Activity Modification and Load Management of Adolescents With Patellofemoral Pain

A Prospective Intervention Study Including 151 Adolescents

Rathleff, Michael Skovdal; Graven-Nielsen, Thomas; Hölmich, Per; Winiarski, Lukasz; Krommes, Kasper; Holden, Sinéad; Thorborg, Kristian

Published in:
The American Journal of Sports Medicine

DOI (link to publication from Publisher):
10.1177/0363546519843915

Publication date:
2019

Document Version
Accepted author manuscript, peer reviewed version

Activity modification and load management in adolescents with patellofemoral pain - a prospective intervention study including 151 adolescents

Abstract

Background: Patellofemoral pain (PFP) affects 7% of adolescents, especially those that are highly active. Exercise-focused treatments show limited effect, and overlook activity modification and load management. As many adolescents continue at high levels of sports despite pain, a new strategy addressing this problem is warranted.

Purpose: Investigate the effects of a treatment strategy for adolescents focusing on activity modification and load management.

Study design: Prospective cohort study

Methods: One hundred and fifty one adolescents aged 10-14 years with PFP were included. The 12-week intervention included four supervised sessions with physiotherapist, which both adolescents and parents were required to attend. The intervention included activity modification (week 0-4) to reduce loading of the patellofemoral joint using an activity ladder and pain monitoring, home-based exercises (week 4-12), and return to sport guidance (week 8-12). Primary outcome was a 7-point global rating of change (GROC), ranging from “much improved” to “much worse”. Adolescents were considered to have a successful outcome if they reported “much improved” or “improved”. The primary endpoint was at 12 weeks, with additional follow-up at 4, 24 and 52 weeks. Secondary outcomes included Knee Injury and Osteoarthritis Outcome Score (KOOS), hip and knee torque, sports participation, satisfaction with treatment, and use of pain killers.

Results: At 12 weeks, 87% completed the full questionnaire, of which 86% reported a successful outcome, which was 77%, 95%CI: 68-83%at 6 months , and 81%, 95%CI: 73-88% at 12 months . There were large clinically relevant improvements in KOOS pain, sport and recreation and quality of life (13-24 points). Hip and knee torque increased by 20-33%. In total, 68% were back playing sport after 3 months, which increased to 79% at 6 months, and 81% at 12 months. The majority (90%) were satisfied with the treatment, and (95%) would recommend it to a friend.

Conclusion: A treatment strategy focusing on activity modification and load management was associated with high rates of successful outcomes in adolescents with PFP, at both 12 and 52 weeks. These short and longer term outcomes were supported by improvements in symptoms, and objective measures of hip and knee torque.

What is known about the subject:

- Patellofemoral pain affects 7% of the adolescent population, especially the high sports active.
- Current exercise-focused trials are only effective for 1 in every 3, and substantial impairments in knee function and pain persists even after a year.

What this study adds to existing knowledge:

- This novel strategy focusing on educating adolescents and their parents on activity modification and load management seems promising due high rates of succesfull outcomes at both 12 and 52 weeks. These short and longer term outcomes were supported by large improvements in subjective reports of knee specific pain and sporting function, treatment satisfaction, and in objective measures of hip and knee torque.

Introduction

Musculoskeletal pain affects at least one in three adolescents, with the knee being the most common pain location[7,18]. Patellofemoral pain (PFP) represents the second most common knee complaint in adolescents[4,17]. It affects 6-7% of the general adolescent population, with an even higher prevalence (up to 25%) among sports-active adolescents[17]. PFP is characterised by diffuse anterior knee pain, provoked by activities that load the knee such as squatting and stair climbing[2]. Approximately four out of ten adolescents with PFP continue to have pain into early adulthood, and this is severe enough to impact quality of life, knee function, physical activity and sport (blinded reference).

One of the mainstays in treating PFP in adults is exercise therapy (usually resistance training[7]), with evidence for its' short and long-term effectiveness on pain and function[2,19]. Adding supervised exercises to patient education also improves outcomes for adolescents (aged 15-19 years) in the short (3 months), and long term (24 months)[12]. However, the results of an execise-focused approach in adolescents are not as promising as data from adults, with only one in three responding favourably to exercise and education[14].

Intense and frequent sports participation with insufficient recovery is considered a main cause for developing PFP during adolescence, due to repetitive loads on the knee joint[6,14]. This may be a period where adolescents are vulnerable, as there is a steep increase in MSK injuries during the transition into adolescence, indicating they may be more susceptible to MSK problems[18]. Exercise therapy neglects this potential influence of repetitive activity and knee joint loading during adolescence, which may explain the limited effect in this population [14]. Successful treatment may need to consider behaviours such as high physical activity, which are thought to have led to knee

pain in the first place[6]. This could include educational components tailored for the cognitive considerations specific to the needs of adolescents, to help them modify their high sports participation and manage their current situation. Such information and self-management strategies could help address how adolescents can reduce their symptoms, while progressively enabling them to get them back to their desired activity level.

Therefore, the aim of this study was to test a treatment strategy specific for adolescents with PFP focusing on educating adolescents on activity modification and load management. The outcomes were self-reported global rating of change, knee specific function (KOOS), hip and knee strength, and the use of painkillers. A secondary aim was to explore prognostic factors, and whether adherence to the intervention (activity modification and exercises) were associated with response to treatment, in light of other patient characteristics.

Methods

Study design

This study was designed as a multi-centre single-cohort prospective study (with one centre in [redacted] and one [redacted]) on adolescents with PFP. Adolescents with knee pain were recruited from local schools, social media and general practice, and subsequently assessed for PFP according to predefined criteria as outlined below. The study was approved by [redacted]) and the [redacted] Data Protection Agency and pre-registered on clinical trials ([redacted] Written informed parental consent was required from all participants prior to inclusion, as well as participant assent. All procedures were pilot tested on adolescents before initiation of the study to ensure feasibility and that both

adolescents and their parents were comfortable with the procedures. The study was conducted according to the Declaration of Helsinki. Reporting adheres to the STROBE guidelines and checklist for prospective cohort studies [5]. Reporting of the intervention follows a best-practice approach combining thorough descriptions, videos and educational material that was used during the study [7].

Recruitment

Potentially eligible adolescents with knee pain were identified between March 2015 and February 2016. This was done by having local schools inviting students (age 10-14) to answer an online questionnaire on musculoskeletal pain. This was supplemented by using social media to identify adolescents with knee pain. Potentially eligible participants were subsequently telephoned and invited for a clinical examination by one of two physiotherapists. This recruitment strategy recruited participants for both this trial (adolescents with PFP) and an external study on adolescents with Osgood Schlatter Disease (clinical trial registration XXXXXXXXX).

The diagnosis of PFP was made by one of two trained physiotherapists according to established recommended criteria [3] as follows: insidious onset of anterior or retro-patellar knee pain for more than 6 weeks and provoked by at least two of the following positions or functions; prolonged sitting or kneeling, squatting, running, hopping or stair walking; tenderness on palpation of the patella, or pain with stepping down or double leg squatting; worst pain experienced during the previous week should be reported to be more than 30 mm on a 100 mm Visual Analogue Scale (VAS). Exclusion criteria included: currently being treated for PFP, aged less than ten or older than 14, previous surgery to the knee, a diagnosis of other knee conditions (e.g. Osgood Schlatter),

patellofemoral instability or concomitant injury or pain from the hip or lumbar spine.

Intervention

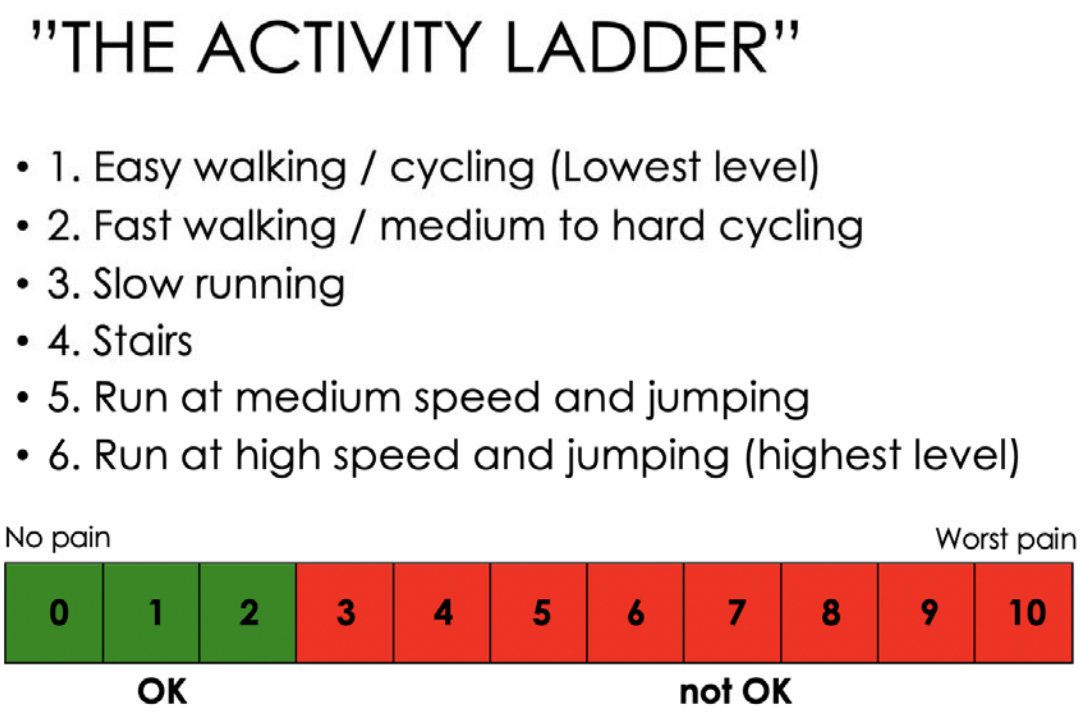
The intervention was developed in collaboration between researchers, clinicians with previous experience in adolescent musculoskeletal pain, and informed by adolescents and parents from a previous trial. The aim was to counteract the previous difficulties with compliance and limited clinical effects[12,14]. The aim of the intervention was to change the behaviour considered one of the likely contributors to the onset of pain, and persistence of pain in adolescents with PFP: high knee joint loading through high volumes of physical acticity[6,14]. To investigate changes in target behaviour we used objective measure of physical activity (via wrist Actigraphy) and self-report questionaires (see full description in section on outcomes).

The intervention was delivered by one of two physiotherapists to all adolescents, irrespective if the currently participated in sport. After the inclusion visit where adolescents were screened for eligibility and consent, adolescents and parents needed to attend four supervised visits, over a 12-week period. Parents were required to take part in all five visits. All information from the physiotherapists was also delivered in a patient leaflet (patient leaflet in English can be seen in appendix 1 and manual for physiotherapists in appendix 2b).

The intervention was structured around three blocks of 4 weeks, with specific clinical tools introduced in each of the three blocks (Table 1, Figure 1, appendix 1). The intervention was focused on activity modification and load management, where the adolescents, after an initial reduction in sports participation (to reduce knee joint loads), were gradually introduced and

exposed to increasing knee joint loads. The initial activity and load modification in block 1 included a temporary removal from sports participation from week 0-4, and avoiding activities that aggravate their knee beyond what the pain monitoring model considered "OK". During block 2 (week 4-8), adolescents were instructed in further load-management via progressive home-based hip and knee exercises (see full description of exercises in appendix 1), and an activity ladder. The aim of the activity ladder was to gradually expose the adolescent to activities with higher knee joint loads based on their own assessment of symptoms (maximum 2 on NRS scale during, after, or the day after a given activity). When they could perform an activity within the "OK" zone, without a pain flare-up, they were instructed to progress to the next level.

Figure 1: The combined activity ladder and pain monitoring model. The pain monitoring tool (bottom) guided the adolescent through the six steps in the activity ladder.



In block 3, participants were instructed to perform home-based weight-bearing hip and knee exercises (see description of exercises in appendix 1), and gradually return to sport using a pre-planned model starting with participation in warm-up and then adding 15 minutes per week using the pain monitoring model as guidance. Return to play was only initiated if they had reached level 6 on the activity ladder.

Table 1. Overview of content during the three blocks in the intervention period. A full description of all the components can seen in appendix 2 that contains the leaflet and additional details on the different components.

	BLOCK 1 (WEEK 0-4)	BLOCK 2 (WEEK 5-8)	BLOCK 3 (9-12)
EDUCATIONAL COMPONENTS	Factors contributing to PFP Risk of PFP Load and sport Rationale for treatment	Importance of adherence Proper exercise form Monitor and progress	Progression to sport Monitor and progress Continued exercises
MODALITIES TO GRADUALLY DECREASE/INCREASE KNEE JOINT LOADS	Activity modification Double limb bridge Static holds 10x 30sec (daily)	Hip and knee exercises	Weightbearing hip and knee exercises
SPECIFIC TOOLS INTRODUCED	The activity ladder Pain monitoring	The activity ladder Pain monitoring	Graded return to sport, after step 6 has been reached on "activity ladder"

Self-report outcome measurements

Self-reported data were collected using written forms. Participants were asked to report their most painful knee if they suffered from bilateral knee pain. The primary outcome was self-reported recovery on a 7-point Global Rating of Change scale (GROC) (ranging from "much improved" to "much worse") at 12 weeks' follow-up. This outcome has been used in previous trials on both adults and adolescents with PFP[2,14,26]. Adolescents were categorized as having a successful outcome if they rated their knee pain as "much improved" or "improved". Additional follow-ups were done at 4 weeks, 8 weeks, 6 months, and 12 months.

Secondary outcomes included the patient-reported questionnaire Knee Injury and Osteoarthritis Outcome Score (KOOS) [16] which contains five separate subscales (Pain, Symptoms, Activity in Daily

Living (ADL), Function in Sport and Recreation (Sport/Rec), knee-related quality of life (QoL)), to assess the adolescent´s opinion about their knee and associated problems. This questionnaire was chosen as it has previously been used in young adolescents with knee pain [9,12]. Health related quality of life was measured by the youth version of the European Quality of Life 5 dimensions (EQ-5D-Y) [1]. Adolescents were asked about worst knee pain during the past weeky using a numeric rating scale (NRS), and asked if they considered themselves to be completely free of knee pain at each follow-up.

Self-reported sports participation was collected using questions about sports participation per week (both training and competition) and type of sport. This was supplemented by objective measures of PA, assessed by wrist Actigraphs (ActiGraph, Pensacola, FL). Participants wore actigraphs after inclusion, for two weeks before the intervention including activity modification began (to measure baseline PA), and immediately following block 1 (activity modification).

Satisfaction with the result of treatment was measured on a five-point Likert scale ranging from "highly satisfied" to "not satisfied at all". Additionally, participants were asked using the same scale, if they would be satisfied to live with their current knee symptoms on the same scale and, if they would recommend the same treatment to a friend with the same type of knee pain, with the response dichotomized into no/yes. The final question was related to use of pain killers asked as "do you currently use pain killers for your knee pain".

Demographics

Weight was measured using a weighing scale, and height was measured using a measuring tape against the wall, while the participants stood in bare feet.

Assessment of hip and knee muscle torque

We assessed isometric knee extension torque, hip abduction and hip extension torque for all adolescents. Torque was assessed using the best of three consecutive measurements normalized to body weight and lever length. The testing setup included a portable dynamometer and an examination table. Torque was tested using a Power Track Commander handheld dynamometer (JTech Medical, Salt Lake City, Utah), fixed to the examination bed by a belt. All tests were conducted isometrically and can be seen in web-appendix 1. The testing procedure is identical with previous work in adolescent´s, which demonstrated high reliability[9].

Objective measure of physical activity

Adolescents were asked to wear a wrist wornActiGraph GT3X+ recording at 30 Hz for a minimum of one week following the clinical examination and determination of eligibility, prior to the beginning of the intervention. This was repeated after block 1 of the activity modification. For further information on data analysis, see supplementary appendix 1.

Adherence to the intervention

Adherence to the exercises were collected in self-report training diaries, while adherence to advice to reduce sports participation was collected via both self-report data, and the ActiGraph data. Adolescents were instructed to complete the training diary after every exercise session to record the number of exercises, sets and reps. A missing training diary (i.e. adolescents or parents did not return or forgot at several occasions to return), was interpreted as having done none of the exercises.

232

233 **Sample size**

234 Our previous studies in adolescents with PFP has shown that up to 50% of adolescent do not
235 respond favourable to the intervention[10,12]. We therefore based our sample-size on the ability to
236 test the association between key baseline characteristics and our primary outcome as well as
237 return to sport. Using a recommendation of at least 10 events per prognostic factor,and a rate of
238 successful outcome of around 50% of adolescents[8] we needed around 150 patients to test 5-7
239 potential prognostic factors. The prognostic factors of interest were physical activity level, severity
240 of knee pain (defined as symptom duration and intensity of knee pain) and health-related and
241 knee-related quality of life (EQ5D and $KOOS_{qol}$).

242

243 **Statistical analysis**

244 All data were visually inspected for approximate normality using a Q-Q plot. Mean values and ±SD
245 are reported if data were approximately normally distributed. If data were non-normally
246 distributed they were presented as median and interquartile range (IQR). Repeated measures
247 analysis of variance (RM ANOVA) was used to evaluate changes in strength over time with the
248 independent variable time (baseline, 4 and 12 weeks) for the dependant variables of hip extension
249 torque, knee extension torque and hip abduction torque. Similarly, RM ANOVA was used to
250 evaluate the effect of time (baseline, 4 weeks, 8 weeks, 12 weeks, 6 months, and 12 months) on
251 the KOOS subscales and EQ5D index scores. In cases where the assumption of sphericity was
252 violated, Greenhouse Geisser correction was used. To explore if any baseline characteristics was
253 associated with prognosis (assessed as a successful outcome on the GROC-scale) at the primary

endpoint, we compared the group having a successful outcome with the group not having a successful outcome. All calculations were performed using Stata version 11 (StataCorp, College Station, Texas, USA).

Results

Baseline characteristics

During the 12 months of recruitment, 151 adolescents with PFP between 10 and 14 years of age were recruited (Figure 2). Participants had a median age of 13 years (IQR: 12-14), and a median self-reported symptom duration of 18 months (IQR: 9-24 months) at inclusion (Table 2). Of these, 83% participated in sports, with the most common types of sport being soccer, handball and gymnastics. In total, 28% reported having previously been treated for their knee pain and 24% used analgesics for their knee pain at baseline. The most common treatments were unspecified treatment with a physiotherapist, shockwave and painkillers.

Figure 2: Flowchart

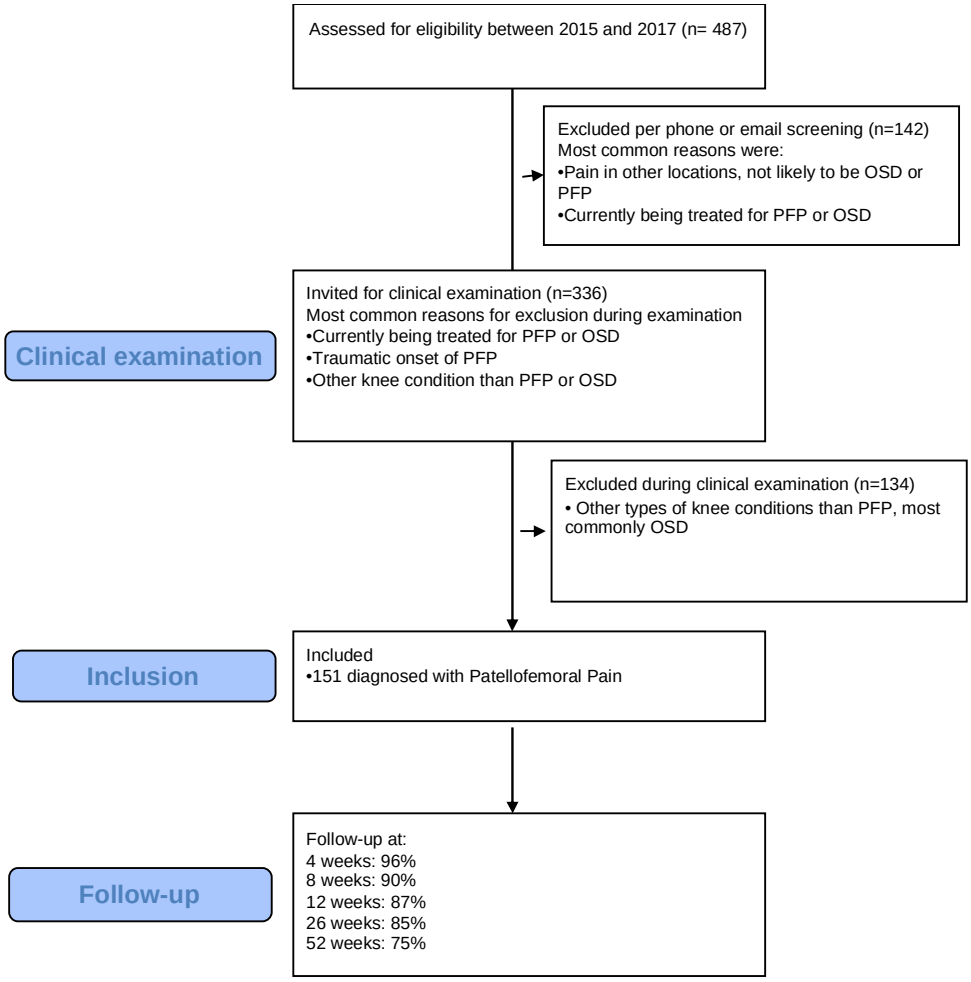


Table 2: Demographics

	Patellofemoral Pain (N=151)
Age	12.6 (1.2)
Gender (% females)	76%
Weight [kg], mean (SD)	50.4 (9.4)
Height [cm], mean (SD)	162.0 (9.6)
BMI [kg/m^2], mean (SD)	19.0 (17.2-20.8)
Duration of symptoms (n)*	
3-6 months	6
6-12 months	31
>12 months	107
Pain duration [months] median (IQR)*	18 (9-24)
Age when knee pain started [years], mean (SD)]**	11 (10-12)
Bilateral pain (% who replied yes)	73.5%
Previously treated for PFP (% who replied yes)	28%
Participated in sports prior to onset of knee pain (% who replied yes)	98%
Pain medication for knee pain (% who replied yes)	24%

* 7 adolescents with PFP were not able to remember when their knee pain started and did not respond to the question

Response rates

Response rates ranged from up to 96% at 4-week follow-up, 88% at the primary endpoint (12 weeks), and down to 75% at 12 months follow-up.

Compliance to the intervention

On average the adolescents decreased moderate to vigorous activity (MVPA) by 20 min (95%CI 12-28) per day (corresponding to 2h:20min per week) after instruction in the activity modification, compared to before the activity modification. ActiGraph data showed that 87/136 adolescents reduced MVPA, with 35/136 reducing their MVPA by more than 45 mins per day compared to baseline. The self-report data showed that 29/141 participated in sports during the activity modification.

In block 1, 51 to 59% of adolescents with available follow-up data were categorised as adherent (i.e they performed more than 80% of the isometric quadriceps activation and double limbs bridges). In block 2, 57% performed more than 80% of the exercises and 44% performed more than 80% of the exercises during block 3.

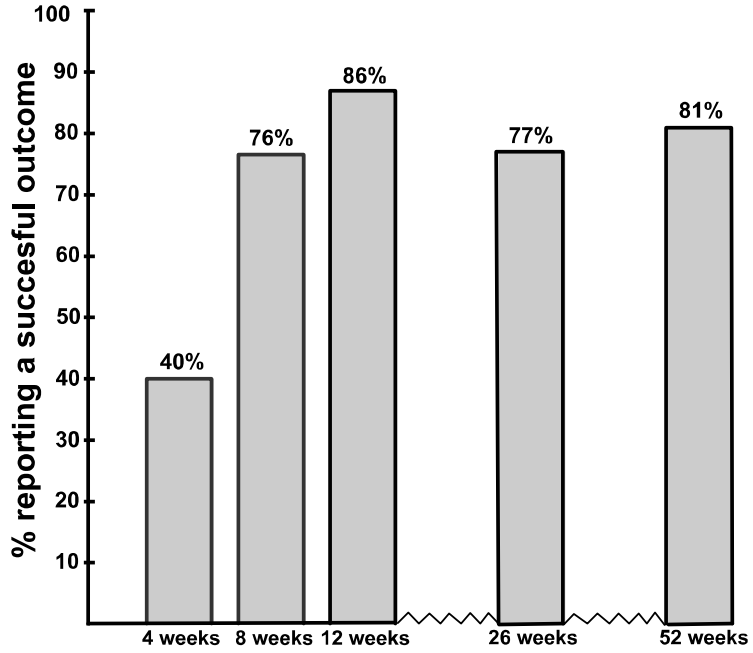
Primary analysis

After the 12-week intervention, 88% (N=132) completed the questionnaire, and of these, 86% (95%CI: 78-91%) were deemed to have a successful outcome (improved or much improved), with a slightly lower proportion at 6 months (77%, 95%CI: 68-83%) and 12 months (81%, 95%CI: 73-88%), Figure 3.

295

296 **Figure 3**: Proportion reporting a successful outcome (success defined as reporting "much

297 improved" or "improved" on the Global Rating of Change Scale).



298
299

Secondary analyses

Physical activity and sports participation

After 12 weeks, 68% of the participants reported that they were back playing sport, with 79% at 6 months and 81% at 12 months (Table 3).

Table 3: Sports participation

	Pre-intervention	4 weeks	8 weeks	12 weeks	6 months	12 months
Did you participate in sports the previous month? (% reporting yes)	138/151	29/141	47/131	84/124	93/120	91/115
Current sports participation (training + competition per week)? (frequency per week)*	2 (1-3.15)	1 (1-3)	2.5 (1-4)	2.25 (1-3.75)	3 (2-4)	4 (3-5)

***Presented as median and Interquartile range**

Knee pain

KOOS pain significantly improved over time ((F6,105);P<0.001; Table 5). Worst pain previous week on a NRS improved from a median of 7 out of 10 at baseline and down to 3 out of 10 at 12 weeks and 2 out of 10 at 12 months. At 12 weeks 92/133 considered themselves to be completely free from their previous knee pain, with 81/120 at 12 months.

Self-reported knee disability and quality of life

Across the three KOOS domains, ADL, sport and recreation and quality of life, adolescents with PFP improved 13-24 points from baseline to primary endpoint (Table 3; P<0.001) and 14-28 points to 12 months follow-up, (P<0.001). EQ5D index score increased significantly (F(4,52); P<0.001) by 0.20 points at 12 weeks and 0.22 points at 12 months (Table 4).

Table 4: Knee Injury and Osteoarthritis Outcome Score, EuroQoL 5D-3L and pain intensity

X	Pre-intervention Patellofemoral Pain (N=151)	Baseline, mean (SD) N=136	4 weeks, mean (SD) N=138	8 weeks, mean (SD) N=134	12 weeks, mean (SD) N=133	6 months, mean (SD) N=125	12 months, mean (SD), N=120	Change from baseline to 12 weeks, mean (95%CI)	Change from baseline to 12 months, mean (95%CI)
$KOOS_{pain}$ [0-100, worst to best]	66 (16)	68 (14)	74 (16)*	80 (15)*	86 (13)*	89 (14)*	88 (15)*	17 (15-20)	21 (18-24)
$KOOS_{symptoms}$ [0-100, worst to best]	77 (14)	78 (13)	82 (13)*	87 (12)*	90 (11)*	90 (12)*	90 (13)*	11 (9-14)	12 (9-15)
$KOOS_{ADL}$ [0-100, worst to best]	77 (15)	79 (14)	82 (14)*	87 (13)*	92 (10)*	94 (11)*	93 (12)*	13 (10-15)	14 (11-17)
$KOOS_{Sport/rec}$ [0-100, worst to best]	54 (23)	55 (21)	63 (28)*	71 (24)*	80 (20)*	82 (22)*	83 (21)*	24 (20-28)	28 (23-33)
$KOOS_{QOL}$ [0-100, worst to best]	50 (18)	49 (16)	49 (19)	57 (21)*	66 (22)*	75 (23)*	78 (23)*	16 (12-20)	28 (23-32)
EuroQol 5D 3L* [index score]		0.72 (0.63-0.78)	0.72 (0.60-0.80)	0.78 (0.71-0.82)*	0.82 (0.78-1.00)*	0.84 (0.78-1.00)*	0.83 (0.78-1.00)*	0.20 (0.16-0.24)	0.22 (0.17-0.27)
Worst pain last week (numeric rating scale), meadin (IQR)	7 (5-8)	7 (5-8)	5 (3-7)	4 (2-5)	3 (1-5)	2 (1-4)	2 (0-4)	3.5 (3.0-4.1)	4.3 (3.7-5.0)
Proportion considering themselves "free of knee pain"		N/A	52/144	68/135	92/133	87/125	81/120		

*indicates significant changes from baseline

Hip and knee torque

There was a significant effect of time for hip extension torque (F(2,139); P<0.001), hip abduction torque (F(2,24);P<0.001) and knee extension torque (F(2,64); P<0.001). Post-hoc tests revealed there was a significant increase in torque over time (Table 5) with the largest changes in hip extension torque with an 34% increase during the 12 weeks.

Table 5: Changes in isometric hip and knee torque from baseline to 12 weeks.

	Baseline (SD)	4 weeks (SD)	12 weeks (SD)	Change from baseline to 12 weeks (95%CI) (% increase)
Hip abduction torque (Nm/kg)	1.23 (0.42)	1.35 (0.48)*	1.49 (0.37)*	0.25 (0.17-0.33) 20.3%
Knee extension (Nm/kg)	1.85 (0.72)	1.96 (0.70)*	2.39 (0.84)*	0.48 (0.40-0.57) 27.9%
Hip extension (Nm/kg)	1.17 (0.44)	1.32 (0.41)*	1.56 (0.41)*	0.38 (0.34-0.43) 32.5%

* indicates significant increase from baseline at P<0.01

Satisfaction with treatment

At the primary endpoint (12 weeks), 74% participants reported being very satisfied with the result of treatment. One adolescent was very unsatisfied with the results of the treatment. 95% would recommend it to a friend with the same type of knee pain. Fifty percent were very satisfied to live with their current knee symptoms while 8% were very unsatisfied.

At 12 months follow-up 75% were very satisfied with the results of the treatment. 51% would be very satisfied to live with current level of symptoms, while 8% would be very unsatisfied. Ninety two percent would recommend it to a friend with similar knee pain.

Use of medication and additional treatments

At 12 weeks follow-up, 7% adolescents reported using painkillers, compared to 24% at baseline (P>0.001). Three percent reported having sought additional treatments at 12 weeks follow-up. Use of additional treatments, types, and use of pain killers across all time point can be found in appendix 3.

Prognostic factors

The were no statistically or clinically relevant differences in clinically measurable patient characteristics or adherence between those having a successful outcome and adolescents not having a successful outcome (appendix 4).

Discussion

This prospective study showed that 86% of adolescents with PFP were considered to have a

successful outcome (based on the GROC) at 12 weeks, with a slightly lower proportion after 6 and 12 months. Adolescents reported large improvements in knee pain and function, and 20-33% increase in hip and knee torque. This is the first study to test an intervention focussing specifically on activity modification and load management, where a high proportion of adolescents returned to sport at follow-up.

Prognostic factors

Preliminary evidence indicates that certain pain characteristics, as well as quality of life are associated with outcome in both short term and long term[11]. These findings were not replicated in the current study. None of the patient characteristics, or adherence to the intervention were different between those having a successful outcome and those who did not. The clinical implications of this, is that the large improvements seen may exist across sports active and non-sports active adolescents and both those with high and low levels of pain intensity.

Rates of success compared to previous studies on adolescent patellofemoral pain

A previous cluster randomised trial on supervised exercise plus patient education, versus patient education alone, using similar outcome as the present study, showed much lower success rates (29%) in both arms[12]. The current study on the other hand had 86% success rate, according to the same definition of success. Similarly, a pilot study in younger adolescents with PFP showed limited success on supervised exercise for young adolescents with PFP[10]. The poor results and adherence resulted in the conclusion that it was impractical to undertake a full clinical trial centered on exercise alone in young adolescents with PFP.

In contrast the current intervention focusing on activity modification and load management,

resulted in higher succes rates, and significantly improved KOOS scores, with improvements in KOOS sport/rec more than double compared to the two previous studies on adolescent PFP[12 10]. There are many potential reason for the greater effect of the current intervention compared to previous trials on adolescents with PFP[10,12]. Despite the underlying reason cannot be determined in the current investigation, some plausible explanations include that the current intervention focussed on modifying the sports/activities that are thought to be associated with the development of knee pain. Further, the intervention provided a structured approach to expose and build up tolerance to aggravating activities, helping adolescents be guided back to sports in a graded manner. This could potentially avoid the 'all or nothing' approach some patients take if not specifically guided on how to balance this- a balance that may be particulary difficult for adolescents. Another factor that may play a role in the positive results could be age, as no previous studies have investigated adolescents with PFP at such a young age. It is however unknown if these adolescents at 10-14 of age have a better natural history, than those who are older in previous research. However, these are all postulative and the intervention needs to be further evaluated and compared to a relevant control to determine its efficacy.

Despite the positive results, the improvement stagnated after 12 weeks, and after 12 months average KOOS (Sport/rec) was 83 points, which is still lower than the average 100 points for controls (blinded reference). Despite reporting improvement on the GROC, the sustained impairments in sports function and participation indicates this is a long-term condition that needs ongoing management . As a high proportion of adolescents will stop playing sports due to knee pain[11], effective treatments need to consider how to target return to sport, as this is an important aspect of their life.

Although 2/3 successfully returned to sport at three months, 1/3 did not, and at 12 months 1/5 were still not back playing sport. The majority of those who had not returned at 12 months had reported a desire to return, but 4/120 had given up due to knee pain.

In the present trial self-reported weekly sports participation was overall increased from inclusion to twelve months. This suggests that despite that participants reported they had reduced participation at inclusion due to knee pain, quite a large proportion were able to return and increased their activity after the intervention. This is encouraging, as a previous trial on adolescents between 15 and 19 years of age with PFP actually reduced their overall sports participation from inclusion to 12 months[12].

Good adherence and strength improvements

The adherence to refrain from sports participation in block 1 was good (almost 80%). Adherence to the exercise part was very high (44-57% with more than 80% adherence) compared to previous trials where almost none participated in more than 80% of the prescribed exercises[12 10].

Previously, only minor with-in group strength improvements (between 0 and 10%) have been reported in adolescents receiving an exercise program[10,13]. One exception is a technology supported intervention which gave feedback on the execution of exercises and reported a 25% strength increase [15]. Whether the the 20-33% increased hip and knee torque occuring in the current study is a result of the large pain reduction or the good adherence to the strengthening exercises is unknown, and needs further investigation. However, regardless of the underlying

mechanism, such an improvement in hip and knee muscle strength could be an important adaptation as this may reflect an increase in the the load bearing capacity of hip and knee specific tissues.

Satisfaction with results of treatment was high

75% participants were "very satisfied" with the results of treatment, which is higher compared to two previous studies in adolescents with PFP (50-60% despite pooling "very satisfied" and "somewhat satisfied") [10,13 12] . However, only 1 in 2 would be "very satisfied" to live with their current symptoms at the end of the trial and only 68% considered themselves being free from knee pain even after 12 months. Based on this, the GROC may paint an overly positive representation of treatment outcome, and just because they report an improvement in symptoms, does not mean they do not continue to suffer from pain, and experience deficits in important domains, such as sport. Therefore, while the current results are better than previous studies using the same outcome, it is unknown if the the dose and delivery of the intervention could still be optimised in order to ensure the goal (being pain-free and normal function) is better attained in subsequent iterations of the intervention.

Painkiller usage in adolescents with PFP

In the current study, 24% participants used painkillers at inclusion, which decreased to 7% after 3 months. The reduction in use of painkillers was associated with a drop from 7 to 3 in pain intensity (NRS) in the same period. This is particularly note-worthy as no advice on painkillers was given in the education, and indicating a decreased requirement for pain relief. The effect of the intervention on painkiller use is larger than in previous trials on adolescents with PFP. In particular,

in one study 24% adolescents used painkillers at the beginning which decreased to 18 % after 3 months[12] and far greater than a pilot study involving 20 adolescents with PFP between 12 and 16 who found no effect of the intervention on use of painkillers[10].

Limitations

The lack of comparator and randomization hinders a direct comparison to previous exercise therapy focused trials. The long duration of knee pain (on average 18 month) do suggest that quick recovery is unlikely and suggest a specific effect of the intervention. This trial cannot disentangle natural recovery versus the specific effects of the intervention. However, due to the dearth of effective interventions for this specific age group and population, the current intervention including only four supervised sessions over a 12 week period seems relevant to adopt in clinical practice, as best available evidence on this particular young age group. The study was underpowered for the investigation of prognostic factors as we had far higher rates of successful outcome than anticipated.

Future research

Patellofemoral pain in adolescents has been notoriously difficult to treat and highlighted as a research priority[17]. The current study is the first to provide evidence of an intervention with both good short and longer term effects (up to 12 months). Despite the intervention was considered a "success" based on the GROC, not all considered themselves completely free from knee after 12 months with 20% not returning to sport, which suggests that ongoing management of this condition is still needed. Future research should investigate how to optimize the treatment of

young adoslescent with PFP further, including optimal timing of interventions and comparisons to a control intervention.

Conclusion

A treatment strategy focusing on activity modification and load management was associated with high rates of successful outcomes in adolescents with PFP, at both 12 and 52 weeks. These short and longer term outcomes were supported by improvements in symptoms, and in objective measures of hip and knee torque.

References

1. Burström K, Egmar AC, Lugnér A, Eriksson M, Svartengren M. A Swedish child-friendly pilot version of the EQ-5D instrument—the development process. *Eur J Pub Health*. 2011;21.

2. Collins NJ, Barton CJ, van Middelkoop M, et al. 2018 Consensus statement on exercise therapy and physical interventions (orthoses, taping and manual therapy) to treat patellofemoral pain: recommendations from the 5th International Patellofemoral Pain Research Retreat, Gold Coast, Australia, 2017. *Br J Sports Med*. 2018;52(18):1170-1178. doi:10.1136/bjsports-2018-099397.

3. Crossley KM, Stefanik JJ, Selfe J, et al. 2016 Patellofemoral pain consensus statement from the 4th International Patellofemoral Pain Research Retreat, Manchester. Part 1: Terminology, definitions, clinical examination, natural history, patellofemoral osteoarthritis and patient-reported outcome measures. *Br J Sports Med*. 2016;50(14):839-843. doi:10.1136/bjsports-2016-096384.

4. de Lucena GL, Santos Gomes dos C, Guerra RO. Prevalence and Associated Factors of Osgood-Schlatter Syndrome in a Population-Based Sample of Brazilian Adolescents:. *Am J Sports Med*. 2010;39(2):415-420. doi:10.1177/0363546510383835.

5. Elm von E, Altman DG, Egger M, et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *J Clin Epidemiol*. 2008;61(4):344-349. doi:10.1016/j.jclinepi.2007.11.008.

6. Hall R, Barber Foss K, Hewett TE, Myer GD. Sport specialization's association with an increased risk of developing anterior knee pain in adolescent female athletes. *J Sport Rehabil*. 2015;24(1):31-35. doi:10.1123/jsr.2013-0101.

7. Holden S, Rathleff MS, Jensen MB, Barton CJ. How can we implement exercise therapy for patellofemoral pain if we don't know what was prescribed? A systematic review. *Br J Sports Med*. 2017;25:bjsports–2017–097547. doi:10.1136/bjsports-2017-097547.

8. Ogundimu EO, Altman DG, Collins GS. Adequate sample size for developing prediction models is not simply related to events per variable. *J Clin Epidemiol*. 2016;76:175-182. doi:10.1016/j.jclinepi.2016.02.031.

9. Rathleff CR, Baird WN, Olesen JL, Roos EM, Rasmussen S, Rathleff MS. Hip and knee strength is not affected in 12-16 year old adolescents with patellofemoral pain--a cross-sectional population-based study. *PLoS ONE*. 2013;8(11):e79153.

10. Rathleff MS, Rathleff CR, Holden S, Thorborg K, Olesen JL. Exercise therapy, patient education, and patellar taping in the treatment of adolescents with patellofemoral pain: a prospective pilot study with 6 months follow-up. *Pilot and Feasibility Studies 2018 4:1*. 2018;4(1):73. doi:10.1186/s40814-017-0227-7.

11. Rathleff MS, Rathleff CR, Olesen JL, Rasmussen S, Roos EM. Is Knee Pain During Adolescence a Self-limiting Condition? *Am J Sports Med*. 2016;44(5):1165-1171. doi:10.1177/0363546515622456.

12. Rathleff MS, Roos EM, Olesen JL, Rasmussen S. Exercise during school hours when added to patient education improves outcome for 2 years in adolescent patellofemoral pain: a cluster randomised trial. *Br J Sports Med*. 2015;49(6):406-412. doi:10.1136/bjsports-2014-093929.

13. Rathleff MS, Samani A, Olesen JL, Roos EM, Rasmussen S, Madeleine P. Effect of exercise therapy on neuromuscular activity and knee strength in female adolescents with patellofemoral pain-An ancillary analysis of a cluster randomized trial. *Clin Biomech (Bristol, Avon)*. 2016;34:22-29. doi:10.1016/j.clinbiomech.2016.03.002.

14. Rathleff MS, Vicenzino B, Middelkoop M, et al. Patellofemoral Pain in Adolescence and Adulthood: Same Same, but Different? *Sports Med*. 2015;45(11):1489-1495. doi:10.1007/s40279-015-0364-1.

15. Riel H, Matthews M, Vicenzino B, Bandholm T, Thorborg K, Rathleff MS. Feedback Leads to Better Exercise Quality in Adolescents with Patellofemoral Pain. *Med Sci Sports Exerc*. 2017;Publish Ahead of Print:1. doi:10.1249/MSS.0000000000001412.

16. Roos EM, Lohmander LS. The Knee injury and Osteoarthritis Outcome Score (KOOS): from joint injury to osteoarthritis. *Health Qual Life Outcomes*. 2003;1(1):64. doi:10.1186/1477-7525-1-64.

17. Smith BE, Selfe J, Thacker D, et al. Incidence and prevalence of patellofemoral pain: A systematic review and meta-analysis. *PLoS ONE*. 2018;13(1):e0190892. doi:10.1371/journal.pone.0190892.

18. Swain M, Kamper SJ, Maher CG, Broderick C, McKay D, Henschke N. Relationship between growth, maturation and musculoskeletal conditions in adolescents: a systematic review. *Br J Sports Med*. March 2018:bjsports–2017–098418. doi:10.1136/bjsports-2017-098418.

19. van der Heijden RA, Lankhorst NE, van Linschoten R, Bierma-Zeinstra SM, van Middelkoop M. Exercise for treating patellofemoral pain syndrome: an abridged version of Cochrane systematic review. *Eur J Phys Rehabil Med*. 2016;52(1):110-133.