GENDER DIFFERENCES OF HIGH LEVEL GYMNASTS ON POSTURAL STABILITY: THE EFFECT OF ANKLE SPRAIN INJURIES

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Abstract

Artistic gymnastics is the sport with the highest number of injuries for the athletes involved. Several studies supported that the ankle and knee joints are the most commonly injured body parts of gymnasts. Ankle instability in particular is often caused by damage to passive structures leading to neuromuscular impairment. The purpose of this study was to assess gender differences on postural stability of high level gymnasts, with the effect of lateral ankle sprains injuries partially out. Ten high level female and 10 high level male gymnasts who experienced lateral ankle sprains injuries volunteered to participate in the study. Participants were assessed for postural stability on the NeuroCom EquiTest Computerized Dynamic Posturography system. Three tests were used to evaluate the: a) Unilateral Stance, b) Motor Control Test, and c) Adaptation Test. The scores for Unilateral Stance, Motor Control, and Adaptation tests were recorded. Significant gender differences were found on Unilateral Stance-Right Foot Eyes closed in slow velocity, on Motor Control Test for Amplitude Scaling on Left and Right Foot in Backward direction, and on Adaptation Test Toes down balance. Conclusively, female athletes exhibited better balance scores compared to males, when controlling for the number of lateral ankle sprains injuries they experienced during the last two years. These findings are discussed with respect to the severity of previous lateral ankle sprains injuries, and the experience from training and competing in different events, for males and females respectively.

***Keywords**: balance, ankle joints, gymnastics.*

INTRODUCTION

Artistic gymnastics (AG) is a sport that requires a great sense of body awareness (Robertson & Elliott, 1996). During training and competition, even small distribution in postural stability may adversely affect performance (Vuillerme et al., 2001). According to Hootman et al. (2007) AG is the sport with the highest number of injuries for the athletes involved. Several studies supported that the ankle and knee joints are the most commonly injured body parts of gymnasts (Tenvergert et al., 1992). When the passive structures are damaged (capsular structure and ligaments), they usually result in either objective (anterior drawer, talar tilt) and/ or subjective (giving-way) instability (Hootman et al., 2007). Neuromuscular impairments, in turn, incorporate decrements in dynamic balance (Sawkins et al., 2007) and postural control respectively (Liaw et al., 2008; Hrysommalis, 2007; Uchiyama & Demura, 2009).

According to Hutchison and Ireland (1995), the ankle sprains experienced often lead to chronic pain, swelling, and an increase in the postural sway (Jaussen, 2012). As previous studies have showed, ankle sprains associated with reoccurrence of injury (Holmes & Delahunt, 2009), that may result in damage to proprioceptors (Hertel et al., 2006; Sawkins et al., 2007), often result in instability of the joint and decrements in performance (Holder-Powell & Rutherford, 1999; 2000). According to Peterka (2002), in order to maintain an upright stance, the destabilizing torque due to gravity must be countered by a corrective torque exerted by the feet against the support surface. This correction is achieved by feedback mechanisms that generate an appropriate corrective torque based on body-sway motion detected by the visual, vestibular, and proprioceptive sensory systems. However, the primary source of information is provided by the visual system (Uchiyama & Demura, 2009; Winter et al., 1990).

Gender differences in postural stability, were recorded in the past for participants who were tested with their eyes either opened or closed. The limited research findings were conflicting, leaving this area open for future research (Blaszczyk et al., 2014; Kim et al., 2012; Lamoth et al., 2009). Concerning the reported number of injuries, Kobayashi and Gamada (2014) and Hootman et al (2007) found that gymnasts had higher injury rates compared to athletes in baseball, softball, e.t.c. The findings of Hootman et al (2007) are promising, since they summarize data collected from a national survey for a long period of 16 years, from 15 different sports in the USA. Overall, previous studies have shown that a decrement in balance can result from musculoskeletal injuries (Malliou et al., 2004), while the effect of vision is not confirmed (Blaszczyk et al, 2014; Kim et al., 2012; Lamoth et al, 2009). With respect to gymnasts, gender differences are conflicting, since one study reported higher balance scores for females (Milosis & Siatras, 2012), while the other study reported no gender differences (Davlin, 2004). With regard to the musculoskeletal injuries causing balance deficits, previous findings are evident in both the dynamic (Jibi & Nagarajan, 2014) and the static (Majlesi & Azadian, 2014) form, when the injured lower limbs of athletes from different sports were compared to the uninjured. In a recent study (Dallas & Dallas, 2016) investigated the effect of ankle sprain injuries on postural stability measuring the Limits of Stability (LOS) variables and found that females gymnasts recorded significantly lower values in Reaction Time and higher values in Movement Velocity during LOS test. However, it has not been reported whether: a) the number of these lateral ankle sprains injuries (LASI) influenced the gymnast's postural stability and b) gender differences would still be evident, regardless the number of LASI experienced by the athletes. The Computerized Dynamic Posturography provides researchers with an objective mean to evaluate the postural components of balance, by assessing the postural sway velocity of either leg, with or without vision (eyes open and closed). The purpose of the present study therefore was to examine gender differences in dynamic and static postural stability of high level artistic gymnasts, who have suffered LASI in the past. The number of injuries served as a covariate. It is hypothesized that LASI affect gymnast's postural control and the number of these injuries may have an additional influence on postural control. However, if there is no gender differences it is speculated that other factor such as the training may have a positive effect on this ability. Based on previous research findings (Milosis & Siatras, 2012), it was hypothesized that female gymnasts would be more stable than their male counterparts, when the lower limb number of injuries was controlled. Further, following Winter et al (1990), it was anticipated that females would exhibit higher balance scores, compared to males, when vision was eliminated during balance testing.

METHODS

Ten female (age = 16.66 ± 3.20 years, mass = 47.30 ± 8.00 kg, height = 158.00 ± 5.7503 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. They had at least 10 to 15 years of training experience, training 6 days per week (25 – 30 hours per week), 3 to 5 hours daily**.** The primary researcher interviewed the coaches and participants who reported a) the total number of LASI (M = 2.00 ± 1.03, Females = 1.50 ± 0.34, Males = 2.50 ± 0.71), b) time before (months) the last LASI (M = 11.20 ± 2.65, Females =11.40 ± 2.80, Males = 11.00 ± 2.62), c) absence from training due to ankle injury and d) previous injuries in the lower limbs. The research took place during gymnasts' competitive period for national championships. Gymnasts were measured approximately 18 hours after the last training in order to exclude the influence of fatigue (Lin et al, 2009). The athletes reported that they a) spent less than 5 days without training due to past LASI and b) had no experience from previous injuries in the lower limbs.

One hour prior to the experimental protocol, a familiarization session and anthropometric measurements were performed. Three different tests for a total duration of 2 - 5 minutes approximately, including brief resting sessions (US: 6 trials * 10 sec = 60 sec = 1 min; MCT: 6 trial * 1 sec = 6 sec; ADT: 10 trials * 3 sec = 30 sec) were performed by each participant. All testing sessions were conducted at the same time of day (13:00 to 16:00). The study was conducted in accordance to the ethical principles regarding human experiments set by the Declaration of Helsinki.

Postural Stability was examined using the EquiTest Computerized Dynamic Posturography system. The Computerized Dynamic Posturography (CDP) protocol includes the following tests: a) Unilateral Stance (US), b) Motor Control Test (MCT), and c) Adaptation Test (ADT). The US quantifies postural sway velocity (deg/sec) with gymnasts standing on either the right or left leg, with eyes open and with eyes closed. Gymnasts were trying to react as the supporting surface moved in three different velocities; slow, medium, fast. The test was assessed by the mean CoG Sway Velocity that displays CoG stability while the gymnast stood independently on each leg. The MCT assesses the ability of the automatic motor system to quickly recover following an unexpected external disturbance. This consisted of sequences of small, medium or large platform translations which were scaled to the subject's height, in forward and backward directions to elicit automatic postural responses. The transportation of the supporting surface occurred regularly, in the same order, to the participants.

MCT records latency responses, which is a measure of how long it takes to restore normal balance following an unexpected perturbation. The measured parameters are the a) Weight Symmetry (a scale around 100 indicates that both legs are rearing equal weight, more than 100 means the subject bears more weight on their right leg and less than 100 means more weight on the left leg), b) Latency that quantifies the time between stimulus onset and initiation of the subject's active response and c) Amplitude Scaling that quantifies the strength of motor responses for both legs and for the three translations sizes. The ADT assesses the gymnast's ability to minimize sway when exposed to surface irregularities and unexpected changes in support surface inclination (toes-up or toes-down). For each platform rotation trial, a sway energy score (SES) quantifies the magnitude of the force response required to overcome induced postural instability**.** A smaller SES represented the ability of the gymnasts to react more efficiently.

A MANCOVA was used to examine gender differences (independent variable) in the postural stability tests, while number of LASI served as a covariate. Univariate analyses were used for post hoc comparisons. The Unilateral Stance Right Foot with Eyes Closed (US RF EC), Motor Control Test for Amplitude Scaling on Left Foot in Backward direction (MCT AS LF B) and Motor Control Test for Amplitude Scaling on Right Foot in Backward direction (MCT AS RF B) were the dependent variables. Further, a 2 X 5 MANCOVA examined the interaction effect between gender and time (5 trials), with respect to the Adaptation Test Toes down (ADTTd) scores. The independent variables were gender and time (5 trials), and the dependent variable was the ADTTd scores. Univariate analyses and the t-parameter estimates were used to evaluate the interaction effect. The intraclass coefficient assessed the reliability of the ADTTd scores.

The formula of Grimm (1993) was used to estimate the appropriate sample size. The calculated effect size was based in the study of Torres et al (2014) with the ML scores of 20 active men ($M = 0.95 \pm 0.25$) and 20 women ($M = 0.77 \pm 0.22$). The power analysis revealed that for an effect size of 0.766, power of 0.80 and a 0.05 alpha level, a total sample of 14 participants would be required to detect significant differences between groups.

RESULTS

Female gymnasts exhibited significantly lower number of LASI than male gymnasts on the right ankle joint ($p = .042$), the left ankle joint ($p = .048$), and the sum of both legs ($p = .025$) (table 1).

The MANCOVA for Unilateral Stance Right Foot with Eyes Closed (US RF EC) was significant (Wilks $\Lambda = .545$, $F = 4.166$, $p = .025$, $\eta^2 = .455$). The univariate post hoc analysis was significant for US RF EC in slow velocity ($F = 5.639$, $p = .030$, $\eta^2 = .249$). Examination of the adjusted balance mean score in US RF EC revealed that the group of female gymnasts scored lower from their male counterparts. The above findings with respect to the US RF EC scores and adjusted scores, for both female and male gymnasts may be found in table 1.

The MANCOVA on Motor Control Test for Amplitude Scaling on Left Foot in Backward direction (MCT AS LF B) was significant (Wilks $\Lambda = .515$, $F = 4.708$, $p = .016$, $\eta^2 = .485$). The univariate post hoc analysis was significant for MCT AS LF B in slow translation ($F = 12.884$, $p = .002$, $\eta^2 = .431$), in medium translation ($F = 13.597$, $p = .002$, $\eta^2 = .444$) and in large translation ($F = 7.531$, $p = .014$, $\eta^2 = .307$). Examination of the adjusted balance means score MCT AS LF B revealed that the group of female gymnasts scored lower from their male counterparts. The above findings, with respect to the MCT AS LF B scores and adjusted scores, for both female and male gymnasts, may be found in table 2.

The MANCOVA on Motor Control Test for Amplitude Scaling on Right Foot in Backward direction (MCT AS RF B) was significant (Wilks $\Lambda = .230$, $F = 16.716$, $p = .001$, $\eta^2 = .770$). The univariate post hoc analysis was significant for MCT AS RF B in slow translation ($F = 37.199$, p

= .001, η^2 = .686), in medium translation (F = 41.558, p = .001, η^2 = .710) and in large translation (F = 16.320, p = .001, η^2 = .490). Examination of the adjusted balance mean score in MCT AS RF B revealed that the group of female gymnasts scored lower from their male counterparts. The above findings with respect to the MCT AS RF B scores and adjusted scores, for both female and male gymnasts, may be found in table 3.

Table 1
Means and adjusted means in Postural Stability (Unilateral Stance Right Foot with Eyes Closed - US RF EC) for female and male gymnasts (deg/sec).

	Female	Male	p
Number of injuries *	1.55 ± 0.34	2.50 ± 0.71	.025
Postural Stability (US RF EC) (deg/sec)			
Slow Velocity*	1.55 ± 0.29	2.16 ± 1.01	.030
Medium Velocity	1.48 ± 0.51	1.92 ± 1.02	N.S
Fast Velocity	1.66 ± 0.50	1.84 ± 0.82	N.S
Adjusted Slow Velocity*	1.41 ± 0.24	2.29 ± 0.24	.030
Adjusted Medium Velocity	1.37 ± 0.27	2.02 ± 0.27	N.S
Adjusted Fast Velocity	1.56 ± 0.23	1.94 ± 0.23	N.S

* Significant gender differences (p < 0 .05)

Table 2
Means and adjusted means score in Motor Control Test for Amplitude Scaling on Left Foot in Backward direction (MCT AS LFB) for female and male gymnasts. Motor Control Test Left Foot Backward direction (MCT AS LF B)

	Female	Male	p
Number of injuries	1.55 ± 0.34	2.50 ± 0.71	.025
Postural Stability (MCT AS LFB)			
Slow translation *	1.80 ± 0.79	3.80 ± 1.31	.002
Medium translation *	3.00 ± 1.41	6.80 ± 2.15	.002
Large translation *	4.00 ± 1.49	8.00 ± 3.09	.014
Adjusted Slow translation *	1.77 ± 0.38	3.83 ± 0.38	.002
Adjusted Medium translation *	3.13 ± 0.63	6.67 ± 0.63	.002
Adjusted Large translation *	4.27 ± 0.84	7.73 ± 0.84	.014

* Significant gender differences (p < 0 .05)

Table 3
Means and adjusted means score in Motor Control Test for Amplitude Scaling on Right Foot in Backward direction (MCT AS RF B) for female and male gymnasts.

	Female	Male	p
Number of injuries	1.55 ± 0.34	2.50 ± 0.71	.025
Postural Stability (MCT AS RF B)			
Slow translation *	1.70 ± 0.82	4.40 ± 0.97	.001
Medium translation *	2.60 ± 0.97	7.70 ± 1.83	.001
Large translation *	3.50 ± 1.35	9.50 ± 3.41	.001
Adjusted Slow translation *	1.61 ± 0.31	4.48 ± 0.31	.001
Adjusted Medium translation *	2.65 ± 0.51	7.65 ± 0.51	.001
Adjusted High translation *	3.77 ± 0.89	9.23 ± 0.89	.001

* Significant gender differences (p < 0 .05)

Table 4
Means and adjusted means in Adaptation Test toes down (ADTTd) for female and male gymnasts.

	Female	Male
	Sway energy score	
ADTTd$_1$ (F = .387, p = .542, η^2 = .022)	60.30 ± 12.22	63.80 ± 19.74
Adjusted balance	59.35 ± 5.74	64.75 ± 5.74
ADTTd$_2$ (F = .004, p = .949, η^2 = .000)	57.20 ± 12.91	56.50 ± 21.13
Adjusted balance	56.55 ± 6.14	57.15 ± 6.14
ADTTd$_3$ (F = .765, p = .394, η^2 = .043)	54.40 ± 8.03	49.20± 11.48
Adjusted balance	54.10 ± 3.48	49.50 ± 3.48
ADTTd$_4$ (F = 3.658, p = .073, η^2 = .177)	51.80 $\pm$ 8.52	65.60 + 24.40
Adjusted balance	49.63 ± 6.27	67.76 ± 6.27
ADTTd$_5$ (F = 2.242, p = .153, η^2 = .117)	51.40 ± 5.05	59.30 ± 17.52
Adjusted balance	50.28 ± 4.47	60.42 ± 4.47

The Intraclass Correlation Coefficient, for the Adaptation Test Toes down (ADTTd), was .924 for the whole sample, and .845 and .956 for females and males respectively. The 2 X 5 MANCOVA revealed a significant interaction effect (Wilks Λ = .358, F = 6.286, p = .004, η^2 = .642). No significant main effect was found for time (F = 1.498, p = .256, η^2 = .300) and gender (F = .674, p = .423, η^2 = .038). Post hoc univariate analysis revealed that the interaction was significant in the 4th trial (F = 14.401, p = .001, η^2 = .459). Examination of the t-parameter estimates revealed that the females exhibited higher ADTTd scores in the 3rd trial (t = .875, p = .394, η^2 = .043) (Mean Females = 54.40 $\pm$ 8.03) compared to males (Mean Males = 49.20 ± 11.49), while the differences were reversed in the 4th trial (t = -1.913, p = .073, η^2 = .177) since females (Mean Females = 51.80 ± 8.52) scored lower than their male counterparts (Mean Males = 65.60 ± 24.40). The balance (ADTTd) scores and adjusted balance scores, for both female and male gymnasts across the 5 trials may be found in table 4.

DISCUSSION

This was the first study examining gender differences on static and dynamic postural stability of high level artistic gymnasts, when controlling for the number of previous LASI. Female gymnasts showed better postural stability in a) Unilateral Stance for Right Foot with Eyes Closed (US RF EC) in slow velocity, b) Motor Control Test for Amplitude Scaling on both feet in backward direction (MCT AS B) and c) ADTTd in 4th trial. The results of the present study verify data of Ekdalh et al (1989), who found that females demonstrated better balance postures than males. According to Winter et al (1990), when the equilibrium perturbation is small and the support surface is firm, female gymnasts use more effectively postural adjustments controlled by ankle muscles and overall restoration of the Center of Mass (CoM) to a central position, compared to males (Winter et al., 1990). Further, the ability to maintain balance is dependent on visual cues, vestibular function, and somatosensory feedback from structures in the lower limb (Nashner, 1993). When visual sensory information is absent (Accornero et al., 1997), the sensorimotor control of upright balance is based on information from ankle proprioceptors, in combination with plantar mechanoreceptors. Previous injuries damage the somatosensory information transmitted from the ankle proprioceptors leading to decrements in postural stability. Even though, in the present study the number of previous LASI was controlled, males exhibited lower balance scores compared to females, leading to the speculation that it was the severity of these past injuries that may have caused higher somatosensory damage in males, reduced proprioception and overall decrements in postural stability compared to females.

The severity or chronic musculoskeletal injuries may also explain the gender differences in the Motor Control Test for Amplitude Scaling, in backward direction. Chronic musculoskeletal conditions impair postural control (McKeon & Hertel, 2008) and have been reported in the unstable ankle (Ryan, 1994). The musculo-tendinous changes around the ankle are leading to a reduction of proprioceptive information and may contribute to the deficient postural control mechanisms after injury. This argument is supported by previous studies which showed that ankle symptoms may remain one year after lateral ligament injury (Moller-Larsen et al., 1988). It appears that the joint tissue of male gymnasts in the present study may have exhibited chronic musculo-tendinous changes around the ankle which, in turn, may have led to loss of proprioceptive information and overall deficient postural control, compared to females. Although no significant differences were found on MCT Weight Symmetry, examination on Amplitude Scaling on Left and Right Foot in Backward direction (MCT AS LF B) revealed that females achieved better use of their automatic motor system and recovered quicker from an unexpected external disturbance. Simply stated, the surrounding joint tissue of male gymnasts may not have been as sufficient for an effective function compared to females. Possibly, the previous severity of musculoskeletal injuries in the ankle joint along with the contribution of foot mechanoreceptors and cutaneous sensation may have influenced balance control (Meyer et al., 2004). However, our findings opposed those of Peterka and Loughlin (2004) who reported that healthy adults reacted more effectively on unstable supporting surfaces. The differences with Peterka and Loughlin may be attributed to the: a) sample of healthy adults examined and b) in the case of unstable base of support, the fact that male gymnasts examined in the present study may not use as effectively as their female counterparts their visual inputs (Peterka & Loughlin, 2004). This argument partially supports the results of Vuillerme and colleagues who found that elite male gymnast are more able to use the remaining sensory modalities to compensate for the lack of vision in unstable postures compared to non-expert counterparts (Vuillerme et al., 2001). In addition, our results reinforce findings of Kochanowicz et al. (2017) who found that gymnastic training had influence in postural control of young and adult gymnasts and those of Gautier et al. (2008) who stated that experts in sports requiring fine perceptive-motor control develop a shorter sensory–motor delay. Further, the fact that females scored better than male's maybe attributed to the specificity of training. Female gymnasts, for example, who practice gymnastic exercises on the balance beam, perform much better in balance than others who do not force the "balance system" as much (Wilke, 2000). Based on this logic, female gymnasts maybe considered as experts compared to males that have no similar experiences. In contrast, male athletes compete in two events actively using their lower limbs (vaulting horse and floor exercises), compared to females who compete in three events respectively (vaulting horse, balance beam, and floor exercises). In other words, females are spending more training time using their lower limbs, especially on the balance beam which is an exclusive apparatus for females requiring extensive balance training and skill. The above speculation is explained by Hubbard who claimed that the muscle spindle itself has been recognized as one of the afferent nerves that are potentially modifiable through training (Hubbard, 2005). In this sense, the ability to stabilize body position is mandatory for the performance of motor skills and is dependent upon the grade of experience (Wilke, 2000).

Analysis of the present data support the hypothesis that female gymnasts would be more stable than their male counterparts, when the lower limb number of injuries was controlled and that females would exhibit higher balance scores, compared to males, when vision was eliminated during balance testing. The present study showed that artistic gymnasts were dependent on vision in their postural stability tests and that differences were found in dynamic postural stability, especially when unstable supporting surfaces were used. These findings seem to suggest that female artistic gymnasts were more stable than their male counterpart, possibly due that practicing on the balance beam which allows them to practice and specialize in anterior-posterior direction of postural control. This finding verifies the results of Vuillerme et al (2001) who supported that postural skill may be influenced by the sport itself. Certain limitations, do not allow generalization of the present findings without caution. First, previous knee injuries were not recorded in the present study. Second, the external focus of attention may be another 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 et al., 2006). Attention however was not recorded in the present study. Third, certain anthropometric variables affecting postural balance, such as vision (Alonso et al., 2012) were not examined. Fourth, balance related gender differences may be due to other factors, based on body somatotype, independently of body size; for example the fact that boys have larger body mass and moments of inertia (Lee & Lin, 2007). Finally, other intrinsic factors such as age, gender, phase of menstrual cycle, type and severity of previous injuries, inadequate rehabilitation of previous injuries, aerobic fitness, fatigue, limb girth, anatomic alignment, gait, and foot morphology may play a role in the number of injuries experienced and overall balance scores (Murphy et al., 2003). The above limitations are useful for researchers to consider and re-examine in the future.

Certain recommendations may stem from the present findings. Coaches, physicians, physiotherapists and other experts in the field may need to monitor the rehabilitation process following ankle sprains. Even when athletes return to practice, the damage to the joint tissue may not have fully recovered. Assessing certain variables, such as strength in the muscles surrounding the ankle joint, range of motion, etc may be a useful indicator for coaches to consider for their injured athletes. Since limitations in balance have a negative impact upon performance, coaches may also consider adding balance sessions within their practice routines. If (male) athletes perform better in balance, they may also improve their overall performance (e.g. during the landing phase). Finally, coaches may need to constantly monitor the injuries experienced in the lower limbs, record them in detail and allow gymnasts to enter full practice and competition only when they have experienced full recovery.

CONCLUSIONS

The present findings showed that female gymnasts exhibited better postural stability scores compared to males, when controlling for the number of previous LASI. Taking into account that these injuries were recorded from 7 to 17 months prior to data collection, it appears that they may affect postural control long after acute injury resolution. Besides the rehabilitation treatment that these athletes were exposed, the training requirements for both male and female athletes may also have had an impact upon postural stability. No funding was provided for the designing and implementation of the present study. There was no conflict of interest, with an individual or organization, for the designing and implementation of the present study.

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