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Original Article

The effect of an individualised functional retraining intervention on pain, function and biomechanics in participants with patellofemoral pain: a series of n of 1 trial

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Abstract. [Purpose] To determine the effect of an individualised functional retraining intervention on pain, function, kinematics and self-reported recovery in participants with PFP. [Participants and Methods] Thirty-one participants with unilateral PFP between the ages of 14–40 were included. Data collection and treatment sessions were conducted at the Tygerberg 3D Motion Analysis Laboratory and Physiotherapy Clinic at the University of Stellenbosch Medical School in Cape Town, South Africa. Participants underwent motion analysis testing pre- and post-intervention and attended physiotherapy weekly for a 6-week individualised intervention. [Results] Thirty of the thirty-one participants (96.8%) demonstrated improved pain levels (NPRS) post intervention. Participants demonstrated a statistically significant improvement in function (AKPS) immediately post intervention and continued to improve with greater functional scores at 6-month follow up. Fifteen participants (48.4%) rated themselves as fully recovered on a 7-point Likert scale at 6-month follow up. Nineteen of the 31 participants (61.3%) demonstrated a clinically significant improvement in their priority kinematic outcome post intervention. [Conclusion] Individualised functional retraining may improve pain, function, kinematics and long-term recovery in participants with PFP presenting with kinematic contributing factors. Clinicians need to be educated on common biomechanical contributing factors and how to tailor treatment accordingly.

Key words: Anterior knee pain, Gait analysis, Individualised intervention

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INTRODUCTION

Patellofemoral pain (PFP) is characterised by retropatellar or peripatellar pain during activities such as squatting, stair climbing and prolonged sitting that load a flexed knee joint[1)]. It has an estimated prevalence of 19–31% in a young athletic population[2)]. The causes of PFP are multifactorial and biomechanical factors may play an important role in its development[3)]. Many of the proposed causes of PFP are likely to be associated with patient biomechanical dysfunction or poor dynamic stability during weight-bearing activities[4)]. The impact of PFP is considerable as it hinders participation in sport, physical activity, work, and school[5)]. In addition, it has the tendency to become chronic. As many as 50% of participants with PFP will still experience symptoms after 5–8 years[6)].

Conservative approaches, primarily physiotherapy, are preferred for the treatment of PFP. Surgical options such as lateral retinacular release, chondroplasties, proximal realignments and distal realignments should be considered a last resort thereafter[7)]. In addition, surgery should only be considered when there are specific indications and the pathology is clearly defined[8)]. At the recent Patellofemoral Pain Research Retreat in 2016, a document of current evidence-based treatment guidelines was

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created[9]. According to this, current recommended treatment options include exercise therapy in the short, medium and long term; multimodal interventions in the short and medium term; and foot orthoses in the short term. The authors concluded that exercise should be considered the first choice of treatment due to the large body of evidence supporting it[9]. This recommendation is supported by a high-quality systematic review that investigated the effect of exercise in the treatment of PFP[10]. Despite the tendency of PFP to become chronic, the review showed that long-term evidence was limited. Three studies followed up on pain and functional outcomes 4–12 months post intervention[11–13]. Of these, only one study[13] measured self-reported long-term recovery at 12-month follow up. In this study, the exercise group was no more recovered than a control group that had not received an exercise intervention. It is unclear why exercise appears to improve pain and function in the short term, but recovery in the long term remains challenging. There is evidence that suggests that an individually tailored approach to exercise interventions improves patient outcomes in participants with other musculoskeletal conditions such as lower back pain[14]. Therefore, further investigation of this approach in an PFP population is needed.

Since the 2015 Cochrane review[10], a prospective cohort study investigated the long-term effects of a multimodal individualised intervention for PFP[15]. Thirty-seven participants with AKP received four treatments over a 4-week period, namely local interventions which focused on stretching the quadriceps; fourteen days of taping; fourteen more days of specialised lower limb movement and postural correction; followed by continued self-management. Subsequently a 3 year follow up yielded positive results with 73% pain-free and 27% having less pain than previously. Moreover, 82% returned to their sporting activities, while 54% took up new sports. Only 7% experienced a recurrence of PFP. The inclusion criteria for this study only required that patients had a 1-month duration of symptoms. Therefore, treatment success can be ascribed to early interventions and the effect of this intervention on persistent PFP remains unknown.

According to McMaster University's hierarchy of evidence[16] and the Oxford Centre for Evidence-Based Medicine[17], a n of 1 design can be regarded as level 1 evidence for treatment decisions as it enables the assessment of the intervention for a specific person[18]. Recent studies have acknowledged the difficulty in applying the mean response (as assessed in an RCT) to a specific person[19]. The selected methodological design attempts to address this problem by facilitating the translation of evidence into practice. This study will provide new information on potential risk factors associated with PFP and attempt to correlate biomechanics to functional and clinical outcomes through long-term follow up. To our knowledge no studies have assessed the effects of an individualised functional retraining intervention that targets specific biomechanical factors in participants with PFP. In addition, our study design is novel as we are using a series of n of 1 design. By using participants as their own controls, we are allowing for individual variation in aetiology and symptoms.

We hypothesise that an exercise intervention tailored to the individual can improve pain, function and kinematics in participants with PFP post-intervention compared to pre-intervention. The aims of this study are to determine the effect of an individualised functional retraining intervention on 1) lower limb kinematics and 2) short- and long-term pain and functional outcomes in 31 participants with PFP.

PARTICIPANTS AND METHODS

Approval for this study was given by the Health Research Ethics Committee (HREC) of Stellenbosch University, under ethics number N13/05/038. Informed consent was obtained for all included participants.

The study was conducted using a series of single-participant design with each participant acting as his or her own control.

The population comprised 31 participants between the ages of 14–40 with unilateral PFP, residing in the Cape Metropolitan. Our sample size was determined from a priori power analysis for a single-group pre-test post-test design and the effect size using pilot data on a sub-sample of eight participants. A two-tailed Wilcoxon-signed rank test was used as the data was abnormally distributed. Assuming that alpha=0.05, power=0.95 and effect size=0.75, we needed a sample size of n=27. We recruited 31 participants to allow for drop out.

An evidence-based screening tool was developed specifically for this study (Appendix A) to ensure standardised diagnosis and exclusion of other pathologies. This checklist is based on an up-to-date evidence synthesis on systematic reviews. An initial screening was done at recruitment. Potential participants were asked to complete a short, screening questionnaire via email, containing the subjective indicators required for the diagnosis of PFP. Participants were considered based on age, area of pain, duration of pain, aggravating factors and previous medical history. Sixty-seven participants inquired and of these 31 met the subjective criteria. The most common reason for exclusion was age (>40 years old).

Individuals who met the criteria in the preliminary screening were booked for a testing session at the 3D Motion Analysis Laboratory at the Tygerberg campus of Stellenbosch University. At the first session written informed consent was obtained and all participants were screened based on the objective criteria described in the evidence-based diagnostic checklist. All 31 participants met the criteria and could therefore proceed to the 3D motion analysis assessment. VICON-specific anthropometric measurements that were obtained prior to the motion analysis included: height, mass, leg length, knee diameter and ankle diameter.

A fast, accurate, reliable and high-resolution motion-capturing 3D device, the T10 VICON Analysis (LTD) (Oxford, UK) T10 system[20] was used to obtain the 3D movement analysis data. Retro-reflective markers with a diameter of 9.5 mm were applied. The standard plug-in gait model was used, providing the angle output sought in the current study. Nexus 1.8 software was used for preliminary marker reconstruction, labelling and processing of data. All marker placements were done by an

experienced researcher (DL), to reduce marker bias. Gap filling was performed using the standard Woltring filter supplied by Vicon. Segment and joint kinematics were calculated using the PIG-model and filtered with a 4th-order Butterworth filter at a 34 10 Hz cut-off frequency. Data was exported to MATLAB to extract the joint kinematics of the lower limbs.

Participants were required to attend gait analysis sessions at week 1, week 2, and week 8. Gait analysis was used to screen for kinematic factors associated with PFP that could be targeted with treatment, as there are well-established normative values for these outcomes. The normative dataset is based on gait data from healthy, pain-free participants walking at a self-selected speed tested in the Tygerberg motion analysis laboratory.

Testing was repeated on three occasions. Sessions 1 and 2 were to establish the test-retest reliability of the kinematic outcomes and to quantify measurement error. Session 3 was done post intervention to determine the effects of the intervention. Therefore, the duration of the entire testing period was eight weeks. Function was measured using the anterior knee pain scale (AKPS) and was assessed pre- and post-intervention on the same day as the gait analysis assessment to evaluate the subjective impact of the treatment on the patient's function and daily activities. The validity and reliability of the AKPS has been established in an PFP population[21]. The AKPS was followed up at three months, one month after the end of the intervention period, and again at six months. The AKPS can be found attached as Appendix B. The testing procedure and timing of outcome measures can be seen in Fig. 1.

The intervention has been described according to the template for intervention description and replication (TIDieR) checklist[22]. Individualised functional retraining is an approach to exercise that targets participant-specific biomechanical risk factors by focusing on correcting a dysfunctional movement pattern rather than addressing a specific muscle group. Experts in the field[23] recommend incorporating movement pattern retraining as part of the exercise plan for participants with PFP, as it is unclear whether specific muscle group strengthening translates to improved movement performance[24]. A progressive exercise database adapted from a recent textbook on functional rehabilitation[25] was created to assist with the choice of exercises. Two exercise database spreadsheets were created. The first focused on components of walking and was used to choose exercises for weeks 1–3. The second focused on components of squatting and was used to choose exercises for weeks 4–6. Functional retraining during these exercises focused on the specific kinematic factor exhibited by the patient. The exercises were ranked according to three levels of difficulty within task and area. Exercises were progressed according to the following principles: bilateral before unilateral, stable surface before unstable surface, and body weight before loading[25]. Examples of proximal and local focused exercises at different levels of difficulty from the database are available as supplementary file 1 (online only).

Participants were required to exclusively attend the Tygerberg Physiotherapy Gym weekly for six weeks for individual supervised treatment sessions. The progress of the exercises was assessed weekly and adjusted as needed. Examples of the individually tailored exercises over the 6-week period can be seen as supplementary online data. The therapist's instructions to the patient as well as criteria for progression has been described in detail in a previous study[26].

The participants were required to do the exercises at home three times a week apart from their weekly supervised treatment sessions because published reports suggest that supervision is beneficial in the early phases of rehabilitation to monitor technique. However, participants should be motivated to independency as quickly as possible[27].

The clinician asked patients to complete a weekly pain monitoring and exercise compliance diary at each treatment session (Appendix C). The treatment sessions were administered by one of two experienced musculoskeletal physiotherapists (DL and MM).

The data was initially analysed for each individual participant by describing measures of central tendency (means) and variation expressed (standard deviations) of pelvis, hip, knee and ankle kinematics, at baseline and post-intervention. The 2-standard deviation (SD) band method was used to determine which participants obtained clinically meaningful improvements in their priority kinematic factor[28]. This method has been previously used to analyse single-participant design data as it accounts for individual variability[29]. The two standard deviation band method is based on the computation of the deviation for the pre-intervention baseline data. Once the standard deviation is computed for the baseline data, bands are drawn on the graph that contain scores within two standard deviations from the mean. If the mean post-intervention data points fall outside of the 2SD band the change in kinematics is considered clinically significant[30].

The pain and functional outcome scores were used to determine who improved, whose condition was unchanged or whose worsened. The data was categorised according to severity of pain and level of functional impairment. A χ^2 test established categorical changes following treatment and at 3- and 6-month follow up. Stata version 13 was used for data analysis.

Primary outcomes included priority kinematic factor identified for each participant based on decision-making algorithm using gait analysis as a screening tool (Appendix D). This algorithm was developed specifically for the study and is based on a systematic review of the evidence[31], pain ratings using the numeric pain rating scale (NPRS) over the 8-week testing period and 3- and 6-month follow up (post-intervention period), functional scores using the AKPS at week 1, week 8 and 3-month and 6-month follow up (post-intervention period), and self-reported long-term recovery on a 7-point Likert scale at 6-month follow up (post-intervention period).

RESULTS

Thirty-one participants (13 males, 18 females) with unilateral PFP (20 left-sided, 11 right-sided) were included in this

Table 1. Sample description (affected side, age, gender, height and mass)

	Sample size (n)	Affected leg	Average age (years) Mean (SD)	Average height (cm) Mean (SD)	Average mass (kg) Mean (SD)	Average BMI (kg/m^2) Mean (SD)
Males with PFP	13	8 Left	31.5	176.9	85.62	27.4
		5 Right	(8.7)	(8.2)	(24.19)	(6.0)
Females with PFP	18	12 Left	29.22	165.3	65.56	24.3
		6 Right	(7.9)	(11.6)	(23.98)	(6.1)
All participants	31	20 Left	30.2	170.2	77.50	26.8
		11 Right	(8.4)	(10.5)	(25.70)	(6.1)

Table 2. Proportion of participants in different categories of pain severity (NPRS) throughout the follow-up period

Categories	Actual scores (NPRS)	Pre-intervention	Post-intervention	3-month follow up	6-month follow up
0	0 (pain-free)	0 (0%)	18 (50.1%)	18 (50.1%)	18 (50.1%)
1	1–3 (mild)	12 (38.7%)	10 (32.3%)	12 (38.7%)	11 (35.5%)
2	4–6 (moderate)	15 (48.4%)	3 (9.6%)	1 (3.2%)	2 (6.5%)
3	7–9 (severe)	4 (12.9%)	0 (0%)	0 (0%)	0 (0%)

Table 3. Proportion of participants in different categories of functional impairment (AKPS) throughout the follow-up period

Categories	Actual scores AKPS (100)	Pre-intervention	Post-intervention	3-month follow up	6-month follow up
1	<60 (severe functional impairment)	2 (6.5%)	0 (0%)	0 (0%)	0 (0%)
2	60–79 (moderate functional impairment)	21 (67.7%)	6 (19.4%)	4 (12.9%)	3 (9.7%)
3	80–99 (minor functional impairment)	8 (25.8%)	24 (77.4%)	20 (64.5%)	19 (61.3%)
4	100 (No functional impairment)	0 (0 %)	1 (3.2%)	7 (22.6%)	9 (29%)

study. The average age was 30 (range 14–40; SD=8.4), height (mean=170.1 cm; SD=10.4 cm) and weight (mean=77.5 kg; SD=25.7 kg). The average duration of symptoms was 16.5 months and 64% of the participants had tried previous treatment such as massage, taping, pain medication and strength training. Participant characteristics are depicted in Table 1.

The weekly pain diary using the NPRS showed that 30 of the 31 participants (96.8%) demonstrated improved pain levels (NPRS) post-intervention (8 weeks). Table 2 shows the changes in pain severity based on NPRS scores throughout the follow-up period. The percentage of participants in each category differed significantly pre- versus post-intervention $X^2(4, N=31)=12.4$, $p=0.02$. These positive changes reflected a significantly greater percentage of participants in the "pain-free" and "mild" pain categories post-intervention.

There were no significant changes between pain categories post-intervention (8 weeks) compared to the 3-month follow up $X^2(4, N=31)=8.1$, $p=0.9$ and 6-month follow up indicating that the effects were maintained without improvement. The same applied at the 6-month follow up compared to the post-intervention showing that the treatment effects were maintained in the long term $X^2(4, N=31)=3.7$, $p=0.4$. Pain diary results for each participant throughout the treatment period are available online only as supplementary file 2. Table 3 shows the changes in functional impairment based on AKPS follow-up scores. The percentage of participants in each category differed significantly pre-versus post-intervention $X^2(4, N=31)=10.8$, $p=0.03$. These changes were positive with a significantly greater percentage of participants in the minor disability categories following the intervention.

There were no significant changes between pain categories post-intervention (8 weeks) compared to the 3-month follow up $X^2(4, N=31)=6.3$, $p=0.2$ indicating that the effects were maintained but not improved. The same applied at the 6-month follow up compared to the post-intervention showing that the treatment effects were maintained in the long term $X^2(4, N=31)=2.8$, $p=0.6$.

Self-reported long-term recovery was measured on a 7-point Likert scale at the 6-month follow up as seen below in Fig. 2[13]. The measurements ranged from fully recovered to worse than before. If participants regarded themselves as having recovered well or having recovered completely, they were classified as "recovered". Those who were "not recovered", identified as worse than before or as minimally recovered[13, 32]. Fifteen participants (48.4%) rated themselves as fully recovered, whereas only one participant (AKP12) rated herself as not recovered. The remaining 48.4% reported being "partially recovered" with scores of between 3 and 5.

The test retest reliability of the kinematic outcomes was established in a previous study[33]. A comparison of session 1 and

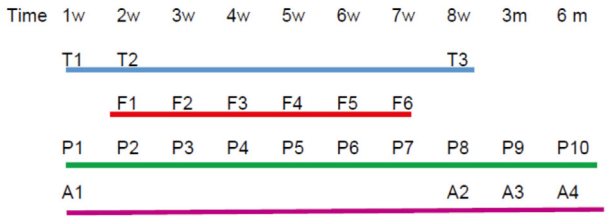

Fig. 1. Timeline for measurement procedure for study outcomes. T: Gait analysis test; F: Functional movement retraining intervention; P: Pain measurements (NPRS); A: Anterior knee pain scale (functional measurements); w: weeks; m: months.

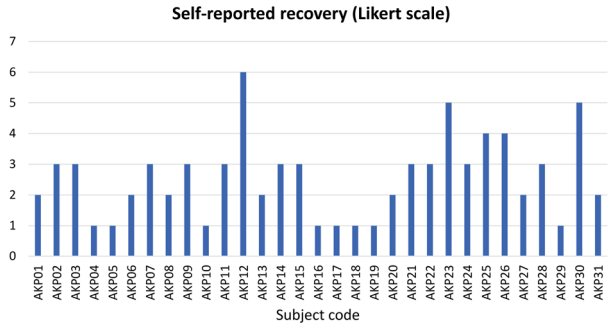

Fig. 2. Self-reported recovery for all participants on a Likert scale at 6 months post intervention.
1. Completely recovered, 2. Strogly recovered, 3. Significant improvement, 4. Moderate improvement, 5. Little improvement, 6. Slightly recovered, 7. Worse than ever.
AKP: Anterior knee pain.

Table 4. Results for priority kinematic factor

Priority kinematic factor identified on affected side	Number of participants presenting with this factor n (%)	Number of participants demonstrating clinically significant changes n (%)	Number of participants not demonstrating clinically significant changes n (%)
Decreased knee flexion in stance	5 (16.1)	1 (5)	4 (36.4)
Increased bilateral knee extension throughout the gait cycle	10 (32.2)	9 (45)	1 (9)
Increased R peak hip adduction	8 (25.8)	5 (25)	3 (27.3)
Decreased L peak hip internal rotation	8 (25.8)	5 (25)	3 (27.3)
Total	31	20	11

2 kinematic data, tested one week apart with no intervention in between revealed that all outcomes obtained were acceptable to excellent test-retest reliability scores for both measures of relative reliability (ICC=0.78–0.9) and measures of absolute reliability (SEM=0.9 −4.2 degrees). Hip frontal plane and ankle sagittal plane outcomes were the most reliable with the lowest measurement error. Hip transverse plane outcomes were least reliable and demonstrated the highest measurement error.

Results for participant's priority kinematic factor are summarised in Table 4. Detailed individual findings can be found online only as supplementary file 3. Of the 31 participants, 20 (64.5%) showed clinically significant changes post-intervention compared to pre-intervention. Of these 19 (61.3%) improved (positive change) and one (3.2%) worsened (negative change). Ten participants (32.3%) showed no significant change in their priority kinematic factor following treatment. There were no significant differences between genders with 11/18 (61%) of females and 8/13 (61%) of males showing clinically meaningful improvements. The 25 adult participants aged 20–40 did slightly better than the six adolescents, with 64% and 50% improving respectively. However, a bigger adolescent group is required to draw further conclusion.

DISCUSSION

The results of this study showed that most participants demonstrated improvements in self-reported pain and function following an individualised functional retraining intervention. The effect of the intervention on average pain levels had improved one month later (3-month follow up). As had the average functional scores (AKPS) with 96.8% of the participants reporting clinically significant improvements in function. Given that the participants had all experienced PFP for longer than three months at the time of recruitment, it is possible that central mechanisms were involved[34]. This can be classified as sub-acute going on chronic pain. Therefore, function could be a more important indicator of treatment success than pain.

These findings concur with a recent high-quality systematic review[10] that exercise is effective in improving short-term pain and function. In the current study, the participants demonstrated improved pain levels in the medium term at 3 months following completion of the intervention and these were maintained in the long term at 6-month follow up. In terms of functional outcomes, the participants showed improved functional scores at 3 months and they reported that their functional scores had continued to improve at 6-month follow up.

There is limited and low-quality long-term evidence for the effect of exercise in the treatment of PFP[35]. One study[12] found that proprioceptive neuromuscular facilitation (PNF) and aerobic exercise interventions resulted in significantly reduced pain and significant improvements in function in participants with PFP at 4 months post intervention. The effects of these two intervention groups were equal and demonstrated greater improvements in all outcomes than a third group that only received stretching. However, this was not followed up at 6 or 12 months post intervention. Another study[11] did a long-term follow up for four different treatment groups 1) exercise, taping and education, 2) exercise and education, 3) taping and education and 4) education only. The exercise intervention focused on eccentric strengthening of the lower limb extensors and participants received 6 sessions over a 3-week period. At 12-month follow up, the exercise groups showed significantly greater improvements in pain compared to the other groups. However, the long-term functional scores where equal. This shows that reductions in pain do not necessarily result in improvements in function. The reasons for this are unclear, however it is possible that a 3-week intervention period was insufficient to address functional impairment in the participants. It is also possible that participants did not continue with self-management after the treatment period especially if pain had decreased. The findings of the current study showed improvements in pain and function at a 6-month follow up; however, it is unclear how this compares to other exercise interventions and if the effects would be maintained at 12 months or even a few years later. These limitations should be addressed in future research.

A major challenge in the treatment of PFP is that participants tend to improve with exercise but don't recover fully[13]. The 6-month follow up showed that half of the participants (48.6%) recovered fully and half reported being partially recovered. This is similar to findings from a previous exercise intervention study that found that 43% had recovered at 3-month follow up and 62% at 12-month follow up[13]. Exercise interventions need to prevent reoccurrence; therefore, one needs to ascertain what inhibits full recovery. In the current study, one of these factors could be compliance with continued self-management after the 6-week supervised exercise period, as this was not measured.

Several recent studies have established which patients are most likely to experience favourable outcomes with different conservative treatment approaches[36–38]. A longer duration of symptoms (>4 months) will most likely result in a poor outcome. Other prognostic factors include older age, greater usual pain severity and lower baseline AKPS score[38]. One study[37] found that females respond better than males to exercise therapy. Kinematic differences may exist between genders. These factors include increased dynamic measures of knee valgus angle, hip internal rotation angle and decreased dynamic measures of knee flexion angle compared to males[39]. Females may have decreased hip strength compared to pain-free controls[40] and thus exercise that strengthens hip muscles might be more beneficial for women than for men. We identified males and females with hip kinematic risk factors and found no significant differences between the genders with both benefiting equally from hip-focused interventions.

Nineteen participants showed clinically significant changes in their priority kinematic factor, targeted with functional exercises. Eleven demonstrated no significant change and one participant (AKP18) worsening of his main kinematic factor identified in session 1. The reason for this is unclear as the participant reported a full recovery, with no pain (0/10 on the AKPS) and full function (100% on AKPS) at the 6-month follow up. The participant was a trail runner and reported decreasing his training load during the intervention period and gradually progressing again once his pain had subsided. This suggests that training factors such as medication or load and intensity may have contributed to his symptoms.

It is estimated that 60% of overuse running-related injuries stem from training errors, including rapid increases in running distance and intensity[41]. It is impossible to control for all factors and accurate monitoring of training variables (such as a weekly exercise diary) is essential. A recent RCT conducted on 69 participants with PFP[42], randomised participants to one of three groups: 1) education on activity modification alone, 2) education and strength exercises and 3) education and gait retraining. The authors unexpectedly found that all groups improved equally after the 8-week intervention period and at 3-month follow up suggesting that exercise and gait retraining provided no additional benefit to education on activity modification alone. This not only highlighted the importance of education and activity modification, but also challenged the recommendation that exercise should be the cornerstone of treatment for participants with PFP[15] by suggesting that activity modification should be the central component of treatment in runners with PFP. It would be interesting to see if the results were the same if the participants were followed up at 6 to 12 months post intervention. It is unclear if an individualised exercise approach might influence the findings. However, it is clear that targeting kinematics is just one component of individualised treatment. Activity modification and load management is vital and should be included in an individualised treatment plan.

Our results suggest that an individualised approach to exercise may be beneficial in reducing short-term pain and improving short-, medium- and long-term function in participants with PFP. Kinematics during gait may also improve in patients presenting with kinematic contributing factors. In order to provide individualised interventions more research needs to be done using an n of 1 design. The vision of this study is to move away from an approach whereby all patients receive the same intervention and to move towards an individualised approach that addressed participant-specific impairments.

A limitation of the current study is that the gait analysis re-assessment was only done immediately post intervention. Future research should include a biomechanical reassessment at the long-term follow up to establish whether the biomechanical results were maintained or improved and how this relates to long-term pain and function. Another limitation is that the kinematic factors that were identified are based on cross-sectional studies and therefore we cannot establish if they are factors predictive of PFP or rather effects of the pain. The current intervention is only relevant for participants with PFP presenting

with kinematic risk factors and cannot be generalised to all participants with PFP. If we are trying to achieve a holistic person-centred approach to treatment, an individually tailored treatment approach based only on biomechanics is insufficient as it only addresses one aspect of the biopsychosocial model of treatment. Future research should develop ways to tailor treatment to the individual taking into consideration the interplay of physical, biological, psychological and social factors[14].

In conclusion, most participants (64.5%) demonstrated clinically meaningful improvements in their priority kinematic outcome post intervention. The effects of the intervention were maintained in the long term and half of the participants reported that they had recovered fully at 6 months post intervention. Future research should investigate factors preventing individuals with PFP from full long-term recovery.

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Appendix A. Checklist for diagnosis of patellofemoral pain

Subjective information:

	YES	NO
Age (must be yes)		
14–40[1–5)]		
Area (must be yes)		
Front of knee or retropatella[1–5)]		
Chronicity		
Longer than 3 months[1, 3, 5)]		
Aggravated by (must be yes for 2 or more of the following)		
Squatting[1–5)]		
Prolonged sitting[1–5)]		
Stairs (ascending or descending)[1–5)]		
Kneeling[1–5)]		
Excluded if any of the below known		
Previous lower limb surgery[1, 3, 5)]		
History of trauma[1, 3, 5)]		
Rheumatological conditions[1, 3, 5)]		
Known intra-articular pathology: ligament and osteoarthritis[1–5)]		
Patellar instability[1, 4)]		
Knee effusion[1, 5)]		
Patella subluxation/ dislocation[1, 5)]		
Fat pad impingement/ bursitis[3, 5)]		
Osgood Sclatter[1,3)]		

OBJECTIVE TESTS:

Symptom reproduction with (must be positive for at least 1 of the following activities)		
Squatting[1–5)]		
Kneeling[1–5)]		
Ascending or descending stairs[1–5)]		
Positive for at least one of the following		
Patella compression test[1, 4)]		
Patella tilt test[1, 4)]		

OR

(Minimum 2/3) positive for combination of

Squatting[3)]		
Isometric quads[3)]		
Palpation of patella borders[3)]		

Excluded if positive for

Lachmen's Test[6–8)]	ACL		
Posterior Drawer Test[6, 8)]	PCL		
Valgus Stress Test[6, 8)]	MCL		
Varus Stress test[6, 8)]	LCL		
McMurray's Test[6, 8)]	MENISCUS		
Patellar Ballotment Test[5)]	Effusion		

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Appendix B. Anterior knee pain scale

ANTERIOR KNEE PAIN (Sheet code_____)

Name: _____ Date: _____

Age: _____ Knee: L/R

Duration of symptoms:_____ years _____months

For each question, circle the latest choice (letter), which corresponds to your knee symptoms.

1. Limp
(a) None (5)
(b) Slight or periodical (3)
(c) Constant (0)

2. Support
(a) Full support without pain (5)
(b) Painful (3)
(c) Weight bearing impossible (0)

3. Walking
(a) Unlimited (5)
(b) More than 2 km (3)
(c) 1-2 km (2)
(d) Unable (0)

4. Stairs
(a) No difficulty (10)
(b) Slight pain when descending (8)
(c) Pain both when descending and ascending (5)
(d) Unable (0)

5. Squatting
(a) No difficulty (5)
(b) Repeated squatting painful (4)
(c) Painful each time (3)
(d) Possible with partial weight bearing (2)
(e) Unable (0)

6. Running
(a) No difficulty (10)
(b) Pain after more than 2 km (8)
(c) Slight pain from start (6)
(d) Severe pain (3)
(e) Unable (0)

7. Jumping
(a) No difficulty (10)
(b) Slight difficulty (7)
(c) Constant pain (2)
(d) Unable (0)

8. Prolonged sitting with the knees flexed
(a) No difficulty (10)
(b) Pain after exercise (8)
(c) Constant pain (6)
(d) Pain forces to extend knees temporarily (4)
(e) Unable (0)

9. Pain
(a) None (10)
(b) Slight and occasional (8)
(c) Interferes with sleep (6)
(d) Occasionally severe (3)
(e) Constant and severe (0)

10. Swelling
(a) None (10)
(b) After severe exertion (8)
(c) After daily activities (6)
(d) Every evening (4)
(e) Constant (0)

11. Abnormal painful kneecap (patellar) movements (subluxations)
(a) None (10)
(b) Occasionally in sports activities (6)
(c) Occasionally in daily activities (4)
(d) At least one documented dislocation (2)
(e) More than two dislocations (0)

12. Atrophy of thigh
(a) None (5)
(b) Slight (3)
(c) Severe (0)

13. Flexion deficiency
(a) None (5)
(b) Slight (3)
(c) Severe (0)

PAIN DIARY: RECORDED AT SAME TIME AND DAY ONCE A WEEK

Date	Time	Description of pain	0-10	What aggravated pain	What eased pain	Other comments (pain, mood, activities, medication, etc)

EXERCISE COMPLIANCE DIARY: RECORDED AT SAME TIME AND DAY ONCE A WEEK

Date	Time	How many times this week did you do your exercises (1-7 days)	On those days were all sets or repetitions performed?	Other comments

Appendix D. Evidence-based algorithms for screening during gait

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