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Assessment of balance among adolescent track and field athletes

Adam C. Knight[a], Megan E. Holmes[a], Harish Chander[a], Amari Kimble[b] and Joshua Ty Stewart[a]

[a]Department of Kinesiology, Mississippi State University, Mississippi, MS, USA; [b]College of Chiropractic Medicine, Logan University, Chesterfield, MO, USA

ABSTRACT

Track and field events place different demands on athletes and may have an effect on balance. This study investigated the effects of event specialty, gender, and leg dominance on balance among adolescent track and field athletes. Forty healthy adolescent track and field athletes (male = 23, female = 17) categorised into three different groups (sprinter = 20, distance runners = 13, throwers = 7) had their single leg static balance measured with the eyes open and the eyes closed using an AMTI force platform. Dependent variables included average displacement (cm) of the centre of pressure (COP) in the anterior/posterior direction and medial/lateral directions, the average velocity of the COP (cm/s) and the 95% ellipse area (cm^2). Variables were analysed using a 3 (event specialty) × 2 (gender) × 2 (leg) ANOVA with repeated measures on the leg variable ($p < 0.05$). There was a significant difference ($p < 0.05$) in the average displacement of the COP in the medial/lateral direction for both the eyes open and closed condition, with the non-dominant leg demonstrating greater displacement than the dominant leg. This might increase the risk of injury for the non-dominant leg, but additional data should be collected and analysed on both dynamic balance and performance.

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Centre of pressure; injury prevention; balance training

Introduction

Balance, which is defined as the ability to preserve the body over its base of support (Flanagan, 2014), is a critical aspect of many activities (Plisky, Rauh, Kaminski, & Underwood, 2006), especially in sports such as track and field. Reports of increased susceptibility for ankle injuries among high school basketball players and Australian football players with poor static balance (Hrysomallis, McLaughlin, & Goodman, 2007; McGuine, Greene, Best, & Leverson, 2000) highlight the need for increased attention on balance assessments in athletic populations. Non-contact injuries, such as many ankle sprains or similar injuries, comprise around 20% of all injuries sustained during practice and 40% of all injuries sustained during games in collegiate athletics (Hootman, Dick, & Agel, 2007). Since track and field is an

CONTACT Adam C. Knight aknight@colled.msstate.edu

individual sport, the majority of injuries from participation would be non-contact injuries. If risk factors for non-contact injuries can be identified, it may be possible to reduce the risk, and in turn number, of non-contact injuries (Plisky et al., 2006). Deficits in balance have been identified as a key predictor of non-contact injuries (Plisky et al., 2006; Sabin, Ebersole, Martindale, Price, & Broglio, 2010), and improvements in balance may reduce the risk of such injuries (Bressel, Yonker, Kras, and Heath (2007), which have important implications for both athletes and coaches.

Balance requirements for athletes are dependent upon the nature and the type of sport played. Each sport has different balance requirements that are necessary to safely and effectively execute sporting movements without losing balance. Balance assessments have been performed previously on both male and female athletes. Differences have been reported between males and females regarding walking kinematics (Cho, Park, & Kwon, 2004) and dynamic balance as assessed by the star excursion balance test (SEBT) (Gribble, Robinson, Hertel, & Denegar, 2009; Sabin et al., 2010). Gribble et al. (2009) reported that young healthy female participants had a greater reach distance on the SEBT than young healthy male participants. Sabin et al. (2010) reported that male collegiate basketball players had a greater reach distance on the SEBT in the posterior direction than female collegiate basketball players. However, a recent study that examined dynamic postural control using the SEBT found no differences in reach distance between male and female adolescent athletes from multiple sports (Holden, Boreham, Doherty, Wang, & Delahunt, 2014).

Another study compared collegiate female soccer, basketball, and gymnastics athletes and found that the gymnastics and soccer athletes had better static and dynamic balance than the basketball athletes (Bressel et al., 2007). However, more recently a study on female collegiate athletes showed differences in both static and dynamic balance perturbations among volleyball, soccer, and dance teams (Chander et al., 2014). Hence, with these contrasting findings and with female athletes having a higher rate of non-contact lower extremity injuries compared to male athletes (Hootman et al., 2007), there is a need for balance assessments among female athletes. While these previous studies have examined differences between male and female athletes and among different types of sports, they did not specifically examine track and field athletes (Bressel et al., 2007; Cho et al., 2004; Gribble et al., 2009; Sabin et al., 2010), a sport that encompasses a variety of somatotypes and athletic skills among the various events. Different sports or different events (or positions) within the same sport, like track and field, likely require different control processes and muscle activation patterns in order to be successful and reduce the risk of injury (Bressel et al., 2007). There has been a call to examine and compare balance measures of athletes that participate in different sports or different events/positions within the same sport (Bressel et al., 2007). It is possible that different track and field events place different demands on the neuromuscular system and could cause differences in balance performance.

To the authors' knowledge, there have not been any previous studies examining balance measures exclusively among adolescent track and field athletes, and specifically looking at balance among different event specialties. Only one previous study has examined adolescent track and field athletes, but as part of a larger sample including athletes from six different sports in an investigation on dynamic postural control (Holden et al., 2014). Therefore, the purpose of this study was to measure static balance among adolescent track and field athletes and to determine if balance differed among different event specialties, between the dominant and non-dominant legs, and between male and female participants. Based on the results of previous research and the demands that different track and field events place on these athletes, the authors' hypothesised that there would be a difference in static balance performance between the different event specialties, and that there would be a difference in static balance performance between the female and male adolescent track and field athletes. The authors' also hypothesised that there would not be a difference in static balance performance between the dominant and non-dominant limbs since previous research has not reported differences among young, healthy adult participants (Kiyota & Fujiwara, 2014; Lin, Liu, Hsieh, & Lee, 2009; Muehlbauer, Mettler, Roth, & Granacher, 2014).

Methods

All study procedures were approved by the Mississippi State University Institutional Review Board. Since all the participants were age 18 or younger, each participant signed an assent document and a legal guardian for each participant signed a parental consent form. Data collection was conducted inside the fieldhouse at a local high school.

Forty healthy participants, which included 17 female participants (age: 15.6 ± 1.4 years; height: 161.8 ± 6.7 cm; mass: 60.1 ± 13.0 kg) and 23 male participants (age: 16.3 ± 1.1 years; height: 174.5 ± 8.4 cm; mass: 71.3 ± 13.7 kg) were included in the study. This included 20 participants that were classified as sprinters, 13 participants that were be classified as distance runners, and seven participants that participated in a field event that involves throwing (discus or shotput). After receiving the signed consent and assent forms from each participant, data collection began with the measurement of the participant's height, weight, and body fat percentage. Stature was measured using a portable stadiometer (Weigh and Measure, LLC, Maryland, USA) with the participant standing erect, without shoes, with weight distributed evenly between both feet, heels together, arms relaxed at the sides, and the head in the Frankfort horizontal plane. Body mass was measured without shoes and excess clothing on a digital scale that also calculates per cent body fat through foot to foot bioelectrical impedance analysis (Tanita Corporation, Japan). Leg dominance was determined by the leg the participants would use to kick a ball (Knight & Weimar, 2013). In the current study, 37 of the participants were right leg dominant, and 3 participants were left leg dominant.

Since the age range of the participants spans the period of puberty and numerous body size and physiological functions and capacities vary by pubertal status (Tanner, 1962), an indicator of biological maturity status was assessed via the maturity offset method. The maturity offset technique is a non-invasive method of indicating biological maturity and was calculated as outlined by Mirwald, Baxter-Jones, Bailey, and Beunen (2002). Anthropometric variables are used to create a value that is aligned to the estimated age of peak height velocity. Approximately 44% of the girls were average maturers and 56% were late maturers, with a mean estimated age of peak height velocity of 12.5 years. Likewise, 65% of the boys were average maturers and 35% were late maturers, with a mean estimated age of peak height velocity of 14.3 years. Additionally, all participants were verbally screened to make sure they were not currently suffering from any lower extremity injury.

Balance assessment

A portable AMTI (Watertown, MA, USA) AccuGait force platform was used to measure each participant's unilateral static balance. While there are clinical tests that are used to assess balance, such as the balance error scoring system (BESS) and the SEBT that have been demonstrated to be reliable, a computerised system, such as a force plate and computer, is considered to be a superior choice (Riemann, Guskiewicz, & Shields, 1999). All balance measures were conducted in a barefoot manner to eliminate the possible influence of footwear or socks. The force platform was set up in the fieldhouse approximately 5 feet in front of the nearest wall and away from other people. The force platform was connected to a notebook computer. AMTI's NetForce software was used to collect the balance data, and AMTI's Bioanalysis software was used to analyse the data. For each balance assessment, the participant was instructed to stand with the testing foot in the centre of the force platform, with the contralateral hip and knee flexed to approximately 30º, and the arms placed by the participant's side. The participants were instructed to look straight ahead at a piece of paper taped at eye level on the wall in front of them (Figure 1). Both the dominant and non-dominant legs were tested with the eyes open and the eyes closed, in a counterbalanced order. Three trials were performed for each condition. The eyes open trials were 20 s, and the eyes closed trials were 10 s. During pilot testing, the participants had much difficulty maintaining balance on one leg with the eyes closed for 20 s. Therefore, the duration of the eyes closed trials was reduced to 10 s. The data was collected at a frequency of 100 Hz. The main outcome measure was the centre of pressure (COP), measured in centimetres (cm). The variables that were analysed from the COP included the average displacement (cm) of the COP in the medial/lateral (x) direction, the average displacement of the COP in the anterior/posterior (y) direction, the average velocity of the COP (cm/s), and the 95% ellipse area (cm^2). These are some of the more common reported measures of postural control using a force platform (Palmieri, Ingersoll, Stone, & Krause, 2002). To determine if there was a difference in static balance performance between the different event specialties, male and female participants, and the dominant and non-dominant leg, the data was analysed with a 3 (event specialty) × 2 (gender) × 2 (leg) ANOVA with repeated measures on the leg variable ($p < 0.05$). A separate analysis for each of the above-dependent variables was conducted for the eyes open and eyes closed conditions.

Results

The results did not reveal any significant interactions between the three independent variables or any significant main effects for the two independent variables ($p > 0.05$) of event specialty or gender for any of the balance measures (i.e. eyes open vs. closed and dominant vs. non-dominant leg). There was a significant difference in the average displacement of the COP in the medial/lateral (x) direction for the eyes open and eyes closed conditions, with the non-dominant leg demonstrating greater displacement than the dominant leg. The specific values of each test, along with the means and standard deviations, can be found in tables one through three.

Discussion and implications

The primary objective of this study was to measure static balance performance among adolescent track and field athletes and examine if event specialty, gender, or leg dominance had an impact on static balance. The authors' hypothesised that there would be a difference in static balance performance between the different event specialties and between the female

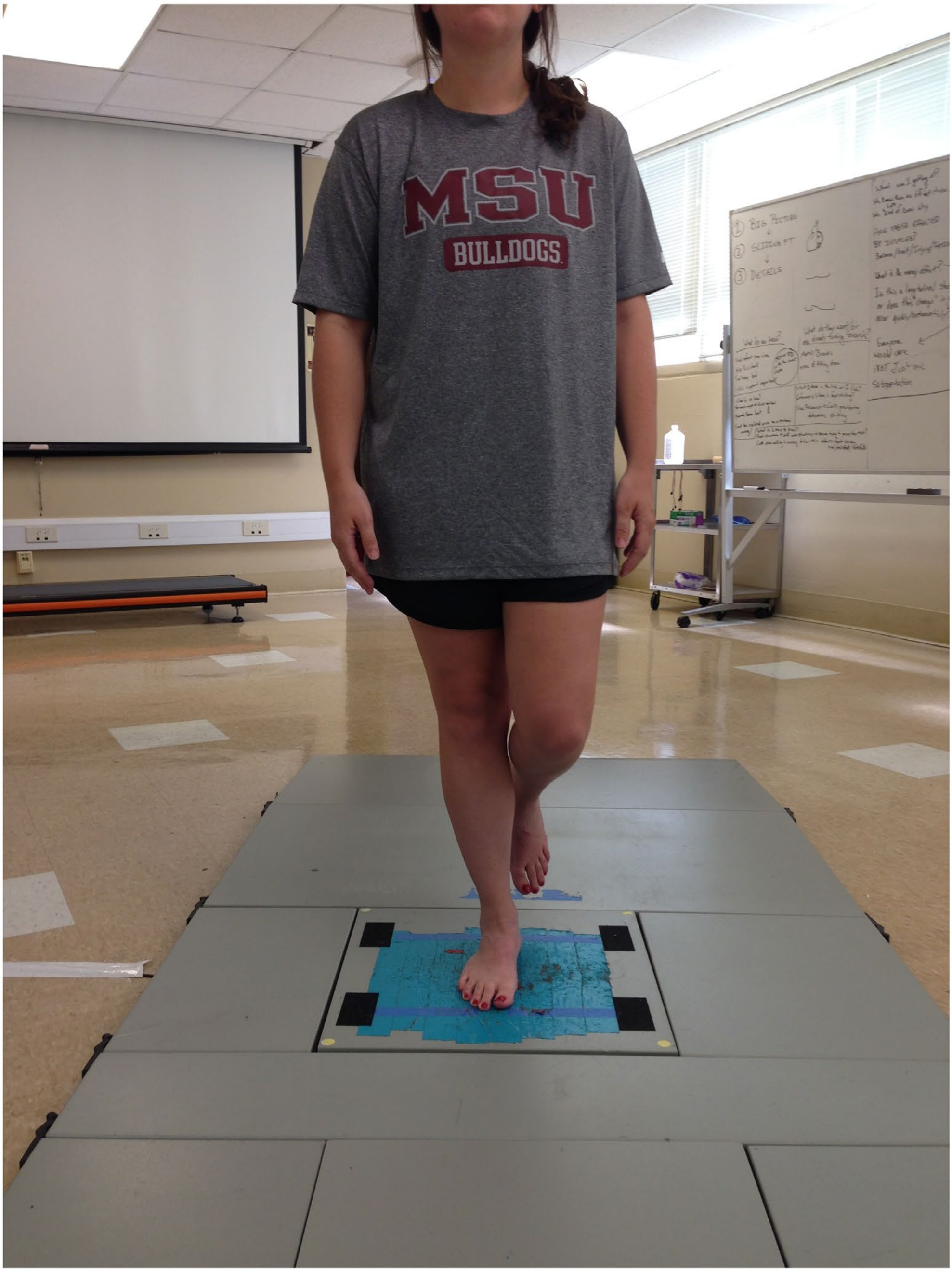

Figure 1. Participant performing the single leg stance balance assessment.

and male participants, and that there would not be a difference in static balance between the dominant and non-dominant limbs. The results revealed that there were no significant differences in any of the static balance performance variables between the different event specialties and the male and female participants. However, there was a difference in the amount of average COP displacement in the medial/lateral direction between the dominant and the non-dominant legs. These findings do not support the authors' hypotheses. Possible explanations and implications of these findings will be discussed further.

To the knowledge of the authors, this was the first study to specifically measure static balance performance among adolescent track and field athletes and look at the effect that event specialty might have on static balance. Since other studies have examined athletes from different sports and primarily looked at dynamic balance, it is difficult to directly compare the results of the current study to these previous studies. However, due to the lack of studies examining static balance among athletes, an indirect comparison has been made. A recent study examined adolescent athletes and assessed their dynamic balance performance on the SEBT (Holden et al., 2014). The average age of the athletes was 13 years, and they participated in a wide variety of sports, including court-based sports, field-based sports, track and field, and gymnastics. The authors reported no significant differences in dynamic balance performance between the male and female athletes. The authors also reported no significant differences in balance between the dominant and the non-dominant limbs (Holden et al., 2014). While there are some inherent differences between static balance in which the base of support does not change and dynamic balance, during which the base of support changes, the act of maintaining balance still involves positioning your centre of gravity within that base of support. Hence, these findings may offer support to the results of the present study. Furthermore, the Holden et al. (2014) study measured participants from across six different sports; however, the researchers did not examine differences in dynamic balance between the different sports. The present investigation adds to the current body of literature regarding balance because it measures static balance and looks at athletes within the same sport with different event specialisations.

One previous investigation of female athletes examined differences in both static and dynamic balance across different sports. Bressel et al. (2007) measured the static and dynamic balance of 34 NCAA Division I soccer, basketball, and gymnastics athletes. Static balance was assessed using the BESS and dynamic balance was assessed using the SEBT. The authors reported no difference in static and dynamic balance between female soccer players and gymnasts, but the female basketball players had worse static balance than the gymnasts and worse dynamic balance when compared to the soccer players (Bressel et al. 2007). The authors attributed these differences to the different demands placed upon the postural control systems of the athletes by their different sports, and suggested that basketball players may need a greater amount of balance training as part of their strength and conditioning programme to help improve their balance and reduce the risk of injury (Bressel et al. 2007). More recently, balance performance was assessed among female NCAA Division I collegiate soccer, volleyball, and dance teams, with results demonstrating that volleyball and dance teams possess better static balance than soccer players, while the soccer and volleyball athletes had better balance during dynamic perturbations compared to the dance team, suggesting no relationship between static balance and dynamic balance perturbations and the need for their separate training and assessment (Chander et al., 2014). The present study examines this question in a younger population using static balance as the assessment tool.

Two additional studies examined dynamic balance using the SEBT and compared male and female basketball players (Sabin et al., 2010) and male and female adults (Gribble et al., 2009). These studies reported contrasting results. Sabin and colleagues (2010) compared a mixed sample of male and female Division I basketball players to a healthy, non-athlete control group. The authors reported that the female participants had a lesser amount of reach in the posterior direction on the SEBT than the male participants. They also reported that the control group had a greater amount of reach in all directions when compared to the participants that played basketball (Sabin et al., 2010). The Gribble et al. (2009) study did not look specifically at athletes, but healthy adults with a mean age of 22.5 years. Gribble et al. (2009) reported that female participants had greater reach distances than male participants in all three directions of the test. It appears that gender differences in balance may be present among athletes and non-athletes, making early identification of possible gender- and sport-specific differences essential.

From a practical perspective, the purpose for measuring balance among athletes is to possibly identify those at an increased risk for injury, and then implement a balance training programme to improve balance and reduce the risk of injury. Decrements in balance have been demonstrated to lead to an increased risk of lower extremity injury (McGuine et al., 2000), as basketball players with an increased amount of postural sway during single leg stance had a greater number of ankle sprains over the course of a basketball season. A study that examined the effectiveness of a balance training programme on preventing ankle sprains among high school basketball and soccer players found that the participants that completed the balance training programme had a significant reduction in their risk for an ankle sprain (McGuine & Keene, 2007). Another study instituted a proprioceptive balance board training programme for both male and female volleyball players, and reported that among the participants with a history of ankle sprains, the balance training programme significantly reduced their risk of a future ankle sprain (Verhagen et al., 2004). Therefore, if athletes can be screened during the preseason and decrements in balance can be identified, then the athletes who are at a greater risk of injury can perform a balance training programme as part of their strength and conditioning programme. Likewise, if particular sports or event groups can be identified as having a higher risk for balance decrements, preventive strategies could be implemented as part of the normal training regime.

The only statistically significant difference in the current study was the amount of average COP displacement in the medial/lateral direction for both the eyes open and eyes closed condition, with the non-dominant limb demonstrating a greater amount of displacement than the dominant limb (Table 1). It is important to note, however, that there was not a significant difference between the dominant and non-dominant limbs for any of the other COP variables. Three recent studies that compared static balance measures between the dominant and non-dominant limbs of young healthy adults reported that there were no differences between the two limbs (Kiyota & Fujiwara, 2014; Lin et al., 2009; Muehlbauer et al., 2014). Another study that examined static balance measures between the two limbs reported that the participants of their study, which included young, healthy adults, had less postural sway on the right limb compared to the left limb (Vieira, Coelho, & Teixeira, 2014). While that study did not specify leg dominance for their participants, the right leg is the dominant leg in around 90% of the population (Chapman, Chapman, & Allen, 1987; Peters, 1988). In the present study, the right leg was the dominant leg for 93% of the participants.

While there were only differences between the limbs in the average COP displacement in the medial/lateral direction in the current study, this difference could possibly place the participants at a greater risk of sustaining an injury to the non-dominant limb (McGuine et al., 2000). A study that examined balance training among young female volleyball players

Table 1. Average displacement of the COP in the ***x*** and ***y*** directions with the eyes open and the eyes closed.

Variable	*N*	Mean (±SD) non-dominant leg	Mean (±SD) dominant leg	*F*	*p* value
Avg COP x displacement (cm) eyes open					
Sprinter	20	1.85 (2.31)	−0.41 (2.02)		
Distance	13	2.09 (2.48)	−0.93 (1.59)	0.172	0.842
Thrower/field events	7	2.00 (3.24)	−0.84 (1.84)		
Total	40	2.10 (1.97)	−0.66 (1.82)	20.10	0.001*
Avg COP y displacement (cm) eyes open					
Sprinter	20	−3.99 (1.46)	−3.37 (2.85)		
Distance	13	−4.49 (3.13)	−4.30 (2.65)	0.454	0.639
Thrower/field events	7	−2.94 (2.34)	−3.86 (2.51)		
Total	40	−3.97 (2.27)	−3.76 (2.70)	0.007	0.936
Avg COP x displacement (cm) eyes closed					
Sprinter	20	1.91 (2.25)	−0.12 (2.93)		
Distance	13	1.95 (2.94)	−1.12 (1.65)	0.584	0.563
Thrower/field events	7	2.09 (2.63)	−0.44 (2.58)		
Total	40	1.95 (2.49)	−0.50 (2.50)	12.28	0.001*
Avg COP y displacement (cm) eyes closed					
Sprinter	20	−3.20 (1.44)	−2.92 (2.41)		
Distance	13	−4.42 (1.95)	−4.20 (2.79)	1.65	0.206
Thrower/field events	7	−2.98 (2.47)	−3.47 (2.96)		
Total	40	−3.56 (1.87)	−3.44 (2.63)	0.026	0.873

Table 2. 95% ellipse area and average velocity of the COP with the eyes open and eyes closed.

Variable	*N*	Mean (±SD) non-dominant leg	Mean (±SD) dominant leg	*F*	*p* value
95% ellipse area (cm²) eyes open					
Sprinter	20	13.65 (7.00)	17.28 (14.82)		
Distance	13	15.41 (11.32)	12.14 (4.41)	0.430	0.654
Thrower/field events	7	12.64 (6.90)	12.04 (5.95)		
Total	40	14.04 (8.47)	14.69 (11.19)	0.027	0.820
95% ellipse area (cm²) eyes closed					
Sprinter	20	32.08 (17.46)	30.84 (14.77)		
Distance	13	33.81 (16.15)	30.92 (13.07)	0.038	0.962
Thrower/field events	7	33.33 (18.20)	30.16 (16.19)		
Total	40	32.86 (16.74)	30.75 (14.12)	1.114	0.299
Sway velocity (cm/s) eyes open					
Sprinter	20	5.04 (2.73)	6.48 (7.11)		
Distance	13	4.66 (1.24)	4.32 (0.95)	0.610	0.549
Thrower/field events	7	4.13 (0.91)	4.39 (1.32)		
Total	40	4.75 (2.09)	5.41 (5.13)	0.428	0.518
Sway velocity (cm/s) eyes closed					
Sprinter	20	11.54 (7.23)	11.78 (9.00)		
Distance	13	9.23 (1.83)	8.51 (1.91)	768	0.472
Thrower/field events	7	8.92 (1.89)	11.95 (10.05)		
Total	40	10.33 (5.34)	10.75 (7.65)	0.582	0.451

reported that a six-week training programme reduced the amount of postural sway for the non-dominant limb during single leg stance testing (Pau, Loi, & Pezzotta, 2012). Therefore, a balance training programme could be beneficial for the participants in the current study to reduce the amount of sway for the non-dominant limb. It is also possible that since there were no significant differences in the current study between the dominant and non-dominant

Table 3. Comparison of static balance measures between male and female adolescent track and field athletes (mean ± SD).

	Male		Female	
Variable	Non-dominant leg	Dominant leg	Non-dominant leg	Dominant leg
COP *x* displacement (cm) eyes open	1.70 (2.05)	−0.65 (1.41)	2.33 (2.57)	−0.66 (2.33)
COP *y* displacement (cm) eyes open	−4.12 (2.04)	−3.80 (3.03)	−3.76 (2.60)	−3.71 2.25)
COP *x* displacement (cm) eyes open	1.64 (1.90)	−0.45 (2.39)	2.37 (3.12)	−0.58 (2.71)
COP *y* displacement (cm) eyes closed	−3.48 (1.55)	−3.11 (2.78)	−3.67 (2.27)	−3.88 (2.41)
Sway velocity (cm/s) eyes open	4.79 (2.32)	5.73 (6.14)	4.71 (1.79)	4.98 (3.48)
Sway velocity (cm/s) eyes closed	10.72 (5.86)	11.59 (8.29)	9.81 (4.68)	9.62 (6.78)
95% ellipse area (cm^2) eyes open	12.46 (5.23)	16.00 (13.91)	16.19 (11.34)	12.91 (5.75)
95% ellipse area (cm^2) eyes closed	31.80 (13.65)	31.96 (13.97)	34.30 (20.57)	29.10 (14.58)

limbs for the other measures of postural sway that the current participants do not have a meaningful deficit in postural control for the non-dominant limb that would increase their risk of injury. Additional research is needed to investigate this question (see Tables 2 and 3).

The current study did not find any differences in static balance among adolescent female track and field athletes with different event specialties, or between female and male participants. There was a difference in the average displacement of the COP in the medial/lateral direction. This study was a preliminary step in better understanding balance performance among adolescent track and field athletes. Future studies should include a larger sample size, adolescent athletes from additional sports, measures of dynamic balance, and should track the relationship between balance and future injury. If a relationship exists between balance performance and injury risk among adolescent athletes, as it appears to in adults, a balance training programme can be incorporated into their normal strength and conditioning regimen. Likewise, if balance performance differs by sport or event group, balance training programmes can be better tailored to individual athletes.

Conclusion

In the present study, there were no differences in static balance measures among adolescent track and field athletes of different event specialties and between the male and female participants. There was a difference in the amount of average COP displacement in the medial/lateral direction between the dominant and non-dominant legs, with the non-dominant leg demonstrating greater displacement. This could potentially increase the risk of injury for the non-dominant leg, as previous research has indicated that balance decrements may be a predictor of future injury. If balance decrements are detected, a training programme could be prescribed for the athlete to improve balance and potentially reduce his or her risk of injury.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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