THE EFFECTS OF NEUROMUSCULAR TRAINING ON COUNTER-MOVEMENT JUMP PERFORMANCE IN HEALTHY YOUNG STUDENTS

Yen-Ting Wang[1], Yu-Tien Tsai[2], and Alex J.Y. Lee[2]

National Taiwan Sport University, Taoyuan, Taiwan[1]
National HsinChu University of Education, HsinChu, Taiwan[2]

Neuromuscular training (NT) programs are effective for improving measures of performance and used by athletes in all types of sports to increase sports performance. The purpose of this study was to evaluate the effects of NT on arm counter-movement jump (CMJ) performance in healthy young students. Thirteen healthy collegiate female students volunteered and underwent a series of NT exercise. The NT was performed for 50 minutes three times per week, for six weeks. Paired *t*-tests were used to analyze the differences in each parameter before and after training. The arm CMJ in explosive power, flight time, and jump height was statistically improved in post-training compared to pre-training. It is concluded that six weeks NT can improve the arm CMJ performance in young female students.

KEY WORDS: vertical jump, core strength training, plyometric training.

INTRODUCTION: Neuromuscular training (NT) is a kind of exercise training which designed to both increase the strength, endurance, and the awareness of particular joint. Previous studies demonstrated that NT programs are effective for improving measures of performance, such as power, agility, and speed (Kraemer, Duncan, & Volek, 1998; Wroble, & Moxley, 2001). Female athletes may benefit from multi-component NT because they often display lower baseline levels of strength and power compared with their male counterparts. Several studies support the use of NT programs to reduce the incidence of lower extremity injuries (Hewett, Ford, & Myer, 2006; Mandelbaum et al., 2005; Myer, Brent, Ford, & Hewett, 2008). The most effective programs emphasize several common components, including plyometric training in combination with biomechanical feedback and technique training (Thacker, Stroup, Branche, Gilchrist, Goodman, & Kelling, 2003). 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 (Hewett, Myer, & Ford, 2005).
Without the performance-enhancement training effects, athletes may not be motivated to participate in a NT program. It has not been demonstrated in the literature that performance-enhancement and injury-prevention training effects can be reached through a single NT protocol. If such a program design were widely available, prevention-oriented training could be instituted on a widespread basis with highly motivated athletes. Therefore, the purpose of this study was to evaluate the effects of NT on counter-movement jump performance in healthy young students.

METHODS: Thirteen healthy collegiate female students (height: 162.3 ± 4.2 cm, weight: 55.6 ± 4.7 kg, age: 19.8 ± 1.2 yrs) from a national university participated in this study. They were sedentary and had no previous experience with NT prior to participation. All participants completed a self-reported 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, and were restrictions to underwent other forms of training during this study. 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 study (Mandelbaum et al., 2005) and included plyometrics and core strength training. The training program was conducted three days per week on Mondays, Wednesdays, and Thursdays. Each training session lasted for approximately 50 minutes. Before each training session, an active warm-

up was used that included jogging, backwards running, lateral shuffling, and carioca. 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 plyometrics 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 which 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, including the transversus abdominus, multifidus, diaphragm and pelvic floor muscles. This component focused on providing an appropriate balance between developing the proprioceptive abilities of the subject. 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 arm counter-movement jump (CMJ) performance was evaluated via flight time as the maximal height on AMTI force pate (AMTI, Advanced Mechanical Technology, Inc, USA) with a sampling rate of 1500 Hz. Body mass was measured on the force plate, which was calibrated prior to each measurement. Participants were instructed to begin from a standing position, perform a crouching action immediately followed by a jump for maximal height without arm movement restriction. Jump technique was demonstrated by one of the investigators, followed by two sub-maximal attempts by the participant as familiarizaiton.

All participants completed a controlled warm-up consisting of jogging and stretching and 3 practice jumps at submaximal effort. Each subject was allowed 3 test jumps with a 3-minute recovery between each jump. The jump with the greatest height, and all of the associated kinetic data were subsequently used for analysis. The jump height was calculated by flight time. The power was measured directly by the AMTI force platforms. The flight time was calculated as the time off the forceplate. No specific instructions were provided that would influence landing mechanics during testing.

All statistical procedures were performed by using SPSS version 12 for Windows (Chicago, IL, USA). Repeated-measures *t* test were used to examine the differences in each parameter before and after training. The Bonferroni correction is used to reduce the chances of obtaining false-positive results (type I errors). Intra-class correlation coefficients (ICC) assessed the test-retest reliability of comparing the mean of the dependent variables between testing sessions. For all analyses, the level of statistical significance was set at $P < 0.05$.

RESULTS: The compliance rate for training program participation was 92%. The ICC test-retest reliability analyses revealed that jump height of arm CMJ (0.93), flight time (0.94), and explosive power (0.91) were consistent between sessions. The arm CMJ explosive power (127.1 ± 14.8 % BW vs. 143.6 ± 15.3 % BW, t=-4.4, fig 1), flight time (0.5X ± 0.1X sec vs. 0.5X ± 0.0X sec, t=-4.7), and jump height (30.1 ± 6.4 cm vs. 33.2 ± 5.5 cm, t=-4.9) was statistically significantly improved in post-training compared to pre-training.

DISCUSSION: Dynamic jump performance is thought to be an important factor influencing specific performance in sports. Female athletes participating in sports that require jumping and/or rapid changes in direction (e.g., soccer, basketball, and volleyball) are up to six times more likely to suffer a non-contact anterior cruciate ligament (ACL) injury compared to their male counterparts participating in the same sport (Arendt, Agel, & Dick, 1999; Harmon & Ireland, 2000). The multi-factorial nature of non-contact ACL tears (AAOS, 2001) and the differences in neuromuscular activation patterns between men and women may be a contributing factor in the elevated risk of ACL injuries (Chappell, Yu, Kirkendall, & Garrett, 2002; Hanson, Padua, Troy Blackburn, Prentice, & Hirth, 2008; Landry, McKean, Hubley-Kozey, Stanish, & Deluzio, 2007a, 2007b).

The maximal vertical jump is a common test and a measure of lower limb muscular power used by practitioners and coaches in a variety of game sports to monitor the effects of training and/or rehabilitation. It is an established measure of lower body explosive power and, as such, should be used as part of a battery of tests for assessing the athletes (Cardinale & Bosco, 2003; Delecluse, Roelants, & Verschueren, 2003). Additionally, jumping movements generally involve an arm swing, so information regarding vertical jump performance with an arm swing (countermovement vertical jump) after NT is warranted and possibly meaningful. Although the significant improvement in arm CMJ height was seen in this study cannot be directly extrapolated to predict field sport performance, it would have relevance in game situations such as jumping shoot, changing direction, lunging, and acceleration, where maximal explosive power is important.

The current study did not include EMG recordings and therefore it is not possible to directly assess any neurogenic enhancement. However, it has been reported that the stretch-shortening cycle of the jump activates the spinal reflexes to enhance jump height compared to that of a concentric squat jump (Bobbert et al., 1996). Therefore, it is reasonable to propose that any neurogenic changes are ably detected by countermovement vertical and horizontal jump. The accentuated jump height after NT may suggest that better neural coordination and synchronized motor unit firing. Furthermore, in the absence of measures of neural function, the explanation about the increased sensitivity of the stretch reflex mechanism remains speculative and a better understanding awaits further investigation. Moreover, the use of an arm swing in the jump measure in the present study is unlikely to have contributed to the greater enhancement of jump performance, unless NT somehow improves the coordination of arm and leg movements. Additionally, arm swing in the countermovement jump has been proven to require less practice than a countermovement jump with no arm swing and has been described as a natural practiced movement (Keogh, Weber, & Dalton, 2003).

CONCLUSION: In conclusion, for the female collegiate individuals studied, implementing a 6-week NT program had positive effects on jump performance; improving the maximum vertical jump height in the arm CMJ test. Enhanced motor unit synchronization and firing rates, facilitated muscular contraction stretch-shortening cycle, and improved lower extremity neuromuscular coordination could account for these enhancements. This study demonstrates significant benefits of a 6-week NT program highlight the potential of extra NT during the off-season and/or pre-season to improve the jump performance in young female individuals.

REFERENCES:

AAOS (2001). Prevention of noncontact ACL injuries. Rosemont: American Academy of Orthopaedic Surgeons.

Arendt, E. A., Agel, J., & Dick, R. (1999). Anterior cruciate ligament injury patterns among collegiate men and women. *Athletic Training*, 24, 86-92.

Bobbert MF, Gerritsen KGM, Litjens MCA, et al. (1996). Why is countermovement jump height greater than squat jump height? *Medicine and Science in Sports and Exercise*, 28, 1402-1412.

Cardinale M, Bosco C. (2003). The use of vibration as an exercise intervention. *Exercise and Sport Science Review*, 31, 3-7.

Chappell, J. D., Yu, B., Kirkendall, D. T., & Garrett, W. E. (2002). A comparison of knee kinetics between male and female recreational athletes in stop-jump tasks. *American Journal of Sports Medicine*, 30, 261-267.

Delecluse C, Roelants M, Verschueren S. (2003). Strength increase after whole-body vibration compared with resistance training. *Medicine and Science in Sports and Exercise*, 35, 1033-1041.

Hanson, A. M., Padua, D. A., Troy Blackburn, J., Prentice, W. E., & Hirth, C. J. (2008). Muscle activation during side-step cutting maneuvers in male and female soccer athletes. *Journal of Athletic Training*, 43, 133–143.

Harmon, K. G., & Ireland, M. L. (2000). Gender differences in noncontact anterior cruciate ligament injuries. *Clinics in Sports Medicine*, 19, 278-302.

Hewett, T. E., Ford, K. R., & Myer, G. D. (2006). Anterior cruciate ligament injuries in female athletes: part 2, a meta-analysis of neuromuscular interventions aimed at injury prevention. *American Journal of Sports Medicine*, 34, 490-498.

Hewett, T. E., Myer, G. D., Ford, K. R., Heidt, R. S. Jr., Colosimo, A. J., McLean, S. G., van den Bogert, A. J., Paterno, M. V., & Succop, P. (2005). Biomechanical measures of neuromuscular control and valgus loading of the knee predict anterior cruciate ligament injury risk in female athletes: a prospective study. *American Journal of Sports Medicine*, 33(4), 492-501.

Keogh JWL, Weber CL, Dalton CT. (2003). Evaluation of anthropometric, physiological, and skill-related tests for talent identification in female field hockey. *Canadian Journal of Applied Physiology*, 28, 397-409.

Kraemer, W. J., Duncan, N. D., & Volek, J. S. (1998). Resistance training and elite athletes: Adaptations and program considerations. *J Orthop Sports Phy Ther*, 28, 110-119.

Landry, S. C., McKean, K. A., Hubley-Kozey, C. L., Stanish, W. D., & Deluzio, K. J. (2007a). Neuromuscular and lower limb biomechanical differences exist between male and female elite adolescent soccer players during an unanticipated run and crosscut maneuver. *American Journal of Sports Medicine*, 35, 1901-1911.

Landry, S. C., McKean, K. A., Hubley-Kozey, C. L., Stanish, W. D., & Deluzio, K. J. (2007b). Neuromuscular and lower limb biomechanical differences exist between male and female elite adolescent soccer players during an unanticipated side-cut maneuver. *American Journal of Sports Medicine*, 35, 1888-190

Mandelbaum, B. R., Silvers, H. J., Watanabe, D. S., Knarr, J. F., Thomas, S. D., Griffin, L. Y., et al. (2005). 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.

Myer, G. D., Brent, J. L., Ford, K. R., & Hewett, T. E. (2008). 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.

Thacker, S. B., Stroup, D. F., Branche, C. M., Gilchrist, J., Goodman, R. A., & Kelling, E. P. (2003). Prevention of knee injuries in sports. A systematic review of the literature. *J Sports Med Phys Fitness*, 43, 165-179.

Wroble, R.R., & Moxley, D.R. (2001). The effect of winter sports participation on high school football players: Strength, power, agility, and body composition. *J. Strength Cond. Res*., 15, 132-135.