or lower back). 		

Questionnaire

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173	The online questionnaire comprised three parts. The first part contained eight items and
174	evaluated general patient characteristics (e.g., sex, age, body weight and length, and
175	hours of sport participation per week). The activity level was rated according to the
176	Tegner Score [8–10], which contains 11 response options ranging from 0 to 10. Higher
177	scores indicated higher activity levels. The Dutch version of the Tegner Score is reliable
178	(ICC = .97) with moderate correlations with other knee- and quality-of-life related
179	questionnaires ($r = .4248$) [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').

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196	A previous study found no PFJ loading variables (e.g., peak PFJ contact force), but
197	kinesiophobia being associated with self-reported pain and disability in subjects with
198	PFP [15]. Since prolonged sitting lacks PFJ loading, evaluation of kinesiophobia in
199	subjects with PDPS may be relevant. Therefore, the Tampa Scale for Kinesiophobia
200	(TSK) was also administered. The TSK is a 17-item questionnaire for evaluating pain-
201	related fear and avoidance behaviour [16]. Participants were asked to rate their level of
202	agreement with statements regarding fear of movement behaviour on a 4-point Likert
203	scale from 'strongly disagree' to 'strongly agree'. Scores range from 17 to 68 points,
204	with higher scores indicating greater levels of kinesiophobia [16].
205	The third section contained four items and specifically evaluated the characteristics of
206	PDPS (SUPPLEMENTARY FILE 1). Participants were asked to rate their worst sitting
207	pain in the past seven days (VAS-W sitting) on a 10 cm-line with a continuous score
208	from '0 cm' (no pain) to '10 cm' (maximal pain) [12]. The minimum degree of knee
209	flexion required to provoke PDPS was evaluated by presenting four pictures with the
210	knees flexed at 0°, 45°, 90°, or beyond 90°. The minimum time to onset of PDPS with
211	the knees in 90° was evaluated in seven response options ('0–5 min', '6–10 min', '11–
212	15 min', '16–20 min', '21–30 min', '31–40 min', and '> 40 minutes'). The minimum
213	time required for disappearance of PDPS after extending the knees from 90° flexion was
214	evaluated using the same response options. Items of this category were dichotomised by
215	defining a 'smaller flexion angle' group (< 90°) and a 'greater flexion angle' group (\geq
216	90°); a 'fast-onset' group (≤ 10 minutes) and a 'slow-onset' group (> 10 minutes); and a
217	'fast-disappearance' group (≤ 10 minutes) and a 'slow-disappearance' group (> 10
218	minutes).

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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

[SD] and range [R]). When data were not normally distributed, they were analysed non-

data (p > .05) were analysed parametrically and presented as mean (± standard deviation

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

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242	analysed using the Fisher's exact test. A priori, a significance level of $p < .05$ was
243	established as the criterion for statistical significance. The effect sizes (ES) for normally
244	distributed data were calculated using Cohen's d to determine the magnitude of the
245	differences. For non-normally distributed data, <i>ES r</i> using the formula $r = Z/\sqrt{(n_a + n_b)}$
246), with Z being the Z-score from the Mann-Whitney U test and n_a and n_b being sample
247	sizes of both groups, has been determined [18]. For dichotomous variables Phi has been
248	calculated based on the chi-square statistic χ^2 [18]. An <i>ES</i> of 0.2, 0.5, and ≥ 0.8 was
249	considered small, medium, and large, respectively [19]. Statistical analyses were
250	performed using SPSS version 25.0 (SPSS Inc., Chicago, IL, USA).
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252	RESULTS
253	A total of 107 subjects with PFP were invited to participate, of whom 20 were excluded
254	(patella dislocation [$n = 1$], symptom duration <3 months [$n = 2$], traumatic origin [$n =$
255	1], VAS-W <3 [$n = 8$], and non/partial respondents [$n = 8$]). (SUPPLEMENTARY
256	FIGURE 1). The remaining 87 (81%) subjects were eligible for inclusion (61 [70%]
257	females, mean age 22.0 years [IQR 4.0], BMI 23.1 [IQR 4.7]).
258	Sixty-three (72%) participants reported PDPS (TABLE 2). More participants with
259	PDPS had bilateral symptoms (71%), compared to those without PDPS (46%) ($p =$
260	.044). Participants with PDPS demonstrated a median total score on the AKPS that was
261	12 points lower when compared to participants without PDPS (small to medium ES),
262	including lower scores on items 3 'walking' (small ES), 5 'squatting' (small ES), 8
263	'prolonged sitting' (medium ES), and 9 'pain' (small ES). Most participants with PDPS
264	(n = 52 [85%]) reported symptoms that occurred when the knees were flexed to 90° or

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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, <i>n</i> (%)	46 (73)	15 (63)	.433	Phi = 0.10
Age (years)	22.0	23.0	.242	<i>r</i> = 0.13
	(<i>IQR</i> 6.0)	(<i>IQR</i> 9.3)		
BMI (kg/m ²)	23.5	21.7	.207	r = 0.14
	(<i>IQR</i> 4.9)	(<i>IQR</i> 4.0)		
Sport participation (h/week)	3.0	3.5	.466	r = 0.08
	(<i>IQR</i> 3.0)	(<i>IQR</i> 1.9)		
Tegner Score (0–10)	4.0	5.0	.138	<i>r</i> = 0.16
	(<i>IQR</i> 3.0)	(<i>IQR</i> 2.0)		
VAS-W (0–10)	6.0	5.0	.212	r = 0.13
	(<i>IQR</i> 3.0)	(IQR 2.0)		
Bilateral PFP, n (%)	45 (71)	11 (46)	.044	Phi = 0.24
Symptom duration (months)	40.0	20.0	.337	r = 0.07
	(IQR 64.0)	(IQR 45.0)		
AKPS (0-100)	74.0	86.0	< .001	r = 0.41
	(IQR 14.0)	(<i>IQR</i> 11.5)		
Item 1 'limp' (0–5)	5.0	5.0	.197	r = 0.14
	(IQR 2.0)	(IQR 2.0)		
Item 2 'support' (0–5)	5.0	5.0	.207	r = .014
	(IQR 2.0)	(<i>IQR</i> 0.0)		
Item 3 'walking' (0–5)	3.0	5.0	.004	r = 0.31
	(IQR 2.0)	(IQR 2.0)		
Item 4 'stairs' (0–10)	8.0	8.0	.992	r = 0.00
	(IQR 3.0)	(<i>IQR</i> 5.0)		
Item 5 'squatting' (0–5)	4.0	4.0	.009	r = 0.28
	(IQR 1.0)	(<i>IQR</i> 1.0)		
Item 6 'running' (0–10)	6.0	7.0	.286	r = 0.11
	(IQR 2.0)	(IQR 2.0)		
Item 7 'jumping' (0–10)	7.0	7.0	.090	r = 0.18
	(<i>IQR</i> 3.0)	(<i>IQR</i> 3.0)		
Item 8 'prolonged sitting' (0–10)	6.0	10.0	< .001	r = 0.51
	(IQR 4.0)	(<i>IQR</i> 0.0)		
Item 9 'pain' (0–10)	8.0	8.0	.025	r = 0.24
	(IQR 5.0)	(IQR 0.0)		
Item 10 'swelling' (0–10)	10.0	10.0	.077	r = 0.19

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

- 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 flexionangles

²⁷³ Data are presented as numbers (percentages), and median (interquartile range 25%–75% [IQR]).

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Characteristics	Smaller flexion angle (< 90°)	Greater flexion angle (≥ 90°)	<i>P</i> -value	ES
Participants, n (%)	9 (15)	52 (85)	n/a	n/a
Female, <i>n</i> (%)	7 (78)	37 (71)	.515	Phi = 0.05
Age (years)	20.0	22.0	.018	r = 0.30
	(<i>IQR</i> 4.0)	(<i>IQR</i> 5.8)		
BMI (kg/m ²)	23.2	23.8	.190	r = 0.17
	(<i>IQR</i> 4.8)	(<i>IQR</i> 5.2)		
Sport participation (h/week)	3.0	3.6	.400	d = 0.11
	$(SD \pm 2.1, R \ 6.0)$	$(SD \pm 2.2, R \ 10.0)$		
Tegner Score (0–10)	4.0	4.0	.452	r = 0.10
	(<i>IQR</i> 5.0)	(<i>IQR</i> 3.0)		
VAS-W (0-10)	7.0	5.0	.002	<i>r</i> = 0.39
	(<i>IQR</i> 1.0)	(<i>IQR</i> 3.0)		
Bilateral PFP, n (%)	9 (100)	36 (69)	.096	Phi = 0.2
Symptom duration (months)	48.0	38.0	.445	<i>r</i> = 0.10
	(IQR 74.5)	(IQR 64.0)		
AKPS (0-100)	66.0	77.0	.005	<i>r</i> = 0.36
	(IQR 13.5)	(IQR 13.0)		
TSK (17–68)	36.0	32.0	.029	<i>r</i> = 0.28
	(IQR 14.5)	(IQR 8.0)		
VAS-W sitting (0–10)	6.8	5.0	.001	<i>r</i> = 0.41
	(<i>IQR</i> 1.1)	(<i>IQR</i> 3.0)		

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.

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

294 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

298 (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)	<i>P</i> -value	ES
Participants, n (%)	14 (32)	30 (68)	n/a	n/a

22 (73)

 $(IOR \ 6.3)$

(IQR 5.9)

(*IQR* 4.0)

(*IQR* 3.0)

(IQR 48.0)

(*IQR* 16.3)

(IQR 10.5)

 $(IQR \ 4.0)$

24 (80)

40.0

74.0

32.5

5.0

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

 $(SD \pm 2.0, R 7.0)$

22.0

24.0

3.0

3.0

5.0

.316

.577

.821

.934

.096

<.001

.701

.696

.109

.940

.038

Phi = 0.16

r = 0.08

r = 0.03

d = 0.03

r = 0.25

r = 0.50

r = 0.06

r = 0.24

r = 0.01

r = 0.31

Phi = 0.10

8 (57)

(IQR 7.0)

(*IQR* 3.0)

(*IQR* 2.3)

(IQR 2.0)

(IQR 87.0)

(IQR 10.0)

(IQR 8.0)

(IQR 2.0)

Analogue Scale for Worst sitting pain; ES, Effect Size as Cohen's d, r or Phi; n/a, not applicable.

10(71)

42.0

68.0

32.5

6.0

 $(SD \pm 2.1, R 6.0)$

21.5

24.0

3.1

4.0

7.0

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Data are presented as numbers (percentages), mean (\pm standard deviation [<i>SD</i>] and range [<i>R</i>]), or median (interquartile range 25%-75% [<i>IQR</i>]).
TABLE 5. Characteristics of participants with PDPS with faster and slower

with PDPS with faster and slower 309 TABL

disappearance of symptoms 310

Female, n (%)

Age (years)

BMI (kg/m²)

Sport participation (h/week)

Symptom duration (months)

Tegner Score (0–10)

Bilateral PFP, n (%)

VAS-W sitting (0-10)

VAS-W (0-10)

AKPS (0-100)

TSK (17-68)

Characteristics	Fast-	Slow-	<i>P</i> -value	ES
	disappearance	disappearance		
	(≤ 10 min)	(> 10 min)		
Participants, n (%)	25 (57)	19 (43)	n/a	n/a
Female, <i>n</i> (%)	16 (64)	14 (74)	.534	Phi = 0.10
Age (years)	22.0	20.0	.229	r = 0.18
	(<i>IQR</i> 6.0)	(<i>IQR</i> 5.0)		
BMI (kg/m ²)	24.1	22.4	.112	r = 0.24
	(<i>IQR</i> 4.1)	(<i>IQR</i> 5.0)		
Sport participation (h/week)	3.6	2.3	.036	<i>d</i> = 0.66
	$(SD \pm 2.0, R\ 7.0)$	$(SD \pm 1.9, R \ 6.0)$		
Tegner Score (0–10)	4.0	3.0	.197	r = 0.19
	(<i>IQR</i> 3.0)	IQR (2.0)		
VAS-W (0–10)	5.0	6.0	.379	r = 0.13
	(<i>IQR</i> 3.0)	(IQR 2.0)		
Bilateral PFP, n (%)	17 (68)	17 (90)	.148	Phi = 0.25
Symptom duration (months)	36.0	42.0	.406	r = 0.13
	(IQR 54.5)	(IQR 60.0)		
AKPS (0-100)	74.0	67.0	.005	r = 0.43
	(IQR 16.0)	(IQR 12.0)		
TSK (17–68)	32.0	33.0	.374	r = 0.13
	(IQR 8.0)	(IQR 14.0)		

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VAS-W sitting (0–10)	5.0	6.0	.156	<i>r</i> = 0.21	
	(IQR 4.0)	(IQR 2.0)			
Abbreviations: n, number; BMI, Body Ma	ass Index in kilograms o	f body weight per i	n ² ; h/week, hours pe	er week; VAS-W, V	isual
Analogue Scale for Worst pain: AKPS, A	nterior Knee Pain Scale	: TSK. Tampa Scal	e for Kinesiophobia	: VAS-W sitting. Vi	isual

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 (\pm standard deviation [SD] and range [R]), or median (interquartile range 25%-75% [IQR]).

317 DISCUSSION

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Subjects with PDPS more often reported bilateral PFP and higher levels of disability, 318 compared to those without PDPS. Subjects typically described PDPS to be induced 319 when the knees were flexed to 90° or beyond. The median time to reported onset of 320 PDPS was 16 to 20 minutes, and the time for disappearance of PDPS was generally 6 to 321 10 minutes. Subjects with PDPS at smaller knee flexion angles were younger and had 322 323 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 324 of pain, compared to those with slower onset. Subjects with PDPS with slower 325 326 disappearance of PDPS reported to be less physically active and had higher levels of disability, compared to subjects with faster disappearance of PDPS. 327 In the present study, the prevalence of PDPS in subjects with PFP was 72%. This is in 328 line with the previously reported prevalence of 77%–80% [3,20]. Bilateral symptoms 329 occurred more frequently in subjects with PDPS than in those without. As bilateral PFP 330 331 is a prognostic factor for an unfavourable course [21], PDPS may similarly exert prognostic influence. Nonetheless, definitive establishment necessitates a prospective 332 333 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

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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 Enseignement Superieur (ABES) . Protected by copyright, including for uses related to text and data mining, Al training, and similar technologies.

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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.

368 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

- 380 [34]. Since intermittent quadriceps muscle training (two seconds of rest between
- valuable alternative for subjects with PFP and PDPS at smaller flexion angles and with

repetitions) reduces patellar bone blood flow in healthy participants [33], this could be a

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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

402 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

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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, *IOR* 9.3, respectively) compared to the participants from the

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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.

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STATEMENTS

454	Conflicts of interest: None. The authors declare that they have no affiliations with or
455	financial involvement in any organisation or entity with direct financial interest in the
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457	
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460	
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463	
464	Data statement: Research data will be available upon reasonable request.
465	
466	Authorship: MO and IT designed the study, established the methods and wrote the study
467	protocol. GK contributed to development of the study protocol. MO, SF, and IT collected
468	the data. MO and SF managed the data entry and preparation of the database. Statistical
469	analyses were performed by MO, SF, GK, and IT. MO wrote the first draft of the
470	manuscript, supported by SF and IT. GK provided comments on the draft, and all authors
471	read and approved the final version of the manuscript prior to submission.
472	

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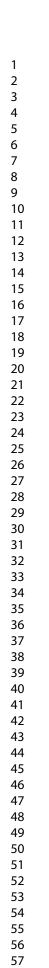
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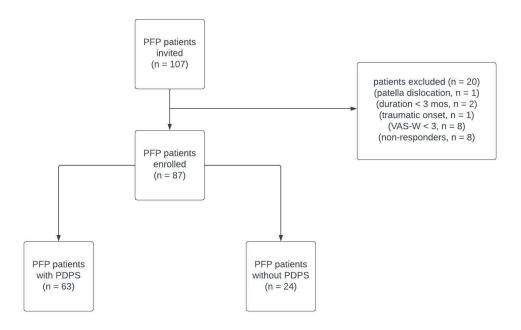
SUPPLEMENTARY FIGURE 1. Flowchart of the inclusion process.

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

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ONLINE SUPPLEMENTARY FILE 1

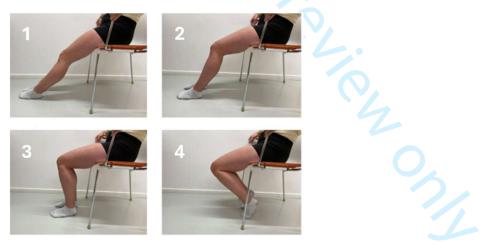
PDPS QUESTIONNAIRE (Part 3 'Characteristics of PDPS')

Item 1: What was the <u>worst sitting pain</u> 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?

- \circ I experience knee pain if my knee is in a 0° bent position (picture 1).
- \circ I experience knee pain if my knee is in a 45° bent position (picture 2).
- \circ I experience knee pain if my knee is in a 90° bent position (picture 3).
- \circ 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?

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

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\circ > 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?

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

BMJ Open

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

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1	Pain during prolonged sitting in subjects with patellofemoral pain in Dutch
2	physical therapy clinics: an online questionnaire-based analysis
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Objectives: This study aimed to describe 1) differences between subjects with 40 patellofemoral pain (PFP) with and without pain during prolonged sitting (PDPS), 2) 41 minimum knee flexion angle and time to onset/disappearance of PDPS, and 3) 42 differences between those with PDPS at smaller/greater flexion angles, and with 43 44 fast/slow onset and disappearance of PDPS. Design: Patient-reported online questionnaire. 45 46 Setting: Private physical therapy clinics in the Netherlands between May 2021 and March 2023. 47 Participants: 87 participants (61 [70%] females, mean age 22.0 years [IQR 4.0], BMI 48 23.1 [4.7]). 49 **Outcome measures:** VAS for worst pain (VAS-W) and sitting pain (VAS-W sitting), 50 the Anterior Knee Pain Scale (AKPS), knee flexion angle to provoke PDPS, and time to 51 onset/disappearance of PDPS. 52 Results: Sixty-three of 87 (72%) participants reported PDPS. Participants with PDPS 53 experienced bilateral symptoms of PFP more frequently (71% vs. 46%, p = .44) and 54 scored 12 points lower on the AKPS (p < .001). Most participants (85%) reported a 55 56 minimum knee flexion angle of $\geq 90^{\circ}$, median time to PDPS onset of 16–20 minutes, and 6-10 minutes for disappearance. Participants experiencing PDPS at smaller flexion 57 angles exhibited higher VAS-W and VAS-W sitting scores (7.0 [1.0], 6.8 [1.1]) than 58 those at greater flexion angles (5.0 [3.0], for both) (p = .002, p = .001). Participants with 59 fast-onset of PDPS reported higher VAS-W and VAS-W sitting scores (7.0 [2.0], 6.0 60 [2.0]) than those with slow-onset $(5.0 \ [3.0], 5.0 \ [4.0])$ (p < .001, p = .025). 61

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Conclusions: Participants with PDPS reported higher levels of disability than those

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

Keywords: patellofemoral pain syndrome, knee, orthopaedics

without. PDPS was typically induced at knee flexion of $\geq 90^{\circ}$, with delayed

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89 Strengths and limitations of this study

90	•	Characteristics of pain during prolonged sitting were evaluated using an online
91		patient-reported questionnaire rather than clinician-based measures.
92	•	Subgroups of participants with pain during prolonged sitting were created by
93		dichotomizing item response options, based on clinical experience, which may be
94		arbitrary and subject to debate.
95	•	The final sample size was slightly smaller than the commonly accepted guideline for
96		an appropriate sample size for online questionnaires, which may lead to a lower
97		external validity of the current study.
98	•	Subjects were recruited from Dutch private physical therapy clinics, which may
99		explain why participants were slightly younger compared to those in other studies.
100	٠	The reliability and validity of self-reported items evaluating the characteristics of
101		pain during prolonged sitting are not yet known.
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111	INTRODUCTION
112	Patellofemoral pain (PFP) is a common musculoskeletal condition that has an annual
113	prevalence of up to 36% [1]. A significant proportion of subjects with PFP experience
114	'pain during prolonged sitting' (PDPS), which is also referred to as the "movie goers'
115	sign" due to the extended periods of sitting with flexed knees in a seat with little leg
116	space during a cinema visit [2]. A large study of 458 subjects with PFP reported a
117	prevalence of PDPS in 80% within the sample population [3].
118	The mechanisms underlying PDPS in subjects with PFP are unelucidated. No data were
119	found regarding patellofemoral joint reaction forces (PFJRF) during sitting. It is well
120	established that PFJRF increase with greater knee flexion angles and higher quadriceps
121	muscle forces [4]. For example, PFJRF in subjects with PFP are higher during stair
122	ascent (3.2 [SD ± 0.7] times body weight [BW]) compared to walking (0.9 [SD ± 0.4]
123	BW) [4]. Given that quadriceps muscle forces decrease during sitting relative to
124	walking, and that patellofemoral contact area increases with greater knee flexion [4],
125	PFJRF during sitting are expected to be lower than during walking. Although PFJRF are
126	not entirely absent during sitting, their small magnitude calls into question whether they
127	sufficiently reflect the underlying mechanism of PDPS. Additionally, a recent study
128	employing magnetic resonance imaging (MRI) found no association of any
129	morphological parameters, such as alignment or structural characteristics of the PFJ,
130	with PDPS in subjects with PFP [5].
131	Previously, only one study evaluated differences in characteristics between subjects
132	with and without PDPS [3]. It reported that subjects with PFP and PDPS were younger,
133	more likely to be female, had a lower body mass index (BMI), higher pain severity,

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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.

153 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.

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158	Patient and public involvement
159	Four subjects with PFP and PDPS (median age 22.5 years [interquartile range, IQR 1.5];
160	three females and one male) who met the inclusion and exclusion criteria were
161	interviewed to identify criteria for assessing PDPS characteristics. Then they reviewed
162	the developed preliminary questionnaire and assessed it for readability and item clarity.
163	Minor changes were made to two items to ensure their readability and feasibility.
164	Following publication, enrolled participants will receive a comprehensive manuscript
165	encompassing the full text, as part of our commitment to patient involvement.
166	
167	Participants
168	Subjects were recruited by nine physical therapists (PT) working in private clinics in the
169	Netherlands with a special interest in the rehabilitation of knee injuries and PFP. These
170	PTs were informed about the inclusion and exclusion criteria (Table 1), and asked to
171	carefully evaluate history of knee pain, perform clinical examination (hip, and knee
172	including exact site of pain), and consecutively invite subjects with PFP to participate in
173	the current study as they became available (using convenience sampling). The inclusion
174	and exclusion criteria are based on the Manchester consensus statement (definition of
175	PFP, exclusion of other pathologies) [8]. A minimum pain level was established as an
176	inclusion criterion to prevent the enrollment of participants with symptoms of PDPS
177	that are too mild to be effectively evaluated. The invitation was sent between May 2021
178	and March 2023. Informed consent was obtained online as the first item of the survey
179	questionnaire.

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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 or serious pathology (e.g., malignancy). Previous or current other clinical diagnosis of specific knee conditions (e.g., Osgood-Schlatter, Sinding–Larsson, patella instability or dislocation, jumper's knee meniscal tears, or ligament injury). History of surgery (e.g., ankle, knee, hip or lower back).

184 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].

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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

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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 ($< 90^{\circ}$) and a 'greater flexion angle' group (\geq 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, CLICK 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

245	Only data from participants who completed the questionnaire were analysed. The
246	normality of the data distribution was evaluated using the Shapiro-Wilk test. Normally
247	distributed data ($p > .05$) were analysed parametrically and presented as mean (±
248	standard deviation $[SD]$ and range $[R]$). When data were not normally distributed, they
249	were analysed non-parametrically and presented as the median (interquartile range
250	[IQR], 25–75%). Differences between groups (with and without PDPS, smaller and
251	greater flexion angles, fast and slow onset, fast and slow disappearance) in continuous
252	characteristics were analysed using Student's <i>t</i> -test (normally distributed data) or the
253	Mann–Whitney U-test (non-normally distributed data). Differences in dichotomous
254	characteristics were analysed using the Fisher's exact test. A priori, a significance level
255	of p < .05 was established as the criterion for statistical significance. The effect sizes
256	(ES) for normally distributed data were calculated using Cohen's d to determine the
257	magnitude of the differences. For non-normally distributed data, ES r using the formula
258	$r = Z/\sqrt{(n_a + n_b)}$, with Z being the Z-score from the Mann-Whitney U test and n_a and
259	n_b being sample sizes of both groups, has been determined [19]. For dichotomous
260	variables <i>Phi</i> has been calculated based on the chi-square statistic χ^2 [19]. An <i>ES</i> of 0.2,
261	0.5, and \geq 0.8 was considered small, medium, and large, respectively [20]. Statistical
262	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]

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267	1], VAS-W <3 [$n = 8$], and non/partial respondents [$n = 8$]) (Supplementary Figure 1).
268	The remaining 87 (81%) subjects were eligible for inclusion (61 [70%] females, mean
269	age 22.0 years [IQR 4.0], BMI 23.1 [IQR 4.7]).
270	Based on the responses to item 8 of the AKPS, 63 (72%) participants reported PDPS
271	(Table 2). More participants with PDPS had bilateral symptoms (71%), compared to
272	those without PDPS (46%) ($p = .044$). Participants with PDPS demonstrated a median
273	total score on the AKPS that was 12 points lower when compared to participants
274	without PDPS, a difference that was statistically significant (small to medium ES
275	[0.41]). This included statistically significant lower scores on items 3 'walking' (small
276	ES [0.31]), 5 'squatting' (small ES [0.28]), 8 'prolonged sitting' (medium ES [0.51]),
277	and 9 'pain' (small <i>ES</i> [0.24]). Most participants with PDPS ($n = 52$ [85%]) reported
278	symptoms that occurred when the knees were flexed to 90° or beyond. Only a small
279	proportion ($n = 9$ [15%]) of participants with PDPS experienced symptoms in smaller
280	knee flexion positions (0° or 45°). Two participants with PDPS omitted this item.
281	
282	Table 2. Baseline characteristics of the participants
	Characteristics Participants Participants P-value ES

Table 2. Baseline characteristics of the participants

Characteristics	Participants with PDPS	Participants without PDPS	<i>P</i> -value	ES
Participants, n (%)	63 (72)	24 (28)	n/a	n/a
Female, <i>n</i> (%)	46 (73)	15 (63)	.433	Phi = 0.10
Age (years)	22.0	23.0	.242	r = 0.13
	(IQR 6.0)	(<i>IQR</i> 9.3)		
BMI (kg/m ²)	23.5	21.7	.207	r = 0.14
	(IQR 4.9)	(IQR 4.0)		
Sport participation (h/week)	3.0	3.5	.466	r = 0.08
	(<i>IQR</i> 3.0)	(IQR 1.9)		
Tegner Score (0–10)	4.0	5.0	.138	<i>r</i> = 0.16
	(<i>IQR</i> 3.0)	(IQR 2.0)		
VAS-W (0-10)	6.0	5.0	.212	r = 0.13
	(<i>IQR</i> 3.0)	(IQR 2.0)		

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

284 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 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.

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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 flexionangles

Characteristics	Smaller flexion angle (< 90°)	Greater flexion angle (≥ 90°)	<i>P</i> -value	ES
Participants, n (%)	9 (15)	52 (85)	n/a	n/a
Female, <i>n</i> (%)	7 (78)	37 (71)	.515	Phi = 0.
Age (years)	20.0	22.0	.018	r = 0.30
	(<i>IQR</i> 4.0)	(<i>IQR</i> 5.8)		
BMI (kg/m ²)	23.2	23.8	.190	r = 0.17
	(<i>IQR</i> 4.8)	(IQR 5.2)		
Sport participation (h/week)	3.0	3.6	.400	d = 0.11
	$(SD \pm 2.1, R \ 6.0)$	$(SD \pm 2.2, R \ 10.0)$		
Tegner Score (0–10)	4.0	4.0	.452	r = 0.10
	(<i>IQR</i> 5.0)	(<i>IQR</i> 3.0)		
VAS-W (0-10)	7.0	5.0	.002	r = 0.39
	(<i>IQR</i> 1.0)	(<i>IQR</i> 3.0)		
Bilateral PFP, n (%)	9 (100)	36 (69)	.096	Phi = 0
Symptom duration (months)	48.0	38.0	.445	r = 0.10
	(IQR 74.5)	(IQR 64.0)		
AKPS (0-100)	66.0	77.0	.005	r = 0.36
	(<i>IQR</i> 13.5)	(IQR 13.0)		
TSK (17–68)	36.0	32.0	.029	r = 0.28
	(IQR 14.5)	(<i>IQR</i> 8.0)		
VAS-W sitting (0–10)	6.8	5.0	.001	r = 0.41
	(<i>IQR</i> 1.1)	(<i>IQR</i> 3.0)		

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.

305 Data are presented as numbers (percentages), mean (\pm standard deviation [*SD*] and range [*R*]), or median (interquartile range 25%-306 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,

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

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

Characteristics	Fast-onset	Slow-onset	P -value	ES
	(≤ 10 min)	(> 10 min)		
Participants, n (%)	14 (32)	30 (68)	n/a	n/a
Female, <i>n</i> (%)	8 (57)	22 (73)	.316	Phi = 0.16
Age (years)	21.5	22.0	.577	r = 0.08
	(<i>IQR</i> 7.0)	(<i>IQR</i> 6.3)		
BMI (kg/m ²)	24.0	24.0	.821	<i>r</i> = 0.03
	(<i>IQR</i> 3.0)	(IQR 5.9)		
Sport participation (h/week)	3.1	3.0	.934	<i>d</i> = 0.03
	$(SD \pm 2.1, R 6.0)$	$(SD \pm 2.0, R\ 7.0)$		
Tegner Score (0–10)	4.0	3.0	.096	<i>r</i> = 0.25
2	(<i>IQR</i> 2.3)	(<i>IQR</i> 4.0)		
VAS-W (0–10)	7.0	5.0	<.001	r = 0.50
	(<i>IQR</i> 2.0)	(<i>IQR</i> 3.0)		
Bilateral PFP, n (%)	10 (71)	24 (80)	.701	Phi = 0.10
Symptom duration (months)	42.0	40.0	.696	r = 0.06
• •	(IQR 87.0)	(IQR 48.0)		
AKPS (0-100)	68.0	74.0	.109	r = 0.24
× ,	(IQR 10.0)	(<i>IQR</i> 16.3)		
TSK (17–68)	32.5	32.5	.940	r = 0.01
	(<i>IQR</i> 8.0)	(<i>IQR</i> 10.5)		
VAS-W sitting (0-10)	6.0	5.0	.038	r = 0.31
(10)	(<i>IQR</i> 2.0)	(<i>IQR</i> 4.0)		. 0.51

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 (\pm standard deviation [SD] and range [R]), or median (interquartile range 25%-75% [IQR]).

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

Characteristics	Fast-	Slow-	P -value	ES
	disappearance	disappearance		
	$(\leq 10 \text{ min})$	(> 10 min)		

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Participants, n (%)	25 (57)	19 (43)	n/a	n/a
Female, <i>n</i> (%)	16 (64)	14 (74)	.534	Phi = 0.10
Age (years)	22.0	20.0	.229	<i>r</i> = 0.18
	(<i>IQR</i> 6.0)	(IQR 5.0)		
BMI (kg/m ²)	24.1	22.4	.112	r = 0.24
	(<i>IQR</i> 4.1)	(IQR 5.0)		
Sport participation (h/week)	3.6	2.3	.036	d = 0.66
	$(SD \pm 2.0, R\ 7.0)$	$(SD \pm 1.9, R \ 6.0)$		
Tegner Score (0–10)	4.0	3.0	.197	<i>r</i> = 0.19
	(<i>IQR</i> 3.0)	IQR (2.0)		
VAS-W (0–10)	5.0	6.0	.379	<i>r</i> = 0.13
	(<i>IQR</i> 3.0)	(<i>IQR</i> 2.0)		
Bilateral PFP, <i>n</i> (%)	17 (68)	17 (90)	.148	Phi = 0.25
Symptom duration (months)	36.0	42.0	.406	<i>r</i> = 0.13
	(IQR 54.5)	(IQR 60.0)		
AKPS (0-100)	74.0	67.0	.005	r = 0.43
	(IQR 16.0)	(IQR 12.0)		
TSK (17–68)	32.0	33.0	.374	<i>r</i> = 0.13
	(IQR 8.0)	(IQR 14.0)		
VAS-W sitting (0–10)	5.0	6.0	.156	r = 0.21
	(<i>IQR</i> 4.0)	(IQR 2.0)		
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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% [IOR]). Zie.

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

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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'.

357 Higher levels of problems with squatting were also identified in the PDPS group by

358 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

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364	and analysed as a distinct category. In contrast, Collins et al. considered this subgroup
365	as a distinct category in their study [3]. Another reason for not confirming these
366	findings could be the smaller sample size in the current study $(n = 87)$ compared to that
367	in the study by Collins et al. $(n = 458)$ [3].
368	A smaller proportion of participants with PDPS reported experiencing knee pain at
369	smaller flexion angles, and with faster onset of PDPS. They also reported higher pain
370	levels (VAS-W and VAS-W sitting). Various theories have been proposed to explain
371	the underlying mechanisms of PDPS in subjects with PFP. Biomechanical theories often
372	attribute PFP to increased PFJRF. While PFJRF are not entirely absent during sitting,
373	they are expected to be lower than 0.9 times bodyweight [4], with an even greater
374	reduction likely in subjects with PDPS at smaller knee flexion angles. Although the
375	patellofemoral contact area decreases in smaller flexion angles, overall, increased
376	PFJRF seems to be a less satisfactory explanation for PDPS. The homeostasis model
377	[24] may be a more suitable construct because it proposes disturbed homeostasis of
378	osseous and soft tissues in the anterior knee after supraphysiologic loading.
379	Homeostatic disturbance is then induced by vascular stress and stretching of the
380	peripatellar anastomotic ring, resulting in increased intraosseous water content and
381	pressure of the patella, and triggering a cascade of ischaemic nociceptive responses
382	[6,7,25–30]. This would not only explain the delayed onset of PDPS but also the shorter
383	time for disappearance of PDPS after prolonged sitting.
201	Possarch and clinical implications

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Research and clinical implications

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

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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**

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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.

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

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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, IOR 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.

456	
457	CONCLUSION
458	Participants with PDPS more often reported bilateral PFP and higher levels of disability.
459	PDPS typically occurred when the knees are flexed 90 degrees or beyond. Participants
460	identified a delayed onset of PDPS occurring after 16 to 20 minutes, whereas the time
461	for its disappearance was shorter, between 6 to 10 minutes. Younger participants with
462	PDPS at smaller knee flexion angles reported higher pain, disability, and kinesiophobia
463	than those with PDPS at greater flexion angles. Additionally, participants with faster
464	onset of PDPS experienced higher pain levels, while those with slower PDPS
465	disappearance were less physically active and had greater disability than those with
466	faster disappearance. This study provides a detailed description of the characteristics of
467	PDPS as experienced by subjects with PFP. Future research should focus on
468	understanding the underlying mechanisms of PDPS and developing targeted
469	interventions to improve long-term outcomes in subjects with PFP.
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STATEMENTS

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489	
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490 491 492	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.
490 491 492 493	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
490 491 492 493 494	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

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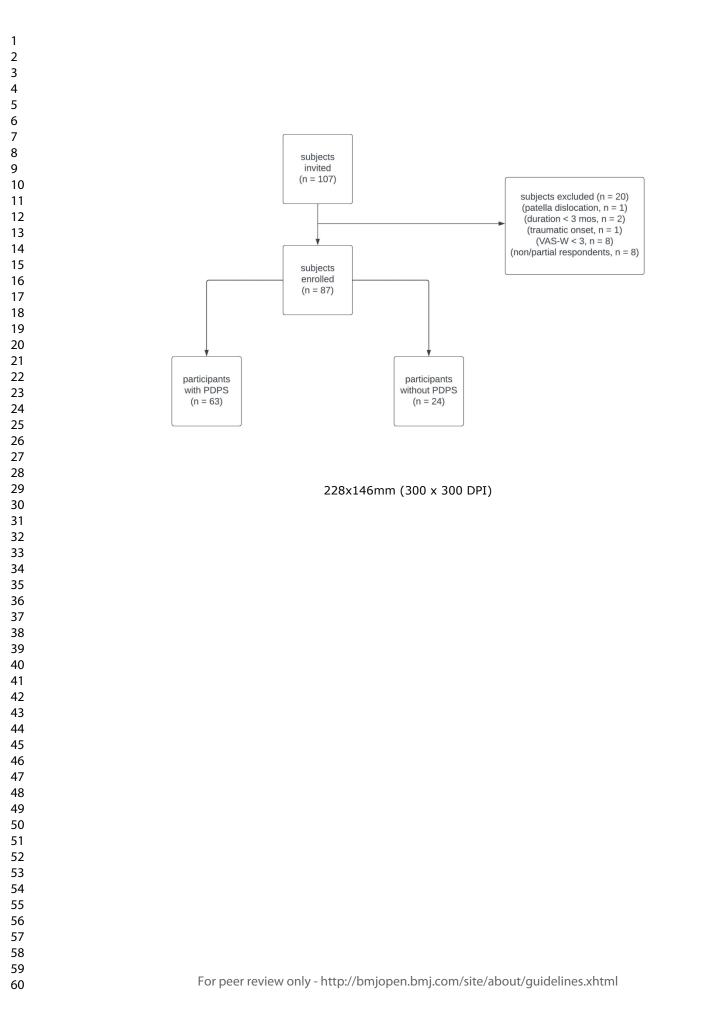
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629 Captions of illustrations

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

to perteries only



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ONLINE SUPPLEMENTARY FILE 1

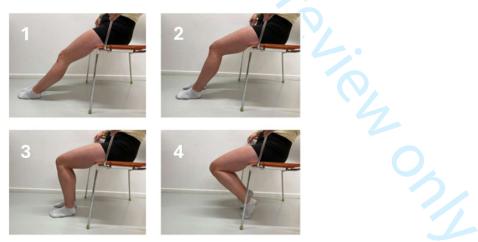
PDPS QUESTIONNAIRE (Part 3 'Characteristics of PDPS')

Item 1: What was the <u>worst sitting pain</u> 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?

- \circ I experience knee pain if my knee is in a 0° bent position (picture 1).
- \circ I experience knee pain if my knee is in a 45° bent position (picture 2).
- \circ I experience knee pain if my knee is in a 90° bent position (picture 3).
- \circ 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?

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

\circ > 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?

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