CHAPTER-V
SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1. Summary
Patellofemoral pain syndrome (PFPS) is a disorder related to peripatellar or retropatellar pain\(^1\) and it is one of the most prevalent musculoskeletal conditions of the lower limb, with incidences estimated as high as 25% within the general population and 60% within the athletic population\(^2\). Vastus medialis oblique (VMO) and vastus lateralis (VL) are the two principle muscles that work synergistically to stabilize the patella during dynamic knee extension.

The ratio of VMO:VL has a theoretical ideal of 1:1\(^3\), and research has shown this ratio to be as low as 0.54:1 in people with PFPS\(^4\). Any disturbance in the VMO:VL ratio, owing to a decreased medial pull, may lead to patella maltracking\(^5\), and consequently inflammation, pain, premature cartilage degeneration, and ultimately PFPS\(^6\). It has been suggested that reestablishing this imbalance can be achieved by strengthening exercises specifically targeting VMO.

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The existing evidence base supports this as a successful method of preventing and reducing PFPS\textsuperscript{7,8}, and current literature is flooded with research concerning the best exercises to preferentially activate VMO. Nonetheless, debate still remains as to an agreed “gold standard” exercise and controversy litters the evidence base. Patellofemoral pain syndrome (PFPS) is a commonly experienced knee disorder that can result in altered muscle activation of the surrounding musculature.

Patellofemoral pain syndrome is a common condition characterized by diffuse anterior knee pain, particularly when climbing stairs, kneeling, or sitting with the knees flexed for a long period of time\textsuperscript{9} PFP may be caused by a faulty extensor mechanism in which the patella does not move smoothly through the femoral groove when the knee is flexed and extended\textsuperscript{10}. Patellar position is maintained by the balance of static and dynamic forces that act upon the patella\textsuperscript{11}. However, patellar position is primarily controlled by the dynamic action of the vastus medialis obliquus (VMO), especially in the last 30° of knee extension\textsuperscript{12}.

For normal tracking to occur the lateral and medial forces acting upon the patella must be balanced\textsuperscript{13}. An altered motor control pattern between the VMO and vastus


lateralis (VL) has been reported as a common dynamic dysfunction that disrupts this force balance\textsuperscript{14}.

It is thought that the VMO may be weak relative to the VL, or delayed firing of the VMO cannot counteract the lateral force vector produced by the VL and iliotibial band. Therefore, the patella may be pulled laterally\textsuperscript{15}.

There is little evidence on the effects of fatigue on quadriceps torque and EMG activation of the vastus medialis obliquus (VMO) and vastus lateralis (VL) so overall purpose of this study was to identify the effect of fatigue on the ratio of electrical activity of oblique vastus medialis and vastus lateralis before any training program and also after 6 weeks plyometric training program.

The research was an experimental Study and hence standard Procedure was followed while conducting the research. This study consisted of an experimental design, research design was pre and post-test two group design consists of experimental and control group.

The population of this study was consisting of all the boys’ students in the BU ALI SINA University of Hamedan – Iran.

Sample of this study was 30 male students in the BU ALI SINA University of Hamedan – Iran, which students selected as 15 samples in the experimental group and 15 samples in the control group. Non random sampling method was used in this study.

These subjects were absolutely healthy with a view to orthopedic, neurological, internal and cardiovascular terms and have not attended athletic activity for at least 5 years.

The profile study followed standard procedures of research. The test items were finalized after taking the opinions of experts and finding supportive literary references.


evidence in the body of literature. The reliability of the testers and the data was determined by the test - retest method. The procedure of data collection was determined keeping in view, the standard protocols of measurement. A detailed schedule was designed and followed for the collection of data.

For analyzing collected data of this study researcher employed IBM SPSS Statistics 21 software, in two level of descriptive statistics consist of mean, standard deviation, skewness and kurtosis and inferential statistics consist of Mixed or Spilit-Plot test, Dependent and Independent Samples T-test.

5.2. Major Findings

In a state of fatigue the muscles surrounding the knee joint may lose the ability to protect the joint. Altered neuromuscular control due to fatigue can be reflected by changes in electromyography (EMG) activity so the present research aimed at finding out the effect of fatigue on the ratio of electrical activity of oblique vastus medialis and vastus lateralis before any training program and also after 6 weeks plyometric training program and also finding out the effect of 6 weeks plyometric training program on maximum voluntary contraction (MVC), in closed kinetic chain. The objectives of the study were successfully accomplished.

With the objective of finding out the effect of fatigue on the ratio of electrical activity of oblique vastus medialis and vastus lateralis before any training program and also after 6 weeks plyometric training program and also finding out the effect of 6 weeks plyometric training program on maximum voluntary contraction (MVC), in closed kinetic chain, the data were analyzed in depth.

- Ratio of electrical activity of oblique vastus medialis and vastus lateralis at all angles knee extension (0°, 15°, 30°, 45°, 60°, 75°,90°), in closed kinetic chain before a plyometric training program was found to not be significantly different in post-test in comparing with pre-test and fatigue couldn’t change the amount of these variables. Hence the null hypothesis $1H_0$ to $7H_0$ is failing to reject for these variables; therefore fatigue has no significant effect on these variables.
• Ratio of electrical activity of oblique vastus medialis and vastus lateralis at all angles knee extension (0°, 15°, 30°, 45°, 60°, 75°, 90°), in closed kinetic chain after 6 weeks plyometric training program was found to not be significantly different in post-test in comparing with pre-test and fatigue couldn’t change the amount of these variables. Hence the null hypothesis \( H_0 \) to \( 14 \ H_0 \) are failing to reject for these variables; therefore fatigue has no significant effect on these variables.

• Knee extensor muscles maximum voluntary contraction (MVC) at (30° and 75°) knee extension, in closed kinetic chain was found to be significantly different in post-test in comparing with pre-test so 6 weeks plyometric training program could increase the amount of these variables. Hence null hypothesis \( 15 \ H_0 \) and \( 16H_0 \), are rejected for these variables, therefore six weeks plyometric training program can increase the amount of MVC.

5.3. Discussion

The purpose of this study was to investigate the effects of fatigue on the ratio of electrical activity of oblique vastus medialis and vastus lateralis before and also after plyometric training program in males.

It was hypothesized that, as a result of muscular fatigue, the ratio of electrical activity of oblique vastus medialis and vastus lateralis at all angles knee extension (0°, 15°, 30°, 45°, 60°, 75°, 90°), in closed kinetic chain before and also after a plyometric training program to be significantly different.

Following the data analysis, we found no significant differences in the ratio of electrical activity of oblique vastus medialis and vastus lateralis across all knee flexion angles in closed kinetic chain before and also after a plyometric training program. This finding has been reported by previous studies.

Atarzadeh, R\(^\text{16}\) (2003) and Poon et al.\(^\text{17}\) (2000) investigated about the effect of fatigue on the ratio of electrical activity of oblique vastus medialis and vastus

lateralis in closed kinetic chain before and after training program and the results of their studies showed that there was no significant change in the ratio of electrical activity of oblique vastus medialis and vastus lateralis after fatigue either before and after the training program.

In addition it was hypothesized that, as a result of 6 weeks plyometric training program, the knee extensor muscles maximum voluntary contraction (MVC) at 30° and 75° knee extension, in closed kinetic chain, to be significantly different. The results of the present study showed that there is a significant difference in the knee extensor muscles maximum voluntary contraction (MVC) at 30° and 75° knee extension, in closed kinetic chain after plyometric training. This finding has been reported by previous studies. 

**Portage et al.** 18 (1999) showed that a plyometric training (PT) program could bring about significant increases in leg extensor muscle power and whole muscle fiber hypertrophy.

**Malisoux et al.** 19 (2006), on the other hand, focused on the contractile properties of single fibers of VL muscle of recreationally active men (n= 8; age: 23 ± 1 year). After eight weeks of PT induced significant increases in peak force and maximal shortening velocity in the myosin heavy chain (MHC) isoforms Type I, IIa and hybrid IIa/IIx fibers, while peak power increased significantly in all fiber types. PT significantly increased maximal leg extensor muscle force, and VJ performance was also improved 12% (p<0.01) and 13% (p<0.001), respectively. Peak force increased 19% in Type I (p<0.01), 15% in Type IIa (p<0.001), and 16% in Type IIa/IIx fibers (p<0.001).

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Kyröläinen et al. (2005) found that 15-weeks of maximal-effort PT performed by recreationally active men (n=23; age 24 ± 4 years) showed no significant changes in muscle fiber type or size. Plantar flexor strength did improve with significant increases in muscle activity, but not the rate of force development (RFD) and without any changes in either the muscle fiber distributions or CSA. Although no changes were found in the maximal strength or muscle activation for knee extensor muscles, the enhancements in jumping performance were due to improved joint control and increased RFD at the knee joint.

Kubo et al. (2007) showed in a 12-week comparative study of PT and WT upon untrained male participants (n=10; age: 22 ± 2 years), PT induced changes in the strength of plantar flexors, but not in that of the knee extensors. Plantar flexors showed significant hypertrophy and significant increases in maximal voluntary contraction with increased muscular activation.

Maffiuletti NA, et al. investigated the Effect of combined electro stimulation and plyometric training on vertical jump height. It was reported that at week 2, MVC significantly increased (+20% knee extensors, +13% plantar flexors) as compared to baseline (< 0.05).

Shankar, R, et al. Studied the effect of high intensity and low intensity plyometric on vertical jump height and maximum voluntary isometric contraction in football players. Their results demonstrated that that High Intensity Plyometric training has significant effect on Vertical Jump Height and Maximum Voluntary Isometric Contraction as compared to Low Intensity Plyometric.

Vissing et al. (2008) showed that weight training (WT) and PT seemed to lead to similar gains in maximal strength, whereas PT induced far greater gains in muscle power.

In present study and also above literature, PT induced significant improvements in neuromuscular function for power development. PT appears to enhance motor unit recruitment patterns, with increases in muscle fiber hypertrophy for optimal maximal power output. PT significantly increased maximal leg extensor muscle
force, with improved countermovement jump (CMJ) performance and increased rate of force development (RFD) at the knee joint in recreationally active males. These changes were accompanied with increased muscle fiber cross-sectional area (CSA) in whole muscle and in single fiber studies. PT has also significantly improved maximal shortening velocities of leg extensor muscles. Plyometric exercises can too optimize performance and assist with injury prevention by improving hamstring strength, eccentric control and stability of the pelvis and knee.

5.4. Conclusion

The results indicate that fatigue have no effect on the ratio of electrical activity of oblique vastus medialis and vastus lateralis at all angles knee extension (0°, 15°, 30°, 45°, 60°, 75°, 90°), in closed kinetic chain before and also after a plyometric training program. Contrary to expectations a similar pattern of fatigue was found in these two muscles.

This means that, although muscles were fatigue, the ratio did not change. As previously cited, this ratio is indicated as defining the dynamic stability of the knee joint. Therefore, the dynamic stability of knee joint does not change after this type of fatigue protocol.

Several factors may have a role in this situation. The patterns of muscle activity may change after actions that need more force. For example, in proximal muscles fatigue, the distal muscles, by increasing their activities compensate for this problem.

Also, at muscle fatigue conditions, co-activation of agonist to antagonist muscle groups changes, so that this could help maintain dynamic joint stability. This

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means that hamstring and quadriceps co-activation is a factor that helps knee stability\textsuperscript{21,22,23}.

Mechanical changes in other joints, particularly in distal ones, are other factors that help compensate for thigh muscle fatigue\textsuperscript{24}.

In spite of fatigue, the neuromuscular system tries to maintain its function at optimal conditions. Perhaps by using a severe fatigue protocol and calculation of ratios at specific angle torques, complementary results will be achieved.

A greater understanding of fatigue may help prevent needless injury that can occur from a loss of performance capacity.

**5.5. Recommendations**

- This research has determined the effect of fatigue on the ratio of electric activity of oblique vastus medialis and vastus lateralis before and after plyometric training program in males, it is recommended that such a study be done on the female population of the same age and status.
- It is highly recommended that the same study be done on patient with PFPS.
- It is recommended that the same study be done by performing the general fatigue protocol.
- Researcher recommends that the same study be done in the effects of fatigue and training on the ratio of electrical activity of VMO and Tensor fascia lata (TFL) or rectus femoris (RF), as VL, TFL and RF all produce a lateral force moment on the patella and the VMO counteracts this lateral force moment.


5.6. Contributions To The Knowledge

- The knowledge as evolved from the present piece of research could contribute a new direction for enriching the literature of physical education and sports science.
- The knowledge evolved from this study seems to be new in literature: in fact, this study will be directly helpful to coaches, trainers, patient with PFPS. This contribution will enrich the overall physical education.
- This study will enrich the literature of sport medicine, sport injury and physical education.