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Pain, Sports Participation, and Physical Function in Adolescents With Patellofemoral Pain and Osgood-Schlatter Disease

A Matched Cross-sectional Study

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- 1 **Pain, sports participation, and physical function in 10-14 years olds with Patellofemoral Pain and**
- 2 **Osgood Schlatter: A matched cross-sectional study of 252 adolescents**
- 3

4 **Abstract**

5 **Background:** Patellofemoral pain (PFP) and Osgood Schlatter (OSD) are common in adolescents,
6 but we lack knowledge on these conditions and their impact in young adolescents (<15 years).

7 **Objectives:** Compare pain, physical activity, quality of life, strength and knee function between
8 adolescents with PFP or OSD, compared to pain-free controls.

9 **Methods:** Self-report questionnaires were used to describe pain, physical activity, knee function,
10 and quality of life in participants with PFP (N=151), OSD (N=51), and pain-free controls (N=50)
11 aged between 10 and 14 years. Hip and knee strength were measured by handheld dynamometry.
12 Physical activity levels were measured using wearable accelerometers.

13 **Results:** More than 98% with PFP or OSD participated in sports prior to knee pain, and 60%
14 reported reduced sports participation due to pain. Despite this, the adolescents were highly active
15 (accumulating >120min vigorous physical activity per day), with no differences between OSD, PFP,
16 or controls.

17 Adolescents with knee pain (PFP and OSD) scored 23-57 points lower than controls ($P<0.001$) in
18 the Knee Osteoarthritis Outcome Score. Adolescents with OSD had lower knee extension strength
19 compared to controls ($P<0.05$, effect size (ES) 1.25). In the PFP group, only females displayed
20 lower hip abduction strength compared to female controls ($P<0.05$, ES 0.49). Both girls and boys
21 with PFP had lower hip extension strength compared to controls ($P<0.05$, ES 0.73).

22 **Conclusion:** Adolescents with PFP or OSD are characterized by high physical activity levels, despite
23 impaired sports participation and knee function relative to pain-free controls.

24 **Key Terms:** adolescents; musculoskeletal pain; anterior knee pain; knee function

25

26 **What is known about the subject: Please state what is currently known about this subject to**
27 **place your study in perspective for the reviewers.**

28 Adolescent knee pain is common. The two most common knee complaints are
29 Patellofemoral Pain and Osgood Schlatter. Patellofemoral pain presenting as retro or
30 peri patellar pain in the absence of other identifiable pathologies which is aggravated
31 by activities which load the patellofemoral joint (e.g. squatting, descending stairs).
32 On the other hand, OSD is a traction apophysitis of the tibial tuberosity during
33 growth, characterized by pain and swelling localized at the tibial tuberosity.

34

35 **What this study adds to existing knowledge: Please state what this study adds to the existing**
36 **knowledge.**

37 Adolescents' with Patellofemoral Pain and Osgood Schlatter are characterized by
38 impairments in sports participation, knee function and quality of life. More than 1 of
39 2 adolescents with PFP or OSD reduced their sports participation due to knee pain.
40 Despite these impairments, adolescents continue with high levels of physical activity.
41 Adolescents with PFP demonstrated reduced hip extension strength. However, only
42 females with PFP and OSD had lower hip abduction strength compared to female
43 controls.
44 Adolescents with OSD demonstrated reduced knee extension strength compared to
45 their matched healthy counterparts.

46

47 **Introduction**

48 Knee pain affects one in three adolescents, making it one of the most common sites of pain¹.

49 Persistent knee pain is associated with reduced quality of life and physical activity². Perhaps due
50 to its commonality, knee pain is sometimes considered to be self-limiting with no long-term
51 impact. However, data indicates this does not appear to be the case, with many continuing to
52 have pain into adulthood^{3,4}.

53

54 There is a four-fold increase in the years lived with disability due to musculoskeletal conditions
55 during the transition from childhood to adolescence⁵. In the same period, there is a corresponding
56 8-fold increase in the number of contacts to general practice due to knee symptoms^{6,7}.

57 Approximately 6 -7% of the adolescent population are affected (with varying severity) by

58 patellofemoral pain (PFP)^{8,9}, while around 10% are affected by Osgood Schlatter -also known as

59 Osgood Schlatter Disease (OSD)¹⁰. Despite the high prevalence of these conditions, there is

60 limited information regarding their impact and associated deficits in adolescents, and particularly

61 in young adolescents. This lack of knowledge presents a barrier to developing evidence-informed

62 treatment strategies for young adolescents with PFP and OSD. OSD is thought to be related to

63 maturation of the tibial tuberosity with incidence peaking between ages 12 to 13¹¹, with the

64 incidence of PFP is also highest during maturation¹². Despite this, there is little data examining

65 knee conditions in this age-group⁸.

66 Both PFP and OSD are characterized by anterior knee pain during knee joint loading, and are

67 aggravated by physical activity and sports participation^{13,14}. PFP often has a diffuse presentation

68 of pain around the patella, while patients with OSD experience pain localized to the tibial

69 tuberosity^{13,14}. Nearly one in two adolescents with PFP report having knee pain after five years

70 severe enough to impact sports participation⁴. In comparison, OSD has often been described as
71 typically lasting between 12 and 24 months with more than 90% having no residual symptoms at
72 all¹³.

73
74 Understanding differences between adolescents with PFP and OSD and their respective deficits
75 compared to adolescents without knee pain provides information on two of the most common
76 knee complaints in adolescents. Ultimately, this may help identify future treatment targets for
77 these conditions.

78
79 The aim of this matched cross-sectional study is to describe potential differences in pain, physical
80 activity, quality of life, strength and physical function in adolescents between 10 and 14 years of
81 age diagnosed with either PFP or OSD, compared to pain free controls. Specifically, self-reported
82 pain and function, quality of life, physical activity and hip and knee strength were assessed.

83

84

85 **Methods**

86 **Study design**

87 This study was designed as a cross-sectional study, embedded within two single cohort studies of
88 PFP and OSD (NCTXXXXXXX and NCTXXXXXXX). This cross-sectional exploratory analysis compares
89 50 pain-free adolescents with 151 adolescents diagnosed with PFP and 51 adolescents with OSD.
90 All three groups were recruited from local schools, social media and general practice. The study
91 was approved by the Ethics committee of XXXXXXX (N-XXXX-XXXX) and the Data Protection
92 Agency. All participants were required to have parental written informed consent. The study was

93 conducted according to the Declaration of Helsinki. The reporting of the study follows the
94 'Strengthening the Reporting of Observational studies in Epidemiology' (STROBE) statement¹⁵.
95 The data included were from the two prospective cohort studies, collected at inclusion specifically
96 for the purpose of this cross-sectional investigation. Baseline pre-treatment measures were
97 collected when the intervention was initiated (two weeks after inclusion) and thus are not
98 presented in the current study. The baseline data from participants with PFP are published in a
99 prospective study investigating the effect of activity modification and load management¹⁶. Pain
100 drawings (i.e. pain location) for those with PFP have been included as part of a larger study
101 investigating pain patterns in patients from the age of 10 to 40 years of age¹⁷.

102

103 **Recruitment**

104 Between March 2015 and April 2017 students (aged 10-14 years) from local schools were invited to
105 answer an online questionnaire on musculoskeletal pain, including knee pain. This was
106 supplemented by using social media to recruit adolescents with knee pain, and controls without
107 knee pain. Potentially eligible adolescents (i.e. those reporting knee pain via the questionnaire or in
108 response to recruitment adverts on social media) were subsequently screened by telephone and
109 invited for a clinical examination if PFP or OSD could not be excluded by phone interview.

110

111 **Participants and diagnostics**

112 The clinical examination was conducted by one of two physiotherapists (with four and seven years
113 of clinical experience). Diagonosis was made using a predefined set of criteria for either PFP or OSD
114 (outlined below).

115

116 The diagnosis for PFP was made according to established recommended criteria^{7,13} as follows:
117 Insidious onset of anterior or retro-patellar knee pain for more than 6 weeks and provoked by at
118 least two of the following positions or functions: prolonged sitting or kneeling, squatting, running,
119 hopping or stair climbing and tenderness on palpation of the patella, or pain with stepping down or
120 double leg squatting. In addition, participants were required to report more than 30 mm on a 100
121 mm Visual Analogue Scale (VAS) for worst pain experienced during the previous week.

122

123 The criteria used to diagnose OSD was in line with the literature, and included participants reporting
124 current pain and tenderness at the tibial tuberosity, pain upon palpation of the tibial tuberosity and
125 pain with resisted isometric knee extension¹³. Exclusion criteria for both PFP and OSD were
126 determined through patient's medical history and clinical examination and included: Sinding-
127 Larsen-Johansson disease, concomitant injury or pain from the hip, lumbar spine, or other
128 structures of the knee (e.g. tendinopathy); previous knee surgery; patellofemoral instability; knee
129 joint effusion and contraindications to MRI scan (for PFP group and included to ensure no serious
130 pathology was missed).

131

132 Inclusion criteria for the pain-free controls were: no current self-reported musculoskeletal pain, no
133 self-reported prior surgery in the lower extremity, no self-reported neurological or medical
134 conditions, and no contraindications to MRI scan. Furthermore, at the time of screening controls
135 were required to have a similar sports participation to those with knee pain to prevent differences
136 being detected due to comparing to a population with lower levels of sports participation. The aim
137 was to have groups that were comparable on whether or not they were sports active (yes/no) and
138 secondly, on the approximate amount of weekly sports participation. This was done to the best of

139 the ability of the two assessors during the telephone screening before testing. Control participants
140 were also matched by age (age 10-14 years). The proportion of females included in the control
141 group was targeted to be approximately between that of those with PFP and OSD, to prevent a
142 significantly different proportion of female controls from either the PFP or OSD groups.

143

144 **Data collection**

145 The testers (XX and XX) had previous experience testing adolescents. Assessors were not blinded
146 to status of the participant (PFP, OSD or control). Information from previous non-structured
147 interviews with adolescents and parents informed choice of outcome domains. Based on these,
148 limitations in sports and physical activity were considered the most important domain. Additional
149 domains of interest were pain and knee function.

150 Quality of life, knee and hip strength were collected as part of the researchers' interest to inform
151 future research and interventions. All data were collected at inclusion, before any intervention or
152 treatment was prescribed. Groups were assessed on the following domains: physical activity and
153 sports participation, pain symptoms, knee function, quality of life and isometric strength. All
154 procedures were pilot tested on adolescents (with and without knee pain) before initiation of the
155 study.

156

157

158 Height and weight

159 Bodyweight was measured using a weighing scale. Height was measured using a measurement
160 tape taped to a wall, with participants standing against the wall in their bare feet. Body Mass

161 Index (BMI) was calculated based on this.

162

163 Collection of self-report data

164 Self-report questionnaires included data on physical activity and sport, pain, function and quality
165 of life (outlined below). If participants with PFP or OSD had bilateral pain, they were instructed to
166 answer about their most painful knee.

167

168 Sports participation

169 Participants were asked to report their current sports participation (type, duration and frequency
170 per week), and prior to onset of knee pain (PFP and OSD only). If participants had reduced or
171 stopped sports due to knee pain, they were asked if they desired to return to their previous level
172 of sport. Questions were piloted in a similar age group before this study to ensure
173 comprehensibility.

174

175 Physical activity data

176 Objective measures of physical activity were captured by a wrist worn Actigraph GT3X+
177 (ActiGraph, Pensacola, FL) recording at 30 Hz. ActiGraphs are commercially available 3-axis
178 accelerometers, validated for collecting physical activity¹⁸. Accelerometers such as ActiGraphs are
179 wearable devices that measure accelerations, which are filtered and processed to obtain activity
180 counts, i.e. accelerations due to body movement. These are used to calculate time spent in
181 activities of differing intensities, by classifying activity counts in specific time intervals (epoch
182 lengths) according to predefined thresholds.

183 Adolescents were instructed to wear the ActiGraph on the wrist of their non-dominant arm for a
184 week after inclusion, and not to remove it unless deemed unsafe during specific activities (e.g.

185 taekwondo, water-polo). Data were analyzed using ActiLife, a commercially available software
186 package. Raw data were converted into files with 10s epoch length for subsequent wear time
187 validation and intensity classification. Non-wear time was defined as bouts of greater than or
188 equal to 60minutes of consecutive zero counts (defined as less than or equal to 100counts/min),
189 allowing interruptions of up to two consecutive non-zero counts (defined as 2 epochs of >100
190 counts per min). Adolescents were told to record the type of activity missed by the ActiGraph
191 during non-wear. A valid day was defined as 600 valid wear-time minutes per 24 h, and four valid
192 days required for analysis. The Evenson et al¹⁹ cut-points were used for categorizing sedentary (0 -
193 100 counts/min), light (101 - 2295 counts/min), moderate (2296 - 4011 counts/min) and vigorous
194 (4012 - ∞ counts/min) intensity physical activity, as per previous research in children and
195 adolescents¹⁸. The time spent in consecutive sedentary bouts of greater than or equal to 10 mins
196 were used to calculate average weekly sedentary time. In addition, whether or not participants
197 met the WHO weekly physical activity recommendations (i.e. >150 mins moderate to vigorous
198 physical activity (MVPA) or greater than 75mins vigorous activity) was calculated.

199

200 Pain and symptoms

201 To assess pain and symptoms, the respective subscales from the Knee Injury and Osteoarthritis
202 Outcome Score (KOOS) were used²⁰. This questionnaire was chosen as it has previously been used
203 in young adolescents with knee pain^{8,21}. Health related quality of life was measured by the youth
204 version of the European Quality of Life 5 dimensions (EQ-5D Y)²².

205 Participants also reported their worst pain in the past week on a numeric rating scale, ranging
206 from zero to ten, from 'no pain' to 'worst pain imaginable'. Pain duration was determined by the
207 question "for how long have you experienced knee pain" (open-ended, and subsequently

208 calculated in months).

209

210 Self-reported function and quality of life

211 The patient-reported questionnaire Knee Injury and Osteoarthritis Outcome Score (KOOS)²⁰ (adult

212 version) which contains five separate subscales (Pain, Symptoms, Activity in Daily Living (ADL),

213 Function in Sport and Recreation (Sport/Rec), knee-related quality of life (QoL).

214

215 Hip and knee muscle strength

216 Isometric knee extension strength and hip abduction strength were recorded for all adolescents.

217 Hip extension strength was assessed in PFP and controls only. Strength was measured in the

218 symptomatic knee or most symptomatic knee in the cases of bilateral pain. In pain-free

219 adolescents, it was randomly chosen if right or left leg was the test leg. Three consecutive strength

220 measurements were taken for all participants. The testing setup included a handheld

221 dynamometer and an examination table. Muscle strength was tested using a Power Track

222 Commander handheld dynamometer (JTech Medical, Salt Lake City, Utah), fixed to the

223 examination bed by a belt. All strength tests were conducted isometrically and have previously

224 been shown to be reliable^{21,23}. Average force output of the three tests (Newtons) was

225 subsequently multiplied by lever length to calculate torque, which was then normalized to

226 bodyweight. Lever length for hip abduction was measured from anterior superior iliac spine to the

227 position of the dynamometer at the lateral side of the lower leg, (5 cm above the lateral

228 malleolus). Lever length for knee extension was measured as the knee joint line to the position of

229 the dynamometer 5 cm above the medial malleolus. Lever length for hip extension was measured

230 from trochanter major to the position of the dynamometer 5 cm above the popliteal fossa.

231

232 During knee extension, the dynamometer strap was positioned 5 cm proximal to the medial
233 malleolus, perpendicular to the anterior or posterior aspect of the tibia. Knee extension was
234 tested in 60 degrees of knee flexion. For hip abduction, participants were lying supine on an
235 examination table with the leg in 0 degrees flexion and 0 degrees abduction. The strap was
236 positioned 5 cm proximal to the medial malleolus perpendicular to the medial or lateral aspect of
237 the tibia. Hip extension, was measured using the short lever version described by Thorborg et al²³,
238 with a strap to fixate the dynamometer at the posterior thigh.

239

240 Participants were instructed to stabilize themselves by holding on to the sides of the examination
241 table during strength testing. A cloth was placed between their legs and the strap from the
242 dynamometer to reduce pain from the pressure created by the dynamometer. After receiving
243 standardized instructions participants performed two sub-maximal practice trials. Afterwards, the
244 individual test was administered three times, with approximately 1 minute between each test. The
245 maximal voluntary contraction was initiated by a standardized command given by the examiner:
246 ‘Go ahead-push-push-push-push and relax’ corresponding to approximately 5 seconds to ensure
247 adequate time to generate maximal force.

248

249 **Sample size considerations**

250 No formal sample-size calculation was conducted for this cross-sectional study, as no data exists
251 on young adolescents with PFP and OSD compared to pain-free controls. The final sample-size was
252 a convenience sample, determined by the number of adolescents with PFP and OSD that was
253 enrolled in one of two prospective cohort studies (NCTXXXXXXXX and NCTXXXXXXXX) with the aim

254 of investigating the clinical effect of load-management intervention in adolescents with PFP and
255 OSD.

256 **Statistical analysis**

257 Data were visually inspected for approximate normality using a Q-Q plot. Mean values and
258 standard deviations are reported for normally distributed data. Non-normally distributed data are
259 presented as median and interquartile range (IQR). Data on physical activity and sport are
260 described descriptively. KOOS and EQ5D scores were analyzed using a one-way analysis of
261 variance (ANOVA) and LSD hoc test to test the difference in between groups (control vs OSD vs
262 PFP). A two-way ANOVA was used to investigate the effect of group (control versus PFP versus
263 OSD) and sex (male versus female) and the group * sex interaction on isometric strength
264 measures. Effect size (ES) of the differences in isometric hip and knee strength were calculated
265 using Cohens *d* with $ES > 0.80$ being considered as large²⁴. Sex was included in the model for
266 strength measures due to previously documented sex-specific differences in strength²⁵.

267

268 Based upon peer-review comments a regression model was constructed to investigate which of
269 the measures were most strongly associated with KOOS sport/rec. This was done using linear
270 regression to estimate the association between sex, worst pain last week, isometric strength,
271 diagnosis and KOOS sport/rec. Univariable analyses were initially performed and variables of
272 $P < 0.15$ in the univariable analyses were included in the multi-variable model²⁶. A separate
273 regression model was also developed for the PFP group only to allow for the inclusion hip
274 extension strength data. All calculations were performed using Stata version 11 (StataCorp,
275 College Station, Texas, USA) and SPSS v. 21 (IBM Corp, Armonk, New York, USA). Significance was
276 accepted for P-values less than 0.05.

277 **Results**

278 Demographics

279 Two hundred and fifty-two adolescents (151 with PFP, 51 with OSD and 50 pain-free controls) age
280 10 and 14 years were recruited and tested (Figure 1). We assessed 85 controls for eligibility, of
281 which 35 were excluded: 34 due to not being a match, and 1 for reporting knee pain during phone
282 screening.

283

284 Age was similar across the three groups (Table 1). One third of those with knee pain had
285 previously received treatment for knee pain. The reported treatments were: treatment by
286 physiotherapist (14/51), acupuncture (3/51) and shockwave (2/51) in those with OSD, and
287 treatment by physiotherapist (34/151), acupuncture (4/151) and painkillers (2/151), in
288 adolescents with PFP.

289

290 Sports participation and objective physical activity

291 Almost all adolescents with PFP and OSD reported participating in sports prior to onset of their
292 knee pain (98% and 100%, respectively). More than 50% reported reducing their sports
293 participation, with the most common causes being “pain” and “I am afraid to damage my knee”.
294 Nine percent of adolescents with PFP reported a complete stop of sports due to knee pain,
295 compared with 26% of adolescents with OSD. All adolescents except one had a desire to return to
296 sport (Table 2). Using objective measure of physical activity from the ActiGraphs, there were no
297 differences between groups in average time spent in sedentary, light, moderate or vigorous
298 physical activity (Table 2). (Based on ActiGraph data from 132 with PFP; 36 with OSD and 48

299 controls. Loss of data due to ActiGraph malfunctioning / data could not be properly extracted from
300 the device/excluded due to non-wear-time).

301

302 Pain and symptoms

303 Adolescents with PFP and OSD reported pain for an average of 21 months. Pain and symptoms are
304 reported in Table 3.

305

306 Function and quality of life

307 There was a significant difference between groups for KOOS ADL ($F= 55$; $p <0.001$), KOOS sport
308 and recreation ($F=52$; $p <0.001$) and KOOS quality of life ($F= 217$; $p <0.001$). Post hoc pairwise
309 comparisons revealed adolescents with OSD or PFP were lower than pain free controls ($P <0.001$;
310 mean differences in Table 4). Adolescents with OSD had significantly lower KOOS Scores compared
311 to adolescents with PFP in quality of life domain ($P <0.05$) (Table 4) but not in ADL or sport/rec
312 domains ($p >0.05$).

313 EQ 5D scores were significantly different between groups ($F=56$; $p <0.001$). Compared to controls,
314 the EQ 5D index score was significantly lower in both the PFP (mean difference = 0.38, 95% CI 0.31
315 to 0.45; $p <0.001$) and OSD (mean difference = 0.37, 95% CI 0.28 to 0.46; $p <0.001$) groups (Table
316 4). There was no difference between OSD and PFP groups ($p=0.762$; Table 4).

317 There was a significant sex*group interaction for hip abduction strength ($(F=3.9)$; $p=0.02$), Post
318 hoc testing revealed a simple main effect of group on hip abduction scores which was statistically
319 significant for females ($F=7.7$; $p=0.001$) but not males. Compared to control females, hip abduction
320 strength was significantly lower for females with OSD (mean difference = 0.41, 95%CI 0.20 to 0.61;

321 $p < 0.001$, ES 1.16 95%CI 0.57-1.73; Figure 2) and PFP (mean difference = 0.21, 95% CI 0.06 to 0.36,
322 $p < 0.01$, ES 0.49 95%CI 0.08-0.88) with no differences between males ($p = 0.398$).

323 For knee extension strength, there was not a significant interaction ($p > 0.05$), but there was a
324 significant main effect for group ($F = 19$; $p < 0.001$). The group with OSD had significantly reduced
325 knee extension strength compared to controls (mean difference = 0.65, 95% CI 0.39 to 0.92
326 $p < 0.001$, ES 1.25 95%CI 0.82-1.68) and those with PFP (mean difference = 0.65, 95% CI = 0.43 to
327 0.87; $p < 0.001$, ES 0.99 95%CI 0.64-1.32; Figure 2). There were no differences between PFP and
328 controls for knee extension strength ($p = 0.986$).

329 For hip extension strength, there was no sex * group interaction. There was significant difference
330 between groups, with lower strength in the PFP group compared to controls ($F = 17$; $p < 0.001$;
331 mean difference = 0.36, 95% CI 0.18 to 0.53, ES: 0.73 95% CI 0.40-1.05; Figure 2).

332

333 Factors associated with KOOS sport/rec

334 In the univariable analyses, higher knee extension torque was associated with higher KOOS
335 sport/rec, while higher 'worst pain in the past week' was significantly associated with lower KOOS
336 sport/rec (Table 5a). After adjustment in the multivariable model, higher 'worst pain in the past
337 week' and OSD diagnosis remained significantly associated with lower KOOS Sport/Rec Scores.

338 Knee extension torque was not significantly associated with KOOS Sport/Rec in the multivariable
339 model (Table 5a).

340 When examining PFP only, univariable analyses indicated sex, hip extension torque, and 'worst
341 pain in the past week' were associated with KOOS sport/rec scores (Table 5b). Female sex, higher
342 'worst pain in the past week', and lower hip extension torque were associated with lower KOOS
343 sport/rec scores in the PFP group. Except sex, these associations remained significant in the

344 multivariable model. Table 5a and 5b demonstrate the unadjusted coefficients from the
345 univariable models, as well as the adjusted coefficients and p-values for the variables which
346 remained significant in the multivariable model after accounting for other factors.

347

348 **Discussion**

349 This is the first cross-sectional study to characterize pain, physical activity and knee function in 10-
350 14-year-old adolescents diagnosed with PFP and OSD. This study demonstrates that these two
351 common knee pain complaints in young adolescents (PFP and OSD) impact pain, self-reported
352 sports participation, physical function and quality of life. While participants reported having to
353 stop or reduce sport due to knee pain, the ActiGraph data demonstrate that the participants were
354 still very physically active, accumulating approximately two hours of vigorous physical activity (e.g.
355 jogging, fast bicycling, or a soccer game) per day. Strength deficits were identified between
356 groups, but sex was not a factor in the relative hip extension strength deficits identified in PFP.
357 Regardless of sex, adolescents with PFP demonstrated reduced hip extension strength compared
358 to pain free controls, however only females (with PFP and OSD) had lower hip abduction strength
359 compared to female controls. Adolescents with OSD demonstrated reduced knee extension
360 strength compared to their matched healthy counterparts.

361

362 Despite the young age of the participants, the impact of pain on sports and physical function is
363 similar to what has been seen in older adolescents with PFP (aged 15 - 19 years)⁸. Almost all
364 adolescents reported participating in sport prior to the onset of their knee pain, and the majority
365 reduced their participation due to pain. In contrast, in older adolescents with PFP, only two out of
366 three adolescents with PFP participated in sports⁸. As older adolescents with PFP also reported a

367 longer duration of symptoms, this may explain the differences in sports participation.

368

369 In this study, one in every four adolescents with PFP used painkillers. Interestingly, use of pain
370 medication among adolescents with OSD was half this, despite worse symptoms and larger
371 reductions in sports participation due to pain. The reason for the difference between the
372 populations is unclear, and may warrant further examination.

373

374 In PFP, higher hip extension torque was associated with higher KOOS sport/rec scores. Hip
375 abduction torque was not associated with KOOS sport/rec scores. A recent systematic review
376 including both adolescents and adults, highlighted that low hip muscle strength may be a
377 consequence of PFP, rather than the cause²⁵. Interestingly, a previous smaller study found no
378 difference in quadriceps strength between kids between the age of 11 and 18 with OSD compared
379 to 13-year-old soccer players. However, this group was not matched on age and there were no
380 mentioning of sex, height, weight or other patient demographics making a comparison to the
381 current study difficult²⁷. The current data show large deficits in knee extension torque for those
382 with OSD. Interestingly females with OSD also displayed significant hip abduction strength deficits.

383 While knee extension torque was significantly associated with KOOS sport/rec subscale, this
384 relationship did not exist in the multivariable model after accounting for diagnosis (PFP or OSD).

385 Further, there was no relationship between knee extension strength and KOOS Sport/Rec scores in
386 the model examining only PFP. Despite we can't infer cause and effect in this population (i.e. if the
387 changes are prior or subsequent to knee pain), knee and hip strengthening exercises may be
388 worth considering as part of management to improve function and performance to help ensure
389 the adolescent return to sport without large strength deficits. Rest, stretching, or other passive

390 modalities are unlikely to improve the knee extension strength, or hip abduction strength for
391 females with OSD^{10,13,28}.

392 Both PFP and OSD are considered overuse musculoskeletal pain complaints caused by exposure to
393 high repetitive loads^{29 13}. Despite the pain and significant self-reported difficulties on KOOS
394 Sport/Rec, the majority of adolescents with PFP and OSD continued to participate in physical
395 activity. Our results indicate that despite their knee pain, both PFP and OSD were as physically
396 active as the controls, even after reporting that they had decreased their sports participation as a
397 result of knee pain. On average they accumulated more than 2 hours of vigorous activity per day,
398 which is four times the average of the International Children’s Accelerometry Database (ICAD)³⁰.
399 They accumulated more than four hours of MVPA per day, which is 6-8 times as much as the
400 average in the ICAD and twice as much a male players aged 10–14 who participate in grassroots
401 football in three European countries³¹. Adolescents reported participating in sports 3-4 times per
402 week. This does not account for all the objectively measured vigorous activity, suggesting these
403 adolescents also participate in a lot of vigorous activity during school and leisure time.

404 Importantly, this which needs further understanding as it might continue to aggravate their knee
405 pain. More research is needed to understand if continued sports participation should be advised,
406 or if it will impede recovery through persistent loading of their painful knee. Early specialization in
407 a single sport has been shown to be associated with an increased risk of suffering from PFP, OSD
408 and Sinding Larsen Johansson/ patellar tendinopathy in adolescent girls³². This is likely due to
409 repetitive sports specific loading, with OSD demonstrating a 4-fold greater relative risk in single-
410 sport compared with multisport athletes³². The challenge for this population may be to find the
411 type and right amount of physical activity and sport that will keep the adolescents active without
412 aggravating their knee pain or hampering long-term recovery. Modifying or changing loading on

413 specific structures may be a relevant target for future treatments in this population.

414

415 **Clinical implications**

416 In adolescents with OSD, we found large strength deficits in knee extension, which may suggest a
417 rationale for including knee extension strengthening in this group of adolescents (if the desired
418 outcome is to improve muscular function and performance). Recommendations for OSD are
419 diverse but often include rest, stretching and return to sports after pain has settled, despite a lack
420 of evidence supporting this recommendation¹³. Based upon the desire of return to sport, and
421 high activity despite long-standing knee pain, future research is needed to develop load
422 management and return to sport algorithms for both of these populations.

423

424 **Limitations**

425 The two assessors were not blinded to which adolescents suffered from PFP, OSD or who were
426 pain-free controls. This may increase the risk of detection bias and increase potential between-
427 group differences. However, the main conclusion on the severe impact of PFP and OSD is unlikely
428 to be affected by the lack of blinding affected. As hip extension was not collected in OSD we
429 cannot evaluate whether hip extension strength deficits exist in adolescents with OSD. There
430 smaller group numbers when stratifying by sex may have made it difficult to detect sex differences
431 in strength. Further, we did not assess biomechanics which could provide information regarding
432 distinguishing features of these two patient populations. The use of the KOOS adult version is a
433 potential limitation, as this is not validated for this patient population. As this is a cross-sectional
434 study, strong conclusions on clinical implications cannot be drawn, and thus suggestions are
435 speculative based on the observations in the current study.

436

437 **Conclusion**

438 Ten-to-14-year-old adolescents with PFP or OSD are characterized by high levels of vigorous

439 physical activity even in the presence of long-standing knee pain. They report difficulties with

440 sports participation and impaired knee function, relative to pain-free controls. Clinicians treating

441 adolescents with PFP or OSD may use these findings to target treatment to the most common

442 deficits to restore sports-related function and sports participation.

443

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550 Tables and Figures

551 Table 1: Demographics. (Data are reported as mean (SD) or percentages for count data, unless
552 otherwise stated).

	Patellofemoral Pain (N=151)	Osgood Schlatter (N=51)	Pain free controls (N=50)
Age [years]	12.6 (1.2)	12.7 (1.1)	12.3 (1.4)
Gender (% females)	76%	51%	62%
Weight [kg]	50.4 (9.4)	55.8 (10.1)	48.0 (10.4)
Height [cm]	162.0 (9.6)	165.5 (8.4)	159.8 (10.5)
BMI (Interquartile range)	19.0 (17.2-20.8)	20.2 (17.6-22.0)	18.0 (17.1-20.0)
Previously treated for knee pain (% who replied yes)	28%	37%	N/A
Pain medication for knee pain (% who replied yes)	24%	12%	0%
Current sports participation (% who participated in leisure time sports)	91%	74%	88%

553

554 Table 2: Sports participation and physical activity levels

	Patellofemoral Pain (N=151)	Osgood Schlatter (N=51)	Pain free controls (N=50)
Did you participate in sport before onset of knee pain? (% who replied yes)	98%	100%	N/A
Competitive sport before onset of knee pain? (% playing competitive sport)	55%	49%	N/A
Did you reduce the amount of sports participation because of your knee pain? (% who replied yes)	64%	49%	N/A
If you don't participate in sport currently, do you desire to return to sport? (% who replied yes)	100%	98%	N/A
How many times per week do you currently participate in sport (training + competition per week)? *	3 (2-5)	4 (3-5)	3 (1-4.5)
Physical activity levels [measured with ActiGraph]*			
Sedentary [min]	346.6 (333.8-359.4)	344.2 (330.3-358.1)	353.9 (330.3-377.6)
Average light [min]	334.0 (326.8-341.2)	333.8 (315.7-351.9)	318.0 (304.0-331.9)
Average moderate [min]	113.1 (109.2-116.9)	115.5 (106.4-124.6)	109.0 (102.2-115.7)
Average vigorous [min]	127.4 (120.0-134.8)	133.1 (117.5-148.7)	142.5 (128.0-157.0)
Mod to vigorous physical activity (MVPA)	240.5 (229.9-252.1)	248.7 (225.1-272.2)	251.5 (231.3-271.7)
% reaching WHO minimum PA per day	94.7%	91.7%	91.7%
*Based on ActiGraph data from 132 with PFP; 36 with OSD and 48 controls. ActiGraph data reported as mean (95% CI) minutes per day.			

555 Table 3: Pain and symptoms

	Patellofemoral Pain (N=151)	Osgood Schlatter (N=51)	Pain free controls (N=50)	Mean diff PFP v Ctrl (95%CI)	Mean diff OSD v Ctrl (95%CI)	Mean diff PFP v OSD (95% CI)
Age when knee pain started⁵ [years]	11 (10-12)	11 (10-12)	N/A			

Average pain duration (months)	21.3 (17.0)	20.8 (12.5)	N/A			0.5 (-4.7 to 5.7)
Duration of symptoms (n (%))*						
3-6 months	6 (4%)	4 (8%)	N/A			
6-12 months	31 (22%)	2 (4%)	N/A			
>12 months	107 (74%)	44 (88%)	N/A			
Bilateral pain (% who replied yes)	73.5%	71.4%	N/A			2.1 (-12.3 to 16.5))
Worst pain last week (NRS)	6.5 (2.0)	6.4 (2.3)	0			0.1 (-0.6 to 0.8)
KOOS_{pain} [0-100, worst to best]	66 (63-70)	67 (63-68)	100 (100-100)	-22 (-18 to -26)	-26 (-21 to -31)	4 (0 to 8)
KOOS_{symptoms} [0-100, worst to best]	77 (75-80)	73 (69-78)	98 (96-99)	-32 (-28 to -37)	-31 (-26 to -37)	-1 (-5 to 3)
Values presented as mean (SD) except age when knee pain started and percentage with bilateral pain. § median and interquartile range * 1 with OSD and 7 with PFP were not able to remember when their knee pain started and did not respond to the question						

556 PFP: Patellofemoral pain; OSD: Osgood Schlatter; NRS: Numeric rating scale; KOOS: Knee Injury
557 and Osteoarthritis Outcome Score.

558
559 **Table 4: Knee Injury and Osteoarthritis Outcome Score (ADL, Sport; QOL) and EuroQoL 5D-3L**

	Patellofemoral Pain (N=151)	Osgood Schlatter (N=51)	Pain free controls (N=50)	Mean diff PFP v Ctrl (95%CI)	Mean diff OSD v Ctrl (95%CI)	Mean diff PFP v OSD (95% CI)
KOOS_{ADL} [0-100, worst to best]	77 (75-80) †	78 (75-82) †	100 (100-100)	-23 (-19 to -27)	-22 (-19 to -27)	-1 (-3 to 6)
KOOS_{sport/rec} [0-100, worst to best]	54 (50-58) †	43 (37-49) †	100 (100-100)	-48 (-38 to -58)	-56 (-44 to -68)	8 (-2 to 18)
KOOS_{QOL} [0-100, worst to best]	50 (47-53) †#	44 (39-48) †	100 (100-100)	-50 (-45 to -55)	-56 (-50 to -62)	6 (1 to 11)
EuroQoL 5D 3L* [index score]	0.72 (0.63-0.78) †	0.72 (0.44-0.78) †	1 (1-1)	-0.38 (-0.31 to -0.45)	-0.38 (-0.28 to -0.45)	-0.01 (-0.08 to 0.06)
*Presented as median and interquartile range † Significantly different from control # Significantly different from OSD						

560
561 Isometric muscle strength

562
563 **Table 5a and 5b: Univariable and multivariable models testing the association between worst pain**
564 **in the last week, strength, diagnosis and KOOS sport/rec**

Model 1: Association with KOOS sport/rec among all with knee pain	Unadjusted coefficient from univariable analysis	p-value	Adjusted coefficient	p-value Adj coefficient
Knee extension torque	4.6 (0.1; 9.1)	0.04	3.1 (-1.3; 7.6)	0.17
Hip Abduction torque*	3.2 (-5.6; 12.1)	0.47		

Worst pain last week (NRS)	-3.7 (-5.0; -2.4)	<0.001	-4.1 (-5.4; -2.8)	<0.001
Sex*	2.0 (-4.7; 8.8)	0.55		
Diagnosis (OSD vs PFP)	6.0 (-1.1; 13.2)	0.10	9.34 (1.9; 16.8)	0.01

565 *Not included in multivariable model as they did not meet the $p < 0.15$ threshold.

566 NRS: Number rating scale; OSD: Osgood Schlatter; PFP: Patellofemoral Pain.

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Model 2: Association with KOOS sport/rec among adolescents with PFP	Unadjusted coefficient	p-value	Adjusted coefficient	p-value Adj coefficient
Knee extension torque*	1.7 (-3.4; 6.9)	0.50		
Hip Abduction torque*	2.9 (-6.5; 12.3)	0.55		
Hip Extension torque	12.5 (4.3; 20.7)	0.003	10.9 (3.7; 18.0)	0.003
Worst pain last week (NRS)	-4.2 (-5.6; -2.9)	<0.001	-4.2 (-5.5; -2.9)	<0.001
Sex	6.2 (-1.9; 14.4)	0.13	6.1 (-1.0; 13.3)	0.09

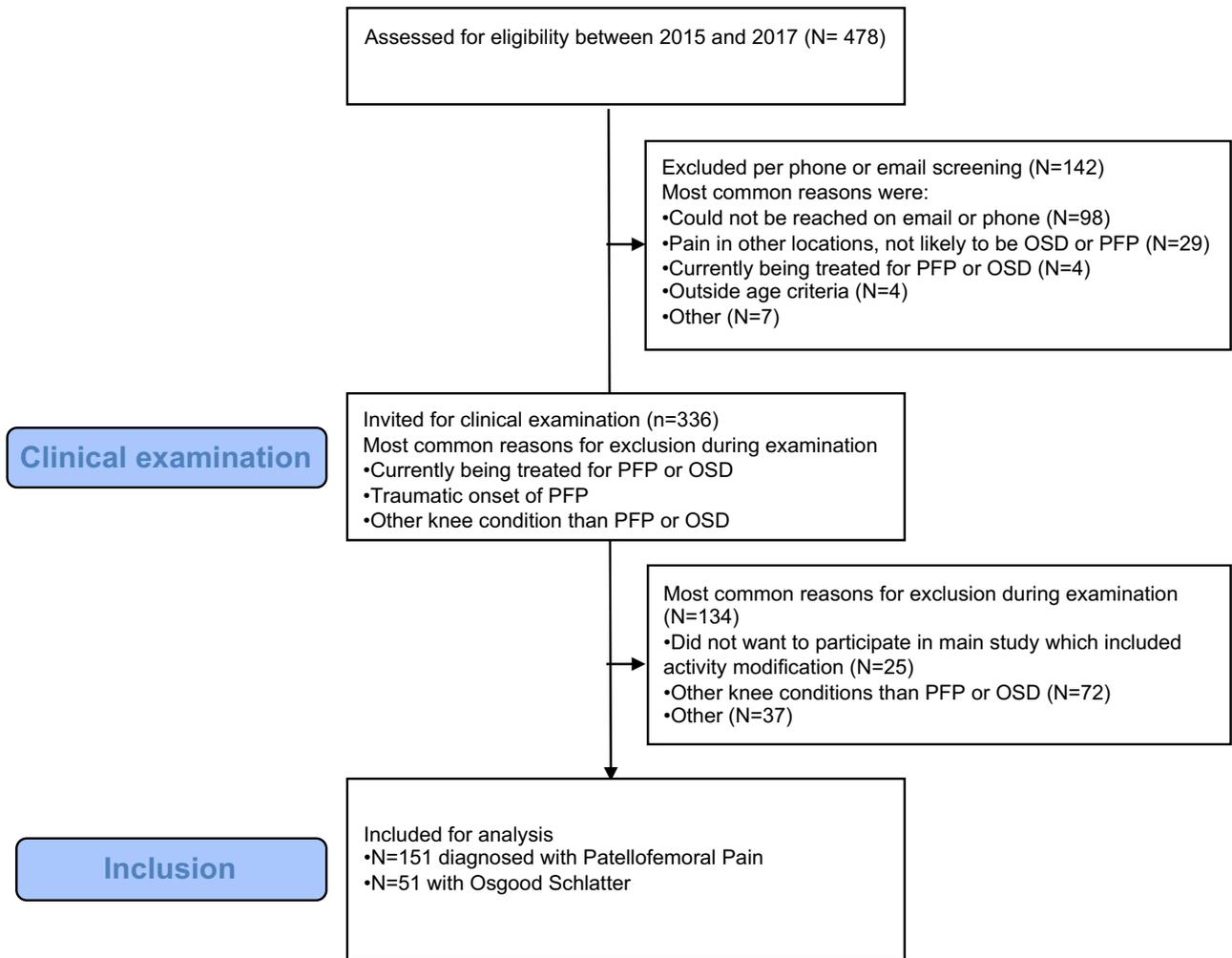
569 *Not included in multivariable model as they did not meet the $p < 0.15$ threshold.

570 NRS: Number rating scale; PFP: Patellofemoral Pain

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577 **Figure 1:** Flowchart

578 PFP; Patellofemoral pain. OSD; Osgood Schlatter.

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585 Figure 2: Comparison of isometric hip and knee strength to controls among girls and boys with
 586 Osgood Schlatter (OSD) and Patellofemoral Pain (PFP). Data presented as mean + 95% CI.
 587 *Denotes statistically significant difference.

