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Pain, Sports Participation, and Physical Function in Adolescents With Patellofemoral Pain and Osgood-Schlatter Disease: A Matched Cross-sectional Study

Knee pain affects 1 in 3 adolescents, making it one of the most common sites of pain.^{2,6} Persistent knee pain is associated with reduced quality of life and physical activity.⁶ Knee pain is sometimes considered self-limiting, with no long-term impact. However, data indicate that this assumption is not correct, with many continuing to have pain into adulthood.^{3,4}

There is a 4-fold increase in the years lived with disability due to musculoskeletal conditions during the transition from childhood to adolescence.¹⁸ In the same period, there is an 8-fold increase in the number of contacts with general practitioners due to knee symptoms.^{1,21} Approximately 6% to 7% of the adolescent population is affected (with varying severity) by patellofemoral pain (PFP),^{17,25} while around 10% is affected by Osgood-Schlatter disease (OSD).⁹ Despite the high prevalence, there is limited information regarding the impact of these impairments on associated deficits in adolescents. This lack of knowledge hinders the development of evidence-informed treatment strategies for young adolescents with PFP or OSD.

The incidence of OSD, which is thought to be related to maturation of the tibial tuberosity, peaks between 12 and 13 years of age.¹⁹ The incidence of PFP is also highest during maturation.¹² Despite this, there are few data about knee conditions in this age group.²⁵ Both PFP and OSD are characterized by anterior knee pain

• **OBJECTIVE:** To compare pain, physical activity, quality of life, strength, and knee function in adolescents with patellofemoral pain (PFP) and Osgood-Schlatter disease (OSD) to those in pain-free controls.

• **DESIGN:** Cross-sectional study.

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

• **RESULTS:** Adolescents were highly active (accumulating greater than 120 minutes of vigorous physical activity per day), with no differences between the OSD, PFP, and control groups. Adolescents with PFP or OSD scored 22 to 56 points lower ($P < .001$) on the Knee injury and

Osteoarthritis Outcome Score subscales compared with controls, with the lowest scores on the "sport and recreation" and "quality of life" subscales. Adolescents with OSD had lower knee extension strength compared to controls ($P < .05$; effect size, 1.25). Adolescents with PFP had lower hip extension strength compared to controls ($P < .05$; effect size, 0.73).

• **CONCLUSION:** Adolescents with PFP or OSD had high physical activity levels, despite reporting long-standing knee pain and impaired knee function that impacted on their sports participation and quality of life. Clinicians treating adolescents with PFP or OSD may use these findings to target treatment to the most common deficits to restore sports-related function and sports participation. *J Orthop Sports Phys Ther* 2020;50(3):149-157. Epub 6 Jan 2020. doi:10.2519/jospt.2020.8770

• **KEY WORDS:** adolescents, anterior knee pain, knee function, musculoskeletal pain

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during knee joint loading and aggravated by physical activity and sport.^{8,13} Patellofemoral pain often has a diffuse presentation of pain around the patella, and OSD presents with pain localized to the tibial tuberosity.^{8,13} Nearly half of adolescents who have had PFP for more than 5 years report knee pain that is severe enough to impact sports participation.²³ In comparison, OSD has often been described as lasting between 12 and 24 months, with more than 90% of cases having no residual symptoms at all.¹³ Understanding the differences between adolescents with these conditions and those without knee pain may help to identify treatment targets.

The aim of this study was to evaluate pain, physical activity, quality of life, strength, and physical function in adolescents 10 to 14 years of age who were diagnosed with PFP or OSD, compared to pain-free controls.

METHODS

Study Design

THIS EXPLORATORY CROSS-SECTIONAL study was embedded within 2 cohort studies of PFP and OSD (ClinicalTrials.gov identifiers NCT02402673 and NCT02799394, respectively), and included a group of pain-free adolescents who served as a control group. The study was approved by the Ethics Committee of the North Denmark Region (N-2014-0100) and the Danish Data Protection Agency. Participants were required to have parental written informed consent. The study was conducted according to the Declaration of Helsinki. The reporting of the study follows the Strengthening of Reporting of Observational Studies in Epidemiology statement.³¹ Data from the 2 prospective cohort studies were collected at inclusion specifically for the purpose of this cross-sectional investigation. Baseline pretreatment measures were collected when the intervention was initiated (2 weeks after inclusion) and are not presented in the current study. Baseline data from participants with PFP were published in a prospective study investi-

gating the effect of activity modification and load management.²² Pain drawings for those with PFP have been included as part of a larger study investigating pain patterns in patients from 10 to 40 years of age.²

Recruitment

Between March 2015 and April 2017, students (10-14 years of age) from local schools were invited to answer an online questionnaire on musculoskeletal pain, including knee pain. This was supplemented by social media and general practice offices to recruit adolescents with knee pain and controls without knee pain. Potentially eligible adolescents (ie, those reporting knee pain via the questionnaire or in response to recruitment advertisements) were subsequently screened by telephone, and invited for a clinical examination if PFP or OSD could not be excluded by the phone interview.

Participants and Diagnostics

The clinical examination was conducted by 1 of 2 physical therapists with 4 and 7 years of clinical experience, respectively. Diagnosis of PFP was made according to established criteria^{7,12}—insidious onset of anterior or retropatellar knee pain for more than 6 weeks; pain provoked by at least 2 of prolonged sitting or kneeling, squatting, running, hopping, and stair climbing; tenderness on palpation of the patella; or pain with stepping down or double-leg squatting. In addition, participants were required to report more than 30 mm on a 0-to-100-mm visual analog scale for worst pain during the previous week.

The criteria used to diagnose OSD were consistent with the literature, and included participants reporting current pain and tenderness at the tibial tuberosity, pain on palpation of the tibial tuberosity, and pain with resisted isometric knee extension.¹³ Exclusion criteria for both PFP and OSD were determined through patient medical history and clinical examination, and included Sinding-Larsen-Johansson disease; concomitant

injury or pain from the hip, lumbar spine, or other structures of the knee (eg, tendinopathy); previous knee surgery; patellofemoral instability; knee joint effusion; and contraindications to magnetic resonance imaging (used to rule out pathology in the PFP group).

Inclusion criteria for the pain-free controls were no current self-reported musculoskeletal pain, no self-reported prior surgery on the lower extremity, no self-reported neurological or medical conditions, and no contraindications to magnetic resonance imaging. At the time of screening, controls were required to have sports participation levels similar to those of participants with knee pain, to prevent differences being detected due to comparison to a population with lower levels of sports participation. The aim was to have groups that were comparable regarding whether or not they were active in sports (yes/no) and regarding the approximate amount of weekly sports participation. This was done to the best of the ability of the 2 assessors during the telephone screening. Control participants were also matched by age (10-14 years). The proportion of girls included in the control group was targeted to be approximately between that of those with PFP and OSD.

Data Collection

The testers (L.W. and K.K.) had previous experience testing adolescents and were not blinded to the status of the participant (PFP, OSD, or control). Information from previous unstructured interviews with adolescents and parents informed the choice of outcome domains. Based on this, limitations in sports and physical activity were considered to be the most important domains. Additional domains of interest were pain and knee function, quality of life, and knee and hip strength. All procedures were pilot tested on adolescents (with and without knee pain) before initiation of the study.

Height and Weight Body weight was measured using a weighing scale. Height was measured using a tape measure fixed to a wall, with participants stand-

ing barefoot against the wall. Body mass index was calculated based on these measurements.

Sports Participation Participants with PFP and OSD were asked to report their sports participation (type, duration, and frequency per week) at present and prior to onset of knee pain. Participants who reported reduced or no sports participation due to knee pain were asked whether they desired to return to their previous level of sport.

Physical Activity Data Objective measures of physical activity were captured by a wrist-worn GT3X+ watch (ActiGraph, LLC, Pensacola, FL) recording at 30 Hz.¹⁶ Participants were instructed to wear the device on the wrist of their nondominant arm for a week after inclusion, and not to remove it unless deemed unsafe during specific activities (eg, taekwondo, water polo). Data were analyzed using ActiLife (ActiGraph, LLC), and the full description of analysis can be seen in Rathleff et al.²² The Evenson et al¹¹ cut points were used to categorize the intensity of participants' physical activity as sedentary (0-100 counts per minute), light (101-2295 counts per minute), moderate (2296-4011 counts per minute), or vigorous (4012 or more counts per minute).¹⁶ In addition, we compared the physical activity levels to the recommendations by the World Health Organization.

Pain, Symptoms, and Quality of Life To assess pain and symptoms, the respective subscales from the Knee injury and Osteoarthritis Outcome Score (KOOS) were used (pain, other symptoms, function in daily living, function in sport and recreation [sport/rec], and knee-related quality of life).²⁸ This questionnaire was chosen because it has previously been used in young adolescents with knee pain.^{20,25} Health-related quality of life was measured by the youth version of the European Quality of Life-5 Dimensions (EQ-5D-Y).⁴ Participants also reported their worst pain in the past week on a numeric rating scale (0 to 10, where 0 is "no pain" and 10 is the "worst pain imaginable"). Pain duration was determined by

the question, "For how long have you experienced knee pain?" (open ended, and subsequently calculated in months). If participants with PFP or OSD had bilateral pain, they were instructed to answer about their most painful knee.

Hip and Knee Muscle Strength Isometric knee extension and hip abduction strength were recorded for all adolescents. Hip extension strength was assessed in those with PFP and in controls only. Strength was measured in the symptomatic knee or most symptomatic knee in cases with bilateral pain. In pain-free adolescents, the right or left leg was randomly chosen as the test leg. Three consecutive strength measurements were taken for all participants. Muscle strength was tested using a PowerTrack Commander handheld dynamometer (JTECH Medical, Midvale, UT), fixed to the examination bed by a belt. All strength tests were conducted isometrically and have previously been shown to be reliable.^{20,29} Average force output of the 3 tests (Newtons) was subsequently multiplied by lever length to calculate torque and normalized to body weight. Lever length for hip abduction was measured from the anterior superior iliac spine to the position of the dynamometer at the lateral side of the lower leg (5 cm above the lateral malleolus). Lever length for knee extension was measured as the distance from the knee joint line to the position of the dynamometer 5 cm above the medial malleolus. Lever length for hip extension was measured from the trochanter major to the position of the dynamometer 5 cm above the popliteal fossa.

During knee extension, the dynamometer strap was positioned 5 cm proximal to the medial malleolus, perpendicular to the anterior or posterior aspect of the tibia. Knee extension was tested in 60° of knee flexion. For hip abduction, participants were lying supine on an examination table, with the leg in 0° of flexion and 0° of abduction. The strap was positioned 5 cm proximal to the medial malleolus and perpendicular to the medial or lat-

eral aspect of the tibia. Hip extension was measured using the short lever version,²⁹ with a strap to fix the dynamometer at the posterior thigh. After receiving standardized instructions, participants performed 2 submaximal practice trials. Afterward, the individual test was administered 3 times, with approximately 1 minute between each test.

Sample-Size Considerations

No formal sample-size calculation was conducted for this cross-sectional study, as there are no data about young adolescents with PFP and OSD compared to pain-free controls. The final sample size was a convenience sample, determined by the number of adolescents with PFP and OSD who were enrolled in 1 of 2 prospective cohort studies (NCT02402673 and NCT02799394).

Statistical Analysis

Data were visually inspected for approximate normality using a Q-Q plot. Mean values and SDs are reported for normally distributed data. Nonnormally distributed data are presented as median and interquartile range. Data on physical activity and sport are described descriptively. Scores on the KOOS and EQ-5D-Y were analyzed using a 1-way analysis of variance and the least-significant-difference post hoc test to test the differences between groups (control versus OSD versus PFP). A 2-way analysis of variance was used to investigate the effects of group (control versus PFP versus OSD) and sex (male versus female) and the group-by-sex interaction on isometric strength measures. Effect sizes of the differences in isometric hip and knee strength were calculated using Cohen's *d*, with effect sizes greater than 0.80 being considered large.⁷ Sex was included in the model for strength measures due to previously documented sex-specific differences in strength.²⁴

Based on peer-review comments, a regression model was used to assess the association between strength measures and the KOOS sport/rec subscale. This was

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done using a linear regression to estimate the association between sex, worst pain in the last week, isometric strength, diagnosis, and KOOS sport/rec score. Univariable analyses were initially performed, and variables with $P < .15$ were included in the multivariable model.³ A separate regression model was also developed for the PFP group only to allow for the inclusion of hip extension strength data. All calculations were performed using Stata Version 11 (StataCorp LLC, College Station, TX) and SPSS Version 21 (IBM Corporation, Armonk, NY). Significance was accepted for P values less than .05.

RESULTS

Demographics

TWO HUNDRED FIFTY-TWO ADOLESCENTS (151 with PFP, 51 with OSD, and 50 pain-free controls) ranging in age from 10 to 14 years were included and tested (FIGURE 1). We assessed 85 controls for eligibility, of whom 35 were excluded: 34 due to not being a match and 1 for reporting knee pain during phone screening. One third of those with knee pain had previously received treatment for knee pain (TABLE 1). The most common reported treatments were treatment by physical therapist (14/51), acupuncture (3/51), and shockwave (2/51) in those with OSD, and treatment by physical therapist (34/151), acupuncture (4/151), and painkillers (2/151) in adolescents with PFP.

Sports Participation and Objective Physical Activity

More than 50% reported reducing their sports participation, with the most common causes being “pain” and “I am afraid to damage my knee.” Nine percent of adolescents with PFP reported a complete stop of sports due to knee pain, compared with 26% of adolescents with OSD. All adolescents except 1 had a desire to return to sport (TABLE 2). There were no differences in physical activity, measured with the GT3X+ watch (ActiGraph, LLC), between groups in average time spent in sedentary,

light, moderate, or vigorous physical activity (TABLE 2). Due to device malfunction, not all data could be properly extracted from the GT3X+ or excluded as nonwear-time data; the included GT3X+ data were from 132 participants with PFP, 36 with OSD, and 48 controls.

Pain, Symptoms, and Quality of Life

Adolescents with PFP and OSD reported pain for an average of 21 months (TABLE

3). There was a significant difference between groups for KOOS function in daily living ($F = 55, P < .001$), KOOS sport/rec ($F = 52, P < .001$), and KOOS quality-of-life ($F = 217, P < .001$) scores. Post hoc pairwise comparisons revealed that adolescents with OSD or PFP had lower scores compared to pain-free controls ($P < .001$) (mean differences in TABLE 4). Adolescents with OSD had significantly lower KOOS scores compared to adolescents with PFP

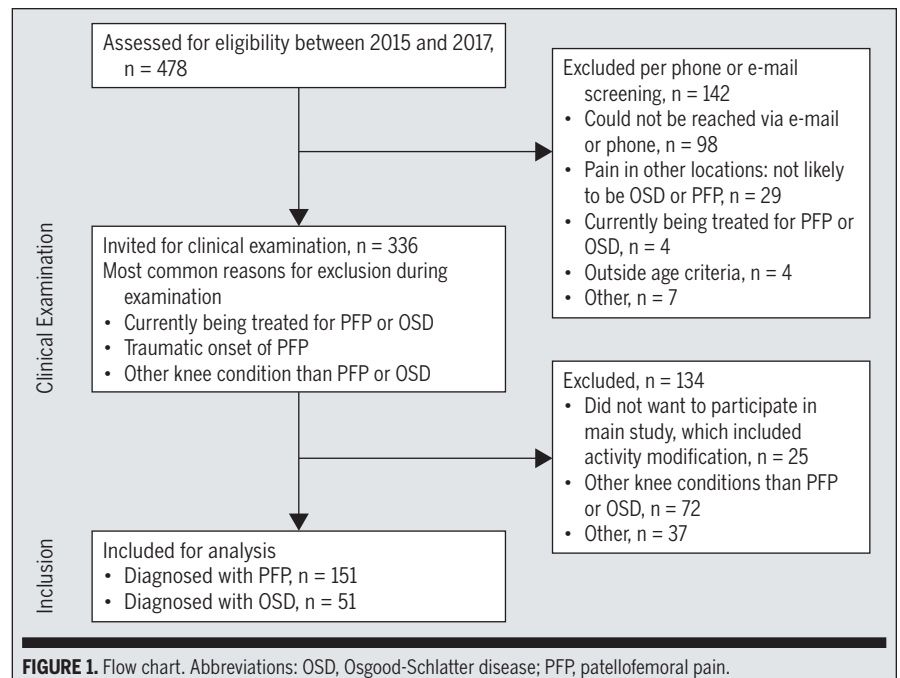


FIGURE 1. Flow chart. Abbreviations: OSD, Osgood-Schlatter disease; PFP, patellofemoral pain.

TABLE 1

DEMOGRAPHICS^a

	Patellofemoral Pain (n = 151)	Osgood-Schlatter (n = 51)	Pain-Free Controls (n = 50)
Age, y	12.6 ± 1.2	12.7 ± 1.1	12.3 ± 1.4
Sex (female), %	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
Body mass index, kg/m ^{2b}	19.0 (17.2-20.8)	20.2 (17.6-22.0)	18.0 (17.1-20.0)
Previously treated for knee pain (yes), %	28	37	NA
Pain medication for knee pain (yes), %	24	12	NA
Current sports participation in leisure-time sports (yes), %	91	74	88

Abbreviation: NA, not applicable.

^aValues are mean ± SD unless otherwise indicated.

^bValues are median (interquartile range).

for the quality-of-life domain ($P < .05$) (TABLE 4), but not for the function in daily living and sport/rec domains ($P > .05$).

Scores on the EQ-5D-Y were significantly different between groups ($F = 56, P < .001$). Compared to controls, the EQ-5D-Y index score was significantly

lower in both the PFP (mean difference, 0.38; 95% confidence interval [CI]: 0.31, 0.45; $P < .001$) and OSD (mean difference, 0.38; 95% CI: 0.28, 0.45; $P < .001$) groups (TABLE 4). There was no difference between the OSD and PFP groups ($P = .762$) (TABLE 4).

Hip and Knee Muscle Strength

There was a significant sex-by-group interaction for hip abduction strength ($F = 3.9, P = .02$). Post hoc testing revealed a simple main effect of group on hip abduction scores, which was statistically significant for girls ($F = 7.7, P = .001$) but not

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? (yes), %	98	100	NA
Did you play competitive sport before onset of knee pain? (yes), %	55	49	NA
Did you reduce the amount of sports participation because of your knee pain? (yes), %	64	49	NA
If you don't participate in sport currently, do you desire to return to sport? (yes), %	100	98	NA
How many times per week do you currently participate in sport (training and competition)? ^a	3 (2-5)	4 (3-5)	3 (1-4.5)
Physical activity levels ^b			
Sedentary	346.6 (333.8, 359.4)	344.2 (330.3, 358.1)	353.9 (330.3, 377.6)
Average light	334.0 (326.8, 341.2)	333.8 (315.7, 351.9)	318.0 (304.0, 331.9)
Average moderate	113.1 (109.2, 116.9)	115.5 (106.4, 124.6)	109.0 (102.2, 115.7)
Average vigorous	127.4 (120.0, 134.8)	133.1 (117.5, 148.7)	142.5 (128.0, 157.0)
Moderate to vigorous	240.5 (229.9, 252.1)	248.7 (225.1, 272.2)	251.5 (231.3, 271.7)
Reached WHO minimum physical activity per day, %	94.7	91.7	91.7

Abbreviations: NA, not applicable; WHO, World Health Organization.

^aValues are median (interquartile range).

^bBased on GT3X+ data from 132 with patellofemoral pain, 36 with Osgood-Schlatter disease, and 48 controls. Values are mean (95% confidence interval) minutes per day.

TABLE 3

PAIN AND SYMPTOMS^a

	Patellofemoral Pain (n = 151)	Osgood-Schlatter (n = 51)	Pain-Free Controls (n = 50)	Patellofemoral Pain Versus Controls ^b	Osgood-Schlatter Versus Controls ^b	Patellofemoral Pain Versus Osgood-Schlatter ^c
Age when knee pain started, y ^c	11 (10-12)	11 (10-12)	NA			0
Pain duration, mo	21.3 ± 17.0	20.8 ± 12.5	NA			0.5 (-4.7, 5.7)
Duration of symptoms, n (%) ^d						
3-6 mo	6 (4)	4 (8)	NA			
6-12 mo	31 (22)	2 (4)	NA			
>12 mo	107 (74)	44 (88)	NA			
Bilateral pain (yes), %	73.5	71.4	NA			2.1 (-12.3, 16.5)
Worst pain in last week (NRS, 0-10)	6.5 ± 2.0	6.4 ± 2.3	NA			0.1 (-0.6, 0.8)
KOOS pain (0-100) ^e	66 (63-70)	67 (63-68)	100 (100-100)	-22 (-18, -26)	-26 (-21, -31)	-1 (-5, 3)
KOOS symptoms (0-100) ^e	77 (75-80)	73 (69-78)	98 (96-99)	-32 (-28, -37)	-31 (-26, -37)	4 (0, 8)

Abbreviations: KOOS, Knee injury and Osteoarthritis Outcome Score; NA, not applicable; NRS, numeric rating scale.

^aValues are mean ± SD unless otherwise indicated.

^bValues are mean difference (95% confidence interval).

^cValues are median (interquartile range).

^dOne participant with Osgood-Schlatter disease and 7 with patellofemoral pain were not able to remember when their knee pain started and did not respond to the question.

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for boys. Compared to girls in the control group, hip abduction strength was significantly lower for girls with OSD (mean difference, 0.41; 95% CI: 0.20, 0.61; $P < .001$; effect size, 1.16; 95% CI: 0.57, 1.73) (FIGURE 2) and PFP (mean difference, 0.21; 95% CI: 0.06, 0.36; $P < .01$; effect size, 0.49; 95% CI: 0.08, 0.88). For boys, there were no differences in hip abduction strength between groups ($P = .398$).

For knee extension strength, there was no significant interaction ($P > .05$), but there was a significant main effect

for group ($F = 19$, $P < .001$). The group with OSD had significantly reduced knee extension strength compared to controls (mean difference, 0.65; 95% CI: 0.39, 0.92; $P < .001$; effect size, 1.25; 95% CI: 0.82, 1.68) and those with PFP (mean difference, 0.65; 95% CI: 0.43, 0.87; $P < .001$; effect size, 0.99; 95% CI: 0.64, 1.32) (FIGURE 2). There were no differences between PFP and controls for knee extension strength ($P = .986$).

For hip extension strength, there was no sex-by-group interaction. There was

a significant difference between groups, with lower strength in the PFP group compared to controls ($F = 17$, $P < .001$; mean difference, 0.36; 95% CI: 0.18, 0.53; effect size, 0.73; 95% CI: 0.40, 1.05) (FIGURE 2).

Factors Associated With the KOOS Sport/Rec Subscale

In the univariable analyses, higher knee extension torque was associated with higher KOOS sport/rec score and higher “worst pain in the last week” was significantly associated with lower KOOS sport/

TABLE 4

KOOS (ADL, SPORT/REC, AND QoL) AND EQ-5D-Y

	Patellofemoral Pain (n = 151) ^a	Osgood-Schlatter (n = 51) ^a	Pain-Free Controls (n = 50) ^a	Patellofemoral Pain Versus Controls ^b	Osgood-Schlatter Versus Controls ^b	Patellofemoral Pain Versus Osgood-Schlatter ^b
KOOS ADL (0-100)	77 (75-80) ^c	78 (75-82) ^c	100 (100-100)	-23 (-19, -27)	-22 (-19, -27)	-1 (-3, 6)
KOOS sport/rec (0-100)	54 (50-58) ^c	43 (37-49) ^c	100 (100-100)	-48 (-38, -58)	-56 (-44, -68)	8 (-2, 18)
KOOS QoL (0-100)	50 (47-53) ^{cd}	44 (39-48) ^c	100 (100-100)	-50 (-45, -55)	-56 (-50, -62)	6 (1, 11)
EQ-5D-Y (0-1)	0.72 (0.63-0.78) ^c	0.72 (0.44-0.78) ^c	1 (1-1)	-0.38 (-0.31, -0.45)	-0.38 (-0.28, -0.45)	-0.01 (-0.08, 0.06)

Abbreviations: ADL, activities of daily living; EQ-5D-Y, European Quality of Life-5 Dimensions (Youth); KOOS, Knee injury and Osteoarthritis Outcome Score; QoL, quality of life; sport/rec, sport and recreation.

^aValues are median (interquartile range).

^bValues are mean difference (95% confidence interval).

^cSignificantly different from control group.

^dSignificantly different from Osgood-Schlatter disease group.

TABLE 5

UNIVARIABLE AND MULTIVARIABLE MODELS TESTING THE ASSOCIATION BETWEEN WORST PAIN IN THE LAST WEEK, STRENGTH, DIAGNOSIS, AND KOOS SPORT/RECREATION SCORE

	Unadjusted Coefficient ^a	P Value	Adjusted Coefficient ^a	Adjusted P Value
All participants ^{bc}				
Knee extension torque	4.6 (0.1, 9.1)	.04	3.1 (-1.3, 7.6)	.17
Hip abduction torque ^d	3.2 (-5.6, 12.1)	.47		
Worst pain in last week (NRS)	-3.7 (-5.0, -2.4)	<.001	-4.1 (-5.4, -2.8)	<.001
Sex ^d	2.0 (-4.7, 8.8)	.55		
Diagnosis (Osgood-Schlatter disease versus patellofemoral pain)	6.0 (-1.1, 13.2)	.10	9.34 (1.9, 16.8)	.01
Only participants with patellofemoral pain ^e				
Knee extension torque ^d	17 (-3.4, 6.9)	.50		
Hip abduction torque ^d	2.9 (-6.5, 12.3)	.55		
Hip extension torque	12.5 (4.3, 20.7)	.003	10.9 (3.7, 18.0)	.003
Worst pain in last week (NRS)	-4.2 (-5.6, -2.9)	<.001	-4.2 (-5.5, -2.9)	<.001
Sex	6.2 (-1.9, 14.4)	.13	6.1 (-1.0, 13.3)	.09

Abbreviations: KOOS, Knee injury and Osteoarthritis Outcome Score; NRS, numeric rating scale.

^aValues in parentheses are 95% confidence interval.

^bFrom the univariable analysis.

^cAssociation with the KOOS sport/recreation score among all participants with knee pain.

^dNot included in the multivariable model because the $P < .15$ threshold was not met.

^eAssociation with the KOOS sport/recreation score among adolescents with patellofemoral pain.

rec score (TABLE 5). After adjustment in the multivariable model, higher “worst pain in the last week” and OSD diagnosis remained significantly associated with lower KOOS sport/rec scores. Knee extension torque was not significantly associated with KOOS sport/rec score in the multivariable model (TABLE 5).

When examining PFP only, univariable analyses indicated that sex, hip extension torque, and “worst pain in the last week” were associated with KOOS sport/rec scores (TABLE 5). Female sex, higher “worst pain in the last week,” and lower hip extension torque were associ-

ated with lower KOOS sport/rec scores in the PFP group. Except for sex, these associations remained significant in the multivariable model. TABLE 5 demonstrates the unadjusted coefficients from the univariable models, as well as the adjusted coefficients and *P* values for the variables that remained significant in the multivariable model, after accounting for other factors.

DISCUSSION

THIS IS THE FIRST STUDY TO CHARACTERIZE pain, physical activity, and knee function in 10- to 14-year-old adolescents diagnosed with PFP or OSD. We found that these 2 common knee pain complaints impact pain, self-reported sports participation, physical function, and quality of life to a similar extent, with no clinically relevant difference between OSD and PFP. While participants reported having to stop or reduce sport due to knee pain, the GT3X+ (ActiGraph, LLC) data demonstrated that the participants were still very physically active, accumulating approximately 2 hours of vigorous physical activity per day. Adolescents with PFP demonstrated reduced hip extension strength compared to pain-free controls; however, only girls with PFP and OSD had lower hip abduction strength compared to female controls. Adolescents with OSD demonstrated reduced knee extension strength compared to their matched healthy counterparts.

Despite the young age of the participants, the impact of pain on sports and physical function was similar to that in older adolescents and young adults with PFP (aged 15-19 years).²⁵ Almost all adolescents reported participating in sport prior to the onset of their knee pain, and the majority reduced their participation due to pain. In contrast, in older adolescents and young adults with PFP, only 2 of 3 adolescents with PFP participated in sports.²⁵ As older adolescents and young adults with PFP also reported a longer duration of symptoms, this may explain the differences in sports participation.

In this study, 1 in every 4 adolescents with PFP used painkillers. Use of pain medication among adolescents with OSD was half that of those with PFP, despite worse symptoms and larger reductions in sports participation. The reason for the difference is unclear and may warrant further examination.

In PFP, higher hip extension torque was associated with higher KOOS sport/rec scores. Hip abduction torque was not associated with KOOS sport/rec scores. A recent systematic review, including both adolescents and adults, highlighted that low hip muscle strength may be a consequence of PFP rather than the cause.²⁴ A previous smaller study found no difference in quadriceps strength between young people between the ages of 11 and 18 years with OSD and 13-year-old soccer players. However, these groups were not matched by age, and there was no mention of sex, height, weight, or other patient demographics, making a comparison to the current study difficult.¹⁵ There were large deficits in knee extension torque for those with OSD. Girls with OSD also displayed significant hip abduction strength deficits. While knee extension torque was significantly associated with KOOS sport/rec subscale score, this relationship did not exist in the multivariable model after accounting for diagnosis (PFP or OSD). Further, there was no relationship between knee extension torque and KOOS sport/rec score in the model examining only PFP. Although we cannot infer cause and effect in this population, knee- and hip-strengthening exercises may be worth considering as part of management to improve function and performance, and to help ensure that adolescents return to sport without large strength deficits. Rest, stretching, or other passive modalities are unlikely to improve knee extension strength or hip abduction strength for girls with OSD.^{5,9,13}

Both PFP and OSD are considered overuse musculoskeletal pain complaints caused by exposure to high repetitive loads.^{13,27} Despite the pain and significant self-reported difficulties on the KOOS

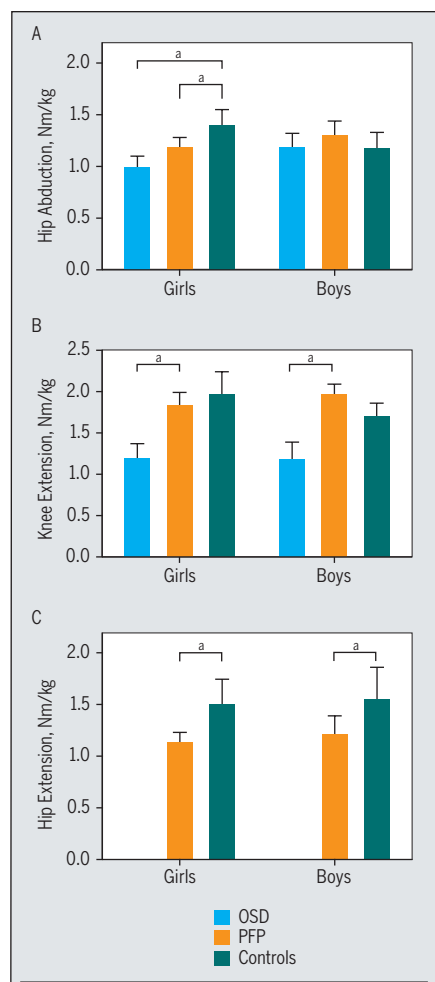


FIGURE 2. Comparison (to controls) of isometric (A and C) hip and (B) knee strength among adolescent girls and boys with OSD and PFP. Values are mean and 95% confidence interval. *Statistically significant difference. Abbreviations: OSD, Osgood-Schlatter disease; PFP, patellofemoral pain.

sport/rec subscale, the majority of adolescents with PFP and OSD continued to participate in physical activity. Our results indicate that despite their knee pain, young people with PFP and OSD were as physically active as the controls, even after they had decreased their sports participation as a result of knee pain. On average, they accumulated more than 2 hours of vigorous activity per day, which is 4 times the average of the International Children's Accelerometry Database.¹⁰ They accumulated more than 4 hours of moderate to vigorous physical activity per day, which is 6 to 8 times as much as the average in the International Children's Accelerometry Database and twice as much as male players aged 10 to 14 years who participate in grassroots football in 3 European countries.³⁰ Adolescents reported participating in sports 3 to 4 times per week. This does not account for all the objectively measured vigorous activity, suggesting that these adolescents also participate in a lot of vigorous activity during school and leisure time. More research is needed to understand whether continued sports participation should be advised, or whether it will impede recovery through persistent loading of the painful knee.

Early specialization in a single sport has been associated with an increased risk of suffering from PFP, OSD, and Sinding-Larsen-Johansson disease/patellar tendinopathy in adolescent girls.¹⁴ This is likely due to repetitive sports-specific loading, with OSD demonstrating a 4-fold greater relative risk in single-sport compared with multisport athletes.¹⁴ The challenge for this population may be to find the right type and amount of physical activity and sport that will keep the adolescents active without aggravating their knee pain or hampering long-term recovery. Modifying or changing loading on specific structures may be a relevant target for future treatments in this population.

Clinical Implications

In adolescents with OSD, we found large strength deficits in knee extension,

which may suggest a rationale for including knee extension strengthening in this group of adolescents. Recommendations for OSD are diverse but often include rest, stretching, and return to sports after pain has settled, despite a lack of evidence to support this recommendation.¹³ The desire to return to sport and high activity despite long-standing knee pain warrant future research to develop load-management and return-to-sport algorithms for those with OSD or PFP.

Limitations

The 2 assessors were not blinded to the status of participants (PFP, OSD, or control). This may increase the risk of detection bias and increase potential between-group differences. However, the main conclusion of the severe impact of PFP and OSD is unlikely to be affected by the lack of blinding. As hip extension was not collected in those with OSD, we cannot evaluate whether hip extension strength deficits exist in adolescents with OSD. The smaller group numbers when stratifying by sex may make sex differences in strength difficult to detect. Further, we did not assess biomechanics, which might have indicated differences between these 2 patient populations. The use of the KOOS adult version is a potential limitation, as it is not validated for this patient population. As this is a cross-sectional study, strong conclusions on clinical implications cannot be drawn, and thus suggestions based on the results of this study are speculative.

CONCLUSION

ADOLESCENTS FROM 10 TO 14 YEARS of age with PFP or OSD are characterized by high levels of vigorous physical activity, even in the presence of long-standing knee pain. They report difficulties with sports participation and impaired knee function, relative to pain-free controls. Clinicians treating adolescents with PFP or OSD may use these findings to target treatment for the most common deficits to restore sports-related function and sports participation. ●

KEY POINTS

FINDINGS: Adolescents with patellofemoral pain (PFP) and Osgood-Schlatter disease (OSD) are characterized by impairments in sports participation, knee function, and quality of life. Despite these impairments, adolescents continue with high levels of physical activity. Adolescents with PFP demonstrated reduced hip extension strength. However, only girls with PFP and OSD had lower hip abduction strength compared to female controls. Adolescents with OSD demonstrated reduced knee extension strength compared to their matched healthy counterparts.

IMPLICATIONS: Clinicians treating adolescents with PFP or OSD may use these findings to target treatment to the most common deficits to restore sports-related function and sports participation.

CAUTION: This was a cross-sectional analysis, and no cause-and-effect relationships can be inferred.

STUDY DETAILS

TRIAL REGISTRATION: The data on which this cross-sectional study is based are registered at www.ClinicalTrials.gov (NCT02402673, NCT02799394).

PATIENT AND PUBLIC INVOLVEMENT: Information from previous nonstructured interviews with adolescents and parents informed the choice of outcome domains. Based on this, limitations in sports and physical activity were considered to be the most important domains. Additional domains of interest were pain and knee function, quality of life, and knee and hip strength.

DATA SHARING: All data presented in the manuscript are available, with a reasonable request, by contacting the corresponding author. Data will be shared in anonymized form and can be used for meta-analytical purposes. For those trying to answer new research questions on the data from this study, a formal request must be made.

AUTHOR CONTRIBUTIONS: All authors made substantial contributions to the conception or design of the work, or the acqui-

sition, analysis, or interpretation of data for the work. All authors were involved in drafting the work or revising it critically for important intellectual content, and gave final approval of the version to be published. All authors also agree to be accountable for all aspects of the work to ensure that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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