POSTURAL CONTROL STRATEGIES IN DANCERS AND NON DANCERS

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Postural stability is typically measured by assessing total excursions of either the center of pressure or whole body center of mass. One problem with measures such as these is that interpretations or postural stability are typically made without references to any stability boundaries. Further, postural control studies are typically only conducted on individuals with balance impairments and compared to healthy controls. Little research has been conducted on athletes with high levels of postural control. This study compares the postural dynamics of elite balancers with matched control subjects using stability measures that take into account the stability boundaries of different postures.

KEY WORDS: postural control, dancers, center of pressure, center of mass, time to boundary

INTRODUCTION: Without the proper level of postural control, simple goal directed motions such as reaching and walking are difficult or impossible to perform (Riccio and Stoffregen, 1988). In older individuals postural instability often causes debilitating falls when performing functional daily tasks. The importance of postural control becomes even greater when performing sporting events that require the production of either high force or high precision movements that utilize multiple degrees of freedom. These movements can typically cause whole body postural perturbations that must be controlled by the postural system. To date, much of the research examining postural control has made inferences of postural stability based on measures that examine anterior-posterior and/or medial-lateral excursions of the center of mass (COM) or center of pressure (COP). Typically it is assumed that large excursions or variability of either the COP or COM is indicative of a postural instability. Two issues emerge when examining postural control in this manner. First, research has suggested that some degree of postural variability may be functional in that it provides information that could be used to actively explore the control space (between the individual and environment) during an activity (Van Emmerik et al., 2002). Second, measures of stability taken without regard to the individual's stability boundaries are arbitrary. For example, a given postural excursion within a large base of support is less destabilizing than the same excursion within a small base of support.

In response to the above issues, more recent research has begun to assess postural stability using boundary relevant measures. These measures assess how the COM varies within the individual's base of support. Thus, a certain magnitude of variability well within the stability boundaries is viewed as less destabilizing than the same magnitude of sway close to the stability boundaries. In the postural control literature, boundary relevant measures are an adaptation of the original *tau* control variables. Lee (1976) found that optical flow is used to control actions based on the time it would take to contact some object in the environment. The final time to boundary measure is the time it would take the COM (or COP in some studies) to contact the stability boundary (perimeter around the feet) at its current position and velocity. Time to boundary measures provide information regarding postural stability that is not available through standard COM or COP measures (van Wegen et al., 2002). Most postural research to date has focused on individuals with balance deficits (i.e. young children or adults with neurological impairments). Little work has been done on athletes who typically show high levels of balance control. Perhaps the methods of elite balancers can offer valuable information about balancing strategies. For example, in dancers, ballet training has been shown to improve overall balance control strategies (Crotts et al., 1996).

In the current study, the time to boundary of the COP and COM trajectories as well as the absolute difference between the COP and COM position (a measure typically used to assess postural control) were compared between ballet dancers and an untrained population as body configurations were changed. It was hypothesized that the average minimum time to boundary of the COM, COP and the position difference between the COM and COP would differ between the dancers (elite trained balancers) and the non-dancers (not formally trained balancers).

METHODS: Twelve trained ballet dancers (age - 19.92 years ± 1.73; height – 1.67 m ± 6.75 cm; mass - 58.75 kg ± 4.98) were recruited from the University dance department. Twelve control subjects (matched in age, height and mass) were also recruited. Kinetic measurements collected on two force platforms (AMTI model BP600600) placed side-by-side under each foot were used to determine the center of pressure. Three-dimensional kinematic data were collected at 100 Hz using six Qualisys digital cameras. A full body marker set was used to calculate whole body movements.

Subjects were barefoot and wore tight fitting clothing during the data collection. The outline of the subjects' feet was traced while standing barefoot so that the area of their base of support could be calculated. A trapezoid boundary was used for each foot in order to obtain a close approximation of the actual stability boundary. The medial and lateral boundaries of the trapezoid were calculated based on a straight line from the 1st and 5th metatarsal heads to a projection of the medial and lateral malleoli to the floor respectively. The anterior boundary was determined by a straight line across the toes intersecting the side boundaries while the posterior boundary was determined by a straight line across the heels intersecting with the side boundaries. In the case of one-footed conditions, lines parallel with the edge of the platform were used. In the case of two footed conditions, the area between the feet was included. A straight line connecting the lateral metatarsal heads was used as a posterior boundary for the demi-pointe condition. All subjects were tested under four different conditions: 1) standing on two feet shoulder width apart; 2) standing on the right foot; 3) standing on the left foot; and 4) standing on demi-pointe on two feet, parallel and hip width apart. The one-footed conditions served to minimize the base of support area in the Medial-lateral (ML) direction while the demi-pointe condition minimized the area in the anterior-posterior (AP) direction. During all conditions, the subjects were asked to remain upright without taking a step (or putting a foot or heel down in the case of certain conditions) and to keep their arms by their sides. They were also given a target 2 m away at eye level on which to focus during the 30 s data collection. Collection started after three seconds of standing still. The conditions were repeated in the same order for each individual subject for a total of three trials per condition.

The COP was determined under each force platform while the net COP between the two platforms was also determined (Winter, 1995). Total body COM was calculated using a segmental method, with subject specific segmental dimensions (Plagenhoef et al.,1983). Coordination between the COM and COP was calculated by taking the mean absolute difference in position over the 30-second trials. In order to determine the proximity of the COM and the COP to the stability boundaries, the minimum time to boundary (TtB) was calculated in both the ML and AP directions. TtB of the COP and COM was calculated as the instantaneous distance to the stability boundary divided by the instantaneous velocity. Any negative values were excluded, since a negative velocity indicates movement away from, not towards, a boundary. The average minimum TtB was calculated by taking the mean of the lowest ten minimum TtBs during the 30 second trial.

Significance was assessed using a two-factor (Group x Condition) repeated measures analysis of variance (ANOVA) with subjects nested in the Group factor and repeated over Conditions. An alpha level of .05 was used to determine statistical significance for all variables.

RESULTS: Postural stability was determined by average minimum TtB measures that were calculated from the trajectories of both the COM and the COP to the AP and ML stability boundaries. In the TtB of the COP to the AP boundary, a significant Group X Condition interaction (p = .01) was observed (Figure 1a). No significant group or interaction effects were observed in TtB of COP to the ML boundary (Figure 1b). No group effects were present in either the AP or ML boundary. In the TtB of COM measures, no significant group or group

X condition effects were observed (Figures 1c & 1d). In the COM-COP measure, no significant group differences or interactions were observed.

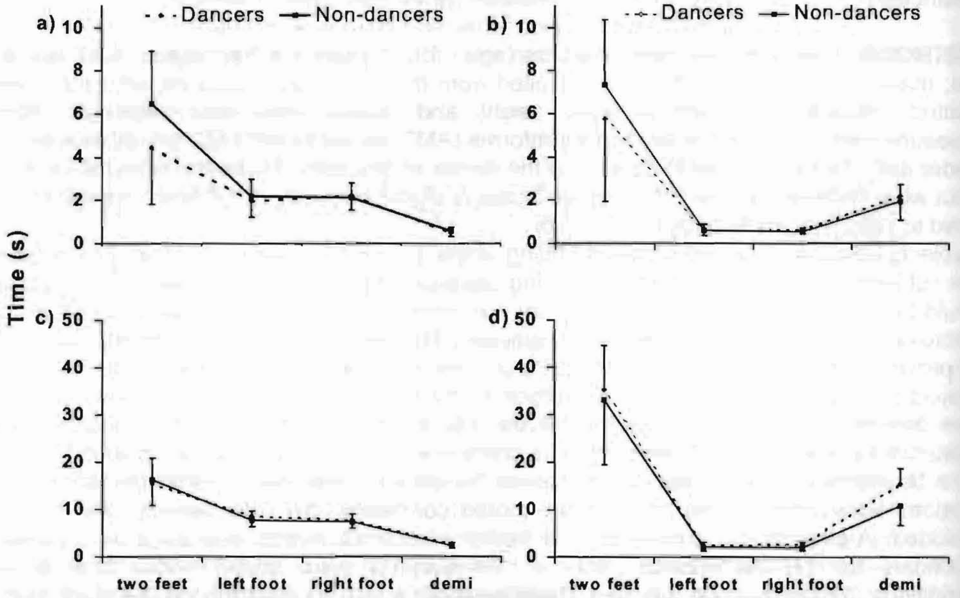

Figure 1 Mean (+SD) of the average minimum TtBs of the COP to a) the AP boundary and b) the ML boundary and of the COM to the c) AP boundary and d) ML boundary.

Condition effects were observed, where in the AP direction a narrowing of the AP boundary (demi-pointe stance) caused a decrease in the TtB to the AP boundary but not in the ML boundary. A narrowing of the ML boundary (one-footed stance) caused a decrease in the TtB to the ML boundary but not in the AP boundary. In the COP-COM AP measures, a lower average difference in distance was observed in the two feet condition. A higher average difference was observed in the demi-pointe condition. In the COP-COM ML measures a narrowing of the base of support caused in increase in the average difference in the two one-foot conditions.

DISCUSSION: The purpose of this study was to determine how the balancing techniques of trained ballet dancers differ from those used by untrained individuals. The dependent measures in this study were the average minimum TtB to both the COM and COP in both the AP and ML boundaries and the difference between the COP and COM. A group X condition interaction was observed in the TtB measures for the COP to the AP boundary. The dancers in this condition showed shorter TtB measures compared to the control subjects. Shorter TtBs may mean that the subjects were more likely to sway freely and comfortably as opposed to trying to tightly control their motion and stay very still or rigid. These results suggest dancers use more exploratory techniques during normal two-footed stance. Once the conditions became more challenging, this difference diminished. Similar results have been observed when comparing postural sway between young and older subjects (van Emmerik and van Wegen 2002). It appears that the amount of variability the system exhibits is related to the difficulty of the task. When the demands of the task are easily met by the neuromuscular system, the person may exhibit greater variability as an exploratory mechanism. If the demands of the task are not met (i.e. the task is difficult for the person), then the person may show less variability. Variability is, therefore, only beneficial if the demands of the task are met; otherwise, a large amount of systemic variability may be destabilizing. The similarity in strategy in one footed and demi-pointe conditions between groups can be explained in two ways: 1) either the dancers and non-dancers use the same strategy to balance in these conditions; or 2) the dancers take on a more rigid posture as a result of their training. The latter conclusion seems more likely since differences are seen in the 2-foot condition. Although these particular conditions are relatively basic ballet moves, they do provide a basis for more advanced maneuvers. The dancers take on a more rigid posture in the one-footed and demi-pointe conditions not because they have to in order to avoid falling, but because they need to in order to perform the elite variations of these positions.

Interestingly, TtB differences emerged only when calculated from COP. No group or interaction differences emerged when TtB was calculated from COM. COP may be the more relevant variable when examining boundary relevant postural control. It is the COP and not the COM that is under active control of the neuromuscular system. The COM is merely a passive variable that is controlled by the COP. Therefore, because the COP controls the COM it also appears to better capture the boundary relevant dynamics of postural control.

There were also no group or group X condition interactions observed when examining the difference in position between the COM and COP. Previous research has identified this variable as a postural error signal that can be detected and controlled by the neuromuscular system. A large difference is indicative of a postural instability (Winter, 1995). It appears that the dancers modulate their COP to control the COM in a similar way to non-dancers. These results suggest that dancers and non-dancers exhibit similar postural control strategies. However, the dancers seem more capable of challenging the limits of their stability boundaries.

Overall, the most important findings of this study was that a group X condition interaction was observed for the COP TtB measures but not when looking at the average COP-COM distance measure (a measure that does not reference a stability boundary). Differences in strategies between groups were thus only observed with measures that reference a stability boundary. Further research will aid in determining why differences between dancers and non-dancers for TtB were present under more relaxed or less challenging conditions than more difficult ones.

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