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A Development Of Neuromuscular Control Exercise Protocol Of The Knee With Patellofemoral Pain Syndrome (PFPS): A Concept Paper

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ABSTRACT: Reestablishing neuromuscular control is a crucial component in the rehabilitation process especially in human joints. The main objective of neuromuscular control activities is to refocus an athlete's awareness of peripheral sensations and process these signals into more coordinated motor strategies (Prentice, 2004). By establishing this component, the injured athlete will be able to control the muscle activities and protect the injured joint from further injuries. Based on current research, the quadriceps strengthening exercise and taping have been used to improve neuromuscular control of Patellofemoral Pain Syndrome (PFPS) patients since the main focus of rehabilitation for (PFPS) is more on strengthening quadriceps muscle, regaining optimal patellar positioning and tracking. However, the effectiveness of this procedure may be questionable due to overlapping activities and protocols. Therefore a specific neuromuscular control exercise protocol (NCEP) will be developed focusing on individuals who had PFPS. This NCEP will involve a series of customized preprogrammed exercise protocols on Balance Trainer Software Suite using BT3 Balance Platform (HurLabs, Tampere, Finland) and will be applied to athletes who experienced PFPS where the effectiveness of this NCEP will then be evaluated.

1.0 INTRODUCTION

Patellofemoral pain syndrome (PFPS) or usually referred as runner's knee is a common pain disorder experienced by general population (Murray, Murray, Mackenzie, & Coleman, 2005; Callaghan & Selfe, 2007). Heintjes, Berger, Bierma-Zeinstra, Bernsen, Verhaar, & Koes (2005) stated that PFPS was experienced most by young adult and adolescent athletes who participate in jumping, cutting and pivoting sports. It has also been reported that PFPS can affect up to 30% of young students (13-19 years) and the symptoms may cause 74% of the PFPS patients limit their sport activities or lead to sports cessation (Blond & Hansen, 1998). The symptoms may also restrict them from participating in recreational activities and limit them from the health benefits of regular physical activtiy.

To date, a number of approaches to physiotherapy management for PFPS have been proposed to alleviate pain through restoration of patellar alignment via use of interventions like muscle strengthening exercises, stretching, patellar taping, bracing, orthoses, manual therapy, electric stimulation and EMG biofeedback (Crossley, Bennell, Green, Cowan, & McConnell, 2002). However, studies showed that approximately 25% of patients continue to have pain and dysfunction for more than one year after physiotherapy has been completed (Piva, et al., 2006).

It seems that restoring patellar alignment it still not enough for a functional recovery among PFPS patients because neuromuscular controlling mechanism is required during daily living and sports specific activities (Williams, Chmielewski, Rudolph, Buchanan, & Snyder-Mackler, 2001). Therefore, both mechanical stability and neuromuscular control are important for long-term functional outcome, and both aspects must be considered in the design of PFPS rehabilitation program.

2.0 STATEMENT OF PROBLEM

One of the very common musculoskeletal disorders that been reported to affect general population is PFPS (Wood, 1998). It has also been listed as one of the common conditions in athletes, especially for sports involving repetitive loading to lower limbs such as running and jumping (Rauth, Koepsell, Rivara, Margherita, & Rice, 2006). This circumstance may limit the bend-knee daily activities and restrict them from participating in sports activities and gain health benefits from it. In fact in 2009, a research have been conducted among Malaysian Badminton athletes and the prevalence rate of PFPS is 7.2 percent (Shariff, George, & Ramlan, 2009) but more serious injuries such as patellar tendinopathy, patellofemoral osteoarthistis, Hoffa's Disease had shown remarkable higher percentage. This may be due to the recurrence of PFPS that later lead to these injuries (Waryasz & McDermott, 2008).

One of the conditions that may ultimately cause PFPS is delayed and decreased electromyographic activity (EMG) of Vastus Medialis Oblique (VMO) (Stendotter, Grip, Hodges, & Hager-Ross, 2008). Such deficit will reduce force from VMO contraction and cause the patella to track laterally, alter the postural control and onset the pain. There have been many documented programs designed to conservatively manage PFPS, with most emphasizing flexibility and quadriceps strengthening (Lun, Wiley, & Meeuwisse, 2005). Although post reports of high success for patients are in the short term, longer-term recurrence of symptoms appears to be questionable (Post, 1997). This may be due to the flexibility and quadriceps strengthening is targeted to build either muscle mass or muscle strength which are important for sports injury prevention (Wong & Ng, 2010) rather than reducing the existing of sports injury.

Simply restoring mechanical restraints is not enough for a functional recovery of the PFPS because the coordinated neuromuscular controlling mechanism is required during daily living and sports specific activities. The rehabilitation programs cannot alter a mechanical knee joint instability but may affect the neuromuscular control and the dynamic joint stability. Therefore, both mechanical stability and neuromuscular control are important for long-term functional outcome, and both aspects must be considered in the design of PFPS rehabilitation program.

Recently, Hubscher, Zech, Preifer, Hansel, Vogt, & Banzer (2010) had showed evidence for the effectiveness of neuromuscular training in reducing the incidence of certain types of sports injuries among adolescent and young adult athletes such as ankle sprains and hamstring injuries. However, there is still lack of evidence that can support the effectiveness of this training method when it applies to PFPS patients. As we know the objective of neuromuscular training is to improve the nervous system's ability in order to generate fast and optimal muscle firing pattern thus increase dynamic joint stability (Risberg, Mork, Jenssen, & Holm, 2001). Therefore, by emphasizing this type of exercise in PFPS rehabilitation programs it will be able to improve the strength, function, and efficiency of biomechanical deficiencies which will greatly improve the alignment of the patella, enhance the patient's function, and greatly reduce the risk of future recurrence.

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3.0 PRELIMINARY LITERATURE REVIEW

3.1 Patellofemoral Pain Syndrome (PFPS)

PFPS is primarily thought as a soft tissue disorder associated with patella tracking problems and stress on the stabilizing structures like Vastus Medialis Oblique (VMO) and lateral or medial retinaculum (Souza, 2001). It is a common problem among athletes and general population, particularly whenever there is repetitive loading of the lower limb. They commonly experience perceived bouts of instability and pain during sport activities and even normal daily activities (Rauth, Koepsell, Rivara, Margherita, & Rice, 2006). The definition of PFPS is a retropatellar or anterior knee pain which exists in the absence of any other pathology and it presents as a diffuse pain which is aggravated by activities like stair climbing, prolonged sitting, squatting and kneeling (Cowan, Hodges, Bennell, & Crossley, 2002). The aetiology of PFPS is believed to be multifactorial, including theories of biomechanics, musculature and overactivity which would all possibly contribute to a maltracking of the patella (Waryasz & McDermott, 2008).

The symptoms of PFPS are generally due to the loading on the knee during flexed position such as walking up and down stairs, squatting or rising from a seated position and the patients generally complains of restriction of gait (Powers, 2000). The symptoms also occur when the patients sit for a long time with the knees flexed (McConnell, 1986) Individuals with PFPS will try to reduce the irritation of symptoms by adjusting their gait and other activities by decreasing their patellafemoral reaction joint force (PFJRF). Common compensation movements includes decrease knee flexion during stance phase of gait, reduced walking velocity and leaning the trunk anteriorly during stair ambulations (Salsich, Brechter, Farwell, & Powers, 2002).

The most essential to the long term success of the PFPS treatment is patient education. The patient should understand the nature of the patellofemoral treatment and program. The patient needs to follow instructions related to activities of daily living, occupational ergonomics and athletic training techniques. The long term outcome would also be improved by a home and gym exercise program (Wood, 1998).

3.2 Criterion Measures of PFPS

Greiwe, Siafi, Ahmad, & Gradner (2010) stated that individuals with PFPS will have altered patellar alignment and thus their static and dynamic postural control will also be altered. Therefore, static and dynamic postural control for PFPS population will be a great marker to identify the changes. It has also been suggested by Crossley, Cowan, Bennell, & McConnell (2007) that using electromyography (EMG) to measure neuro-motor dysfunction will be a good indicator. This has been proven in many studies that individuals with PFPS demonstrated different onset timing of VMO and VL muscle activation compared to normal individuals (Waryasz & McDermott, 2008). Another indicator is perceived pain level. Based on Keet, et. al. (2007) the main symptoms of PFPS is pain at anterior knee or behind patella and the symptom will lessen if factors that contribute to it has been tackled. Thus, the perceived pain level has been used as indicator for PFPS symptoms.

3.3 Treatment

Normally the preferred treatment for PFPS is conservative rehabilitation which is individualized and specific to each patient suffering from the dysfunction (Hammer, 1999). Before the current treatment has been widely used, the PFPS rehabilitation concentrates on avoiding activities that can increase the pain such as squatting and climbing stairs. The focus of rehabilitation at that time is was immobilization of the injured area and strengthening the quadriceps muscle using open kinetic chain (OKC) exercises. However, now the rehabilitation approach has a new direction.

The new goals for PFPS are quadriceps strengthening using closed kinetic chain CKC) exercises, regaining optimal patellar positioning and tracking and regaining neuromuscular control to improve lower limb mechanics (Prentice, 2004). The greatest concern with regards to rehabilitation of the patellofemoral joint is to maximize quadriceps strength while at the same time minimizing the reaction forces and stress on the joint (Tang, Chen, Hsu, Chou, Hong, & Lew, 2001). Another main aim is to facilitate the balance between the medial and lateral structures thus helping the load on the patellofemoral joint to be distributed more evenly (McConnell, 1986). The biomechanical abnormalities associated with PFPS must be corrected in order to decrease the abnormal forces on the patellofemoral joint (Wood, 1998).

A study by Wood, (1998) revealed that the proprioceptive training may speed up the rehabilitation of PFPS. The mechanoreceptors stimulate the muscle around the knee by giving information on motion, change of position and the loading of the patellofemoral joint to the central nervous system. The shorter the time taken for this information to be processed, the lesser the stress will be on the skeletal and ligamentous structures of the knee. The time may be decreased by dynamic neuromuscular joint control exercises such as wobble board, sudden additions of force and rapid transference of weight from one leg to another.

4.0 GOAL STATEMENT

The purpose of this study is to develop and determine the effect of an 8-week computerized neuromuscular training protocol for athletes with PFPS. The criterion measures on its effect will be compared in terms of static postural control (SPC), dynamic postural control (DPC), muscle activation (MA) of Vastus Medialis Oblique (VMO) and Vastus Lateralis (VL) and perceived pain level (PPL) before and after the NCEP training has been conducted.

5.0 RESEARCH QUESTIONS

The study aims to answer the following questions:

1. Will eight weeks of Neuromuscular Control Exercise Protocol (NCEP) improve the static postural control (SPC) of an athlete with Patellofemoral Pain Syndrome (PFPS)?
2. Will eight weeks of Neuromuscular Control Exercise Protocol (NCEP) improve the dynamic postural control (DPC) of an athlete with Patellofemoral Pain Syndrome (PFPS)?
3. Will eight weeks of Neuromuscular Control Exercise Protocol (NCEP) improve the activation (MA) of Vastus Medialis Oblique (VMO) and Vastus Lateralis (VL) while performing step-down task among athletes with Patellofemoral Pain Syndrome (PFPS)?

4. Will eight weeks of Neuromuscular Control Exercise Protocol (NCEP) reduce the perceived pain level (PPL) while performing step-down task among athletes with Patellofemoral Pain Syndrome (PFPS)?

6.0 METHDOLOGY

6.1 Research Design

This is a True Experimental design which will use the Pretest-Posttest Control Group method. The subjects for this study will be from athletes' population and those who experienced Patellofemoral Pain Syndrome (PFPS). All of these subjects will be randomly selected and assigned into two groups which are Neuromuscular Control Exercise Protocol (NCEP) group and Control Group (CG). Both groups will need to go through a pretest, receives a different treatments and a posttest at the end of the study. The posttest scores will be compared to determine the effectiveness of the treatment.

6.2 Subject Sampling And Recruitment

The estimation of sample size will be based on Cohen's formula where there will be a total of 52 subjects with a desired power of 0.80. Based on Cohen (1988), this value refers to the percentage to accept Type I Error in hypotheses testing which results in false positive claims compared to Type II Error which is to accept false negative claims. The reason for social science researchers accepting more Type I error is because the research outcomes are more sensible which make them more acceptable. In order to prevent an effect of power analysis decrease due to drop out, another 20% will be added to the total number of estimation which means a total of 62 subjects in this study.

The identification of potential subjects will be based on stratified sampling. Subjects will be university athletes aged 18 to 35 years old and have been acknowledged to have knee problems. The subjects will be recruited based on convenience sample via advertisements on notice boards and brochures that will be placed around Universiti Teknologi Malaysia (UTM), Skudai campus.

The candidates of the study subjects will be screened by a qualified physiotherapist, who will decide the eligibility as a subject by examining them against a predefined inclusion and exclusion criterias. They will then be assigned into into two different groups,namely the NCEP group and CG group.

6.3 Criterion Measures And Instrumentation

In order to identify the symptoms of PFPS, there are criterion measures that had been used widely as markers by many recent researchers such as Piva, et al. (2006), Keet, Gray, Harley, & Lambert (2007) and Mostamad, Bader, & Hudson (2009). These are static postural control (SPC), dynamic postural control (DPC), muscle activation (MA) of Vastus Medialis Oblique (VMO) and Vastus Lateralis (VL) and perceived pain level (PPL). However, it should be noted that the measures that will used in this study are indirect markers of PFPS symptoms.

For SPC, the computerized balance trainer (BT3, HurLab, Tampere, Finland) will be used while performing Romberg 1-Minute protocol. The Romberg 1-Minute protocol will require subjects to perform two phases of performance which are Eyes Open and Eyes Close phase. While for DPC, the Star Excursion Balance Test (SEBT) will be used. The subjects need to perform one leg stand (injured leg) in the middle of the testing grid and reach as far as possible with another leg (non-injured leg) in three chosen marked directions on the grid. The VMO and VL muscle activation will be measured using 16-channel telemeterized EMG system (Noraxon USA, Inc., Scottsdale, AZ) which is integrated with Myosystem 1400A while performing Step-Down Test. After performing Step-Down Test, the perceived pain level will be rated by subjects on a Visual Analogue Scale (VAS). The VAS incorporates 100 millimeter line marked with 0 indicating no pain and 10 at the other end representing worst possible pain.

6.4 Protocols

All subjects will be requesed to attend an orientation session which consists of study protocol's explanation, Physical Knee Regional Assessment (PKRA) and pre test at Makmal Kecergasan, Fakulti Pendidikan, UTM. Before they go through PKRA and pre test, they will be asked to sign an informed consent. The PKRA consists of physical assessment on lower limb structural such as Q-angle, A-angle, patellar test and etc. This PKRA will be conducted by a licensed physiotherapist. The pre-test will measure the subject's static postural control (SPC), dynamic postural control (DPC), muscle activation (MA) and perceived pain level (PPL).

After the pre test, the CG group will go through their daily normal activities and will be asked to return in eight weeks for the post test. The NCEP group will need to go through 16 sessions of preprogrammed exercise protocols on Balance Trainer Software Suite using BT3 Balance Platform (HurLabs, Tampere, Finland) that has been designed for them within eight weeks. In each session there will be four types of trainers that they need to complete which are Static Pattern Trainer, Chase Trainer, Maze Trainer and Tennis Trainer. Each trainer and rest interval will take approximately five minutes. Once they complete all the sessions, they will need to go through post test. The diagram of this study protocol can be seen in Appendix A.

7.0 ANALYSES OF DATA

There are two types of data analyses that will be executed in this study which are descriptive and inferential. These data analyses will be performed using Statistical Package for Social Science (SPSS) version 17.0.

7.1 Descriptive Analyses

Descriptive analysis will consist of frequencies, means and standard deviations of subject demographic data and PKRA. This analysis aims to provide an overview of the subjects and summarize the characteristic of samples.

7.2 Inferential Analyses

There are a few types of inferential analyses that will be used in this study. These are test-retest reliability, intra-rater reliability, MANCOVA and LSD as a post-hoc analysis.

REFERENCES

Blond, L., & Hansen, L. (1998). Patellofemoral Pain Syndrome in Athletes: A 5.7 year Retrospective Follow-up Study of 250 Athlete. *Acta Ortopaedica Belgica , 64* (4), 393-400.

Cohen, J. (1988). *Statistical Power Analysis for the Behavioral Sciences* (2nd ed.). Hillsdale, New Jersey, United State of America: Lawrence Erlbaum Associates.

Crossley, K., Bennell, K., Green, S., Cowan, S., & McConnell, J. (2002). Physical Therapy for Patellofemoral Pain: A Randomized Double-Blinded, Placebo-Controlled Trial. *American Journal of Sports Medicine , 11* (2), 103-110.

Greiwe, M. R., Siafi, C., Ahmad, C. S., & Gradner, T. R. (2010). Anatomy and Biomechanics of Patellar Stability. *Operative Technique in Sports Medicine , 18*, 62-67.

Hammer, W. I. (1999). *Functional Soft Tissue Examination and Treatment by Manual Methods* (2nd ed.). New York: Aspen Publisher.

Heintjes, E., Berger, M., Bierma-Zeinstra, S., Bernsen, R., Verhaar, J., & Koes, B. (2005). *Exercise Therapy for Patellofemoral Pain Syndrome.* Hobken, New Jersey: John Wiley & Sons Ltd.

Hubscher, M., Zech, A., Preifer, K., Hansel, F., Vogt, L., & Banzer, W. (2010). Neuromuscular Training for Sports Injury Prevention: A Systematic Review. *Medicine & Science in Sports & Exercise , 42* (3), 413-421.

Keet, J. H., Gray, J., Harley, Y., & Lambert, M. I. (2007). The Effect of Medial Patellar Taping on Pain, Strength and Neuromuscular Recruitment in Subjects With and Wthout Patellofemoral Pain. *Physiotherapy , 93*, 45-52.

Lun, V., Wiley, J., & Meeuwisse, W. (2005). Effectiveness of Patellar Bracing for Treatment of Patellofemoral Pain Syndrome. *Clinical Journal of Sports Medicine , 15*, 235-240.

McConnell, J. S. (1986). The Management of Chondromalacia Patellae: A Long Term Solution. *Australian Journal Physiotherapy , 32*, 215-223.

Mostamad, J., Bader, D. L., & Hudson, Z. (2009). The Effect of Patellar Taping on Joint Reaction Forces During Squatting in Subjects with Patellofemoral Pain Syndrome (PFPS). *Journal of Bodywork and Movement Therapies , xx*, 1-7.

Murray, I. R., Murray, A. S., Mackenzie, K., & Coleman, S. (2005). How Evidence Based is The Management of Two Common Sports Injuries in Sport Clinic? *British Journal of Sports Medicine , 39*, 912-916.

Piva, S. R., Fitzgerald, K., Irrgang, J. J., Jones, S., Hando, B. R., Browder, D. A., et al. (2006). Reliability of Measures of Impairments Associated with Patellofemoral Pain Syndrome. *BMC Musculoskeletal Disorders , 7* (33), 1-13.

Post, W. (1997). Patellofemoral Pain: Results of Nonoperative Treatment. *Clinical Orthopeadic , 436*, 55-59.

Powers, C. M. (2000). Patellar Kinematics, Part I: The Influence of Vastus Muscle Activity in Subjects With and Without Patellofemoral Pain . *Physical Therapy , 80*, 956-964.

Prentice, W. E. (2004). *Rehabilitation Techniques for Sports Medicine and Athletic Training* (4th ed.). New York: McGraw Hill.

Rauth, M. J., Koepsell, T. D., Rivara, F. P., Margherita, A. J., & Rice, S. (2006). Epidemiology of Musculoskeletal Injuries Among High School Cross-country Runners. *American Journal of Epidemiology , 163*, 151-159.

Risberg, M. A., Mork, M., Jenssen, H. K., & Holm, I. (2001). Design and Implementation of Neuromuscular Training Program Following Anterior Cruciate Ligament Reconstruction. *Journal of Orthopaedic & Sports Physical Therapy , 31* (11), 620-631.

Salsich, G. B., Brechter, J. H., Farwell, D., & Powers, C. M. (2002). The Effects of Patellar Taping on Knee Kinetics, Kinematics and Vastus Lateralis Muscle Activity During Stair Ambulation in Individuals with Patellofemoral Pain. *Journal of Orthopaedic & Sports Physical Therapy , 32*, 3-10.

Shariff, A. H., George, J., & Ramlan, A. A. (2009). Musculoskeletal Injuries Among Maaysian Badminton Players. *Singapore Medicine Journal , 50* (11), 1095-1097.

Souza, T. A. (2001). *Differential Diagnosis and Management for the Chiropractor* (2nd Edition ed.). New York, USA: Aspen Publisher.

Stendotter, A. K., Grip, H., Hodges, P. W., & Hager-Ross, C. (2008). Quadriceps Activity and Movement Reactions in Response to Unpredictable Sagittal Support-sufrace Translations in Women with Patellofemoral Pain. *Journal of Electromyography and Kinesiology , 18*, 298-307.

Tang, S. T., Chen, C. K., Hsu, R., Chou, S. W., Hong, W. H., & Lew, H. L. (2001). Vastus Medialis Oblique and Vastus Lateralis Muscle Activity in Open and Closed Kinetic Chain Exercises in Patient with Patellofemoral Pain Syndrome: An Electromyographic Study. *Journal of Physical Medicine and Rehabilitation , 82*, 1441-1445.

Waryasz, G. R., & McDermott, A. Y. (2008). Patellofemoral Pain Syndrome (PFPS): A Systematic Review of Anatomy and Potential Risk Factors. *Dynamic Medicine , 7* (9), 1-14.

Williams, G. N., Chmielewski, T., Rudolph, K., Buchanan, T. S., & Snyder-Mackler, L. (2001). Dynamic Knee Stability: Current Theory and Implications for Cliniciams and Scientists. *Journal of Orthopeadic and Sports Physical Therapy , 31* (10), 546-566.

Wong, Y. M., & Ng, G. (2010). Resistance Training Alters the Sensorimotor Control of Vasti Muscles. *Journal of Electromyography and Kinesiology , 20*, 180-184.

Wood, A. (1998). Conservative Management of Patellofemoral Pain Syndrome. *Journal of Sports Chiropracticand Rehabilitation , 12* (1), 1-13.

Appendix A

Diagram of Study Protocol