DOI: 10.22122/jrrs.v15i2.3408 Published by Vesnu Publications

Comparison of the Effect of Hip and Knee Strengthening with Internal Instruction Exercises on Pain and Dynamic Knee Valgus in Patients with Patellofemoral Pain Syndrome

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Original Article

Abstract

Introduction: Patellofemoral pain syndrome (PFPS) is one of the most common musculoskeletal disorders, and is related to biomechanical factors of the lower extremities. Hip and knee muscle strengthening is a well-known method for the treatment of PFPS, but there is insufficient evidence for its effectiveness in combination with other effective interventions. The purpose of this study was to compare the effect of hip and knee strengthening with internal instruction exercises on pain and dynamic knee valgus in patients with PFPS.

Materials and Methods: The present study was a quasi-experimental intervention. 50 men and women with PFPS (18 to 45 years) participated in this study. Subjects were assigned to experimental (n = 25) and control (n = 25) groups. Evaluation of pain was conducted using visual analog scale (VAS) questionnaire, and dynamic knee valgus by two-dimensional video camera. Subjects in the control group received hip and knee strengthening exercises, and in the experimental group performed hip and knee strengthening with internal instruction exercise for six weeks, three sessions per week and each session for 45 minutes. Independent and dependent t tests were used for statistical analysis.

Results: Adding internal focus instruction on hip and knee strengthening exercises affected the dynamic knee valgus angle of the patients with PFPS, and significantly reduced the dynamic knee valgus angle ($P < 0.001$). Moreover, there was no significant statistical effect on pain with the addition of internal focus on hip and knee strengthening exercises.

Conclusion: Hip and knee strengthening with internal instructions exercises seem to be more effective in improving dynamic knee valgus than exercises that focus solely on strengthening the hip and knee muscles.

Keywords: Patellofemoral pain syndrome; Strength training; Feedback; Pain; Dynamic valgus

Citation: Aghakeshizadeh F, Letafatkar A. **Comparison of the Effect of Hip and Knee Strengthening with Internal Instruction Exercises on Pain and Dynamic Knee Valgus in Patients with Patellofemoral Pain Syndrome.** J Res Rehabil Sci 2019; 15(2): 65-71.

Received: 04.04.2019 Accepted: 15.05.2019 Published: 05.06.2019

Introduction

Patellofemoral pain syndrome (PFPS) is one of the most common musculoskeletal disorders (MSDs) with a prevalence of 25 to 40% which affects 25% of people. Given that the patellofemoral joint (PFJ) is one of the most important joints in the body in terms of loading, such a prevalence rate for this injury is not surprising (1). The cause of PFPS has not been fully elucidated and is thought to be multifactorial, often associated with lower extremity biomechanical factors (2). PFPS is caused by a variety of factors, including increased foot pronation, increased internal tibial rotation with increased valgus stress, excessive lateral patellar tracking, muscle imbalance, or overuse (3). Researchers have recently reported a link between hip muscle weakness or motor control impairment (MCI) and PFPS (4-6). Poor hip control may lead to abnormal patellar tracking, increased PFJ stress, and wear on the articular cartilage (7). Some studies have suggested that lowered strength of the abductor and external rotator hip muscles is an important risk factor for patellofemoral pain and anterior cruciate ligament (ACL) injury (8). One of the contributing factors in this issue is the change in

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the pattern of movement called the dynamic knee valgus (DKV) (the knee inward movement during weight bearing) (7) and is characterized by the increased hip proximity, hip internal rotation (HIR), and knee external rotation. DKV increases the PFJ stress and in the long run causes injury and pain (9). Previous investigations have reported that a history of patellofemoral pain increases the risk of developing patellofemoral arthritis over time (10). Given these factors, a treatment strategy for PFPS may include optimizing the function of the abductor and external rotator muscles to control femoral movements and preventing or reducing excessive lateral forces applied on the patella.

Therapeutic guidelines for managing PFPS patients recommend multimodal intervention programs including strengthening exercises such as strengthening the hip muscles (4,8), hip and knee muscles (3), mobilization (2), patient training, and movement pattern correction (9-11). Strong evidence also supports the use of exercise programs with or without other therapeutic considerations to manage patients with PFPS to reduce pain and improve performance (12-14). However, there is insufficient evidence to determine the optimal form of exercise (15). Knee and hip muscles appear to play a significant role in PFPS (3). The findings of studies indicate that strengthening exercises for the hip and quadriceps muscles, compared to strengthening the quadriceps muscles alone, lead to better outcomes in improving pain and performance in individuals with PFPS (3,16-18). On the other hand, motor control approaches have been employed in recent years to prevent and treat chronic musculoskeletal pain and their effects have been reported.

Feedback is an essential tool for learning and performing motor skills and the fastest and easiest form of training available (19). In fact, the use of additional feedback during movement is an essential part of learning motor skills associated with optimizing lower limb movements (19). The results of some studies show that providing visual feedback through mirrors and video or verbal tapes improves DKV and muscle function (18-22), but there is insufficient evidence on their effect in combination with routine interventions. In a study, Baldon et al. concluded that the intervention program, which included strengthening the hip muscles and the lower limb and trunk movement control exercises, was more effective in improving pain, physical performance, kinematics, and muscle strength in comparison to the quadriceps strengthening exercise program (18).

In line with previous studies on feedback and training in subjects with PFPS (18-22), the present study is carried out aiming to investigate and compare the addition of internal feedback to routine exercises (hip and knee resistance exercises). The researcher assumed that adding internal feedback to hip and knee strengthening exercises was more effective than strengthening exercises in kinematic improvement of individuals with PFPS.

Materials and Methods

The samples were collected during a call from the Health and Wellness Center, Kharazmi University of Tehran, Tehran, Iran. Patients aged 18 to 45 years who were eligible for the study were included in the initial assessment. The inclusion criteria for the subjects to enter the study included anterior knee pain for at least three months (23), positive Clark test (24), increased pain in at least two activities including going up and down stairs, squats, kneeling, long sitting (23), and pain when touching the inner or outer part of the patella (23).

Individuals with a history of lower limb surgery, a history of cardiovascular diseases (CVDs), neurological disorders, knee and thigh injuries, pregnancy, osteoarthritis (OA), and rheumatoid arthritis (RA) (23), subjects with other pathologies of the knee, such as patellofemoral dysplasia, patellar instability, ligament rupture, torn meniscus, and tendinopathy, as well as individuals with a difference in leg length of more than 1 cm in the supine position from the upper anterior thoracic spine to the internal ankle (23) were excluded from the study. The second author of the paper, who was blinded to the grouping of patients, examined the inclusion and exclusion criteria.

Prior to the study, written consent was obtained from the subjects. The sample size was estimated to be 25 people in each group using the data from the study by Clark et al. (25) and $\delta = 94$, $\sigma = 141$, a power level of 80%, an alpha level 0.05, and taking into account a possible drop rate of 10%.

The Clark (26) test was employed to identify subjects with PFPS. After the initial evaluation, the subjects were randomly divided into the two control (hip and knee strengthening exercises: n = 25) and experimental groups (hip and knee strengthening exercises with internal instruction exercises: n = 25).

After the initial evaluation of the patients, randomization was performed based on four blocks. A number of consecutive numbers generated by a table of numbers by a computer were randomly placed in opaque envelopes. A person blinded to the patients and intervention groups performed the randomization and allocation of numbers to the groups. In addition, the patients in each group were unaware of the randomization and intervention of the other group. Then the instructions for the interventions and exercises were explained for each group separately.

The visual analogue scale (VAS) was utilized to measure pain. VAS indicates general pain in patients. The internal consistency of this scale was reported to be between 0.77 and 0.79 for PFPS (27,28).

A two-dimensional video camera (SONY®, DCR-SX44E, Japan) was used to measure DKV. The two-dimensional video recording method for lower limb kinematic evaluation was valid with Intraclass Correlation Coefficient (ICC) = 0.92 (29). The DKV angle of the subjects was measured while performing single-leg squats, based on markers placed on the acromioclavicular (AC) joint, patellar center, anterior-superior iliac spine (ASIS), fifth metatarsal, and center of the distance between the two ankles (30). Before testing, the static status of the individual was filmed and its angles were extracted. The displacement of the markers between the two static states and the end of the single-leg squat movement was then calculated. In all patients, the markers were affixed to the desired landmarks by a single tester.

The exercises began two days after the initial test. The patients in both groups performed exercises for six weeks, three sessions per week, and 45 minutes each session. In each group and at the beginning of each session, the relevant exercises were fully explained by the researcher, and then the subjects performed warm-up for 10 minutes. Then, they performed the desired exercises for 30 minutes, and at the end, 5 minutes of cooling down was performed by the researcher. The training sessions in each group were administered by a single tester. The subjects were asked not to participate in any other training programs during the training sessions, and during the first two weeks, if the patients reported severe pain during the movement, the intensity of the movement would be reduced so that the patient could perform it easily and painlessly. The intensity of the exercises at the beginning of the first week was calculated based on the one-repetition maximum for each person. The intensity calculation was repeated at the beginning of the third and sixth weeks in the same manner. The patients began training with low intensity and number of sets, but with high number of repetitions. The exercise intensity increased each week using ankle weights and TheraBand, but the number of sets and repetitions changed every two weeks; in this way, the number of repetitions and sets was respectively decreased and increased.

The training protocol in the present study was organized based on the studies by Baldon et al. (18), Riel et al. (31), and Scali et al. (3). The main goal of the exercises was to increase the strength of the hip and knee muscles and to improve the motor control of the lower limbs during the movements. Internal feedback was used to correct the knee valgus and trunk movements in the experimental group. The participants in the control group received only the hip and knee strengthening exercises, and no feedback was provided to correct movements in this group. Internal feedback was given at the beginning of the training session and generally to familiarize the subject with the movements and the correct direction of the lower limbs, but no feedback was provided by the researcher during the exercises. For example, the subjects were trained to “prevent the hip adduction, prevent the hip internal rotation, or keep the trunk in the correct direction”.

Descriptive statistics were used to describe the data of each group as well as to determine the measures of central tendency [mean and standard deviation (SD)] for all variables and demographic information of the subjects. The Shapiro-Wilk test was employed to measure the normal distribution of data, the paired t-test to compare the mean of the data collected from the kinematic and pain variables in the pre- and post-test stages within each group, and the independent t-test for the inter-group comparisons. Finally, the data were analyzed in SPSS software (version 20, IBM Corporation, Armonk, NY, USA). $P < 0.05$ was considered as the significance level.

Results

There was no significant difference between the groups in terms of demographic characteristics (Table 1).

Table 1. Mean demographic characteristics of subjects

Variable	Experimental (n = 25)	Control (n = 25)	P value
Age (year)	28.64 ± 7.68	28.88 ± 6.52	0.900
Height (cm)	164.56 ± 3.59	163.56 ± 3.78	0.340
Weight (kg)	64.15 ± 5.57	63.40 ± 4.34	0.640

Data are reported based on mean and SD.

There was no significant difference between the two groups in the variables of pain and DKV in the pre-test stage ($P \leq 0.771$), but no significant difference was observed between the two groups in the DKV variable in the post-test stage ($P \leq 0.019$) (Table 2).

Table 2. Comparison of dynamic knee valgus (DKV) scores

Group	Pre-test (Mean ± SD)	Post-test (Mean ± SD)	P value (Intragroup)	Paired t	df	Effect size
Experimental (n = 25)	16.91 ± 1.53	11.58 ± 1.62	< 0.001*	-35.81	24	-2
Control (n = 25)	16.78 ± 1.80	12.75 ± 1.75	< 0.001*	-38.04	24	-1.6
P value (Intergroup)	0.771	0.019	-	-	-	-

*Significant difference
df: Degree of freedom; SD: Standard deviation

Intergroup difference in the DKV scores was not significant in the pretest stage, but it was significant in the posttest stage. There was no significant difference between the two groups in the amount of pain in the pre-test (P ≤ 0.661) and post-test stages (P ≤ 0.697) (Table 3).

In both groups, there was a significant improvement in pain and DKV compared to the pre-test state (Tables 2 and 3).

Discussion

The present study was carried out with the aim to investigate the effect of hip and knee strengthening exercises along with internal focus instructions on pain and DKV in individuals with PFPS. The results suggested that the strengthening exercises for the hip and knee muscles, along with internal feedback on the correct alignment of the lower extremities, are more effective in correcting DKV compared to strengthening the hip and knee muscles without feedback. After six weeks of training, DKV was higher in the internal feedback group and the treatment was more successful compared to the control group. However, both groups showed significant statistical progress after participating in the training programs. Moreover, a significant intragroup difference was observed in the two groups in the DKV variable compared to the initial assessment.

Both groups experienced significant improvements in pain levels, but it should be taken into account that the intergroup changes were not significant for the groups after six weeks of intervention. However, the groups showed significantly lower pain and more successful treatment at the end of the intervention program.

Studies have suggested that patellofemoral pain and functional impairment experienced in patients can be due to high levels of the PFJ stress, caused by the trunk and lower extremity abnormal movements, especially abduction and excessive internal rotation of the hip (32,33). Defects in in the dynamic direction are believed to be associated with the weakness of the abductors and external rotators of hips (32), and given this, the probable reason for the success of the strengthening intervention in the present study may be a link between the strength of the hip muscle and dynamic direction of the lower limbs. The hip adductor and external rotator muscles act to prevent hip adduction and internal rotation during functional activity, along with eccentric weight bearing (34). However, in subjects with patellofemoral pain, hip abductors are unable to effectively control hip adduction through eccentric contraction (35). As a result, weakness of the hip muscles is one of the factors influencing the development and treatment of PFPS and should be considered in the treatment of these patients (35).

In the current study, the rehabilitation protocol included exercises that targeted the muscles of both the hip and knee joints. Therefore, given the findings on the significant intragroup changes in both groups, it can be argued that the hip muscle strengthening exercises should be considered in preventing musculoskeletal injury as well as in treatment. However, a review study found that the outcomes on the effect of strengthening exercises on the kinematics of the lower extremities are contradictory. In a study, strengthening exercises did not lead to the improved kinematics (36); however, it improved kinematics in two other studies (18,21). The authors of these studies stated that the changes observed were most likely due to feedback used in the exercise protocol (37).

Table 3. Comparison of level of pain

Group	Pre-test (Mean ± SD)	Post-test (Mean ± SD)	P value (Intragroup)	Paired t	df	Effect size
Experimental (n = 25)	6.32 ± 2.07	3.80 ± 1.89	< 0.001*	21.50	24	-0.8
Control (n = 25)	6.08 ±1.75	4.00 ± 1.70	< 0.001*	10.02	24	-0.8
P value (Intergroup)	0.661	0.697	-	-	-	-

*Significant difference
df: Degree of freedom; SD: Standard deviation

In the present study, feedback was used in combination with exercises to address the shortcomings of the strengthening programs alone and to increase the desired clinical aspects and achieve better consequences. The findings revealed that the DKV angle was significantly better in the feedback group, which was consistent with the findings of previous investigations on the effectiveness of feedback in improving the symptoms and biomechanics of patients with PFPS (9,10,18-22,31). Baldon et al. reported that the feedback approach is very important to influence changes in the kinematics of the lower extremities, and that the hip-strengthening exercises alone may not be sufficient to alter motor patterns (18).

Conducting a study, Emamvirdi et al. concluded that training DKV control during exercise improves pain, function, and kinematic characteristics in women with PFPS (38). Graci and Salsich carried out a study in order to examine the kinematics of the trunk and lower extremities while performing single-leg squats on women with PFPS, and concluded that under the valgus pattern correction conditions, subjects experienced a reduction in hip adduction and internal rotation of the hips (22).

Based on the above-mentioned issues, the results of the present study were in line with the findings of previous studies which stated that a rehabilitation program including hip and knee strengthening exercises with feedback on the dynamic direction of the lower limbs, was more effective than a therapeutic program that only targeted muscle strengthening (18-22,31). Therefore, the use of feedback to correct body and lower limb posture while performing movements is effective for patients with PFPS, especially those who perform movements with inappropriate movement patterns.

Limitations

The present study was accompanied by some limitations, including the fact that the training program used was performed for only six weeks. Therefore, the long-term effects of this program cannot be determined. Additionally, patients with PFPS in the present study were active and non-athletic individuals. Furthermore, a two-dimensional video camera was used to record and evaluate the kinematic data of the lower extremities on the frontal plane.

Recommendations

It seems necessary to conduct a study to examine the effects of the interventions applied in the present study. In future studies, the impact of these interventions on athletes should also be measured. Although the two-dimensional method of measuring the DKV angle indicated a high validity, it is recommended that future studies use three-dimensional motion analysis to assess the lower extremity kinematics.

Conclusion

The hip and knee strengthening along with the internal focus instruction exercises are more effective in improving the kinematics of the lower limbs on the frontal plane compared to the exercises that focus only on strengthening the hip and knee muscles.

Acknowledgments

The present study was taken from a M.Sc. thesis performed on Sports Pathology and Corrective Movements, with the code of ethics DBSI20102018 and the clinical trial registration code UMIN000038672 from Kharazmi University of Tehran. The Vice Chancellor for Research, Kharazmi University of Tehran and all the patients who cooperated in the implementation of this study are appreciated.

Authors' Contribution

Fatemeh Aghakeshizadeh: Study design and ideation, attracting financial resources for the study, supportive, executive, and scientific services of the study, providing study equipment and samples, data collection, analysis and interpretation of results, specialized statistics services, manuscript preparation, specialized manuscript evaluation in scientific terms, confirmation of the final manuscript to be sent to the journal office, responsibility for maintaining the integrity of the study process from beginning to publication, and responding to the referees' comments; Amir Letafatkar: Study design and ideation, attracting financial resources for the study, supportive, executive, and scientific services of the study, providing study equipment and samples, data collection, analysis and interpretation of results, specialized statistics services, manuscript preparation, specialized manuscript evaluation in scientific terms, confirmation of the final manuscript to be sent to the journal office, responsibility for maintaining the integrity of the study process from beginning to publication, and responding to the referees' comments.

Funding

The present study was conducted based on the secondary analysis of part of a M.Sc. thesis on Sports Pathology and Corrective Movements with the code of ethics DBSI20102018 and the clinical trial registration code UMIN000038672 as well as with the financial support of the authors and Kharazmi University of Tehran. Kharazmi University did not comment on data collection, analysis, and reporting, manuscript compilation, and final approval of the study for publication.

Conflict of Interest

Authors declare no conflicts of interest. Dr. Amir Letafatkar works as an Assistant Professor, Sports Pathology and Corrective Movements, Kharazmi University of Tehran. Fatemeh Aghakeshizadeh has been an MSc Student, Sports Pathology and Corrective Movements, School of Physical Education and Sport Sciences, Kharazmi University of Tehran since 2017.

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