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Balance Performance in Female Collegiate Athletes

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Abstract: Proper balance is essential for athletes during competition and training as sport places different balance requirements on the human body. The purpose of the study was to analyze balance performance among female athletes using COP (center of pressure) sway parameters. Twenty one NCAA (National Collegiate Athletic Association) division I female athletes (soccer, volleyball and dance) completed the study. Static balance was assessed using UST (unilateral stance test) and dynamic balance was assessed using MCT (motor control test) on the NeuroCom Equitest. Sway velocities, root mean square sway and reaction time latencies were used to quantify balance. A one-way between subjects ANOVA (analysis of variance) was performed to analyze these balance parameters. Significant ($p < 0.05$) differences between groups were found and post hoc comparisons revealed that the volleyball and dance groups had better static balance compared to soccer players, while both soccer and volleyball groups had better dynamic balance compared to the dance group. The results from the study indicate two points: first, differences in balance performance among female athletes in different sporting discipline; second, there is no relationship between static and dynamic balance. This indicates that it may be more beneficial to assess and train for static and dynamic balance individually.

Key words: Athletes, static balance, dynamic balance, center of pressure.

1. Introduction

Balance which is defined as the ability to maintain the center of gravity within the base of support with minimal sway [1, 2] is crucial for athletes during competition. Static postural control is the ability to maintain a stable base of support with minimal movement while dynamic postural control is the ability to maintain a stable position during motion or re-establishment of posture following a perturbation [2, 3]. The importance of both static and dynamic balance is profound in athletes who are required to maintain their balance while performing dynamic tasks in competitive sport. Additionally, different sports have different balance requirements and demands on the performer, based on the nature of the physical task at hand during the sport [4]. Assessments of both static and dynamic balance help to analyze the effectiveness and the role of the somatosensory-proprioceptive, visual and the vestibular systems along with the neuromuscular efficiency of the athletes [2, 4, 5]. The resulting motor responses during balance assessment brought about by the coordination of lower extremity joints, their range of motions and strength ultimately have a direct influence on postural control and balance [6, 7]. For example, poor postural control has been linked with an increased risk of acute ankle sprains which is extremely common with athletes and moreover previous episodes of ankle sprain or chronic ankle instability have shown to impair the postural control system [8, 9].

Balance training for athletes in different sports has grown over the past decades and recently gained recognition with the inclusion of balance performance

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as one of the components of fitness in the ACSM (American College of Sports Medicine) guidelines for physical fitness [10]. Moreover, balance training in congruence with traditional resistance training programs may be beneficial in the prevention and rehabilitation of musculoskeletal injuries in the ankle joint [11, 12]. Balance training for even as little as 2-4 weeks has statistical improvements in balance performance [12, 13] and subsequently a reduction in the rates of ankle injuries.

To prescribe balance training to athletes from different disciplines of sport performance, a better understanding of their balance performance under static and dynamic conditions is required. The sports that are of interest to this study (soccer, volleyball and competitive dance) place different demands on the proprioceptive and the somatosensory system which may invariably affect balance maintenance of these athletes. Studies have compared balance performance among different athletes [7, 8, 14], dancers [14-16], between normal and chronic ankle instability conditions [8, 17] and using balance training as an intervention [13]. Studies have also used various balance training protocols under static and dynamic testing conditions using the BESS (balance error scoring system) and the SEBT (star excursion balance tests), respectively [7, 8, 12, 17]. However, there is still a dearth of literature on balance performance of different sporting disciplines using computerized dynamic posturography [18], specific to static and dynamic balance testing conditions [18]. Furthermore, it is also widely accepted that the most reproducible method to quantify standing balance is based on COP measurements [14, 19, 20]. Hence, the purpose of this study was to compare balance performance of soccer, volleyball and dance athletes under static (unipedal) and dynamic (bipedal) conditions using COP characteristics to evaluate balance. We defined static balance in the context of maintaining unipedal stance and dynamic balance in the context of maintaining bipedal stance under perturbing conditions. It was hypothesized that both static and dynamic balance would be different among these athletes from different sporting disciplines.

2. Methods

2.1 Participants

Twenty one NCAA Division I female athletes from the soccer team (*n* = 10; age = 19.6 ± 1.3 years; height = 165.9 ± 4.8 cm; body mass = 63.7 ± 8.7 kg), volleyball team (*n* = 6; age = 19.8 ± 1.0 years; height = 179.9 ± 5.1 cm; body mass = 76.1 ± 14.1 kg) and dance team (*n* = 5; age = 20.3 ± 1.8 years; height = 163.4 ± 6.3 cm; body mass = 56.8 ± 6.4 kg) volunteered and completed the research protocol. Informed consent from all participants and permission to participate in the study from the coaching staff for their respective sport was obtained. All athletes were injury free and cleared for participation by their coaching staffs.

2.2 Testing Procedures

The testing procedures included an initial familiarization session during which university approved informed consent (IRB# 10-045) was obtained and anthropometric measures were collected from all participants. Participants filled out a PAR-Q (physical activity readiness questionnaire) followed by familiarization of testing procedures. The experimental testing session, separated by at least 24 hours, included balance assessment in unilateral stance under static conditions followed by balance assessment in bilateral stance under perturbed conditions. The static balance was assessed using the UST and the perturbed or dynamic balance was assessed using the MCT on the NeuroCom Equitest balance system (NeuroCom International, Inc. Clackamas, Oregon) which has 18” X 18” dual force plates with translational capabilities. The US balance protocol quantifies postural sway with the participants in unilateral stance on either right or left leg individually under both eyes open and eyes closed conditions to create the following four testing conditions: C1—left leg-eyes open, C2—left leg-eyes closed, C3—right leg-eyes open, C4—right leg-eyes closed in order to assess postural sway under static conditions. The MCT balance protocol uses a sequence of small, medium and large horizontal platform translations in the forward and backward directions to create the following six testing conditions: (1) backward small, (2) backward medium, (3) backward large, (4) forward small, (5) forward medium and (6) forward large dynamic perturbations.

2.3 Data Analysis

The values of the dependent sway variables were derived from the COP movement during the US balance test. The VEL (average sway velocity) and the RMS (root-mean-square) of the COP were used to characterize the postural sway in the anterior-posterior (AP VEL & AP RMS) and the medial-lateral (ML VEL & ML RMS) directions. Sway velocity is determined by calculating distance over time and is a measure of the peak to peak change of the COP per unit time. The RMS estimates the amplitude of sway and the overall amount of movement of the COP during the balance testing time on the NeuroCom Equitest. The MCT balance test uses the latency response times which quantify the time between the onset of the translation and the initiation of the participant's active response using the COP response trace from each leg. Sway VEL determines the rate of this compensation and sway RMS estimates the amount of compensation needed to maintain the center of gravity within the center of the base of support and thereby effectively maintaining balance. Higher values of VEL and RMS indicate decreased postural stability and balance, implying larger angular changes in the location of the center of pressure. The latency measure of reaction time using the MCT also has an inverse relationship with balance, with lower latencies implying faster reaction times to respond to the perturbations and better balance. These two measures were used for static unilateral balance assessment since they show different characteristics of postural sway. The sway RMS and VEL for the US balance test were calculated using the following equations, respectively:

$$\text{SWAY VEL} = \left(\frac{1}{t}\right)\sum_{i=0}^{n}\left|COP_i - COP_{i-1}\right| \quad (1)$$

$$\text{SWAY RMS} = \sqrt{\frac{1}{n}\sum_{i=0}^{n}\left(COP_i - COP_{avg}\right)^2} \quad (2)$$

Avg—average; *t*—time (s); *n*—number of data points.

2.4 Statistical Analysis

The study followed a repeated measures design assessing the balance performance among the three groups of varsity athletes. A one-way between subjects

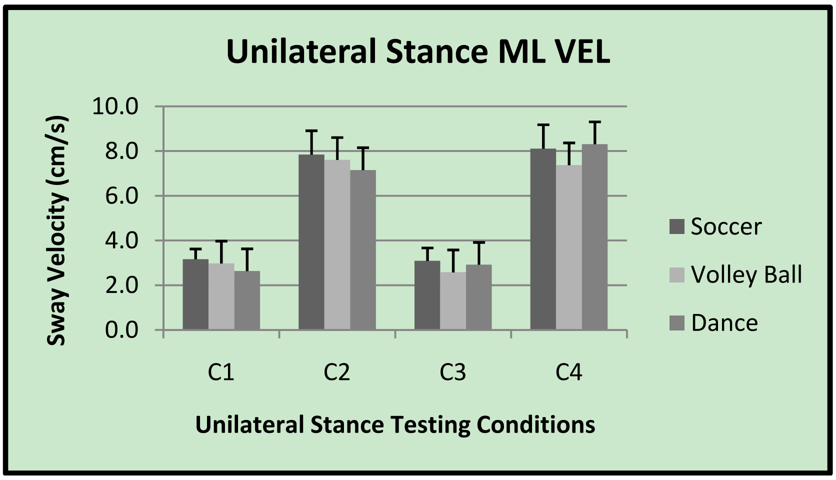

Fig. 1 Medial-lateral sway velocity during unilateral stance testing conditions.

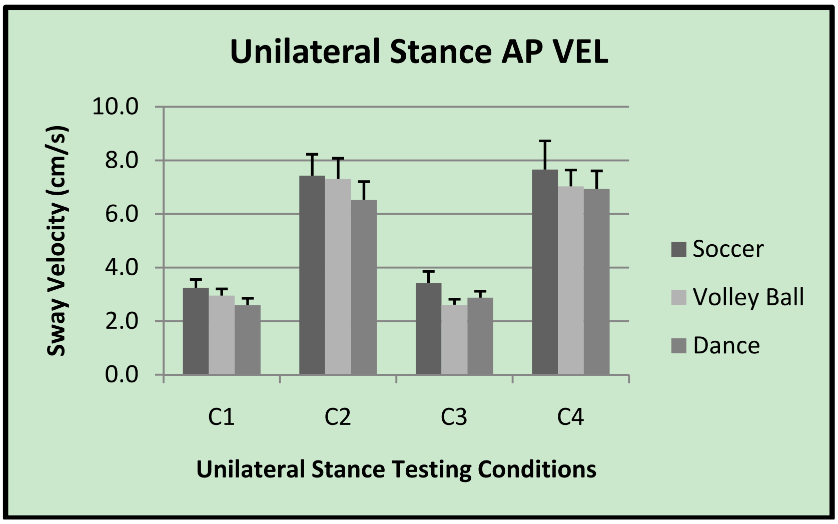

Fig. 2 Anterior-posterior sway velocity during unilateral stance testing conditions.

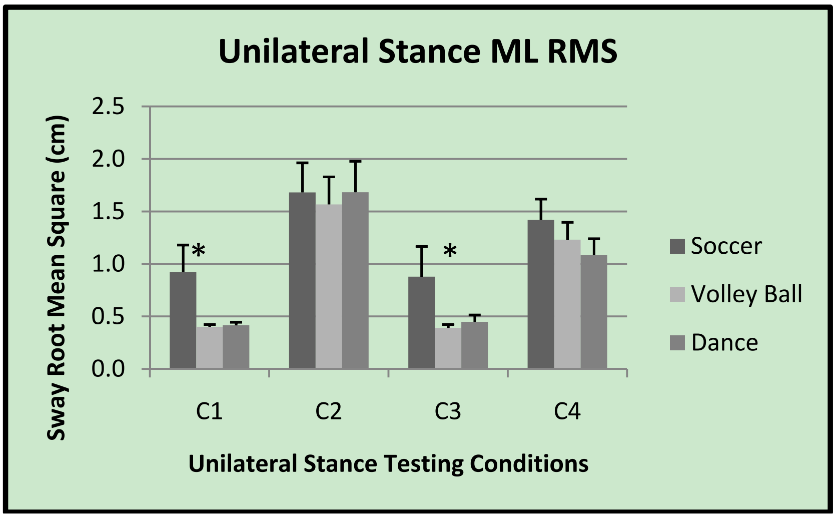

Fig. 3 Medial-lateral sway RMS during unilateral stance testing conditions.

* Represent significant differences and bars represent standard errors

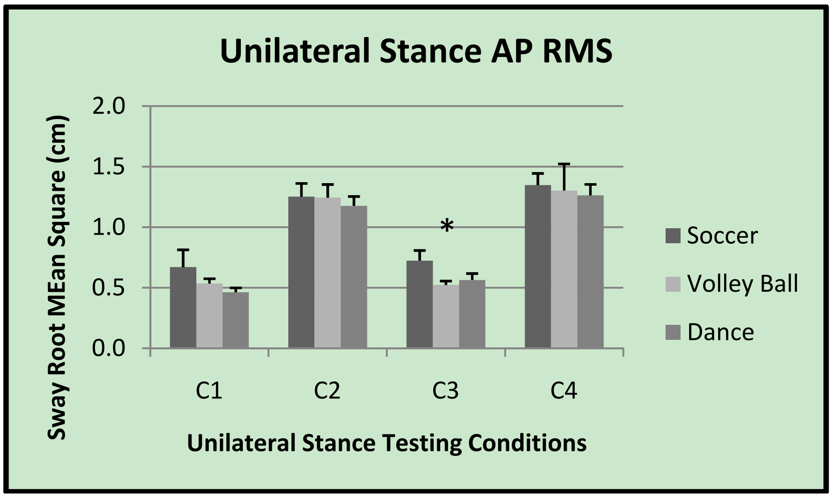

Fig. 4 Anterior-posterior sway RMS during unilateral stance testing conditions.

ANOVA was used to evaluate the balance variables of AP VEL, ML VEL, AP RMS, ML RMS (Figs. 1-4) and the latency response times to identify any existing differences in static and dynamic balance among the athlete groups. If statistical significance was found, post hoc multiple comparisons with LSD (least significant difference) correction were used to determine the group differences. For all analyses, significance was set at an alpha level of $p \leq 0.05$ and all statistical analyses were run using the SPSS 20 statistical software package (SPSS 20 statistical software package (IBM® SPSS® Statistics V20.0), Armonk, New York 10504-172).

3. Results

Statistically significant group differences between soccer, volleyball and dance existed for both static and dynamic balance assessments. The one-way ANOVA revealed significant between group differences for ML RMS for C1 ($p = 0.008$) and C3 ($p = 0.039$) (Fig. 3) and for AP RMS in C3 ($p = 0.037$) (Fig. 4).

Post hoc analyses revealed that both the volleyball and dance groups had statistically lower ML RMS when compared to the soccer group in both left leg-eyes open and right leg-eyes open conditions, and the volley ball group having significantly lower AP RMS than the soccer group in right leg-eyes open condition, with no statistical difference between volley ball and dance groups. No other statistically significant differences were identified for AP VEL and ML VEL in all four conditions of static balance testing.

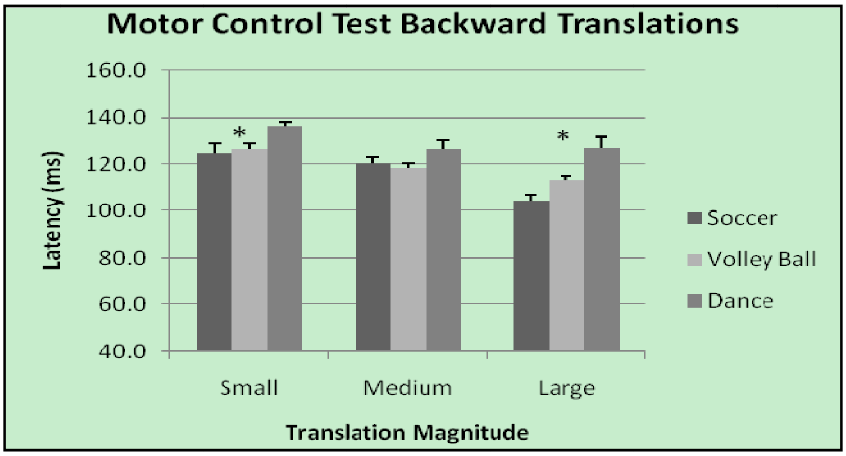

Fig. 5 Latencies during motor control test small, medium and large backward translations.
* Represent significant differences and bars represent standard errors.

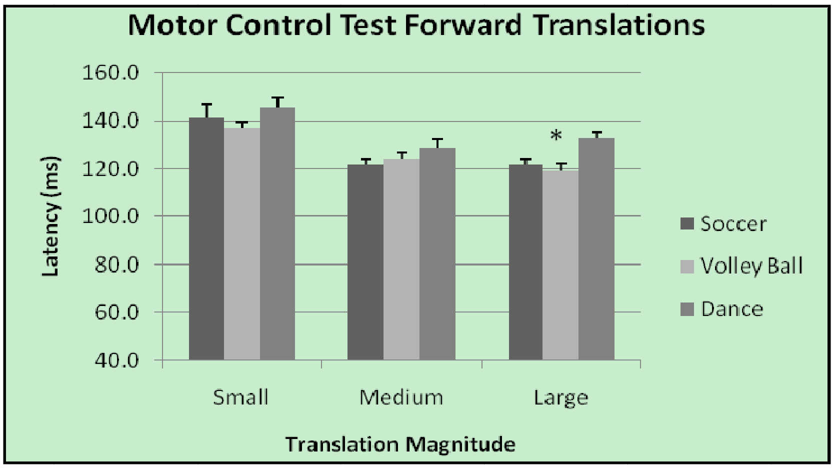

Fig. 6 Latencies during motor control test small, medium and large forward translations.

In testing for dynamic balance, the one-way ANOVA revealed statistically significant between group differences during backward small ($p = 0.02$), backward large ($p < 0.0005$) (Fig. 5) and forward large ($p = 0.006$) (Fig. 6) translations. Post hoc analyses revealed that both soccer and volley ball groups had statistically faster latency response times when compared to the dance group during the backward small and large translations and during the forward large translations. No differences were found between groups for other translations.

4. Discussion

We hypothesized that static and dynamic balance performance would be different among female collegiate soccer, volleyball and dance athletes. Soccer players demonstrated inferior balance performance compared to volleyball and dancers under static balance testing, while both soccer and volleyball players had inferior balance performance compared to dancers under dynamic balance testing. Many sporting activities impose significant dynamic forces on the lower extremity that are imparted during activities such as running, jumping, landing, rapid stopping and/or pivoting [21]. Balance assessments and balance training as an intervention, integrated into regular training, may improve postural control of athletes and dancers which in turn can be helpful in both prevention and rehabilitation of athletic injuries.

The US is commonly used as a measure of lower extremity strength and weight bearing control including the sensory balance control under eyes open and closed conditions. The functional consequences of this protocol are significant for performance of activities that require single-leg balance which is commonly encountered during athletic participation [18]. The results indicated that the soccer players had lower balance performance in both the right and left legs with increased medial-lateral sway and in the right leg alone with increased anterior-posterior sway. However, the significant differences were only found in the eyes open condition, which suggested that under eyes closed condition of unilateral stance, irrespective of the leg, all athletes and dancers had similar balance skills and were able to use their somatosensory-proprioceptive systems equally. However, when all three systems were available to maintain balance, the volleyball players and dancers were able to use these sensory information more efficiently and resulted in a better balance performance. The differences in anterior-posterior sway were evident only in the right leg for soccer players, which can be attributed to the side of dominance. Although, all soccer players in this study were right leg dominant and use the right leg to kick the ball, the left leg that is primarily used to maintain balance of the entire body, resulting in better in the unilateral stance test scores using the left leg.

The MCT assesses the automatic postural responses which act as the primary mechanism for balance recovery following an unexpected external perturbation to the human body [18]. Lower values on the latency scores determine quick response times and better balance maintenance and recovery following a perturbation, while prolonged latencies are indicative of musculoskeletal, biomechanical or motor control issues. Balance performances under perturbing conditions have been argued as an imperative variable in balance assessment. Such assessments may be even more critical for athletes in competitive sport who are required to maintain balance against opposing players and to change directions quickly; while dynamic balance during perturbations may be not be that crucial for dancers who in turn, require more of static balance for precise and controlled movements of their extremities in relation to their body. Our results indicate that the soccer and volleyball players had faster latencies and performed better in the dynamic balance test compared to the dancers. These results can be attributed to the nature of the sport which require quick sudden movements including rapid change of directions based on the ball and the opponent's movement and the nature of training focused on agility with these athletes.

Results from this study are consistent with previous research comparing balance performance between athletes and dancers [14]. However, this was found to be true only for the unipedal static balance performance and not for dynamic balance under perturbing conditions. This dissimilarity is also consistent with a previous study among Australian footballers, which concluded that performance in a static balance test was not reflective of performance in the dynamic balance test [22]. Due to this lack of a direct relationship between static and dynamic balance, it may be more beneficial to assess and train for static and dynamic balance, individually. Another study that used BESS and SEBT showed that soccer players and gymnasts had better balance performance when compared to basketball players [7]. A similar study that used COP sway characteristics showed that soccer players when compared to basketball players, swimmers and non-athletes had lower anterior-posterior and horizontal sway [5]. Even though soccer players have been shown to have better balance performance [5, 7], comparison of these results to our study indicate that soccer players still have lower balance performance when compared to volleyball players and professional dancers, indicating the need for further static balance training. Balance training has been shown to be effective for postural and neuromuscular improvements [23, 24] and also to reduce the rates of athletic injuries especially in the ankle [12, 13]. Furthermore, training individually for static and dynamic balance among these individuals for competitive sport and dance is highly recommended.

5. Conclusions

Based on the results of this work, we conclude that soccer players have poor balance performance under static conditions when compared to volleyball players and dancers, while the dancers showed poor balance under dynamic conditions when compared to soccer and volleyball players, indicating the further need for specific balance training in this athletic population. Our results can also be used to provide a series of recommendations for balance training in different disciplines of competitive sport with specific emphasis given to the static balance training to soccer players and dynamic training to dancers. This study also serves to provide a reproducible assessment to quantify balance performance among these athletes under both static and dynamic balance conditions, as a possible athlete monitoring tool.

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