EFFECT OF NEUROMUSCULAR TRAINING TO PREVENT ANTERIOR CRUCIATE LIGAMENT INJURY AMONG FEMALE ATHLETES

Mohd Yusof Baharuddin & Siti Nadirah Junaid

Faculty of Sports Science and Coaching, Universiti Pendidikan Sultan Idris, Tg Malim, Perak, Malaysia

Abstract

Anterior cruciate ligament (ACL) injury is more prone on female athletes compared to male athletes in non-contact mechanisms. The purpose of the study was to evaluate the effect of four weeks neuromuscular training which closely associated with the dynamic balance and agility performance for preventing ACL injury among female athletes. There were sixteen female athletes from Universiti Pendidikan Sultan Idris (UPSI) who are volleyball, basketball and futsal players participated in this study. The subjects were divided randomly into two groups; control group (CG) and experimental group (EG). The EG experienced four weeks of neuromuscular training while the CG performing their regular training. The pre-test and post-test were measured using Star Excursion Balance Test (SEBT) for dynamic balance and T-Test for agility. Statistical data were analyzed using independent sample t-test and the results demonstrated significant differences ($p \leq 0.05$) for dynamic balance and agility between EG and CG. Therefore, this finding implied that neuromuscular training improved the female athletes in term of dynamic balance and agility which reduce the prevalence of ACL injury.

Keywords: anterior cruciate ligament; neuromuscular training, dynamic balance, agility, injury prevention

INTRODUCTION

The knee joint is prone to injury because of its complexity and weight-bearing function. It is made up of tibia, femur, and patella, which are stabilized by the medial collateral ligament (MCL), lateral collateral ligament (LCL), posterior cruciate ligament (PCL), and anterior cruciate ligament (ACL). The ACL is the primary stabilizing structure of the knee which originates from the posterior aspect of the femur coursing medially, inserting on the anterior aspect of the tibia (Cimino, Volk, & Setter, 2010). ACL injury common occurs in female athletes four to six time compared to

male athletes (Yoo et al., 2010; Noyes & Barber-Westin, 2013). The ACL can become twisted during rapid deceleration and sudden cutting, leading to ACL tears or ruptures (Granan, 2013). Female athletes are more likely to experience ACL injury during high-intensity exercise than male athletes (Herman, 2012). Anterior knee laxity and lower extremity strength are easy to find in female athletes than in male athletes.

The unstable knee structure that leads to ACL injury is more likely to occur for female athletes during certain activity particularly landing. Four-fifths of ACL injuries occur via a non-contact mechanism (Hewett et al., 1999). Non-contact ACL injuries typically occur during running, cutting, and jumping tasks when the knee is slightly flexed and in valgus. Female athletes tend to land in more extended knee joint positions and with increased knee valgus angles during running and side cutting (Zebis et al., 2008). The ACL plays an integral role in knee joint mechanics. When the ACL is ruptured, an individual often experiences multiple functional difficulties including the inability to decelerate, cut and pivot in addition to the presence of pain and effusion in the knee joint (Sugimoto et al., 2014). Time lost from ACL injury can be six months or longer (Sugimoto et al., 2012). Female athletes who suffer ACL injuries are more likely to experience premature osteoarthritis and reduced quality of life because of limited knee function.

Neuromuscular training programs are effective in improving the performance of an athlete. It is often used in physical training programs for athletes and in rehabilitation training for athletes with sports injuries. Proprioceptive and neuromuscular abilities have a convinced impact on the injury risk (Raj, 2015). Risk factors associated with neuromuscular control are potentially modifiable and may reduce the risk of non-contact ACL injury (Sugimoto et al., 2012). The neuromuscular training could be defined as training enhancing unconscious response by stimulating both afferent signals and central mechanisms responsible for dynamic joint control. The neuromuscular training improves the nervous system's ability to generate a fast and optimal muscle firing pattern, which increases dynamic joint stability, decreases joint forces and relearns movement patterns and skills (Raj, 2015). Neuromuscular control emphasizes the conscious control of the body and the coordination of various special movement to maintain stability and it used in lower extremity training for preventing ACL injury (Chang & Lai, 2014). Since the 1990s, several prospective cohort studies have been performed to determine the effect of neuromuscular training interventions targeted to reduce ACL, knee and other lower-extremity injuries (Sugimoto et al., 2012). Neuromuscular training aims to improve neuromuscular control, thus increasing functional joint stability, which may have a protective effect against injury (Tamara et al., 2009).

However, the neuromuscular training has efficiency in improving the joint control and stability. Many of an athletes have been ignoring the importance of the dynamic balance and agility. Failure to maintain balance and agility during the dynamic movement may lead to knee injuries due to improper landing, weak of the muscles and sudden change directions. The coaches and athletes itself should consider to take neuromuscular control in the training programs that focus on dynamic balance and agility. The purpose of this study was to evaluate the effect of

neuromuscular training in improving dynamic balance and agility performance by preventing ACL injury among female athletes.

METHODOLOGY

Research Design

This research was an experimental design study by collecting the data using Star Excursion Balance Test (SEBT) and Agility T-Test. SEBT was instrument that used to measure the dynamic balance and Agility T-Test is instrument used to measure the agility. This method would identify the effect of neuromuscular training to prevent ACL injury in UPSI's female athletes. The population recruited in this study consist of UPSI's female athletes who were volleyball, basketball and futsal players. Sixteen healthy subjects participated in this study. All subjects were randomly assigned into two groups; control group (CG) and experimental group (EG). Every group consisted of eight subjects. To minimize the chances of being bias in both group, randomized control trial design were used to divide them into two groups. All subjects tested using the SEBT and Agility T-Test for the pre-test and post-test. After the pre-test, the CG subjects instructed to perform their weekly physical activities where there are no intervention given to them. On the other hand, the EG subjects given the neuromuscular training intervention under the instruction of the researcher. The intervention conducted for four weeks with two session every week. The subjects required to complete twelve sessions of the design protocol.

Sample Data

Sixteen of UPSI's female athletes who were volleyball, basketball and futsal players involved in this study. The subjects were UPSI female athletes with age ranging from 19 to 24 years old, and the athletes must do not have any health problem of knee injury for six month before and no implant or foreign bodies. All of the subject are randomly divide into two group, which are Experimental Group (EG) and Control Group (CG).

Research Instrument

In this study, there were two instruments required during the test which were used in collecting data and training. The Star Excursion Balance Test (SEBT) were chosen to test the balance performance and Agility T-Test measurement to test the agility performance of the female athletes. Pre-test were conducted on both CG and EG which had been assigned randomly. The SEBT setup consisted of 5 lines at 45° and 90° interval extending from a center point. The angles used extended out from the center at 45°, 90°, 180°, 270° and 315° to provide targeting for the participants as showed in Figure 1. The subjects were instructed to performed single leg stance on one leg to reach out as far as possible in the 8 directions. The distance that the farthest portion of their foot reached was recorded. SEBT testing was conducted with both the dominant and the non-dominant leg as leg stance.
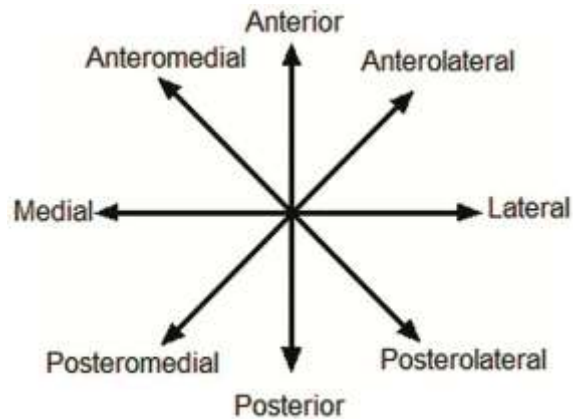
Figure 1. Star Excursion Balance Test (SEBT)

The subject required to reach out 8 directions in SEBT but in this study only restricted to four measurements; anteromedial (AM), medial (M), posterior (P) and lateral (L). The direction was determined in relationship to the stance leg. A standard tape measure (cm) was used to quantify the distance of the subject reach from the center of the grid to the point that the subject managed to reach.

In the Agility T-Test, the subject were instructed to sprint three ways which were forward run, shuffle sideway run and backward run in the 'T' shaped as showed in Figure 2. The subject performed forward run from cone A to cone B and touches the cone, then shuffled sideways to left to cone C and touches, then shuffling sideway to cone D and touches. The subject then shuffle back to cone B and run backward to cone A. The distance from cone A to cone B is 10 meters and the distance from cone B to cone C and D are 5 meters. The subject will performed 2 trials of Agility T-Test and the time were recorded.
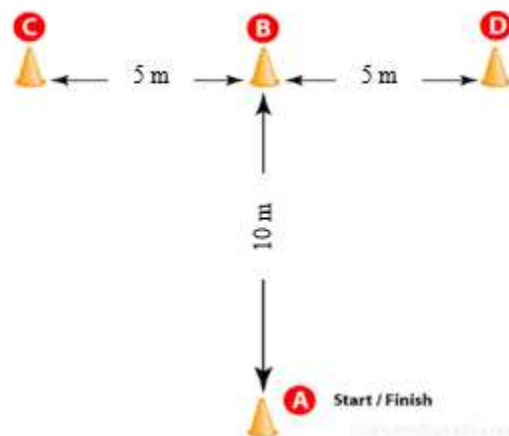

Figure 2. Agility T-Test

Neuromuscular Training Protocols

Experimental Group

For every session, the subjects began with doing general warm up. The duration of warm up was 10 minutes. After that, subjects were instructed to complete the set of protocols for that session. The intensity of the exercise was arranged progressively. The protocols instruction details were demonstrated in Table 1.

Table 1. Neuromuscular Training Program

Week	Session	10 min	Dynamic balance protocol	Reps x Set	Agility protocol	Reps x Set
Week 1 and 2	Session 1, 2 and 3	General warm up	Double leg jump forward	10 x 3	Forward/backward running	5 x 3
			Lunges step	10 x 3	Diagonal run	5 x 3
			Side to side box jump	10 x 3	Bounding run	5 x 3
			Knee lift on box	10 x 3		
			Hop and rotate	10 x 3		
Week 3 and 4	Session 1, 2 and 3		Single leg jump forward	10 x 3	Forward/backward running	5 x 4
			Lunges step forward	10 x 3	Diagonal run	5 x 4
			Single leg side to side box jump	10 x 3	Zig zag running	5 x 4
			Squat jump	10 x 3		
			Lateral bound	10 x 3		

Control Group

The CG were instructed to do their weekly training as usual with their own sport team. There was no intervention given to the subject in control group within four weeks of intervention. The subject in control group were being tested on SEBT and Agility T-Test for pre-test and again after the four weeks of the intervention as post-test.

Data Analysis

The data acquired was analyzed using the scored of Star Excursion Balance Test (SEBT) and the time taken to finish the Agility T-Test. The results were compared to find the different on pre-test and post-test. All the data were analyzed using Statically Package and Social Science (SPSS) version 23. Descriptive statistics were calculated for subjects demographic and the independent t-

test was used to compare the pre-test and post-test result of neuromuscular intervention between the two groups, with $p \leq 0.05$ level was set as the significant level.

RESULT

Demographic Data

Data obtained were analyzed using SPSS program version 23 to determine the effectiveness of the neuromuscular training. Table 2 shows the distribution number of the participants based on their group and the percentages. Total participants involved in this study was 16 female participants and divide into two groups where each group consisting eight participants in EG and CG per se. All selected participants were UPSI female athletes which consist of volleyball, futsal and basketball players. There are 4 participants played in volleyball in each group, and others from futsal and basketball. Table 3 demonstrated the demographic characteristics of participants based on age, height and weight. The results showed that average mean of age, height and weight in experimental group and control group were almost similar.

Table 2. Distribution based on sports involvement

Sports	Experimental Group n (%)	Control Group n (%)
Volleyball	4 (50)	4 (50)
Futsal	3 (37.5)	2 (25)
Basketball	1 (12.5)	2 (25)

Table 3. Demographic characteristics (Mean ± SD) of subjects

Variables / Groups	Experimental Group (Mean ± SD)	Control Group (Mean ± SD)
Age (years)	21.25 ± 1.17	22.25 ± 0.88
Height (cm)	154.96 ± 4.71	155.62 ± 5.64
Weight (kg)	53.96 ± 10.49	54.61 ± 9.48

Dynamic Balance

Table 4 showed the pre and post means of dynamic balance test in four directions which were anteromedial (AM), medial (M), posterior (P) and lateral (L) using SEBT. The finding showed that EG post-test for AM, M, AP and L were statistically significant ($p \leq 0.05$) than pre-test.

Table 4. Dynamic Balance for pre and post tests

Direction		Experimental group (cm)	Control group (cm)	t	p
AM	Pre	76.91	77.25	-.35	0.73
	Post	79.81	77.28	2.38	0.03
M	Pre	82.34	82.97	-0.65	0.52
	Post	84.69	82.63	2.75	0.01
P	Pre	79.03	79.16	-0.15	0.88
	Post	81.50	79.19	2.61	0.02
L	Pre	72.22	74.13	-2.21	0.09
	Post	75.38	73.69	1.77	0.04

Agility

Table 5 showed the pre and post of agility test in EG and CG using agility T-Test. The agility test demonstrated that EG post-test showed significantly difference ($p < 0.004$) than pre-test.

Table 5. Agility for pre and post tests

Test	Experimental Group (seconds)	Control Group (seconds)	t	p
Pre	13.68	13.93	-0.61	0.547
Post	12.62	113.81	-3.52	0.004

DISCUSSION

The main purpose of this study is to evaluate the effect of neuromuscular training in improving dynamic balance and agility for preventing ACL injury among UPSI female athletes. The finding indicated that the four weeks neuromuscular training could improve the dynamic balance and agility of UPSI female athletes. The results is there was significant difference of dynamic balance and agility performance of EG before and after four weeks neuromuscular training.

Neuromuscular training is important for preventing ACL injury and help to improve athlete's performances (Yoo et al., 2010; Noyes & Barber-Westin, 2013). Comprehensive neuromuscular training can lead to simultaneous improvements in athletic performance and movement biomechanics in female athletes (Myer et al., 2005). This training demonstrated not only the positive effects on ACL injury, but also significantly lower rates of injury to the knee ligaments, and reduced moderate and major acute knee or ankle injuries rate (Sugimoto et al., 2012). Moreover, neuromuscular training have both significantly reduced the incidence of ACL

injury and improved aspect of athletic performance, such as strength, speed and agility (Noyes & Barber-Westin, 2013).

Current study defined the intervention as the modification of combination of dynamic balance and agility exercise to form neuromuscular training. Combining multiple types of exercises seems to enhance the effectiveness of neuromuscular training in female athletes (Sugimoto et al., 2012). Neuromuscular exercise programs that combine plyometric, strengthening, and balancing have been shown to decrease the ACL injury risk and to enhance the athletic performance (Yoo et al., 2010). The effects of a comprehensive training program that combines several components, including injury-prevention techniques, not only decrease the potential biomechanical risk factors of lower-extremity injury, but can also provide additive performance-enhancement effects (Myer et al., 2005). Neuromuscular intervention it may take repeated use during several weeks for the athlete to demonstrate early changes in strength, balance, and proprioception (Gilchrist et al., 2008; Donnel-Fink et al., 2015). This might explain the differences in ACL injury rates, which were more pronounced later in the season, suggesting a cumulative benefit of the training. A study identified dynamic valgus of the knee as a predisposing factor for ACL injury in female athletes (Hewett et al., 1999). The balance between medial-lateral hamstring recruitment seems highly important for the control of dynamic valgus.

CONCLUSION

The results discovered that there was significant difference of EG and CG after four weeks neuromuscular training. Therefore, this neuromuscular training can be recommended to the female athletes as one of their training program in order to help to enhance their dynamic balance and agility performance and also to prevent ACL injury which indicated high risk in female athletes.

ACKNOWLEDGEMENT

REFERENCES

Chang, W. D., & Lai, P. L. (2014). Neuromuscular training for prevention of anterior cruciate ligament injury in female athletes. *International Journal of Athletic Therapy & Training,* 19(6), 17-21.

Cimino, F., Volk, B. S., & Setter, D. (2010). Anterior cruciate ligament injury: diagnosis, management, and prevention. *American Academy of Family Physicians,* 82(8), 917-922.

Donnel-Fink, L. A., Klara, K., Collins, J. E., Yang, H. Y., Goczalk, M. G., Katz, J. N., & Losina, E. (2015). Effectiveness of knee injury and anterior cruciate ligament tear prevention programs: a meta-analysis. *PloS ONE,* 10(12), 1-17.

Gilchrist, J., Mandelbaum, B. R., Melancon, H., Ryan, G. W., Silvers, H. J., Griffin, L. Y., Watanabe, D. S., Dick, R.W., & Dvorak, J. (2008). A randomized controlled trial to prevent noncontact anterior

cruciate ligament injury in female collegiate soccer players. *The American Journal of Sports Medicine,* 36(8), 1476-1483.

Granan, L. P., Inacio, M. C. S., Maletis, G. B., Funahashi, T. T., & Engebretsen, L. (2013). Sport-specific injury pattern recorded during anterior cruciate ligament reconstruction. *The American Journal of Sports Medicine,* 41(12), 2814-2818.

Herman, K., Barton, C., Malliaras, P., & Morrissey, D. (2012). The effectiveness of neuromuscular warm-up strategies that require no additional equipment for preventing lower limb injuries during sports participation: a systematic review. *BMC Medicine,* 10(75), 1-12.

Hewett, T. E., Lindenfeld, T. N., Riccobene, J. V., & Noyes, F. R. (1999). The effect of neuromuscular training on incidence of knee injury in female athletes. *The American Journal of Sports Medicine*, 27(6), 699-706.

Myer, G. D., Ford, K. R., Palumbo, J. P., & Hewett, T. E. (2005). Neuromuscular training improves performance and lower-extremity biomechanics in female athletes. *Journal of Strength and Conditioning Research*, 19(1), 51-60.

Noyes, F. R., & Barber-Westin, S. D. (2013). Neuromuscular retraining intervention programs: do they reduce noncontact anterior cruciate ligament injury rates in adolescent female athletes? *The Journal of Arthroscopic and Related Surgery*, 30(2), 245-255.

Raj, S. V. (2015). *Importance of neuromuscular training for athletes.* India: Science Research Publication.

Sugimoto, D., Myer, G. D., McKeon, J. M., & Hewett, T. E. (2012). Evaluation of the effectiveness of neuromuscular training to reduce anterior cruciate ligament injury in female athletes: a critical review of relative risk reduction and numbers-needed-to-treat analyses. *British Journal of Sports Medicine,* 46(14), 979-988.

Sugimoto, D., Myer, G. D., Foss, K. D. B., & Hewett, T. E. (2014). Specific exercise effect of preventive neuromuscular training intervention on anterior cruciate ligament injury risk reduction in young females: meta-analysis and subgroup analysis. *British Journal of Sports Medicine,* 49(5), 282-289.

Tamara, C. V., McLeod, T. A., Mathew, M., & Jamie, L. S. (2009). Balance improvements in female high school basketball players after a 6-week neuromuscular-training program. *Journal of Sport Rehabilitation,* 18(4), 465-481.

Yoo, J. H., Lim, O. B., Ha, M., Lee, S. W., Oh, S. J., Lee, Y. S., & Kim, J, G. (2010). A meta-analysis of the effect of neuromuscular training on the prevention of the anterior cruciate ligament injury in female athletes. *Knee Surgery Sports Traumatology Arthroscopy,* 18(6), 824-830.

Zebis, M. K., Bencke, J., Andersen, L. L., Dossing. S., Tine, A., Magnusson, P., Michael, K., & Per, A. (2008). The effects of neuromuscular training on knee joint motor control during side cutting in female elite soccer and handball players. *Clinical Journal of Sport Medicine,* 18(4), 329-337.

📧 Mohd Yusof Baharuddin,
Faculty of Sports Science and Coaching,
Universiti Pendidikan Sultan Idris,
Tg Malim,
Perak, Malaysia
Email: yusof.b@fsskj.upsi.edu.my