KINEMATIC AND TEMPORAL DESCRIPTIVE COMPARISON OF THREE STATIC BALANCE ASSESSMENT TASKS

S.O. Kennedy, J. D. Wilkerson, and W. J. Zimmermann
Texas Woman's University, Denton, TX USA

Balance is a complex process intrinsic to an individual's movement development, efficiency, and proficiency (Krus, Bruininks, & Robertson, 1981; Williams, 1983). The link between movements to maintain equilibrium and optimizing motor development is the systems ability to apply the physical laws of motion. Therefore, skillful execution of movement appears to be based on the development of one's ability to control the specific position in space relative to the internal and external environmental forces. Research on balance has primarily been based on stunt and novel tasks performance. Such research has suggested that because of low intercorrelation relationships, balance tasks are different (Bundy, Fisher, Freeman, Lieberg, & Israelevitz, 1987; Drowatzky & Zuccato, 1967) and perhaps may be testing different types or aspects of static balance. There is a vast body of literature investigating balance, as defined by the performance of novel and stunt tasks over time; however, there is a dearth of research investigating the overt mechanical process of balance during assessment. The purpose of this study was to describe the mechanical balance behavior of children during the nonlocomotor assessment of three different balance tasks used in the assessment of balance representing three different bases of support.

METHODOLOGY

Male ($\underline{n}$ = 36) and female ($\underline{n}$ = 36) children between 108 to 143 months of age from the Denton Independent School District and North Texas area were randomly selected. Subjects were determined to be free from orthoptic and refractive visual problems and other physical, emotional. and learning difficulties thereby requiring special educational services. All subjects were filmed while performing three selected balance tasks. The single leg stand (SLS), tandem stand on rail (TND), and tip-toe balance stand (TTB) were performed in random order and filmed in the critical view, exhibiting the greatest movement, using a Panasonic AG-450 camcorder at 30 fps with a shutter speed of 1/1000. A maximal balance time for all task was set at 20 s. For all three tasks the view observed represented movement within the smallest base of support.

Filmed data were reduced using the Vu Tech Freez Frame II video image capturing system and the TWU Film Analysis System developed by Noble, Zollman, and Yu (1988) modified by Zimmermann (1990). The entire balance time was observed. Every fifth frame was digitized until the last 3 s of balance when every second frame was digitized. X and Y coordinates were smoothed using the 2nd order Butterworth low pass digital recursive filter advocated by Winter (1978). Temporal and mechanical variables were extracted from the digitized data. The variables observed were (a) time-on-balance, (b) direction of loss of balance, (c) average position of the line of gravity relative to the base of support, (d) vertical displacement of the center of gravity, (e) trunk range of motion, (f) standard deviation of the line of gravity, (g) extreme recoverable line of gravity, and (h) extreme recoverable angle of stability (Donskoi, 1975). Descriptive statistics in the form of range, mean, standard deviation, and standard error of the mean were computed using SPSSX (1988) from which a comparison of variables among tasks were made.

RESULTS AND DISCUSSION

Time-on-balance, the most common assessment criterion score, was determined from film data. Subjects on the TND exhibited the shortest mean balance time (3.88 s) followed by the SLS (13.40s) and the TTB (15.63 s), respectively. No subjects were able to balance the full 20 s on the TND, whereas, for the TTB 44 of the 72 subjects maintained balance the full 20 s.

Direction of the loss of balance was reported as appropriate, inappropriate. or no loss of balance. Appropriate loss of balance occurred when the balance protocol position was broken and a new base of support was established by not crossing the midline of the body nor stepping backwards greater than 1 foot-length. For all three tasks more subjects fell off balance appropriately than inappropriately. The greater number of subjects falling inappropriately was during the TND (32). For the TTB and SLS 13 and 11 subject fell inappropriately, respectively. In contrast 35 SLS, 40 TND, and only 15 TTB fell in the appropriate direction.

The average position of the line of gravity relative to the base of support was expressed as a percent of one-half of the base. If a subject maintained a position directly over the base 0% was reported; as the center of gravity moved toward and outside the outer border of the base the percent of base was increased. The TTB with the widest base and having the longest mean balance time showed the smallest percent of base (26.72%). The TND, with the narrowest mediolateral base and shortest balance time had the greatest average position of the line of gravity from center (52.34%) and was the closest to the outside edge most of the time during time-on-balance.

The standard deviation of the line of gravity was a variable representing the overall variance of the line of gravity (sway) throughout the task to either side of the center of the base. A large standard deviation indicated the greatest movement of the line of gravity to maintain a balanced position. The SLS task was shown to exhibit the largest standard deviation of the line of gravity (1.72) followed by the TND (1.44) and the TTB

(0.96). Variability across tasks was low (0.11 to 0.20).

Vertical displacement of the center of gravity represented the amount of mechanical adjustment made at the hips, knees, ankles, and feet. A larger vertical displacement showed the subjects required greater adjustment to maintain the protocol position. Across all tasks the vertical displacements were small. The TTB was shown to have the largest mean displacement (1.84 cm) followed by the TND (1.74 cm) and SLS (1.54 cm), respectively. The TND had the greatest range and variability of scores. It was indicated that the vertical displacement of the line of gravity was a weak variable that was affected by trunk range of motion.

Trunk range of motion was a variable selected to show the degree to which subjects adjusted the largest segmental mass of the body while trying to maintain a balance position. The TND with the narrowest base showed the greatest degree of trunk range of motion (48.90°) followed by the TTB (35.62°) and the SLS (30.53°). Similar to the vertical displacement, greatest variability of scores were noted during the TND whereas the SLS subjects exhibited the least amount of variability.

The variables extreme recoverable line of gravity and extreme recoverable angle of stability were observed to represent the amount of risk taken by the subjects from which balance was maintained. How far from center or the outside edge could a subject go and still maintain balance? The extreme recoverable line of gravity was the greatest distance from center (nearest to the outside edge) from which balance was recovered. The extreme recoverable angle of stability was the most acute angle formed by the line of gravity and the line which connects the center of gravity to the outside edge (Donskoi, 1975). It is a measure of the object's stability or ability to restore balance when a disturbance occurs.

The most extreme recoverable line of gravity averaged under 3 cm for all tasks. The SLS and TND, exhibiting mediolateral movement, allowed for the least distance for the line of gravity to move and yet recover (2.12 cm, 2.45 cm, respectively). The tip-toe balance, exhibiting anterioposterior movement exhibited the greatest distance from center allowable (2.73 cm). The TND had the greatest variability among scores while the SLS had the smallest degree of variance.

The most extreme recoverable angle of stability scores ranged from 2.0° to 2.6°. The most acute angle allowed while balancing was exhibited during the TTB (2.01°).The subjects tended to risk the least during the SLS (2.58°) and the TND (2.25°) in regard to this variable.

CONCLUSION

Descriptively it was shown that during the balance performance of these 3 balance tasks, purportedly testing the same factor (non-locomotor balance) there were mechanical differences. Although similarities were noted between the SLS and TTB, the TND was the most different task. The three tasks, were shown to be descriptively different mechanically indicating these tasks are testing balance differently.

REFERENCES

Bundy, A., Fisher. A., Freeman. M. , Lieberg, G.. & Israelevitz, T. (1987). Concurrent validity of equilibrium tests in boys with learning disabilities with and without vestibular dysfunction. *American Journal of Occupational Therapy, 41*(1), 28-34.

Donskoi, D. (1975). *Grunlagen der Biomechanik* (pp 190-193). Berlin: Verlag, Bartels, & Wernitz, KG.

Drowatzky, J., & Zuccato, F. (1967). Interrelationships between selected measures of static balance and dynamic balance. *Research Quarterly, 38*, 509-511.

Krus, P.. Bruininks, R., & Robertson G. (1981). Structure of motor abilities in children. *Perceptual and Motor Skills,* 52,119-129.

Noble. L.. Zollman, D., & Yu. B. (1990). *Texas Woman's University film analysis system.* Revised by Wayne J. Zimmermann. Unpublished manuscript. Texas Woman's University, Denton.

Williams, H. (1983). *Perceptual and motor development.* Engelwood Cliffs, NJ: Prentice-Hall.