Effect of six-week static quadriceps stretching on pain and lower extremity kinematics during running in individuals with patellofemoral pain syndrome

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Abstract

Patellofemoral Pain Syndrome (PFPS) is one of the most common influential disorders on individual’s lower limb. A change in kinetics and kinematics of lower limb, structural disorders of lower limb, paresis, the decrease of strength and dynamic malalignment are the risk factors of PFPS. The risk factors playing a role in PFPS development are as follow: kinematic and kinetic changes during functional activities and the decrease of strength and flexibility of knee and thigh joints. Therefore, the goal of the current research is to investigate the influence of 6-week static stretching of quadriceps on pain and kinematics of lower limb during running in individuals with Patellofemoral Pain Syndrome. For this aim, 27 individuals with PFPS in two experimental (age 22/86±2/31, year and BMI 24/89±2/25) and control groups (age 23/38±1/44, year and BMI 23/42±2/94) and also 11 healthy individuals (age 24/27±1/73, year and BMI 24/69±1/74) have been chosen from the volunteers for participating in this test. The amount of pain was measured by VAS scale and the kinematic variables of lower limb with the constant speed of 3/3 m/s during running on treadmill were measured by three-dimensional motion analysis system with six optoelectronics camera. Due to normality of kinematic variables, independent t-test was used for comparison between groups and the repeated analysis of variance test with the significance level of P<0/05 was used for comparison within groups. Due to disapproval of parametric test assumptions, non-parametric tests were used for evaluation of pain. After the period of training, there was no significant difference between kinematic variables of lower limb (hip internal rotation P=0/468, valgus knee P=0/255, knee flexion P=0/717, tibial rotation P=0/208 and foot pronation P=0/199). But the amount of pain was significantly different in comparison between groups (P=0/000). Pain was significantly decreased in experimental group (P=0/001) and was significantly increased in control (P=0/031) and healthy (P=0/018) groups. Generally, the implementation of 6-week stretching of quadriceps did not influence on the kinematics of lower limb but it influenced on the improvement of pain.

Keywords: Patellofemoral pain syndrome, anterior knee pain, kinematic, running.
Introduction
Patellofemoral pain syndrome (PFPS) is one of the most common influential disorders on individuals' lower limb. The anterior knee pain is very common and impresses one athlete from four. 70% of these athletes are between 16 to 25 years old. Due to the fact that Patellofemoral joint is one of the most important joints of the body in terms of loading, the prevalence of this damage is not surprising (2). The chronic pain in Patellofemoral joint is a very serious problem, because it can result in restriction of movement, arthritis, and permanent disability in individuals (3). The individuals with this disease usually complain about a dull pain in the posterior part of patella and surrounding it and this pain intensifies in activities such as going up and down the stairs, running, prolonged sitting and also physical activities. Due to high prevalence of this disorder, the reason of this diseases is not understood clearly (3). Although the study findings have been contradictory, the decrease of lower limb joints flexibility has been seen as a characteristic in individuals with anterior knee pain. The individuals with anterior knee pain show a significant decrease in the flexibility of twin, soleus, quadriceps and Hamstring joints in comparison with control and healthy groups. A futuristic research that is specifically done on athletes shows a relationship between short quadriceps joint and the development of anterior knee pain (2). The decrease in flexibility of quadriceps femoris joints has an important role in the beginning of symptoms related to PFPS and it is usually aimed by training protocols. Static stretching is usually used for the increase of joints' flexibility in clinical conditions. This kind of training is very safe and easy and it is also used as an inseparable part of soft issues rehabilitation. The skeletal-muscular researches show that many of the recognized parameters can be impressed by stretching (1). Due to the fact that patella is in quadriceps joints set, the training of this muscular group is the main intervention for the management of Patellofemoral pain syndrome. Doing the quadriceps joints exercises significantly plays a role in primary cares of individuals with Patellofemoral pain syndrome in terms of pain decrease and performance improvement in short and long term in comparison with typical and painless recommendations (4). PFPS results in kinetic and kinematic changes in a motion system in addition to creating pain and decreasing the performance and these changes result in the development of Patellofemoral pain syndrome (5). A right understanding of how lower limb kinematic impresses Patellofemoral joint is an important issue, the interventions in unnatural control of lower limb mechanic are not concentrated in the area of pain, they are in the upper and lower parts and joints of Patellofemoral joint (6). Different kinds of pathomechanic factors may influence on the prevalence of PFPS and for the effectiveness of intervention, we must concentrate on the underlying factors creating this syndrome and prescribe the treatment according to it (7). Since a wide range of factors may result in the prevalence of PFPS, it is unlikely that the use of treatment will be useful for all patients with PFPS. In order to optimize the rehabilitation, we must aim the influential factors resulting in the prevalence of PFPS for the selection of medical practice. It is hoped that the evaluation and recognition process in the use of treatment for these individuals become better by understanding the potential factors in lower limb kinematics that play a role in functional disorders of Patellofemoral joint (6). Most of the researches done up to now in the field of the treatments' influence on kinematics of the individuals' with Patellofemoral pain syndrome contain of brace and taping and according to
our findings, less research can be found in the field of the influence of training protocols on lower limb kinematics (7-9). Also, the selection of treatments is more based on the therapist's opinion than laboratory evidences (4). Due to the mentioned factors, this question is proposed: Can we improve the pain and modify and change the kinematics such as hip internal rotation, vulgus knee, and the amount of flexion in individuals with Patellofemoral pain syndrome by entering the training protocols based on the reason of the illness (short quadriceps joint)? The goal of this research is to investigate the influence of 6-week static stretching of quadriceps on pain and kinematics of lower limb during running in individuals with Patellofemoral Pain Syndrome.

Materials and Method
This research is futuristic in terms of time, it is descriptive in terms of topic and it is semi-experimental in terms of method and strategy. In order to control the conditions of subjects (daily exercises, nutrition and sleep), the statistical society of the present research is all the soldiers of one of Kerman military garrisons. 52 soldiers of this military garrison whose age are between 21 28 years old are selected by purposive and available sampling. These individuals are placed in 3 experimental, control and healthy groups. The criteria for participating in this research were the presence of pain in front of the knee and behind the patella or surrounding it for at least 6 months and the positivity of Clark test. Having patellofemoral joint pain in at least two of the aforementioned cases and going down the stairs, squat, running and walking, jumping, riding a bicycle, kneeling, sitting with bent knees for a long time, short quadriceps joint are also the criteria for participating in this research. The exclusion criteria from the research are pain score less than 3 in numeric scale, a background of knee locking, patellar luxation, osteoarthritis, unnatural radiography of knee, the knee joint infection, ligament laxity, the background of previous physiotherapy of knee, the background of knee surgery, of genu valgum of knee and Osgood schlatter of knee (1,10).
All medical evaluations are done by physician's recognition and confirmation and the sample are selected by these evaluations. 14 individuals were put aside from the research because of different reasons (10 individuals were absent after the test and 4 individuals had more than 3 sessions of absence in exercises) and the research was finished by the presence of 38 individuals. From the present individuals, 27 had PFPS and they were randomly divided into experimental (14 individuals who had PFPS and were exposed to exercises), control (13 individuals who had PFPS but were not exposed to exercises) and also the healthy (11 individuals who didn’t have PFPS and were not exposed to exercises) groups. After determining the studied individuals and getting their consent, we informed them of the goals, methods and benefits of this research. The individuals participating in this research could refuse participating and continuing the research at any time they want.

The Measurement Method of Knee Bending Range of Motion (Short Quadriceps Joint)
The knee bending range of motion was measured by Ely test shown in figure 1. The individual lied down on his abdomen and 3 markers were placed on big bumps of femoral, big bumps of fibula and external malleolus with glue. Afterwards, the individual bent his knee actively and this angle was measured by goniometer without pelvis rising from a bed (1).
The Measurement Method of Pain
The amount of pain was evaluated by 10-centimeter pain visual analog scale (VAS) whose validity and reliability is acceptable for the evaluation of pain in individuals with PFPS. Zero represents the absence of pain and 10 represents intolerable pain. The subjects report their amount of pain by selecting among 0 to 10 within 48 hours before participating in the test (11-13).

The Recording Method of Lower Limb Kinematic
A three-dimensional motion analysis system (Raptor-H Digital Real Time System Model) with 6 cameras that is made in America and kept in Sports Biomechanics Laboratory of Physical Education and Sports Sciences College of Shahid Bahonar University of Kerman was used for three-dimensional record of subjects during running. This system is able to film in a three-dimensional way with 900 frames in a second. The frequency of the cameras was considered 120 hertz for this research (14-16). The layout of the cameras was in a way that each marker was seen by at least two cameras in every second (figure 2). The calibrated volume was to the extent that treadmill and subject were covered completely. This volume I 2/5 meter in length, 1/5 meter in width and 2/5 meter in height.
After preparing the preliminaries, the subjects attend the laboratory environment with minimum clothing. The markers were fixed on the subjects' body with double-sided glue and elastic (17). Then the laboratory markers were installed for kinematic recording of lower limb as follow:

Belly button, right side sacroiliac joint, right and left side posterior superior iliac spine (PSIS), right side big bumps of femoral, femoral cluster (containing of 4 markers) on right side femoral, exterior epicondyle of right side femoral, interior epicondyle of right side femoral, leg cluster (containing of 4 markers) on right side leg, right side external malleolus, right side interior malleolus, right side heel bone, distal part of right side second metatarsal bones, the lower part of right hand fifth metatarsal bones and on right side foot second finger. It is important to mention that this layout of marker was specifically for the individuals who have a failure in patellofemoral joint of right side foot or both of patellofemoral joints. The aforementioned layout of marker was transferred to the left side of the body for the individuals who have patellofemoral pain syndrome in left foot. At the beginning, the subjects' markers location was filmed statically (figure 3). Then the subjects were given an opportunity to become compatible with treadmill by running on it with a slow speed (TUNTURI brand, J880 model, made in Netherlands). After that, the individuals were running on treadmill with the selected speed for 3 minutes in order to warm up. The treadmill speed reached to 3/3 m/s gradually with the subject's preparation and the examiner's recognition and the individual was running for 2 minutes with this speed and finally 5 consecutive steps of the individual were recorded (18). The recorded data were processed by CORTEX software with version 2/5. And Butterworth low pass filter with frequency of 8 hertz was used in order to eliminate the noises of markers' movement. The output of CORTEX software that was in a form of EXCEL file was transferred into MATLAB software. The data were analyzed by this software and the intended angles of lower limb were extracted. The average of consecutive triple angles of each kinematic variable was entered into SPSS21 software.

Figure 3- Filming the markers' location in static conditions
The Method of Doing the Exercises
The experimental group performed 6-week static stretching of quadriceps and the control (with PFPS) and healthy groups didn’t receive any exercises. It is important to mention that all subjects performed their military activities equally during the research. In order to decrease the danger of possible damages and the subjects' problems and increase the movement of the involved joints, the individuals implemented the warm-up program and recovery for 10 minutes in the beginning and end of each training session. Then, two static stretching exercises were inactively performed on the subjects by the examiner in 3 sessions in a week. Each stretching had 3 times of repetition and the duration of each repetition was progressive; 20-second stretching in the first and second week, 25-second stretching in the third and fourth week and 30-second stretching in fifth and sixth week were done (figure 4) (19).
In 1 or 2 days after finishing the training protocol, pain and kinematics of the individuals in training, control and healthy groups were again assessed by pre-test method.

Figure 4- Static stretching exercises

Statistical Methods
The data analysis was done by SPSS software with version 21. In this research, descriptive statistics was used for data description. The normality of data was assessed by Shapiro-Wilk test and the independency of data was assessed by homogeneity of variance test or Levene test (P>0/05). In order to compare the data in 3 groups (experimental and control) and two times (pre-test and post-test), the combined frequent evaluation test was used. Partial eta square test was used for evaluation of the amount of effectiveness. Due to the disapproval of the parametric test assumptions, nonparametric tests were used for the evaluation of the amount of pain. In this test, the interpretation of data is as follow: 0/01-the amount of low effect, 0/06-the amount of average effect and 0/14-the amount of high effect (Palant, 2007). All the diagrams are drawn by SPSS21 software and Excell2013 and the significance level is considered 0/05.
Results
At first, the information related to average and standard deviation of group specifications of the 3 groups’ subjects was described separately. The results show that there is not a significant difference between anthropometric characteristics of the subjects (table 1).

<table>
<thead>
<tr>
<th>Index</th>
<th>Group</th>
<th>Average</th>
<th>Standard Deviation</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (Year)</td>
<td>Experimental</td>
<td>24/86</td>
<td>2/31</td>
<td>0/084</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>23/38</td>
<td>1/44</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Healthy</td>
<td>24/27</td>
<td>1/73</td>
<td></td>
</tr>
<tr>
<td>Height (Centimeter)</td>
<td>Experimental</td>
<td>176/42</td>
<td>6/00</td>
<td>0/559</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>174/46</td>
<td>6/42</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Healthy</td>
<td>174/27</td>
<td>3/82</td>
<td></td>
</tr>
<tr>
<td>Body Mass (Kilogram)</td>
<td>Experimental</td>
<td>77/24</td>
<td>4/35</td>
<td>0/069</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>71/27</td>
<td>9/53</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Healthy</td>
<td>74/87</td>
<td>3/60</td>
<td></td>
</tr>
</tbody>
</table>

* represents a significant difference (P<0/05)

In table 2, the average of knee bending range of motion is shown in pre-test and post-test.

<table>
<thead>
<tr>
<th>Index</th>
<th>Group</th>
<th>Pre-Test</th>
<th>Post-Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knee Bending Range of Motion</td>
<td>Experimental</td>
<td>5/99±129/29</td>
<td>4/58±138/07</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>2/37±129/15</td>
<td>2/59±129/62</td>
</tr>
<tr>
<td></td>
<td>Healthy</td>
<td>6/50±136/18</td>
<td>6/12±137/36</td>
</tr>
</tbody>
</table>

The results show that none of the kinematic factors of lower limb such as hip internal rotation (P=0/468, F 1.35=0/538) vulgus knee (P=0/255, F 1.35=1/341) and knee flexion (P=0/717, F 1.35=0/134) shows a significant difference between experimental, control and healthy groups based on time. The average of angles of the hip internal rotation, vulgus knee and knee flexion is shown in 3 experimental, control and healthy groups in pre-test and post-test in table 3. The only kinematic variable that becomes significant in the comparison between groups was the amount of angle of knee flexion that shows a significant difference in the comparison between experimental, control and healthy groups in pre-test and post-test. (P=0/004, F 2.35=6/472). In this comparison, the experimental group shows a significant difference than control group (P=0/003).

Due to the disapproval of parametric test assumptions, the nonparametric tests were used in order to compare the amount of pain in pre-test and post-test. The results regarding this hypothesis were as follow: the amount of pain has a significant difference in experimental, control and healthy groups in pre-test and post-test (P=0/000). The comparison between groups showed that no significant difference was seen between experimental and control groups in terms of the...
amount of pain in pre-test (P=0/374), but there was a significant difference between experimental and control groups in comparison with healthy group (P=0/000). In this comparison between groups in post-test, a significant difference was seen between experimental group in comparison with control group (P=0/000), so that after the implementation of stretching exercises, the amount of pain was decreased significantly in an experimental group (P=0/001), but the amount of pain was increased significantly in a control group (P=0/031). No significant difference was seen in the amount of pain between experimental and healthy groups (P=932), because pain was significantly increased in healthy group in post-test (P=0/018) and Clark test of 8 individuals of this group was recorded after the end of training and only after 6-week of military and educational period.

In table 3, The average of the amount of pain is shown for 3 experimental, control and healthy groups in pre-test and post-test.

Table 3: The average of kinematic factors and pain in pre-test and post-test

<table>
<thead>
<tr>
<th>Index</th>
<th>Group</th>
<th>Pre-Test</th>
<th>Post-Test</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hip Internal Rotation</td>
<td>Experimental</td>
<td>6/83±3/04</td>
<td>6/37±1/26</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>8/12±1/62</td>
<td>3/10±0/90</td>
<td>0/468</td>
</tr>
<tr>
<td></td>
<td>Healthy</td>
<td>7/14±3/36</td>
<td>3/47±3/31</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>3/91±4/10</td>
<td>4/54±5/10</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Healthy</td>
<td>6/21±5/26</td>
<td>3/51±5/37</td>
<td></td>
</tr>
<tr>
<td>Knee Flexion</td>
<td>experimental</td>
<td>7/47±35/48</td>
<td>10/76±37/82</td>
<td>0/717</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>7/01±45/38</td>
<td>6/11±45/46</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Healthy</td>
<td>4/63±42/66</td>
<td>6/29±38/80</td>
<td></td>
</tr>
</tbody>
</table>

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negative numbers: flexion decrease)

<table>
<thead>
<tr>
<th>Pain</th>
<th>Experimental</th>
<th>Control</th>
<th>Healthy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1/76±6/79</td>
<td>1/46±6/15</td>
<td>0/00±0/00</td>
</tr>
<tr>
<td></td>
<td>0/616±2/93</td>
<td>1/60±7/31</td>
<td>2/64±2/73</td>
</tr>
</tbody>
</table>

Discussion

The goal of the current research is to investigate the influence of 6-week static stretching of quadriceps on pain and kinematics of lower limb during running in individuals with Patellofemoral Pain Syndrome. The results show that the implementation of 6-week quadriceps muscle stretching has no influence on lower limb kinematics of the individuals with Patellofemoral Pain Syndrome. According to our findings and Mozayedi et al (2011), there is less research in the field of the influence of training protocols on lower limb kinematics in healthy individuals and the individuals with PFPS (20). Because of this reason, the scientific and possible reasons for approval or disapproval of the hypotheses related to lower limb kinematics such as hip internal rotation, vulgus knee and knee flexion will be discussed with each other. The results of current research are contradictory with Balden et al findings (21). Balden et al investigates the kinematics of body and lower limb of individuals with PFPS during squat with one foot after the implementation of 8-week training. This research consists of two training groups. In one group, gold standard exercises (quadriceps muscles, Hamstring, twin and iliotibial band stretching and reinforcing) and in another group, functional stability exercises were used. More clinical benefits were seen in functional stability exercises group in terms of body and lower limb biomechanics than gold standard exercises group. The hip's approaching (internal rotation) and vulgus knee was significantly decreased in functional stability exercises group at a frontal level. They mentioned that one of the reasons of the improvement of lower limb kinematics with functional stability exercises at a frontal level is that due to a weakness in abductors of hip and external muscles of body in individuals with PFPS, it may influence on kinematics change of lower limb at a frontal level, so these muscles were trained in functional stability exercises group.

According to the results of previous studies, different factors can influence on the prevalence of PFPS. In this research, we try to prescribe the treatment and observe its influence on lower limb kinematics based on the reason of illness (19). Due to the fact that the decrease of quadriceps muscles flexibility plays an important role in the beginning of the symptoms of PFPS (1), this research implemented a static stretching on these muscles for 6 weeks by selecting the individuals with PFPS and short quadriceps muscles. No difference was seen in the kinematic variables despite the decrease of the amount of pain. Erel and Hook (2011) mentioned that different factors can result in PFPS but the treatment based on the reasons and symptoms of PFPS is so difficult, because some of the symptoms of this syndrome are not recognized by the current standards (22). According to Balden's study (2014), in lower limb kinematics, doing the standard exercises (stretching-strengthening) can't be enough for the change of movement pattern (21). Erel and Hook (2011) observed that the strengthening exercises of femoral muscles do not
influence on lower limb kinematics of women with PFPS (22). Instead, Balden et al (2012) showed that reinforcement of femoral and the functional exercises combining with motion learning increase the eccentric power of femoral's abductor muscles and decrease the femoral's approaching and vulgus knee during squat with one foot in healthy women (23). Also, Balden (2014) showed that the strengthening exercises of femoral muscles and knee in a combination with malalignment correction of lower limb during the functional activities have more advantages for women with PFPS than strengthening and stretching exercises with a focus on quadriceps muscle (21). Since a wide range of factors may result in the prevalence of PFPS, it is unlikely that the use of treatment will be useful for all patients with PFPS. Inadequacy of exercises duration, the low intensity of exercises, limitation of the number of subjects and the focus of exercises on sagittal plane make the influence of selected exercises on lower limb kinematics not to be significant. Also, due to the fact that the Clark test of 8 individuals from 11 individuals of healthy group was positive after training and 6-week of educational period in military service and a significant amount of pain was reported, it can be concluded that activities in this educational period result in the prevalence of PFPS. This issue decreases the influence of exercises on lower limb kinematics. Due to the fact that PFPS is multifactor and unknown, it is unlikely that the implementation of one treatment will be useful for all patients. The previous studies showed that the treatment exercises containing of one kind of exercise can't influence on the individuals' lower limb kinematics.

The findings of statistical analysis of the sixth aim showed that the amount of pain shows a significant difference between 3 experimental, control and healthy groups in post-test that pre-test. The average of pain that was 6/79 in pre-test in experimental group reached to 2/93 in post-test after the implementation of training protocol. The amount of pain was significantly decreased in this group; this issue showed that stretching exercises of quadriceps has a significant influence on the improvement of pain. The results of the current research are compatible with Mason et al research (2011) (19). Mason et al research was "The influence of the use of taping, strengthening exercises of quadriceps and stretching exercises of quadriceps separately or in a combination with each other on the individuals with Patellofemoral Pain Syndrome". They placed 41 subjects in 4 groups randomly: taping, strengthening exercises of quadriceps, stretching exercises of quadriceps and control groups. In the first week, the subjects performed their exercises separately for a week (control group did not perform any exercises). In the second week, the individuals performed 3 treatments together (taping, strengthening exercises of quadriceps and stretching exercises of quadriceps). 4 indices of pain were measured during functional activities before and after doing the exercises. After the end of the first week, the results of this research showed that the taping group was improved significantly in 1 of the 4 indices and the strengthening and stretching exercises groups were improved significantly in all of the 4 indices and no change was seen in the control group. After the end of the second week in which 3 training groups were received all the exercises, a significant progress was seen in all of the 4 indices (19). Mason described the reason of this influence: short quadriceps muscles especially in rectus femoris muscle are very common in individuals with patellofemoral and this muscle responded to stretching quickly and the length of muscle improved for about 12 centimeters averagely within a week (19). This reason is compatible with the results of this research. The only kinematic variable of lower limb that became significant in the comparison between groups was the increase of flexion than control group. The amount of pain in control
group was increased significantly. One of the controversial results of this research was that the amount of pain was increased significantly in a healthy group. Patellofemoral pain syndrome was occurred due to the intensive physical activities of soldiers during their educational period. The results of this research are different from most of the researches that investigate the influence of training on the amount of pain. Therefore, due to the increase of pain in these two groups and the decrease of pain in experimental group, it can be said that the quadriceps stretching can influence on the prevention of PFPS. At the end, it can be pointed that although the increase of quadriceps flexibility did not result in kinematic change of lower limb, the decrease of quadriceps flexibility may result in kinematic change of lower limb. It is suggested that the individuals use stretching exercises after doing the activities that increase the load of patellofemoral muscle in order to prevent the prevalence of patellofemoral pain syndrome.

Conclusion
According to the results of the current research, the use of one kind of training can't influence on lower limb kinematics, because the prevalence of PFPS is multifactor. And the implementation of stretching on quadriceps can't change the lower limb kinematics. But the implementation of stretching exercises on quadriceps can prevent the prevalence this illness and decrease pain in individuals with PFPS.

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References


