EFFECTS OF ANKLE JOINT INJURIES ON BALANCE IN MALE AND FEMALE GYMNASTS

George Dallas, Kostas Dallas

Kapodistrian University of Athens, Department of Physical Education and Sport Science, Athens, Greece

Original article

Abstract

Gymnastics is a sport where there always exists a real and present danger of physical injury. Athletic injury, whether temporary or permanent, is a painfully disruptive and uncontrollable interruption in a gymnast's career. Injuries can have profound negative consequences on a gymnast's balance, with lower limbs injuries constituting the majority of these injuries. The purpose of this study was to assess differences in postural stability between high level male and female artistic gymnasts who suffered ankle sprain injuries (ASI) on either or both legs in the past. Ten female (age = 16.66 ± 3.20 years, mass = 47.30 ± 8.00 kg, height = 158.00 ± 5.75 cm) and ten male gymnasts (age = 22.30 ± 1.77 years, mass = 62.00 ± 3.33 kg, height = 168.50 ± 3.03 cm) volunteered to participate in this single visit study. Participants were measured for Limits of Stability variables (Reaction Time [RT]; Center of Gravity Velocity [MVL]; Directional Control [DCL]; End Point Excursion [EPE]; Maximum Excursion [MXE]) to examine the effect of ASI on postural stability. Limits of Stability (LOS) test were used to examine postural stability of gymnasts using the EquiTest Computerized Dynamic Posturography system. Results indicated that females had significantly less ASI than male gymnasts and recorded significantly lower values in Reaction Time and higher values in Movement Velocity during LOS test. In conclusion, the number of past ASI influence postural control as the musculo-tendinous changes around the ankle lead to a reduction of proprioceptive information and may contribute to the deficient postural control mechanisms after injury. Furthermore, postural control may be affected even after acute ASI resolution

Keywords: *Limits of Stability, Reaction Time, End Point Excursion, Maximum Excursion.*

INTRODUCTION

Gymnasts must perform various skills with a high degree of technical mastery that rely on postural control. Even small disturbances in postural stability adversely affect performance (Vuillerme et al., 2001). Acrobatic elements require a high level of postural stability. Balance is a coordination ability during which the Center of Gravity of the body (CoG) is maintained within its base of support (Blackbum et al, 2000). It is maintained by three integrated sensory processes working together, the visual, vestibular, and somatosensory processes (Horak, Nashner, & Diener, 1990; Liaw, Chen, & Pei, 2008) of which the visual system provides the primary (most important) sensory information (Uchiyama & Demura, 2009). The lack of vision has detrimental consequence on performance (Gill et al, 2001). One of the indicators of balance ability is postural sway, i.e., the amount of CoG, or centre of pressure (CoP) excursion during static stance. As Shaffer & Harrison (2007) reported, postural control represents a complex interplay between the sensory systems and involves perceiving environmental stimuli and responding to oscillation of whole body around the ankle joint in order to maintain the CoG within the base of support. According to Pincivero, Bachmeier, & Coelho (2001), the ability of athletes to recognize the body's position in space as well as sense movement without visual reference, constitutes another type of information called proprioception or kinesthesia. Impaired proprioception (Robbins & Waked, 1998), muscle weakness, and subtalar instability (Tropp, 1986) were identified as contributing factors to chronic instability. One of the tests that can measure the subject's ability to control the position of the CoG is the Limits of Stability test (LOS) that computes the distance of athletes' CoP displacement in the anterior-posterior plane without raising heels or toes or taking a step. With the use of Computerized Dynamic Posturography, one can objectively measure the postural components of balance. LOS test measures volitional control of CoG.

Gymnastics is a sport with the highest child and adolescent injury rate (Singh, Smith, Fields, & McKenzie, 2008) with the floor exercises being the most hazardous event (Marshall, Covassin, Dick, Nassar, & Agel, 2007). For gymnasts, the increased demands of the sports' requirements, such as the extensive load of the musculoskeletal system during the take-off and landing phases, the high intensity and volume of training, the perfection of routines performance e.t.c., predispose participants to an increased risk of injury (Kirialanis, Malliou, Beneka, & Giannakopoulos, 2003; Kirialanis, Dallas, DiCagno, & Fiorilli, 2015) and absences from training sessions and/ or competition (Kirialanis, Malliou, Beneka, & Giannakopoulos, 2003). Findings of Hutchison and Ireland (1995) showed that the most frequently injured body parts in AG were the lower extremities especially the ankle and knee joints with the ankle sprain injuries (ASI) being the most frequent type of injury. In addition, acrobat gymnasts aged 13 years and over are frequently injured in training and competition with the majority of injuries affecting the lower limb with the most significant injury risk being the great number of training per week (Purnel et al, 2010). The most disabling injuries were the knee injuries (Gilchrist, Mandelbaum, & Melancon, 2008).

A lot of studies refer to the role of balance in gymnastic performance. According to Lee and Lin (2007), girls exhibit less postural sway than boys of similar ages, whereas a positive effect on balance in elite rhythmic gymnasts showed after vibration training (Tsopani et al, 2014). Although, previous studies reported that injured lower limbs have a negative effect on balance (Bonfim, Grossi, Paccola, & Barela, 2008; McKeon & Hertel, 2008; Wikstrom, Fournier, & McKeon, 2010), it was not clear if the amount of these injuries influence postural stability. Further, to the best of our knowledge there is no scientific evidence of gender comparison and the influence of postural stability on high level gymnasts with past ASI. The study of Forklin et al (2013) examined the effect of multiple ankle sprains on eleven active collegiate level gymnasts, aged, 16-22 years, and found that subjects were better at detecting movement during passive ankle motion trials of their uninjured ankles than their injured ankles and concluded that multiple injuries to the lateral ankle structures result in significantly reduced kinesthetic ability. However, no comparison was done between their female and male gymnasts. Having identified that previous work does not focus on elite gymnasts with previous ASI and does not differentiate between gender, this study focuses on elite gymnasts with previous ASI and aims at assessing the differences in postural stability between male and female gymnasts. It is believed that this will be of value as a research finding and both for training and for recovery. Since previous findings concluded that the overall incidence rate for injury was 30% higher among men when compared to women (Peck et al, 2013), it was hypothesized that female gymnasts would be more stable than their male counterparts due to their lower number of injuries.

METHODS

Ten female (age = 16.66 ± 3.20 years, mass = 47.30 ± 8.00 kg, height = 158.00 ± 5.75 cm) and ten male gymnasts (age = 22.30 ± 1.77 years, mass = 62.00 ± 3.33 kg, height = 168.50 ± 3.03 cm) volunteered to participate in this single visit study. All gymnasts had 11 to 15 years of experience in training, at least six days per week, 3 to 5 hours per day. The primary researcher interviewed the coaches and participants who reported a) the total number of acute ankle sprains injuries (ASI) (Mean = 2.00 ± 1.03, Females = 1.50 ± 0.34, Males = 2.50 ± 0.71), b) time before (in months) of their last ASI (Mean = 11.20 ± 2.65, Females =11.40 ± 2.80, Males = 11.00 ± 2.62). The gymnasts reported that they a) spent less than 5 days due to past ASI without training and b) had no experience from previous injuries in the lower limbs. One hour prior to the Limits of Stability (LOS) test, a familiarization session and anthropometric measurements were performed. Research purpose and experimental protocol were explained and informed consent was signed by each subject. This study procedure was respectful to ethical principles regarding human experiments set by the Declaration of Helsinki.

Postural Control was examined using the EquiTest Computerized Dynamic Posturography system (NeuroCom, Int., Inc., Oregon). The Computerized Dynamic Posturography (CDP) protocol includes the Limits of Stability (LOS) test. The LOS test measures the gymnast's ability to displace their CoG without losing balance from the center to each of the eight peripheral targets and quantifies the percentage of the maximum distance each gymnast can intentionally displace the COG without losing balance. An illustrative example of LOS assessment from a single participant in the present study may be found in figure 1.

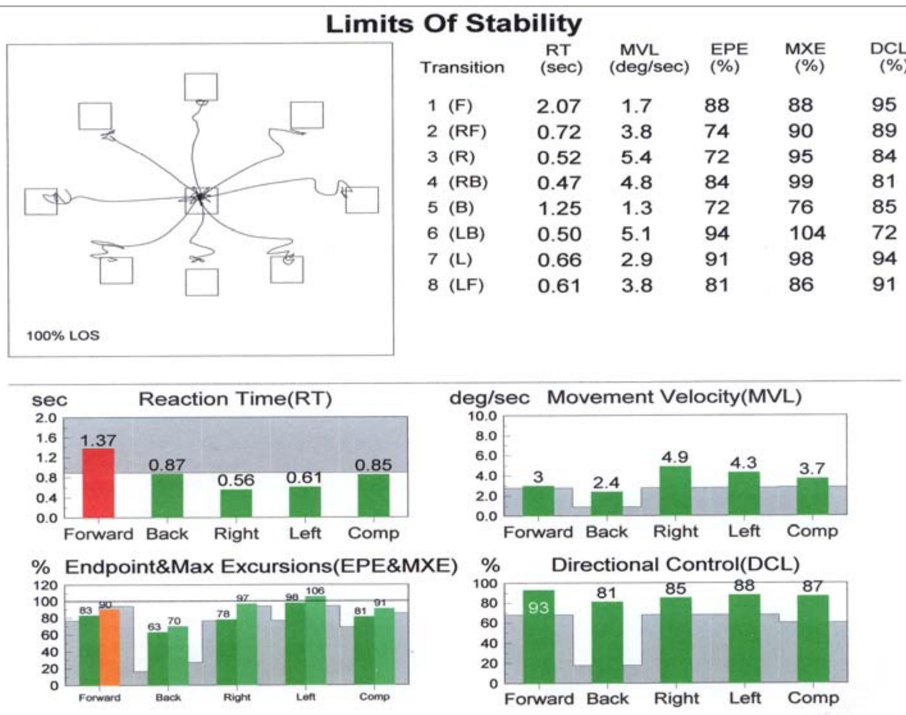

Figure 1. Assessment of Limits of Stability.

In this test, each gymnast shifted the CoG from the center to each of eight peripheral targets, with both feet on the floor. On command, she/he moved the CoG cursor as quickly and accurately as possible towards of the targets located at the limits of stability perimeter and then held a position as close to the target as possible. The LOS measurements, with respect to reaction time (RT), movement velocity (MVL) and end-point excursion (EPE) are presented in Table 1.

The split half method was used to assess the reliability of the postural stability test (LOS), with respect to the RT, MVL and ERE assessments. The results revealed coefficients of .762, .941 and .850 for RT, MVL and EPE, respectively. The construct validity was assessed through multivariate comparisons between the present sample and a separate sample of highly competitive rhythmic gymnasts, without previous experience of ankle injuries (Tsopani et al., 2014). The results provided construct validity evidence since the non injured rhythmic gymnasts had higher scores, compared to artistic gymnasts in the RT ($\Lambda = .544$, $F = 2.752$, $p = .031$, $\eta^2 = .456$), MVL ($\Lambda = .635$, $F = 2.875$, $p = .035$, $\eta^2 = .365$) and EPE ($\Lambda = .352$, $F = 5.064$, $p = .001$, $\eta^2 = .648$) measures, respectively.

A MANCOVA was used to examine gender differences in the postural stability test, while the number of injuries served as a covariate. Univariate ANCOVAs used for post hoc comparisons. The significance level was set at $\alpha = 0.05$.

RESULTS

Female gymnasts showed significantly lower number of injuries than male gymnasts ($p = .025$). The MANCOVA on LOS test was significant for: **a)** Reaction Time (RT) (Wilk's $\Lambda = .225$, $F = 4.299$, $p = .017$, $\eta^2 = .775$); **b)** Movement Velocity (MVL) (Wilk's $\Lambda = .164$, $F = 6.354$, $p = .004$, $\eta^2 = .836$); and **c)** Endpoint Excursion (EPE) (Wilk's $\Lambda = .213$, $F = 4.628$, $p = .014$, $\eta^2 = .787$). The post hoc ANCOVAs were significant for: **a)** RT in Right Backward direction ($F = 5.614$, $p = .030$, $\eta^2 = .248$), approached significance for RT in Forward direction ($F = 4.341$, $p = .053$, $\eta^2 = .203$), **b)** and were significant for the MVL in Right Forward direction (MVLRF) ($F = 8.159$, $p = .011$, $\eta^2 = .324$). Examination of the adjusted balance mean score in LOS RT in Right Backward direction (LOS RT RB) showed that the group of female gymnasts scored lower than their male counterparts. However, female gymnasts scored higher in MVL Right Forward direction (LOS MVL RF) than their male counterparts. The ANCOVA findings with respect to the injuries (covariate) balance scores and adjusted balance scores for female and male gymnasts are found in table 2.

DISCUSSION

This was the first study on postural stability on artistic gymnasts. Results of the present study revealed that female gymnasts have better postural stability, compared to male gymnasts, with respect to the reaction time right backwards and movement velocity right forward. These findings may be attributed to the effective proprioception of the ankle joints. This finding supports previous data, which showed that Reaction Time (RT) could be one of the supporting factors for better dynamic balance performance (Bressel, Yonker, Kras, & Heath, 2007). Additionally, the lower RT of female gymnasts in the Right-Backward direction may be related to the apparatus requirements. For example, on the balance beam, due to the apparatus dimensions, (female) gymnasts loose balance mostly in the lateral direction on account of restricted surface. This requirement makes them more adaptable to this type of balance perturbations. Furthermore, female's ability to move forward with speed was more effective towards the Right direction, compared to males. Female gymnasts therefore, as they move faster to this direction, balance their body more effectively than males.

Table 1
Description of the measured parameters.

Parameter	Description
Reaction Time (RT) (sec)	RT was defined as the time in seconds between the signal to move and the initiation of movement
COG velocity (MVL) (deg/sec)	MVL was defined as the average speed of COG movement (expressed in degrees per second) between 5% and 95% of the distance to the primary endpoint
Directional Control (DCL) (%)	DCL is a comparison of the amount of movement in the intended direction (toward the target) to the amount of extraneous movement (away from the target)
End Point Excursion (EPE) (%)	EPE was defined as the distance of the 1^{st} movement toward the designed target, expressed as a percentage of maximum LOS distance. The endpoint is considered to be the point at which the initial movement toward the target ceases
maximum excursion (MXE) (%)	MXE is the maximum distance achieved during the trial

Table 2
Means and adjusted means in Limits of Stability Test of Reaction Time Right Forward (LOS RT RF) (sec) and Movement Velocity in Right Forward direction (LOS MVL RF) (deg/sec) for female and male gymnasts.

	Female	Male
Number of injuries	1.50 (1.08)	2.50 (0.71)
LOS RT RB (sec)	0.59 (0.19)	0.83 (0.30)
Adjusted LOS RT RB (sec)	0.56 (0.08)	0.86 (0.08)
LOS MVL RF (deg/sec)	4.76 (1.52)	3.09 (0.42)
Adjusted LOS MVL RF (deg/sec)	4.77 (0.39)	3.08 (0.39)

Table 3
Questions to the participants.

1) How long ago did you sustain a lower limb injury**?**
2) What type of injury did you sustain?
3) Where you required to stop training and if yes, for how long?
4) Where you hospitalized? and if yes, for how long?
5) When you returned to training had you fully recovered from your injury/injuries?

The results of the present study verify data of Ekdalh, Jarnl, and Andersson (1989), who found that females demonstrate better balance than males. The ability to maintain balance is dependent on visual cues, vestibular function, and somatosensory feedback from structures in the lower limb (Nashner, 1993). Impaired balance in turn and deficits in postural stability were reported for individuals with ankle injuries (McKeon & Hertel, 2008; Ryan, 1994; Wikstrom, Fournier, & McKeon, 2010). The present results extend previous data which support that not only acute musculoskeletal injury (Bonfim, Grossi, Paccola, & Barela, 2008) but also chronic musculoskeletal conditions, including ankle instability, can impair postural control (McKeon & Hertel, 2008). The musculo-tendinous changes around the ankle or the loss of proprioceptive information may contribute to the deficient postural control mechanisms after injury.

Female gymnasts may have used the ankle strategy more effectively than males which means that they may have used the ankle joint as a pivot point to move their body. The postural adjustments are controlled by the ankle muscles, restoring the Center of Mass (CoM) to a central position (Winter, Patla, & Frank, 1990). The decreased number of injuries therefore did not impair the somatosensory feedback from the ankle joint of females to the same extent compared to their male counterparts.

Certain limitations do not allow generalization of the present findings without caution. The external focus of attention for example may be a factor that differentiates female and male gymnasts (McNevin & Wulf, 2002). Researchers have reported that boys are less attentive and more agitated during the postural stability tests (Steindl, Kunz, Schrott-Fischer, & Schholt, 2006). Attention however was not recorded in the present study. Second, certain anthropometric variables affecting postural balance, such as vision (Alonso et al, 2012) were not examined. The proprioception is produced through the simultaneous action of the visual, vestibular and sensorimotor systems, and each of them has an important role to play in maintaining postural stability (Liaw, Chen, Pei, Leong, & Lau, 2009). Finally, the effect of relevant factors such as the somatotype, body size, body mass, etc (McKeon & Hertel, 2008) may have had an impact upon the postural tests. The above limitations may be useful for future consideration.

CONCLUSIONS

The present findings indicate that elite female gymnasts exhibit better postural stability scores compared to elite males, when controlling their ankle injuries. Taking into account that these injuries occurred 7 to 17 months prior to the test (M =11.20 SD = 2.65), it appears that ASI affect postural control long after acute injury recovery. However, the rehabilitation (treatment) as well as the training requirements of both female and male gymnasts may have also an impact upon their postural stability. Males for example compete only in two events where they support mainly with their feet (vaulting horse and floor exercises), compared to females who compete in three such apparatus (balance beam, vaulting horse, floor exercises). In other words, females are spending more training time using their lower limbs. Further, the balance beam, an apparatus requiring extensive balance training, is exclusively a female event and skill. The event requirements therefore may have assisted to a wider extent the female athletes to overcome their post ASI postural deficiencies examined and to exhibit better postural stabilitywhen compared to their male counterparts. It is recommended that: a) a postural stability/balance evaluation is carried out prior to the gymnast's return to training and competition, b) the gymnast is fully rehabilitated (or has fully recovered from injury) prior to his/her return to training and competition, c) the way the injury happened and the exercise that created the injury, is registered and d) the muscular strength of the injured member is registered.

REFERENCES

Alonso, A.C., Luna, N.M.S., Mochizuki, L.L., Barbieri, F., Santos, S., & Greve, J.M. (2012). The influence of anthropometric factors on postural balance: the relationship between body composition and posturographic measurements in young adults. *Clinics, 67*, 1433-1441.

Blackburn, T., Guskiewicz, K.M., Petschauer, M.A., et al. (2000). Balance and joint stability: The relative contributions of proprioception and muscular strength. *Journal of Sport Rehabilitation, 9*, 315-328.

Bonfim, T.R., Grossi, D.B., Paccola, C.C.A.J., & Barela, J.A. (2008). Additional sensory information reduces body sway of individuals with anterior cruciate ligament injury. *Neuroscience Letter, 41*, 257-260.

Bressel, E., Yonker, J.C., Kras, J., & Heath, E.M. (2007). Comparison of static and dynamic balance in female collegiate soccer, basketball, and gymnastics athletes. *Journal of Athletic Training*, *42*, 42–46.

Ekdalh, C., Jarnl,o G-B., & Andersson, S. (1989). Standing balance in healthy subjects. *Scandinavian Journal of Rehabilitation Medicine*, *21*, 187-195.

Gilchrist, J., Mandelbaum, B.R., & Melancon, H. (2008). A randomized controlled trial to prevent noncontact anterior cruciate ligament injury in female collegiate soccer players. *American Journal of Sports Medicine, 36*, 1476-1483.

Gill, J., Allum, J.H., Carpenter, M.G., Held-Ziolkowska, M., Adkin, A.L., Honegger, F., & Pierchala, K. (2001). Trunk sway measures of postural stability during clinical balance tests: effects of age. *Journal of Gerontology. A Biological Science and Medicine in Sci*ence, *56,* 438-47.

Horak, F.B., Nashner, L.M., & Diener, H.C. (1990). Postural strategies associated with somatosensory and vestibular loss. *Experimental Brain Research, 82*, 167-177.

Hutchison, M.R. & Ireland, M.L. (1995). Knee injuries in female athletes. *Sports Medicine*, 19, 288-302.

Kirialanis, P., Malliou, P., Beneka, A., & Giannakopoulos, K. (2003). Occurrence of acute lower limb injuries in artistic gymnasts in relation to event and exercise performance. *British Journal of Sports Medicine, 37*, 137-139.

Kirialanis, P., Dallas, G., Di Cagno, A., & Fiorilli, G. (2015). Knee injuries at landing and take-off phase in gymnastics. Science of Gymnastics Journal, *7*(1): 17-25.

Lee, A.J., and Lin, W.H. (2007). The influence of gender & somatotype on single-leg upright standing postural stability in children. *Journal of Applied Biomechanics*, *23*(3), 173-179.

Liaw, M-Y., Chen, C-L., Pei, Y-C., Leong, C.P., & Lau, Y.C. (2009). Comparison of the static and dynamic balance performance in young, middle-aged, and elderly healthy people. *Chang Gung Medicine Journal, 32*, 297-304.

Marshall, S. W., Covassin, T., Dick, R., Nassar, L. G., & Agel, J. (2007). Descriptive epidemiology of collegiate women’s gymnastics injuries: national collegiate athletic association injury surveillance system, 1988–1989 through 2003–2004. *Journal of Athletic Training, 42*, 234–240.

McKeon, P.O., & Hertel, J. (2008). Systematic review of postural control and lateral ankle instability, part II: Is balance training clinically effective? *Journal of Athletic Training*, *43*(3), 305-315.

McNevin, N.H., & Wulf, G. (2002). Attentional focus on supra-postural tasks affects postural control. *Human Movement Science*, *21*, 187-202.

Nashner, L.M. (1993). Sensory, neuromuscular, and biomedical contributions to human balance. *Balance: Proceedings of the APTA Forum*, 5-12.

Pincivero, D.M., Bachmeier, B., & Coelho, A.J. (2001). The effects of joint angle and reliability on knee proprioception. *Medicine and Science in Sports and Exercise, 33*, 1708-1712.

Robbins, S.E., and Waked, E. (1998). Factors associated with ankle injuries: preventative measures. *Sports Medicine,* 25, 63–72.

Ryan, L. (1994). Mechanical stability, muscle strength and proprioception in the functionally unstable ankle. *Australian Journal of Physiotherapy, 37*, 211–217.

Shaffer, S., & Harrison, A. (2007). Aging of somatosensory system: A translation perspective. *Physical Therapy, 87*(2), 194-207.

Singh, S., Smith, G. A., Fields, S. K., & McKenzie, L. B. (2008). Gymnastics-related injuries to children treated in emergency departments in the United States, 1990–2005. *Pediatrics, 121*, e954–e960.

Steindl, R., Kunz, K., Schrott-Fischer, A., & Scholt, A.W. (2006). Effect of age and sex on maturation of sensory systems and balance control. *Developmental Medicine & Child Neurology, 48*(6), 477-482.

Tropp, H. (1986). Pronator muscle weakness in functional instability of the ankle joint. *International Journal of Sports Medicine, 22*, 601–605.

Tsopani, D., Dallas, G., Tsiganos, G., Papouliakos, S., DiCagno, A., Korres, et al. (2014). Short-term effect of whole-body vibration training on balance, flexibility and lower limb explosive strength in elite rhythmic gymnasts. *Human Movement Science*, *33*, 149-158.

Uchiyama, M., & Demura, S. (2009). The role of eye movement in upright postural control. *Sport Science Health, 5*, 21-27.

Vuillerme, N., Danion, F., Marin, L., et al. (2001). The effect of expertise in gymnastics on postural control. *Neuroscience Letter*, *303*, 83-86.

Wikstrom, E., Fournier, K., and McKeon, P. (2010). Postural control differs between those with and without chronic ankle instability. *Gait & Posture,* 32, 82-86.

Winter, D.A., Patla, A.E., & Frank, J.S. (1990). Assessment of balance control in humans. *Medical Progress through Technology*, *16*, 31-51.

ACKNOWLEDGEMENT

No funding was provided for, and there was no conflict of interest in, the designing and implementation of the present study.

Corresponding author:

George Dallas
Chlois & Chrisoupoleos, 19002 Paiania, Athens Greece
Mobile phone: 0030 6936 592 665
Fax: +0030 210 72 76028
Email: gdallas@phed.uoa.gr