ORIGINAL ARTICLE

Changes in Muscle Torque and Single Leg Stability after Static or Dynamic Strength Training in Athletes with Knee Pain

TAHIR MASOOD[1], HAFIZ MUHAMMAD MANAN HAIDER KHAN[2], MUHAMMAD NAVEED BABUR[3]
[1]*Department of Physical Therapy and Health Rehabilitation, College of Applied Medical Sciences, Jouf University, Saudi Arabia*
[2]*Pakistan Sports Board, Islamabad, Pakistan*
[3]*Isra University, Islamabad, Pakistan*
Correspondence to Dr. Tahir Masood, E-mail: tmasood@ju.edu.sa; Tel: +966 55 1749236

ABSTRACT

Aim: To evaluate the effects of static and isokinetic strength training on hamstring and quadriceps muscle strength and athletic single-leg stability.
Methods: Fifty athletes (18-35 years) with unilateral knee pain were strength trained either isometrically (N=25) or isokinetically (N=25) in terms of knee flexion and extension at Pakistan Sports Board, Islamabad. Isometric exercise was performed at knee flexion angles of 30°, 45°, and 60° while isokinetic exercise was done at 5 different angular velocities of knee flexion and extension. Stability was evaluated using the athletic single-leg stability test. All athletes in both groups completed 10 training sessions and were evaluated before and after the intervention. Paired samples t test was used to analyze the training-induced changes in either group.
Results: Significant improvement was observed in hamstring muscle torque production after isometric or isokinetic training ($P<0.001$). Quadriceps muscle torque also increased significantly after isometric ($P<0.001$) and isokinetic ($P<0.01$) training. Similarly, Overall leg stability index demonstrated significant improvement in both groups with no between-group differences before or after trainings. Furthermore, training-induced changes in hamstring and quadriceps muscle torque were significantly correlated.
Conclusion: Both static and isokinetic strength trainings caused significant increase in hamstring and quadriceps muscle torque and overall athletic single-leg stability. The changes with muscle torque were correlated with each other but not with the single-leg stability.
Keywords: Isometric, Isokinetic, Biodex, hamstring, quadriceps, torque.

INTRODUCTION

Knee pain is one of the common complaints in athletes[1]. It has been shown that knee injuries and pain constitute half of all sports injuries[2,3]. Knee pain can cause muscular weakness around the knee joint which may result in 5% to 15% deficit in strength of hamstring and quadriceps muscles[4,5]. The most common causes of knee pain in athletes are patellofemoral pain syndrome, jumper's knee, ligamentous and meniscal injuries, altered lower limb biomechanics and muscular imbalance[6]. Arthogenic muscle inhibition of both quadriceps and hamstring after injury can delay the rehabilitation process[7,8].

In addition to muscle inhibition, the practice of advising complete rest to athletes after joint injuries further increase the risk of delay in rehabilitation and consequently delay in return to sports. Early exercises can play important role in effective rehabilitation and return to sports[7]. Strength training plays important role in rehabilitation of knee injuries in term of reducing symptoms, improving hamstring and quadriceps muscle strength, knee range of motion, physical function, and disability[9,10]. Strength training, either static or dynamic, has been reported to be beneficial in improving strength of both hamstring and quadriceps[11-12].

Both submaximal and maximal isometric muscle training can increase isometric strength[13] and induce muscular hypertrophy[14]. Practically however, maximal isometric exercises are utilized for improving strength and conditioning while submaximal isometric exercises are used for physical rehabilitation[15]. Rapid improvement in muscle strength has been achieved by an optimal number of repetitions of resistance exercises in the past[16]. It is generally accepted that maximal voluntary isometric exercises with15 to 20 repetitions maintained for 3 to 5 seconds can increase muscle strength in healthy people. When such exercises are undertaken three times every week, the muscle torque increments can be observable in as less as 2 weeks. Isometric exercises increase the muscle strength at and adjacent to the joint angle used for static strength training. As a rule, training at only one joint angle does not result in a general rise in muscle strength through full range of joint motion however[15].

On the other hand, isokinetic muscle contraction involves a maximal contraction of the whole muscle group at an unvarying angular velocity throughout the range of joint motion. Modern isokinetic dynamometers are capable of adjusting the resistance offered by the device according to the muscle strength generated during the complete range of joint motion. This enables the provision of variable but maximal mechanical resistance to the muscle group while performance[17]. Studies involving isokinetic resistance exercises at various angular velocities as high as 300°/sec have shown that high angular velocity combined with lower mechanical resistance leads to better outcomes as opposed to using higher resistance and slower angular velocity[18].

Balance or stability is integral part of athletic fitness and is influenced by a number of neuromuscular mechanisms based on the afferent input from systems such as vestibular, somatosensory, and visual[19]. Balance can be directly or indirectly evaluated through methods such as Romberg test, unipedal stance test, functional reach test, timed up and go test, star excursion balance test. etc. Computerized dynamic posturography methods like Biodex Balance System SD have also been used to assess both static and dynamic postures[17].

To the best of authors' knowledge, the short-term changes in hamstring and quadriceps muscle torque have not been simultaneously reported isometric and isokinetic strength training along with athletic single-leg stability. Therefore, the main objective of this trial was to evaluate the changes induced by static and isokinetic strength training in hamstring and quadriceps muscle torque. Additionally, the effects of both training programs on overall stability index were also analyzed and compared between the groups. Finally, statistical correlations were computed among changes in isometric and isokinetic muscle torque of hamstring and quadriceps as well as the athletic single-leg stability.

METHODS

This single blinded, positive randomized controlled trial was conducted on 50 volunteer athletes with unilateral knee pain recruited from the Rehabilitation and Treatment wing of the Pakistan Sports Board. The athletes were randomly assigned to two equal study groups: isokinetic training group or isometric training group. Male athletes with unilateral knee pain across various sporting background with a age range of 18-35 years were included in this study. Athletes with structural deformity of the knee or pain in both legs were not included. The study was approved by the institutional review board of the Pakistan Sports Board and conformed to the Declaration of Helsinki. Written, informed consent was obtained from all patients prior to their participation in the study.

Patient information: The mean (SD) age, body mass, height, and body mass index in the isokinetic group were 23.4 (4.8) years, 63.6 (15.5) kg, 1.7 (0.1) m, and 21.8 (4.7) kg/m^2 respectively. Similarly, In the isometric group, the mean (SD) age, body mass, height, and body mass index were 22.8 (5.3) years, 60.3 (9.3) kg, 1.7 (0.1) m, and 21.2 (3.4) kg/m^2 respectively.

Strength Training: Both static (isometric) and dynamic (isokinetic) strength training was administered based on the same protocol used in the earlier study[20]. Both training groups completed 10 rehabilitation sessions performed 3-4 times a week. All training sessions employed Biodex System 3 Pro. Each session was preceded by a warm-up session comprising treadmill walking and static stretching of knee flexors and extensors. A familiarization session was conducted before the training to facilitate the athletes.

Data Collection: Isokinetic evaluation was done while the athletes performed 5 trials of knee flexion and extension each at 5 different knee angular velocities with the injured leg. Each athlete started with 30°/sec and subsequent 4 velocities were used with an increment of 60°/sec. Highest velocity used in both training and evaluation was 210°/sec. Isometric evaluation was done at 3 different knee flexion angles of 30°, 45°, and 60° with 5 repetitions each for both hamstring and quadriceps. Stability was assessed through athletic single-leg stability test on the Biodex Balance System SD at a level of 4 while the athletes stood on the injured leg. Three repetitions of 20 seconds each with 10 seconds rest between the repetitions were performed by each athlete. Overall stability index, anterior posterior index, and medial lateral index were measured. Data was collected before and after 10 training sessions in both groups.

Statistical Analyses: Normality of the data was sought by Shapiro-Wilk test. The training-induced changes in hamstring and quadriceps muscle torque and athletic single-leg stability for both groups were analyzed through paired-samples t test. Between-group differences in terms of overall stability index were analyzed using independent samples t test. Pearson product-moment correlation coefficient was calculated to evaluate the statistical correlation among all variables. Statistical Package for Social Sciences (SPSS) was used for statistical analyses with alpha level of significance of 0.05.

RESULTS

Fig. I. Knee flexion and extension torque before and after the isokinetic strength training in athletes with knee pain. (*** indicates significant change P<0.001, ** indicates significant change P<0.01)

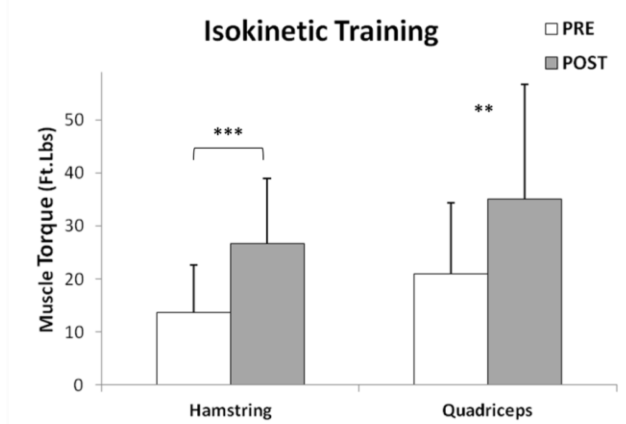
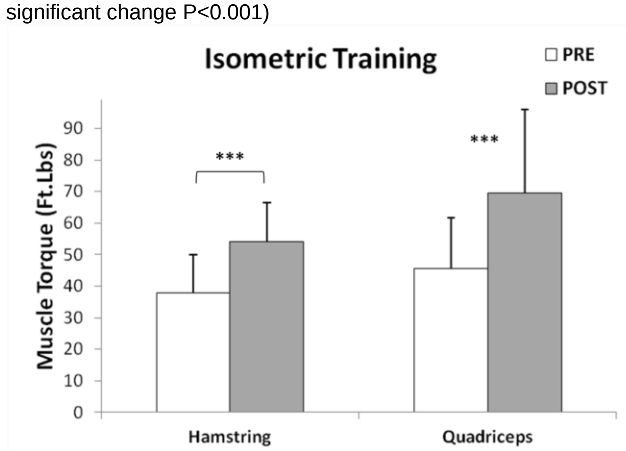


Fig II. Knee flexion and extension torque before and after the isometric strength training in athletes with knee pain. (*** indicates significant change P<0.001)

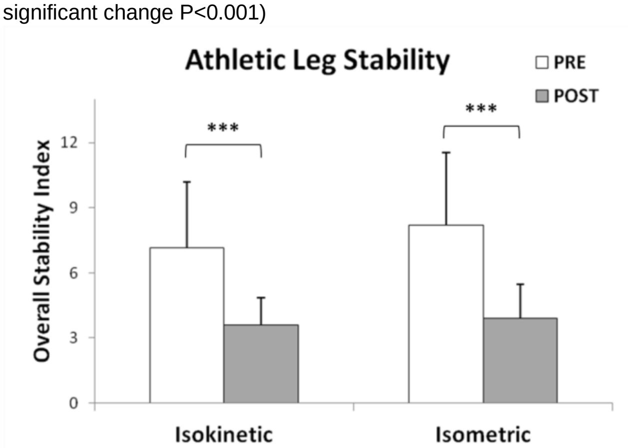


Significant improvement was observed in the muscle torque generated by the hamstring muscle group (13.7±9.0 Vs. 26.7±12.3 ft.lbs) after 10 sessions of isokinetic strength training (P<0.001). Similarly, significantly higher muscle torque was produced by the quadriceps (21.1±13.4 Vs. 35.2±21.5 ft.lbs; P<0.01) after 10 sessions of isokinetic training compared to the baseline (Fig. I).

In the isometric training group, similar significant training-induced muscle torque gains were observed in hamstring (37.7±12.1 Vs. 54.1±12.3 ft.lbs; P<0.001) and quadriceps (45.6±16 Vs. 69.5±26.4) after 10 sessions of isometric strength training (Fig. II).

At baseline, there was no statistically significant difference present between the overall stability index values of the isometric and isokinetic groups. As a result of isokinetic training, there was significant improvement in the stability (7.2±3.0 Vs. 3.6±1.3; P<0.001). Similarly, athletic single-leg stability also improved significantly (8.2±3.4 Vs. 3.9±1.5; P<0.001) after isometric strength training. No significant between-group differences were present with regard to overall stability index after the intervention period (Fig. III).

Fig. III. Athletic single leg stability before and after isometric and isokinetic strength training of the thigh musculature. (***indicates significant change P<0.001)



Significant positive correlation was present between the isometric training-induced changes in the torque production of hamstring and quadriceps (r=0.525; P<0.01). Similarly, the changes in muscle torque production of hamstring and quadriceps in the isokinetic group were also significantly positively correlated (r=0.680; P<0.001). No significant correlation was observed between the changes in the hamstring or quadriceps muscle torque generation and changes in athletic single-leg stability index in either study group.

DISCUSSION

Strength training is important component in physical rehabilitation of knee injuries. Increased strength of two major muscle groups around the knee joint: hamstring and quadriceps can improve symptoms, physical function, and performance in athletes with knee pain. The main findings of the current study are that both static and isokinetic strength training could significantly increase the strength of hamstring and quadriceps after 10 rehabilitation sessions. Additionally, the overall stability of the injured leg could also be improved significantly with both static and isokinetic training.

Literature has shown that isokinetic strength training is an effective method of improving physical fitness in athletes. For example, a study on 34 Taekwondo players reported significantly increased peak muscle torque for both hamstring and quadriceps at an angular velocity of 60°/s after 8 weeks of isokinetic training[21]. The findings of the present study confirm these findings by showing higher torque production of both hamstring and quadriceps after 10 sessions of isokinetic strength training at five different angular velocities. Similarly, a study conducted by Caruso and colleagues reported improved quadriceps strength at an angular velocity of 45°/s after nine weeks of training done twice a week culminating in a total of 18 training sessions as compared to 10 in the current study[22]. Past research has also signified that isokinetic muscle strength for both hamstring and quadriceps improve more at slower angular velocities, for example 60°/s, compared to higher velocities such as 240°/s[23]. The possible explanation of such pattern is the inverse relationship between muscle power and muscle contraction velocity after one-third of the maximal contraction velocity during concentric muscle contractions. In the current study, the muscle torque is not reported at individual angular velocities but rather the mean of average peak torque of all 5 contraction at all 5 angular velocities has been used to represent muscle strength for both hamstring and quadriceps.

In post-orthoscopic menisectomy patients, it has been shown that, except for the angular velocity of 120°/s, the mechanical work done by the quadriceps muscles was lower than the peak torque of quadriceps during isokinetic testing[24]. However, on the contrary, the overall mechanical work done by quadriceps was found to be higher than overall quadriceps strength in the present study. The difference in the findings may stems from the fact that knee menisci were not surgically removed in this study. Concerning effects of isometric training, Huang and coworkers reported concentric peak torque of both hamstring and quadriceps did not improve significantly at 60° knee angle after training[25]. In the present study, torques at individual knee joint angle are not reported and muscle strength is representative of all trials at all 3 joint angle and this overall muscle strength improved significantly in both hamstring and quadriceps. Contrary to the findings of Huang et al., another study reported that knee extensors gained significant strength during both isometric and isokinetic evaluations. The quadriceps were exercised isometrically at 4 different knee flexion angles for 9 weeks in healthy indiiduals and the sessions were repeated three times a week[26].

The current study showed better leg stability after isometric and isokinetic trainings. These findings are supported by an earlier report from DeBolt and McCubbin demonstrating that both static and dynamic strength training could improve balance and mobility. It should, however, be noted that home-based resistance exercises were used to improve balance in the previous study[27]. Effects of neuromuscular training using floor exercises, wobble board exercises, and mat exercises (e.g., squats) in handball athletes were published by Holm et al. It was found that although neuromuscular training significantly improved dynamic balance in athletes, there was no significant changes in muscle strength, flexibility, and static balance[28].

CONCLUSIONS

Both static and isokinetic strength training for 10 sessions could lead to significant increments in hamstring and quadriceps muscle torque production. Furthermore, athletic single-leg stability can also be improved significantly by both types of strength training. Therefore, both techniques can be used in the clinical setting for functional knee rehabilitation of athletes on the discretion of the clinician.

REFERENCES

1. Olsen OE, Myklebust G, Engebretsen L, Holme I, Bahr R. Exercises to prevent lower limb injuries in youth sports: cluster randomised controlled trial. BMJ. 2005 Feb 24;330(7489):449.
2. Ytterstad B. The Harstad injury prevention study: the epidemiology of sports injuries. An 8 year study. British Journal of Sports Medicine. 1996 Mar 1;30(1):64-8.
3. Kujala UM, Kvist M, Österman K. Knee injuries in athletes. Sports Medicine. 1986 Nov 1;3(6):447-60.
4. Calmbach, W. L., & Hutchens, M. A. R. K. (2003). Evaluation of patients presenting with knee pain: Part I. History, physical examination, radiographs, and laboratory tests. American family physician, 68(5), 907-912.
5. Keays, S. L., Bullock-Saxton, J., Keays, A. C., & Newcombe, P. (2001). Muscle strength and function before and after anterior cruciate ligament reconstruction using semitendonosus and gracilis. The Knee, 8(3), 229-234
6. Schlüter-Brust, K., Leistenschneider, P., Dargel, J., Springorum, H. P., Eysel, P., & Michael, J. P. (2011). Acute injuries in taekwondo. International journal of sports medicine, 32(08), 629-634
7. Hopkins JT, Ingersoll CD. Arthrogenic muscle inhibition: a limiting factor in joint rehabilitation. Journal of sport rehabilitation. 2000 May;9(2):135-59.
8. Rice DA, McNair PJ, Lewis GN, Dalbeth N. Quadriceps arthrogenic muscle inhibition: the effects of experimental knee joint effusion on motor cortex excitability. Arthritis research & therapy. 2014 Dec 10;16(6):502.
9. Salli, A., Sahin, N., Baskent, A., & Ugurlu, H. (2010). The effect of two exercise programs on various functional outcome measures in patients with osteoarthritis of the knee: A randomized controlled clinical trial. Isokinetics and Exercise Science, 18(4), 201-209.
10. Masood, T., Khan, HMMH., & Awan, WA. (2017). Effects of isokinetic strength training on subjective and objective knee performance of an anterior cruciate ligament (ACL) injured athlete". J Med Sci; 25: (1) 88-89.
11. Hefti F, Müller W, Jakob RP, Stäubli HU (1993) Evaluation of knee ligament injuries with the IKDC form. Knee Surg Sports Traumatol Arthrosc 1(3-4): 226-234.
12. Juhl, C., Christensen, R., Roos, E. M., Zhang, W., & Lund, H. (2014). Impact of Exercise Type and Dose on Pain and Disability in Knee Osteoarthritis: A Systematic Review and Meta-Regression Analysis of Randomized Controlled Trials. Arthritis & rheumatology, 66(3), 622-636.
13. Alway SE, Sale DG, MacDougall JD. Twitch contractile adaptations are not dependent on the intensity of isometric exercise in the human triceps surae. Eur J Appl Physiol Occup Physiol. 1990;60(5):346-52
14. Schott J, McCully K, Rutherford OM. The role of metabolites in strength training. II. Short versus long isometric contractions. Eur J Appl Physiol Occup Physiol. 1995;71(4):337-41
15. Fleck SJ, Kraemer W. Designing Resistance Training Programs, 4E. Human Kinetics; 2014 Feb 14.
16. Berger RA. Optimum repetitions for the development of strength. Research Quarterly. American Association for Health, Physical Education and Recreation. 1962 Oct 1;33(3):334-8.
17. Heyward VH. Advanced Fitness Assessment and Exercise Prescription. Medicine & Science in Sports & Exercise. 1992 Feb 1;24(2):278.
18. Van Roie E, Bautmans I, Boonen S, Coudyzer W, Kennis E, Delecluse C. Impact of external resistance and maximal effort on force-velocity characteristics of the knee extensors during strengthening exercise: a randomized controlled experiment. The Journal of Strength & Conditioning Research. 2013 Apr 1;27(4):1118-27
19. Jones G. Posture. In: Kandel E, Schwartz J, Jessell T, eds. Principles of neural science. New York: McGraw-Hill, 2000:816–31
20. Masood T, Khan HMMH. Comparison of isokinetic and isometric strength training effects on hamstring and quadriceps torques and physical function in knee pain. 2017. Rawal Medical Journal, 42(3), 320-325
21. Paine R, Chicas E, Bailey L, Hariri T, Lowe W. strength & functional assessment of healthy high school football players: analysis of skilled and non-skilled positions. International journal of sports physical therapy. 2015 Nov;10(6):850.
22. Caruso JF, Signorile JF, Perry AC, Leblanc B, Williams RI, Clark M, Bamman MM. The effects of albuterol and isokinetic exercise on the quadriceps muscle group. Medicine and science in sports and exercise. 1995 Nov;27(11):1471-6
23. Jeon K, Seo BD, Lee SH. Comparative study on isokinetic capacity of knee and ankle joints by functional injury. Journal of physical therapy science. 2016;28(1):250-6
24. Morrissey MC. The relationship between peak torque and work of the quadriceps and hamstrings after meniscectomy. Journal of Orthopaedic & Sports Physical Therapy. 1987 Feb;8(8):405-8.
25. Huang MH, Lin YS, Yang RC, Lee CL. A comparison of various therapeutic exercises on the functional status of patients with knee osteoarthritis. InSeminars in arthritis and rheumatism 2003 Jun 30 (Vol. 32, No. 6, pp. 398-406). WB Saunder
26. Folland JP, Hawker K, Leach B, Little T, Jones DA. Strength training: Isometric training at a range of joint angles versus dynamic training. Journal of sports sciences. 2005 Aug 1;23(8):817-24
27. DeBolt LS, McCubbin JA. The effects of home-based resistance exercise on balance, power, and mobility in adults with multiple sclerosis. Archives of physical medicine and rehabilitation. 2004 Feb 29;85(2):290-7
28. Holm I, Fosdahl MA, Friis A, Risberg MA, Myklebust G, Steen H. Effect of neuromuscular training on proprioception, balance, muscle strength, and lower limb function in female team handball players. Clinical Journal of Sport Medicine. 2004 Mar 1;14(2):88-94.