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Abstract: Balance and postural stability are crucial elements in daily activities and the training of athletes. Volleyball requires the athlete to be capable of regaining balance after jumping and landing. Gymnastics requires the athlete to have focus on multiple aspects of balance during the execution of a skill. Current literature has examined age, comparison of certain sports to other sports, and children in athletics, all with regards to postural stability. Current literature has shown that there is a correlation between balance training and increase of performance and decrease in injuries (Oliver & Di Brezzo, 2009).
This research assessed the balance systems of athletes to determine if there is a relationship between two types of sports and balance function. The comparison of athletes to non-athletes indicated whether athletes have greater postural stability, the comparison of gymnasts to volleyball players indicated whether gymnasts have increased postural stability over volleyball players. A videonystagmography (VNG) and posturography assessment were used to evaluate postural stability. The VNG examines eye movement to check for possible vestibular dysfunction. The posturography assessment measures the participant's center of pressure in five conditions, eyes open and closed on a rigid surface, eyes open and closed on a compliant surface, and limits of stability. Twenty participants, 6 gymnasts, 6 volleyball players and 8 non-athletes, were tested using the VNG and posturography equipment. There is insignificant statistical difference of postural stability between gymnasts, volleyball players and non-athletes.

Keywords: balance, postural stability, volleyball, gymnasts, non-athletes, videonystagmography (VNG), posturography

Balance and postural stability are crucial elements in the daily training of athletes. All athletes require the necessary control of balance to be capable of functioning during and after practices, which includes skill execution, skill development, and injury prevention. Increased training in balance techniques has shown to decrease the number of injuries (Oliver & Di Brezzo, 2009).

Not all sports require the same degree of postural control; therefore, there is a wide range of postural stability needs, depending on the athlete and the sport. Some sports, such as golf and running, require the athlete to be capable of maintaining an upright position, while other sports, such as volleyball and basketball, require the athlete to jump and regain balance for landing. Gymnasts may have multiple tasks involved in the execution of one skill and therefore require heightened postural control to perform safely. For example, a flight series on beam requires the gymnast to know how high she has jumped, how much her body has turned, and where she is in comparison to the beam so that when she lands she can distribute her weight evenly on the four-inch beam to stay balanced. Due to the demands of postural control and safety, gymnastics training integrates balance awareness and balance recovery. It has been speculated that differences between certain sports and the athlete's postural stability exist; however, inconsistencies of methodology and the comparison of certain sports does not provide a definitive conclusion to support these hypotheses.

This research will assess the balance systems of athletes to determine if there is a relationship between two types of sports and balance function. The comparison of athletes to non-athletes indicates whether athletes have greater postural stability, the comparison of gymnasts to volleyball players indicates whether gymnasts have increased postural stability over volleyball players.

This research uses a combination of vestibular assessments and posturography assessments to examine the postural stability of each participant. Videonystagmography (VNG), which was used as a screening tool, examined the participants' vestibular system and may provide information for interpreting skewed or irregular posturography results. Posturography testing provides information on the balance system, the vestibular system, the visual system and the somatosensory system, working together as one.

Based on the understanding of the balance system and the demands of each sport, this research attempts to address the extent to which gymnasts, volleyball players and non-athletes differ with regard to postural stability. The following are hypotheses for this research based upon reviewed literature:

H_1: All participants will score within normal range for both the posturography and VNG subtests.

H_2: Gymnasts will score higher than volleyball players on the posturography test.

H_3: Volleyball players will score higher than non-athletes on the posturography test.

H_4: Gymnasts will score higher than non-athletes on the posturography test.

H_o: Gymnasts will not score higher than volleyball player or non-athletes on the posturography test.

Research on the comparison of postural stability of gymnasts, volleyball players and non-athletes is needed because there is little to no published research comparing gymnasts to other athletes or to non-athletes using posturography. By potentially showing that participation in balance intensive athletics has a correlation to increased balance, this research could encourage a greater push for sports and athletic programs. The study by Oliver and Di Brezzo (2009) shows that there is a correlation between balance training and increase of performance and decrease in injuries. A heightened balance system would decrease the number of falls and injuries, sport and non-sport related, resulting in better daily functioning of those involved in athletic sports. Therefore, by potentially showing that there is a correlation between athletics and postural stability, the training of the sport can be further researched. This research will potentially provide information to support athletics and, specifically, support the sports of gymnastics and volleyball. In addition, information about the sport with the highest postural stability can be applied to other aspects besides sports training. Current literature shows that postural stability decreases with age, which can lead to falls and injuries. Therefore, there are implications for applying this information to increase postural stability, which may help later in life.

LITERATURE REVIEW

Balance and upright posture are maintained by the interaction of three systems: the vestibular system, the visual system, and the somatosensory system. Together, these three systems enable the brain to understand when the body is accelerating, changing head position, or generally moving. The visual system detects visual motion, indicating if one is in motion or if objects are in motion. This system is primarily responsible for helping maintain balance during slow movements (Redfern, Yardley, & Bronstein, 2001). The vestibular system is housed in the inner ear and contains two types of organs: otoliths and semicircular canals. The otoliths respond to gravitational movement while the semicircular canals respond to rotational movement. (Debonis & Donohue, 2008). The somatosensory system encompasses nerve fibers and receptors, muscles and joint systems. This system provides the brain with response to joint movement, muscle contraction, and sensations of touch (Debonis & Donohue, 2008). Collectively, these systems provide constant information to monitor basic balance functioning in daily activities.

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Vestibular Tests

The human body requires information from the vestibular and visual systems for postural stability. Posturography tests the somatosensory system incorporated with the visual and vestibular system. Videonystagmography tests the vestibular and visual system without testing the somatosensory system. Videonystagmography is commonly used by audiologist to detect possible pathologies within the cerebellum or vestibular system.

Videonystagmography (VNG) assessment is a test used by audiologists for patients who experience symptoms of dizziness or vertigo. A VNG measures the rate and direction of nystagmus, or movement of the eyes, during certain testing conditions. Peltier, Quinn, and Ryan (2005) discuss multiple screening examinations and laboratory tests for vestibular function. Each subtest is briefly explained, providing possible pathologies for a positive test. Some of the subtests provide statistical information on the sensitivity and specificity in identifying the vestibular dysfunction. Some tests examined were the head shake test, saccadic tracking, smooth pursuit test, and optokinetic tracking.

The Somefun, Giwa, Bamgboye, Okeke-Igbokwe, and Azeez (2010) study examined patients who complained of dizziness and evaluated them using multiple test batteries. These tests included pure tone audiometry, transient otoacoustic emission, auditory brain stem audiometry, and the VNG subtests optokinetic test, gaze test, smooth pursuit test, saccade tests, and caloric test. The article states, for each VNG test, whether that test was capable of finding a pathology that affects the vestibular system. The following pathologies were examined: benign paroxysmal positional vertigo (BPPV), Meniere's disease, vestibulopathy, cervical vertigo, trauma to inner ear, brain stem lesion, psychogenic, and vestibular schwannoma. Combining the results of the VNG tests, this study concluded that BPPV was the most prevalent disorder found with subjects complaining of dizziness. This is valuable information for my study, as I will be using the VNG tests to screen subjects for possible vestibular, cerebellar, central nervous system, or oculomotor dysfunction. The data collected from the VNG tests may also be used to explain skewed or irregular data collected from the posturography test. However, this study did not examine the specificity or the ability of the test to correctly diagnosis no pathology when there is none present of the VNG tests.

According to the Redfern, Yardley, and Bronstein study, "visual conflicts can have powerful effects on balance" (2001), yet the posturography test done by Jbabdi, Boissy, and Hamel (2008) did not test the visual influence on postural control. The study by Redfern et. Al. (2010) examined how the visual system influences postural control. The study explains how a person sways to the frequency of the movement. The article states that when the visual system is present, the somatosensory system enhances the postural control, but when the somatosensory system is absent, the body heavily relies upon the visual and vestibular systems for postural information. Patients in this study with vestibular disorders showed that there is an increase in reliance of visual cues to maintain upright stance. This article explains why a videonystagmography is necessary to eliminate vestibular, cerebellar, central nervous system, or oculomotor dysfunction.

Posturography Tests

Postural steadiness is often measured via static posturography, which is the measurement of posture while standing still. A common way to measure posturography is by evaluating center of pressure. The center of pressure measures the area where the person stands and how it compares to the base of stability, which is the square border around the feet. This test includes an eyes-open and eyes-closed section to examine the impact of the visual system on the somatosensory system (Prieto et. al., 1996). The boundaries of the base support are measured and the center of pressure is calculated. During testing, when the center of pressure is shifted, the shift in base support is estimated. This provides the information that a change in the postural state has occurred, and the amount of time needed to return to the normal center of pressure is estimated.

Posturography has been used to examine the postural stability of elderly adults, young adults, young athletes and collegiate athletes. Generally the literature shows that the postural stability decreases with age as compared to young adults. Young athletes demonstrate increased postural control over young adolescents who do not play sports. Also, gymnasts and soccer players exhibit greater postural stability compared to athletes in other sports.

Slobounov, Moss, Slobunova and Newell (1998), Prieto, Myklebust, Hoffmann, Lovett, and Myklebust (1996), and Van Emmerik and Van Wegen (2002) have utilized posturography to measure the postural stability in elderly adults and determined that the margins of stability in posture are reduced with aging and that the variability in postural control increased with an increase in difficult arm positioning. Therefore, aging, along with increased difficult arm positioning, decrease the ability to maintain postural control. These conclusions were found by examining older adults, ranging from ages 60 to 99 years, in two separate experiments within the Slobounov et al. (1998) study. The first experiment recruited 21 elderly people ages 67 to 92 years who lived in a residential center. These subjects were asked to complete a posturography test, which included six trials. Three trials required the subjects to keep their eyes open and three trials required their eyes to be closed; all six trials were performed on a rigid force platform with the subjects' arms resting at their side. The findings of this study led to the second study where 61 adult subjects, ranging from ages 60 to 99 years, were asked to complete a posturography test; however, this study changed the arm position of the subject to shoulder height for two of the four tests.

The study completed by Prieto et al. (1996) also examined the postural stability of elderly adults; however, unlike Slobounov et al. (1998), Prieto et al. (1996) compared the posturography data of elderly adults to a test group of young adults. The use of these two groups allows the results to determine that postural stability decreases with age. There were statistical differences between eyes open and eyes closed conditions with elderly adults and not young adults. Twenty healthy young adults and twenty healthy elderly adults were required to complete trials with eyes open and eyes closed. Prieto et al. (1996) also measured the displacement of the center of pressure from the base of support, concluding that there were significant differences between the postural stability of young adults and elderly adults. However, the displacement of center of pressure is not indicative of a decrease in postural stability due to disease, as shown in the study conducted by Van Emmerik et al. (2002), which examined how aging and Parkinson's disease affected stability boundaries and postural control. This study clearly defines what is the base of support and why this is critical for measuring postural stability. The article did not provide the necessary information on the study, the subjects or the methodology to create a reproducible study.

Slobounov et al. (1998) and Prieto et al. (1996) effectively showed that posturography has high sensitivity to measure postural changes due to aging, with regards to visual and non-visual cues. However, both studies failed to examine how the use of a compliant surface, such as foam, rather than a rigid surface affected postural control. Use of the foam surface allows examination of the visual system co-functioning with the vestibular system. By eliminating the rigid surface, the somatosensory system is also eliminated. These studies would have benefitted from determining if the postural instability was due to a decrease in the somatosensory system with the visual system or the somatosensory system with the vestibular system.

Posturography in Athletes

Posturography has not only been utilized for comparing elderly and young adults, but also athletes in various sports. Garcia, Barela, Viana, and Forti Barela (2011), Biec and Kuczynski

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(2010), and Schmit, Regis, and Riley (2005) have all used posturography testing to understand the postural stability of athletes. Garcia et al. (2010) studied the development of postural control in gymnasts as compared to non-gymnasts and concluded that “regular and systematic training of physical exercise, such as gymnastics, might improve postural control.” Younger gymnasts performed better on postural control measurements than younger non-gymnasts, as they were able to use visual information to improve their postural control. Forty-three girls in ages five to seven and nine to eleven were evaluated. Each gymnast must have trained at least twice a week between 2 to 4.5 hours per day. The gymnasts and non-gymnasts were tested in eyes-open and eyes-closed conditions on a rigid surface.

Young athletes were also evaluated by Biec and Kuczynski (2010) using posturography equipment. They found that soccer players had superior postural control compared to non-soccer players. They also stated that the postural control leads to better performance because there is an increased automaticity level. Thus, soccer players have a higher sensory tolerance and can cut out unnecessary noise and focus better on balance. The study concluded this by recruiting forty-four boys age thirteen years old. The participants included twenty-five boys who practiced soccer for five to six years and nineteen healthy boys who did not practice sports but could have been enrolled in a physical education class and not involved in any other regular physical activities.

Schmit et al. (2005) also studied athletes using posturography; however, participants were collegiate level ballet dancers and track athletes. They used a compliant foam surface was to differentiate between a challenging (foam) and non-challenging (rigid) test condition. The use of the two surfaces provided an estimation of the contribution of somatosensory system in their subjects. Ballet dancers were used as subjects because they demonstrate high levels of movement control and balance.

The data from Schmit et al. (2005) shows anomalous results as compared to other literature. This study intended to examine how the visual system and surface type affected postural stability and predicted ballet dancers would have increased postural stability over track athletes. The authors hypothesized that the ballet training would influence the postural control and the track athletes served as the control in this study, as they are not regularly trained in specific balance control. However, ballet dancers had lower stability than the track athletes. While the authors state that dancers may “exhibit different dynamic patterns of postural sway” (Schmit et al., 2005, p. 376), this was only an attempt to explain these results and no evidence was provided to explain the rejected hypothesis.

Hrysomallis (2011) summarizes the results of measuring balance ability and athletic performance between gymnasts and other multiple sports. Gymnasts have equal or superior postural stability compared to non-gymnasts and basketball players. The conclusion to this data is consistent with the reporting from Schmit et al. (2005). Hrysomallis (2011) speculated that gymnasts may have an increase in postural stability due to the intense practice in “stationary balance and dynamic landings” (Hrysomallis, 2011, p. 224). This finding correlates with the Bressel et al. (2007) study. Thirty-four student collegiate athletes in soccer, basketball and gymnastics were evaluated. Unlike the previous studies, this study used the Balance Error Scoring System (BESS) and the Star Excursion Balance Test (SEBT) to evaluate balance stability, rather than posturography equipment. These tests do not provide the same objective data that computerized posturography equipment does, which creates a bias due to subjectivity of the researcher. With the BESS, the observer recorded if the subject opened his or her eyes, lifted hands from hip, touched of non-stance foot, moved of stance foot, etc. If the researcher did not catch this error, then the data would be skewed. The results showed that the basketball players demonstrated inferior balance as compared to gymnasts and soccer players.

The research shown by Hrysomallis (2011) provides a practical application for research in balance systems in that balance training reduces the risk of musculoskeletal injuries. Therefore, knowing which training programs in sports are superior in postural stability will allow athletes and coaches to adjust training in order to obtain this level of stability.

A study by Oliver and Di Brezzo (2009) examined how balance training affected the risks of injury in collegiate athletes. The results show that the volleyball players have a statistically significant difference in the single-leg squat test and the one-minute sit-up test and soccer players showed a statistically significant difference in the one-minute sit-up test. This study compared the one significant injury of the volleyball players to the two previous years' injuries where six significant injuries were reported by members of the volleyball team. This study implemented a pre-test and a post-test for the two test groups, volleyball players and soccer players. The pre-test and post-test included a Skindex, BMI, single-leg squat, Pronequadra-Ped core test, Biodex balance test, and a one-minute sit-up test. The Pronequadra-Ped core test was used to evaluate weakness in core muscles and the Biodex balance test was a single-leg stability test. After the pre-test, the volleyball players received additional balance training with an Indo Board for ten minutes four days a week for thirteen weeks.

Limits of Stability Test in Posturography

The limits of stability test was not discussed any previous studies. Limits of stability tests measure the capability of a subject to lean in a direction field, forward, backward, to the right and to the left, without changing the base of support. It is pertinent that subjects are only shifting weight and not moving at the hips, but rather at the ankle. The trunk of the body should move as a whole, rather than bending independently from the ankle. This allows for the equipment to measure the true limits of stability rather than the flexibility of the subject. Limits of stability help determine the degree to which the participant can lean before losing balance; the greater the limits of stability, the greater the chance for postural stability.

Jbabdi, Boissy and Hamel (2008) did not examine the eyes-open and eyes-closed in relation to postural stability; however, they did examine the limits of stability of each participant. The results of the Jbabdi et al. (2008) study show significant differences between the theoretical limits of stability and the observed limits of stability. This difference could be caused by the differences in the tests subjects, such as fitness level, age, and functional balance capacity. This study establishes performance based limits of stability for elderly adults, which can help provided more realistic information for the true limits of stability. Jbabdi et al. (2008) noted that the theoretical limits of stability are not accurate because the values are created using leaning angles and computerized models. These values are calculated not by human abilities; therefore, the theoretical limits of stability are not actually obtainable. While this study attempts to create more realistic values for the limits of stability, this data can only be applied to elderly adults.

Weakness of Current Literature

The limitations of the Garcia et al. (2011) and Biec and Kuczynski (2010) studies show a gap in the literature that needs to be addressed. The subjects in these studies were young; the gymnasts were 5 to 11 years old, and the soccer players were 13 years old. The data may have been skewed because the somatosensory system does not finish developing until around 18 years of age. Moreover, different children develop differently and at different rates.

Neither gymnasts nor soccer players were tested on a foam surface with eyes closed to evaluate vestibular function. Therefore, only two of the three balance systems were tested. All three balance systems should be tested to obtain more accurate results.

Garcia et al. (2011), Biec and Kuczynski (2010), and Schmit et al. (2005) required gymnasts to have trained at least twice a week between two and four-and-a-half hours a day. While this requirement provides a good starting criterion for the subjects, the researchers failed to recognize gymnasts may practice for the same time period, but the level of difficulty may still vary. This criterion does not ensure that all gymnasts are relatively similar in skill level. Skill level is important when considering posturography because the increase in skill level may affect the test results. Therefore, skill level criteria for gymnasts and volleyball players have been set for the current study.

Previous studies of athletes (Schmit et al., 2007 and Hrysomallis, 2011) did not involve volleyball players. The researchers of this study chose to include volleyball players in my study due to the nature of their training of jumping and landing, which requires balance. For this movement to be successfully completed without injury, the athlete needs postural stability. This population will bridge the gap between gymnasts and non-athletes, as volleyball players are often required to jump and land, like gymnasts. The postural stability training of this sport is more than what a non-athlete would receive but less than what a gymnast receives; therefore, volleyball provides a necessary step between the two extremes of gymnasts and non-athletes.

The results of the Oliver and Di Brezze (2009) study do not provide conclusive evidence that the Indo Board balance training improve postural stability and therefore decreased injuries. The comparison of the injuries over the past two years did not take into account the different players each year and the personal medical history of each player. The injuries sustained in the past years may have been from players no longer on the team during the Indo Board balance intervention. The increase in performance on the single-leg squat and one-minute sit-up tests may be due to the normal strength and conditioning regiments of in-season workouts. These tests were also tests that may have been common to both athletic groups, thus the results may have been skewed. A posturography test may have been more conclusive. Posturography testing should be used rather than other tests, such as Balance Error Scoring System (BESS) and the Star Excursion Balance Test (SEBT), because posturography provides objective empirical data. The current study intends to evaluate if gymnasts have increased postural stability over volleyball players and non-athletes; thus, the training routines of gymnasts could be examined to contribute to balance training in all athletes. This balance training could possibly decrease injuries among athletes.

METHODOLOGY

Participants

The Institutional Review Board at the University of Northern Colorado (UNC) approved this research. All participants are female between the ages 18 to 25. A total of 20 subjects participated in this research: 6 volleyball players, 6 gymnasts, and 8 non-athletes. The volleyball players were all in active training on a collegiate volleyball team. Gymnast participants were required to have competed at least at a USAG level 8 and non-athletes were categorized as never competing or training in any sport. All participants were recruited by word of mouth from the researcher, students and professors.

Procedure

The participants received a videonystagmography (VNG) assessment including four tests: head shake test, saccadic tracking test, smooth pursuit test, and optokinetic tracking. The head shake nystagmus test and the saccadic tracking test assesses if a participant had a vestibular or cerebellar dysfunction. The smooth pursuit tests and the optokinetic tracking test assessed if a participant had a central nervous system or oculomotor dysfunction (Peltier, Quinn, & Ryan, 2005). Participants who showed signs of abnormalities with these tests were not included in the study and were referred for further evaluation. However, no participants in this study showed signs of abnormalities. Participants also completed the posturography assessment. Posturography assessed postural stability on the displacement of the participant's center of pressure (Prieto, Myklebust, Hoffmann, Lovett, & Myklebust, 1996).

The participants completed four VNG subtests, which measured the rate and direction of nystagmus or movement of the eyes. All four tests required the participant to be fitted with VNG goggles. These goggles fit securely on the head and contain cameras to record the eye movement during testing. The head shake nystagmus test required the participant to tilt her head forward at a thirty degree angle and shake her head from side to side at a rate of two shakes per second for a duration of thirty seconds. The participant was asked to open her eyes and look straight ahead as she was observed for nystagmus. The next series of tests were conducted with room lights off except for a desk light and required the participant to sit on an exam table, eye level with a screen. This screen displayed a red dot of light. The saccadic tracking test required the patient to concentrate on the red dot as a moving target and the accuracy of her eye movements were recorded. During the smooth pursuit test, the target was moved in a sinusoidal pattern and the eye movements were compared to the movement of the target. The optokinetic tracking test required the participant to focus on multiple dots light that were moving rapidly from one direction to another (Peltier, Quinn, & Ryan, 2005).

The posturography assessment began with the participant removing her shoes and getting fitted into the harness. The participant was asked to step onto the rigid force plate and the harness was secured to the frame. The participant's medial malleolus, or inside protrusion of the ankle, was lined with the horizontal line, the lateral side of the foot was lined with the vertical lines, and measurements of the foot in comparison with the graph were recorded. The participant completed five tests: eyes open with rigid plate, eyes closed with rigid plate, limits of stability, eyes open with foam surface, and eyes closed with foam surface. All tests ran for thirty seconds. The eyes open on rigid plate test required the participant to stand as still as possible with her arms by her side while staring straight forward at the black mark for thirty seconds. This procedure was the same for eyes closed on the rigid plate. The participant followed the same instructions for eyes open and closed on the foam surface, except the force plate contained a foam covering with the same specifications as the rigid plate. The foam covering was placed in the exact measurements of the rigid surface and the participant's feet were measured and placed accordingly. For the limits of stability test, the participant was asked to lean her body forward, right, left and backward as far as she could without moving the torso of her body or lifting her feet off of the force plate.

Results

The VNG assessment was completed by 15 participants, 3 volleyball players, 4 gymnasts, and 8 non-athletes. All participants passed all subtests of the VNG assessment.

The data from the posturography was collected and sent to Dr. Jeremy Smith in the UNC School of Sport and Exercise Sciences. Custom Mat Lab Software from Math Works was used to analyze each subsection of the posturography test to compute the center of pressure (COP) for each participant. This software processed the COP data and computed the mean medial-lateral (ML) COP frequencies, anterior-posterior (AP) COP frequencies, ML COP velocities, AP COP velocities, 95% confidence ellipse (CE) area if the COP (Figure 1). Fixed base of support (BOS) and functional BOS areas were calculated for the LOS test (Figure 2). The mean scores for ML frequencies, AP frequencies, ML velocities, AP velocities and 95% CE were calculated. Once the data was analyzed, a two factor (surface and vision) ANOVA with repeated measures and a between-subjects factor group ANOVA test were used to determine how COP trajectories were altered during quiet standing. The LOS was analyzed using a single factor ANOVA. The level of significance was set at α=0.05.

The mean ML and AP frequencies, ML and AP velocities, 95% CE, and relative percent of fixed BOS and functional BOS for gymnasts, volleyball players and non-athletes are presented in Tables 1, 2 and 3 respectively. There was no statistical difference between performance of gymnasts, volleyball players, and non-athletes in all four quiet standing conditions for ML and AP frequencies, ML and AP velocities and 95% CE. There was no statistical difference between gymnasts, volleyball players, and non-athletes in percent of functional base of support versus fixed base of support. During quiet standing there was an interaction effect between surface and vision and main effects for surface and vision ($p < .001$ for all effects) for the following variables: 95% CE area, Mean AP velocity, and Mean ML velocity. ML Mean Frequency was altered by changes in vision ($p < .001$) and AP Mean Frequency was altered by changes in surface ($p < .001$) and vision ($p < .001$) conditions. However, for these variables there was no interaction effect between surface and vision ($p > .05$).

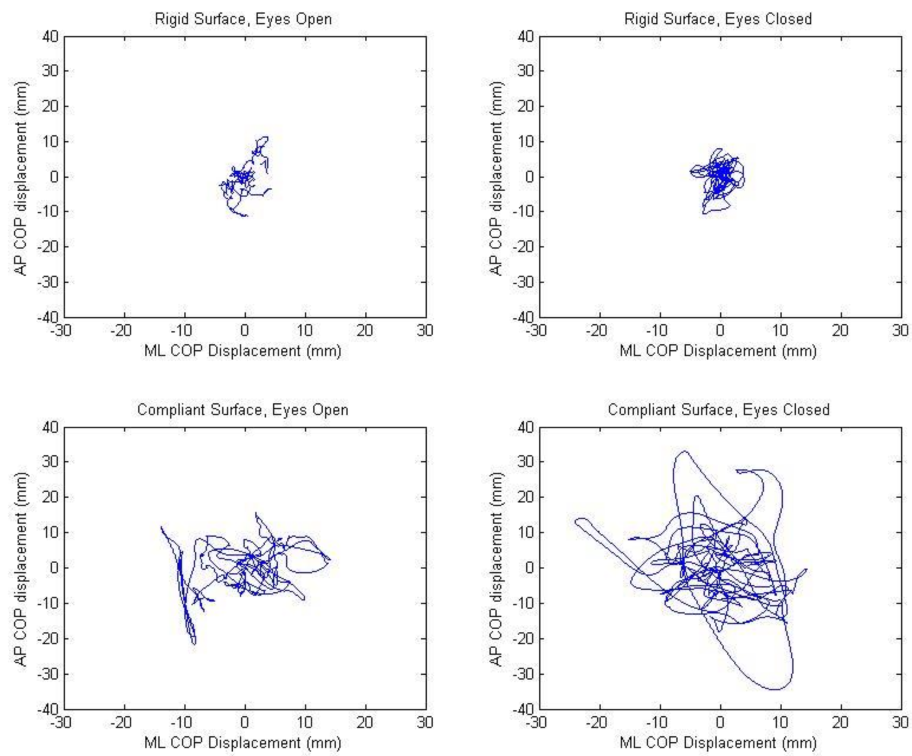

Figure 1. Data from a random participant showing the trajectories for RSEO, RSEC, CSEO, CSEC in quiet stance.

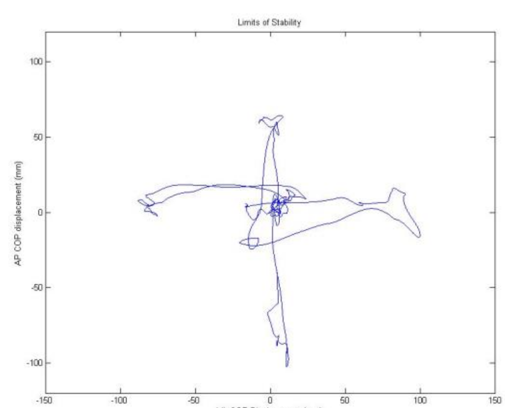

Figure 2. Random participant's trajectory for LOS.

Table 1
Mean Scores of Gymnasts

	Gymnasts				
	Mean Velocity (mm/s)			Mean Frequency (Hz)	
	ML	AP	CE-area	ML	AP
RSEO	4.8	7.14845	350.4723833	0.432683333	0.293933333
RSEC	5.985916667	8.99505	318.1584167	0.557933333	0.393666667
CSEO	11.09703333	12.87658333	812.7402667	0.4403	0.395333333
CSEO	20.37853333	30.64325	1703.971867	0.614816667	0.566283333
	Fixed BOS (mm*mm)	Function BOS (mm*mm)	Relative Percent (%)		
LOS	86728.26667	31033.10765	41.35581667		

Table 2
Mean Scores of Volleyball Players

	Volleyball Players				
	Mean Velocity (mm/s)			Mean Frequency (Hz)	
	ML	AP	CE-area	ML	AP
RSEO	2.630466667	5.282233333	136.3916667	0.420683333	0.348633333
RSEC	3.32865	7.131516667	95.23916667	0.553116667	0.4891
CSEO	8.398833333	12.1406	827.7813833	0.356633333	0.352766667
CSEO	16.62856667	29.39741667	1450.416367	0.523683333	0.599433333
	Fixed BOS (mm*mm)	Function BOS (mm*mm)	Relative Percent (%)		
LOS	82593.95	34125.344	41.21303333		

Table 3
Mean Scores of Non-Athletes

	Non-athletes				
	Mean Velocity (mm/s)			Mean Frequency (Hz)	
	ML	AP	CE-area	ML	AP
RSEO	3.743625	5.0136625	176.6058375	0.456325	0.29025
RSEC	4.27435	6.9912	176.65735	0.585475	0.4034875
CSEO	9.1532625	12.9635125	876.895825	0.3986875	0.405975
CSEO	17.7852375	27.460625	1883.667463	0.529075	0.5411125
	Fixed BOS (mm*mm)	Function BOS (mm*mm)	Relative Percent (%)		
LOS	72453.15	31970.28705	42.6362375		

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Discussion

The data from the VNG assessment support the hypothesis that all participants would have normal vestibular and cerebellar function.

The data from the posturography assessment do not support the hypotheses that gymnasts will have increased postural stability over volleyball players and non-athletes. The data showed no significant difference among these three groups. The mean AP and ML velocity, and AP and ML mean frequency within this study were generally consistent with the young adult findings reported in Prieto et al. (1996).

In general, the results of this study suggest that, regardless of group, as quiet standing conditions became more difficult, CE-area and mean AP and ML velocities increase. That is, these measures increased as vision was removed and as the surface was made compliant. Removing vision and having individuals stand on a compliant surface left participants to rely primarily on vestibular input to maintain posture and balance. Gymnasts appeared to have increased mean ML velocity over volleyball players and non-athletes, and decreased mean ML frequencies over volleyball players and non-athletes in RSEO and RSEC conditions. The data showed trends that gymnasts might have increased postural stability over volleyball players and non-athletes. While there is no statistical difference, the sample size may have limited the ability to detect differences in these measures. Also, the data from one gymnast were an outlier to the rest of the gymnasts' data. She was the first participant, and therefore, her skewed results may have resulted from a lack of complete or detailed instruction.

The biggest limitation of this study was that the number of participants was generally small; therefore, statistical differences may not be detected. With a larger sample size, it may be possible to detect statistical differences between groups. The researchers struggled to find gymnast participants meeting all requirements near the testing site. This may be due to the lack of gymnastics programs within the proximity of testing or the need for the participants to travel to the testing site. Not all members of the collegiate volleyball team who initially signed up for the study actually participated in the study. It was also difficult to find non-athletes. Many people who were initially contacted did not meet the requirement of never having participated in any sport. Many of these people had casually participated in sports in high school.

Gymnasts were not required to have been currently or recently competing or training in gymnastics to participate in this study. There might have been more of a statistical difference if current collegiate gymnasts had participated in the study. Although it was difficult to find participants that met the criteria, it is necessary to keep the criteria as stated in this study. The gymnast requirement of a USAG level 8 ensures that the gymnasts have extensive training in skills that require the maximum balance in the sport. The non-athlete criteria are important because participating in sports in the past may have had lasting effects on postural stability. The collegiate volleyball players were needed to ensure the participant had daily training that incorporated balance related activities into training.

All participants were evaluated using quiet standing conditions during posturography, which may not have been an accurate assessment of postural stability in athletes. Athletes are in constant motion and are not typically in quiet standing conditions; therefore, it might be more useful to evaluate postural stability among athletes using functional balance tests. Also, there was not a controlled fixed base of support for all participants, so each participant established her own base of support. The lack of a controlled fixed base of support may have caused the variability in LOS data, which could have decreased the ability to find statistical differences among the groups. The wider the base of support the more likely there would be an increase in postural stability. Therefore, to eliminate this variable, a controlled fixed base of support should be set.

The results of Oliver and Di Brezze (2009) have shown that balance training decreases injuries among athletes. While this study found no statistical difference among the three groups, further research should be conducted to discover if training regiments in sports increase postural stability in those athletes. The information whether certain sports increase postural stability could be useful in conjunction with the study by Oliver and Di Brezze (2009). This further research could help to decrease injuries by designing balance training to maximize the benefits of postural stability.

Suggestions for further research should include a comparison of gymnasts, other athletes and non-athletes in quiet standing conditions and other balance conditions. This may allow for a more functional test of balance to be examined. Within group differences of gymnasts in testing of quiet standing and functional balance should be tested to determine which test provides the most accurate measurement of postural stability. Difficult procedures or different testing conditions may show differences among athletes and non-athletes. Gymnasts may need to be required to be currently competing at a higher level than USAG level 8. Gymnastics should be compared to a variety of other sports as well. Further research should compare athletes by grouping sports into various levels of balance requirements. Gymnasts, dancers, cheerleaders and martial arts should be grouped together, as these sports require an extensive amount of postural stability. Basketball players, golfers, tennis players and volleyball players should be grouped together because these sports require postural stability when jumping and landing. The results of this study are not conclusive enough to rule out that a difference of postural stability in gymnast, volleyball players and non-athletes exist. Therefore, the methodology of this study could be used to expand this research with a larger sample size to provide conclusive results.

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