

# The Effects of Neuromuscular Training on Limits of Stability in Female Individuals

Yen-Ting Wang, Yu-Tien Tsai, Tzuhui A. Tseng, I-Tsun Chiang, and Alex J.Y. Lee

**Abstract**—This study examined the effects of neuromuscular training (NT) on limits of stability (LOS) in female individuals. Twenty female basketball amateurs were assigned into NT experimental group or control group by volunteer. All the players were underwent regular basketball practice, 90 minutes, 3 times per week for 6 weeks, but the NT experimental group underwent extra NT with plyometric and core training, 50 minutes, 3 times per week for 6 weeks during this period. Limits of stability (LOS) were evaluated by the Biodex Balance System. One factor ANCOVA was used to examine the differences between groups after training. The significant level for statistic was set at  $p < .05$ . Results showed that the right direction LOS scores at level 3 indicated a significant interaction between the trained/untrained groups  $\times$  pre/post repeated measures with post-training scores higher than pre-training scores in the NT experimental group. The study demonstrated that Six weeks NT can improve the postural stability in young female individuals.

**Keywords**—Balance control, neuromuscular control and posture stability.

## I. INTRODUCTION

**B**ASKETBALL is a high-intensity; aggressive body contact game of an intermittent nature, requiring frequent changes in movement, and it includes sprints, jumps, and quick stops. Several studies support the use of interventions such as neuromuscular training (NT) programs to reduce the incidence of lower extremity injuries [1]-[3]. The most effective programs emphasize several common components, including plyometric training in combination with biomechanical feedback and technique training [4], [5]. Implementation of a NT that focuses on core stability exercises is advocated to prevent lower extremity injury, namely in female athletes who have deficits in trunk proprioception and neuromuscular control [6]. Importantly, poor core stability and decreased muscular synergy of the trunk and hip stabilizers have been theorized to decrease performance in power activities and to increase the

incidence of injury secondary to lack of control of the center of mass, especially in female athletes [1], [7].

Comprehensive NT programs designed for young women may significantly increase power, strength, and neuromuscular control and decrease gender differences in these measures [8]. Targeted NT is designed to reduce injury risk, and include interventions that focus on increased control of the center of mass. As the center of mass moves away from the base of support, there is an increased potential for biomechanical deviations to occur in the lower extremity. An improved ability to control this movement has the potential to decrease excessive forces on the lower extremity and ultimately decrease injury risk [6].

Postural control involves a dynamic system of neuromuscular activity, biomechanical interactions, and sensory feedback loops that are used in synchrony to manipulate the orientation of the body's various segments and generate appropriate interaction with the environment. Postural stability is one facet of postural control that can be defined as the ability to maintain a desired orientation while resisting external and internal perturbations [9]. It has been defined as the ability to maintain an upright posture and to keep the center of gravity (COG) within the limits of the base of support [10]. It is preserved through the dynamic integration of internal and external forces and factors involving the environment [11], [12].

Marked evidence shows that NT programs are effective for improving measures of performance. Female athletes may especially benefit from multi-component neuromuscular training because they often display decreased baseline levels of strength and power compared with their male counterparts. Dynamic NT has also been demonstrated to reduce gender-related differences in force absorption, active joint stabilization, muscle imbalances, and functional biomechanics while increasing strength of structural tissues (bones, ligaments, and tendons) [13]-[15]. These ancillary effects of neuromuscular training, which are likely related to the reduction of the risk of injury in female athletes, are positive results of training.

Without the performance-enhancement training effects, however, athletes may not be motivated to participate in a neuromuscular training program. It has not been demonstrated in the literature that performance-enhancement and injury-prevention training effects can be reached through a single neuromuscular training protocol. If such a program design were widely available, prevention-oriented training could be instituted on a widespread basis with highly motivated

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athletes. The purpose of this study was to evaluate the effects of neuromuscular training on limits of stability (LOS) in female individuals.

## II. METHODS

Twenty female basketball amateurs volunteered to participate in the study and were randomly assigned to the NT experimental group (EG, age:  $19.9 \pm 1.2$  yrs, height:  $162.3 \pm 3.5$  cm, weight:  $56.4 \pm 5.4$  kg,) or control group (CG, age:  $20.0 \pm 1.6$  yrs, height:  $162.4 \pm 8.6$  cm, weight:  $55.7 \pm 8.7$  kg.). All participants completed a self-report health history questionnaire and signed a written informed consent before testing. All participants were screened for lower-extremity (ankle, knee, hips) bone and joint injuries and abnormalities as well as for conditions (i.e., concussion, inner-ear disorders, upper-respiratory infection, etc.) that may influence balance. Any participant self-reporting the presence of any injury or condition within the last 6 months was excluded from the study.

The NT program used in this study was adapted from previous studies included plyometrics and core strength training. The training program was conducted on Monday, Wednesday, and Thursday. Each training session lasted for approximately 50 minutes. Before each training session, an active warm-up that included jogging, backwards running, lateral shuffling, and carioca was used. At the end of each training session, the subjects performed self-selected stretching exercises for 10 minutes. The training period lasted a total of 6 weeks.

The NT training component progressively emphasized double- then single leg movements through training sessions. The majority of the initial exercises involved both legs to safely introduce the subjects to the training movements. Early training emphasis was on sound athletic positioning that may help create dynamic control of the subject's center of gravity. The core strengthening component of the protocol followed an organized exercise selection specifically directed at strengthening the core stabilizing muscles. This component focused on providing an appropriate balance between developing the proprioceptive abilities of the subject and exposing the subject to inadequate joint control. The training progression took the subject through a combination of low- to higher-risk maneuvers in a controlled situation. The intensity of the exercises were modified by changing the arm position, opening and closing eyes, changing support stance, increasing or decreasing surface stability with balance training device (BOSU Balance Trainer, DW Fitness LLC, Madison, NJ), increasing or decreasing speed, adding unanticipated movements or perturbations, and adding sports-specific skills. Each NT exercise was demonstrated by the instructor, with feedback given to the subject both during and after training. The NT stressed performance of athletic maneuvers in a powerful, efficient, and safe manner. The progressive nature of the NT was important to achieve successful outcomes from the training. The goal of the next training session was to continue to improve technique while increasing duration, volume, or

intensity of the exercise.

The Limits of stability (LOS) was evaluated by the Biodex Balance System which offers four testing and five training modes (BBS, Biodex Balance System, New York, USA). The BBS allows testing and training in both static and dynamic formats. Using this device, clinicians can assess neuromuscular control by quantifying the ability to maintain dynamic bilateral and unilateral postural stability on a static or unstable surface. The two-leg stance balance test was performed with the BBS, which comprises a multi-axial foot platform connected to a computer and a screen located in front of the subject. The magnitude and direction of the displacements of the tilting platform can be monitored with the help of a cursor moving on the screen. In this study, the subjects carried out the dynamic limit-of-stability protocol, consisting of moving the cursor (platform) back and forth from a central box to eight peripheral boxes appearing successively in a random order on the screen. The BBS offers several levels of difficulty from L1 (most unstable) to L12 (most stable), which determines the rate of deflection of the platform.

Prior to performing the experiment measurements, subjects were familiarized with proper practice. During the test session, subjects warmed up for 5 to 10 minutes on running and performed dynamic stretching lasting approximately 12 seconds for each lower muscle group. The LOS was evaluated with the BBS protocol under level 3 and level 6. The performance is based on their ability to accurately move the display cursor to a target 10 degrees from a level platform position and back to level again. The subject was instructed to start moving the cursor toward the flashing target. The cursor had to stay within the center point for a minimum of 0.5 seconds before it disappeared and showed the next target on the screen. Each trial ended when the eight target points had been reached and cursor was return to the center point.

The dynamic LOS score was calculated for each direction according to the percentage between the straight line distance to target and the number of samples. Therefore, more direct the path to the target and back to center; the higher score will be achieved. The variables chosen for the balance tests were the overall and the eight individual dynamic LOS score for each trial which calculated by the System.

All statistical procedures were performed by using SPSS version for Windows 12 (Chicago, IL, USA). A mixed design, one-way ANCOVA was used to evaluate the difference between groups after training for each parameter. The statistic significance was set at  $p < .05$ .

## III. RESULTS

After six weeks of neuromuscular training, the overall LOS scores for the EG at levels 3 and 6 in pre- and post-training changed from  $22.1 \pm 10.0\%$  to  $27.2 \pm 12.9\%$  and  $26.5 \pm 8.6\%$  to  $35.6 \pm 12.0\%$ , respectively. The overall LOS score for the CG at levels 3 and 6 in pre- and post-training changed from  $25.2 \pm 12.4\%$  to  $23.8 \pm 7.5\%$  and  $31.3 \pm 10.2\%$  to  $31.1 \pm 10.9\%$ , respectively. The results of the ANCOVA for the right

direction LOS scores at level 3 (Fig. 1) indicated a significant interaction between the trained/untrained groups  $\times$  pre/post repeated measures with post-training scores higher than pre-training scores in the EG ( $F=8.56, p < .05$ ).

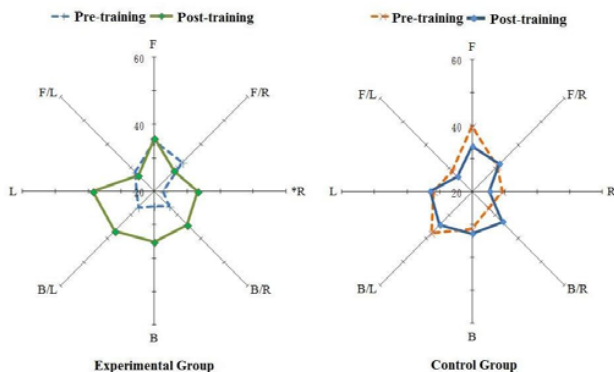


Fig. 1 LOS scores in each direction between groups at level 3 before and after training

#### IV. DISCUSSION

Basketball is a high-intensity; aggressive body contact game of an intermittent nature, requiring frequent changes in movement, and it includes sprints, jumps, and quick stops. It is a popular sport worldwide, and its participants have very high injury rates and require frequent medical treatment [16]. Study demonstrated that more than 50% of all game and practice injuries were to the lower extremity, with ankle ligament sprains being the most common injury overall and noncontact knee injuries being the most common serious injury in collegiate men's basketball players [17], [18]. In addition, most ankle sprains occurred inside the key area of the basketball court with contact, and centers had the highest rate of injury than guards and forwards [19]. Furthermore, the rate of ankle injury in basketball game were ranged from 1.30 to 2.33 injuries per 1000 athlete-exposures, which was 2 times higher than in practices situations according to the National Collegiate Athletic Association (NCAA) injury surveillance data [17], [18]. Therefore, a variety of tests and training programs are being implemented in an attempt to increase performance and prevent basketball-related injuries [20].

Comprehensive neuromuscular training can lead to improvements in athletic performance and movement biomechanics. The main purpose of the present study was to evaluate the effects of six weeks of NT on LOS in female collegiate basketball athletes. The main findings of this study suggest that this kind of NT can improve LOS performance, as shown by the improvement in the dynamic LOS test, especially in the right directions during unstable situations.

The finding of a significant improvement in the right-direction performance on the unstable, level 3 LOS test indicates that a 6-week period of NT can improve postural stability in specific direction. This improvement could be due to enhanced neuromuscular coordination and neural adaptations between the CNS signal and proprioceptive

feedback, or to better facilitation of neural impulses to the spinal cord. A previous study demonstrated that after PT, athletes had significant improvements in lower-extremity coronal plane mechanics parameters during both the drop vertical jump and medial drop landing movements, and suggested that this improvement could be related to awareness, feedback and adjustments made during the dynamic and fast-paced nature of the PT [20]. It is commonly assumed that core strengthening, PT, and jumping exercises can alter the movement patterns of athletes and lower the incidence of injury [4]. Our study provided further support for this hypothesis, since it showed that PT could facilitate voluntary active postural and lower extremity corrections during the unstable LOS test.

Six weeks regular NT can improve the postural stability in young female individuals. A dynamic NT program designed for the prevention of lower-extremity injuries can provide simultaneous improvements neuromuscular control, active joint stabilization, and increasing postural stability in female individuals.

#### REFERENCES

- Myer GD, Brunner HI, Melson PG, Paterno MV, Ford KR, and Hewett TE, "Specialized neuromuscular training to improve neuromuscular function and biomechanics in a patient with quiescent juvenile rheumatoid arthritis", *Phys Ther*, 85(8), 791-802, 2005
- Mandelbaum BR, Silvers HJ, Watanabe DS, Knarr JF, Thomas S D, Griffin LY, et al, "Effectiveness of a neuromuscular and proprioceptive training program in preventing anterior cruciate ligament injuries in female athletes: 2-year follow-up", *American Journal of Sports Medicine*, 33(7), 1003-1010, 2005.
- Myer GD, Brent JL, Ford KR, and Hewett TE, "A pilot study to determine the effect of trunk and hip focused neuromuscular training on hip and knee isokinetic strength", *Br J Sports Med*, 42, 614-619, 2008.
- Myer GD, Ford KR, McLean SG, and Hewett TE, "The effects of plyometric versus dynamic stabilization and balance training on lower extremity biomechanics", *Am J Sports Med*, 34(3), 445-455, 2006.
- Thacker SB, Stroup DF, Branche CM, Gilchrist J, Goodman RA, and Kelling EP, "Prevention of knee injuries in sports. A systematic review of the literature", *J Sports Med Phys Fitness*, 43, 165-179, 2003.
- Zazulak BT, Hewett TE, Reeves NP, Goldberg B, and Cholewicki, J, "Deficits in neuromuscular control of the trunk predict knee injury risk: a prospective biomechanical-epidemiologic study", *Am J Sports Med*, 35, 1123-1130, 2007.
- Hewett TE, Myer GD, Ford KR, Heidt RS Jr, Colosimo AJ, McLean SG, et al., "Biomechanical measures of neuromuscular control and valgus loading of the knee predict anterior cruciate ligament injury risk in female athletes: a prospective study", *Am J Sports Med*, 33(4), 492-501, 2005.
- Kraemer WJ, Hakkinen K, Triplett-Mcbride NT, Fry AC, Koziris LP, Ratamess NA, et al, "Physiological changes with periodized resistance training in women tennis players", *Med Sci Sports Exerc*, 35, 157-168, 2003.
- Cavanaugh JT, Guskiewicz KM, and Stergiou N, "A nonlinear dynamic approach for evaluating postural control: New directions for the management of sport-related cerebral concussion", *Sports Medicine*, 35, 935-950, 2005.
- Karlsso A, and Frykberg G, "Correlations between force plate measures for assessment of balance", *Clin. Biomech*, 15, 365-369, 2000.
- Jonsson E, Seiger A, and Hirschfeld H, "One-leg stance in healthy young and elderly adults: a measure of postural steadiness?", *Clin. Biomech*, 19, 688-694, 2004.
- Mochizuki L, Duarte M, Amadio AC, Zatsiorsky VM, Latash ML, "Changes in postural sway and its fractions in conditions of postural instability", *Journal of Applied Biomechanics*, 22, 51-60, 2006.

- [13] Faigenbaum AD, Kraemer WJ, Cahill B, Chandler J, Dziasos J, Elfrink L D, et al, "Youth resistance training: Position statement paper and literature review", *Strength Cond J*, 18(6), 62-75, 1996.
- [14] Fleck SJ, and Falkel JE, "Value of resistance training for the reduction of sports injuries", *Sports Med*, 3, 61-68, 1986.
- [15] Rooks DS, and Micheli LJ, "Musculoskeletal assessment and training: The young athlete", *Clin Sports Med*, 7, 641-677, 1988.
- [16] Nelson AJ, Collins CL, Yard EE, Field SK, and Comstock RD, "Ankle injuries among United States high school sports athletes, 2005-2006", *J Athl Train*, 42(3), 381-387, 2007.
- [17] Dick R, Hertel J, Agel J, Grossman J, and Marshall SW, "Descriptive epidemiology of collegiate men's basketball injuries: National Collegiate Athletic Association Injury Surveillance System, 1988-1989 through 2003-2004", *J Athl Train*, 42(2), 194-201, 2007.
- [18] Hootman JM, Dick R, and Agel J, "Epidemiology of Collegiate Injuries for 15 Sports: Summary and Recommendations for Injury Prevention Initiatives", *J Athl Train*, 42(2), 311-319, 2007.
- [19] Kofotolis N, and Kellis E, "Ankle Sprain Injuries: A 2-Year Prospective Cohort Study in Female Greek Professional Basketball Players", *J Athl Train*, 42(3), 3881-394, 2007.
- [20] Chappell JD, Limpisvasti O, Chappell JD, and Limpisvasti O, "Effect of a neuromuscular training program on the kinetics and kinematics of jumping tasks", *Am J Sports Medicine*, 36(6), 1081-1086, 2008



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