Intertester Reliability of Assessing Postural Sway Using the Chattecx Balance System

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Abstract:
In this study, we examined intertester reliability of dynamic and static balance using the Chattecx Dynamic Balance System. Ten female and two male subjects were randomly assigned to two testers and completed ten, 10-second preprogrammed double- and single-leg test conditions. Balance was measured as postural sway in centimeters by the Chattecx Dynamic Balance System. Static balance consisted of the platform remaining stable, whereas dynamic balance consisted of the platform tilting in an anterior and posterior direction during testing. The protocols and average postural sway values were:

1. Double-Leg Static Eyes Open (le = .28 cm)
2. Double-Leg Static Eyes Closed (g = .37 cm)
3. Double-Leg Dynamic Eyes Open (R= .86 cm)
4. Double-Leg Dynamic Eyes Closed (g = 1.72 cm)
5. Single-Leg Static Dominant Eyes Open (x = .99 cm)
6. Single-Leg Static Dominant Eyes Closed (x = 1.70 cm)
7. Single-Leg Static Nondominant Eyes Open (g = .65 cm)
8. Single-Leg Static Nondominant Eyes Closed (g = 1.48 cm)
9. Single-Leg Dynamic Dominant Eyes Open (R = .99 cm) 10. Single-Leg Dynamic Nondominant Eyes Open (k = .91 cm).

The mean values of postural sway ranged from .28 cm to 1.72 cm for double-leg stance measures and from .65 cm to 1.70 cm for the single-leg stance measures. The intraclass correlations (ICCs) [2,1] ranged from poor to excellent (ICCs =.06 to .90) and the standard error of measurement (SEM) ranged from .06 to .34 for the 10 trials. We feel that variability exists between subjects and/or testers between trials. The wide range of reliability values suggests that further research should determine both intratester and intertester reliability using a variety of protocols for assessment of static and dynamic balance.

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Article:

Determination of balance characteristics of uninjured individuals for differing test conditions is needed to provide clinicians with a reference for comparison when examining injured individuals. The Chattecx Dynamic Balance System (Chattanooga Group, Inc, Hixson, TN) is a computer-interfaced force platform that allows the examination of balance under static and dynamic conditions (Fig 1). The reliability for dynamic measures of balance using this system has not been previously reported.

Proprioceptive rehabilitation following injury to structures of the lower leg is an integral element in the rehabilitation of the lower extremity.[8] The terminology related to balance and proprioception in the literature has been confusing and is often used interchangeably. Several terms have been used to describe the act of balancing. The state of bodily equilibrium or, more specifically, the ability to maintain the center of body mass over the base of support has been defined as balance[5,8] and postural stability." The ability to maintain postural stability is derived from the integration of visual, vestibular, and proprioceptive neural input to the central nervous system (CNS).

Proprioception (somatosensation) is a distinct component of balance. It is the cumulative neural input from the mechanoreceptors in the joint capsules, ligaments, muscle tendons, and skin to the CNS.[12] When these structures are subjected to mechanical deformation, action potentials are conducted to the CNS where the information can influence muscular response and position sense. The integration of afferent neural input to the CNS contributes to the body's ability to maintain postural stability.

The Chattecx Dynamic Balance System has been used to assess postural stability. It is a relatively new instrument with a limited amount of published data regarding its use.[1,3,4,7,9,10] Relatively few studies have examined the reliability of the Chattecx Dynamic Balance System. Irrgang and Lephart[7] measured postural sway during unilateral stance on a stable platform. Their results indicate reasonable reliability within and between days for stable nonmoving measures of balance.

The purpose of our study was to examine the intertester reliability values for static and dynamic balance using the Chattecx Dynamic Balance System. Testing included double- leg stable and dynamic conditions with the eyes open and closed as well as single-leg stable and dynamic conditions with the eyes open and closed. The study also served to establish more normative data from which clinicians can make comparisons.

METHODS

The statistical design used in our study was a one between- subject and one within-subject repeated measures ANOVA with postural sway as the dependent variable and raters as the independent variable. Twelve healthy university graduate and undergraduate students (10 female, 2 male) participated in this study (age = 24.7 ± 3.3 yr, wt = 62.2 ± 7.5 kg, ht = 164.8 ± 7.1 cm). None of the subjects had sustained an injury to the tested extremity within 1 year before testing. Before testing, each subject read and signed a consent to participate form outlining the potential benefits and risks of the study. Both the dominant and nondominant extremities were tested. We determined dominance by asking each subject to identify the leg he/she would use to kick a ball.

Following the explanation of test procedures, we randomly assigned the subjects to one of two testers. The subjects then performed the 10 testing conditions on the Chattecx Dynamic Balance System. Following a 30-minute rest period, the second examiner retested the subjects.

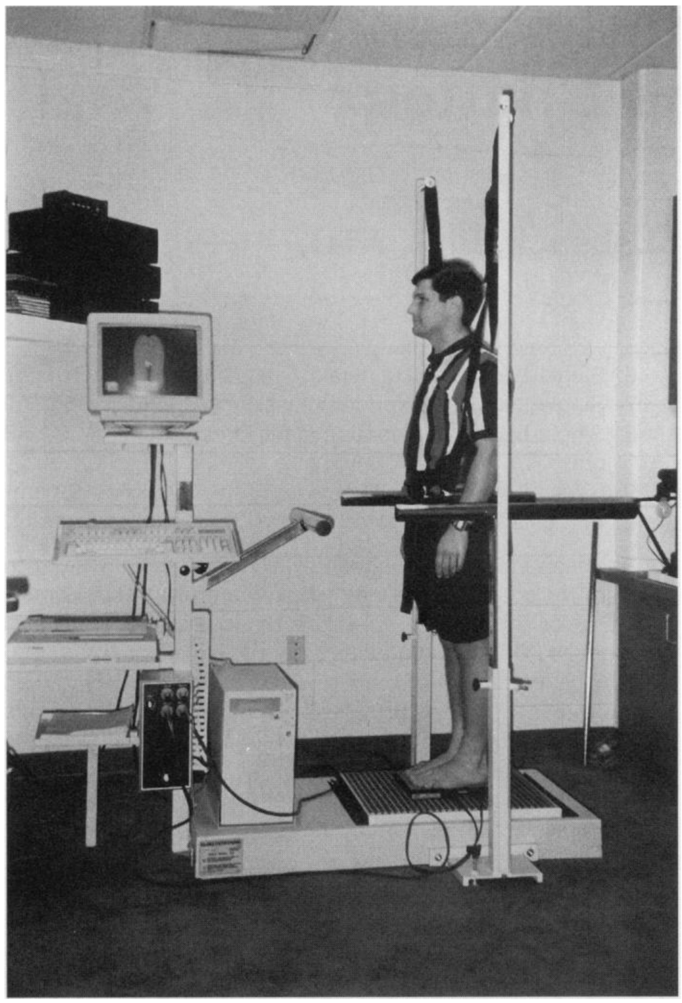


Fig 1: The Chattecx Dynamic Balance System.

Postural Sway Assessment

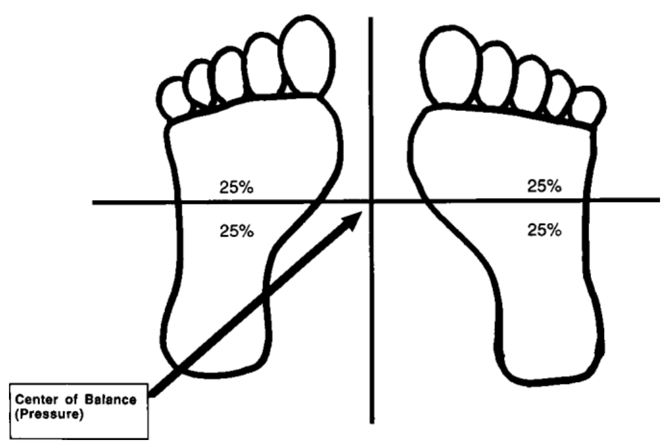
Postural sway is the distance expressed in centimeters that an individual travels away from his/her center of balance. The Chattecx Dynamic Balance System consists of four independent force-measuring transducers that are used to quantify postural stability. Fluctuations in displacement away from the center of balance reflect the amount of postural sway. Center of balance is the point between the feet where the ball and heel of each foot has 25% of the body weight (Figs 2 & 3). Deviation from this center of balance in any direction represents postural sway. A subject's center of balance is indicated graphically on the monitor screen by a red " +" and numerically by the x and y coordinates. The sway index was used as the measure of postural sway. The sway index, produced by the machine, reflects the degree of scatter of data about the subject's center of balance. The data from the force platform measurements are interfaced with software that filters and samples the data at approximately 15 cycles per second, and the sway index is calculated by the determining the distance from the subject's center of balance for each of the data points.

We tested the subjects for a total of ten, 10-second conditions. By adjusting the footplates, we centered the subject's bare feet on the footplate. The positions of the footplates were recorded using the x and y axis numerical values printed on the base platform. This information was stored for the retest condition. The computer monitor was turned away from the subject to eliminate visual feedback. During each testing condition, subjects focused on an X that was marked on the wall directly in front of them.

Subjects stood with their knees slightly flexed (5° to 15°) and their arms held at their sides. In the single-leg testing conditions, the nonweight-bearing extremity was not allowed to touch the supporting leg. We gave the subjects one practice trial before each testing condition and instructed them to stand as still as they could while being tested. We began recording when each subject indicated that he/she was ready.

In the dynamic phases of the test, the platform was tilted anteriorly and posteriorly 4° in each direction so that ankle plantar and dorsiflexion were necessary to maintain the body in an erect and stationary position.
Separate repeated measures ANOVAs were performed for each testing condition using the SPSS statistical package (SPSS, Chicago, IL). Separate ICCs were calculated from the ANOVA data to determine the reliability of the testing. We used the ICC formula[2,1] because trials were considered random effects.[13]

Fig 2: Visual representation of the center of balance for double-leg stance. "Normal" center of balance is the point between the feet where the ball and heel of each foot has 25% of the body weight.



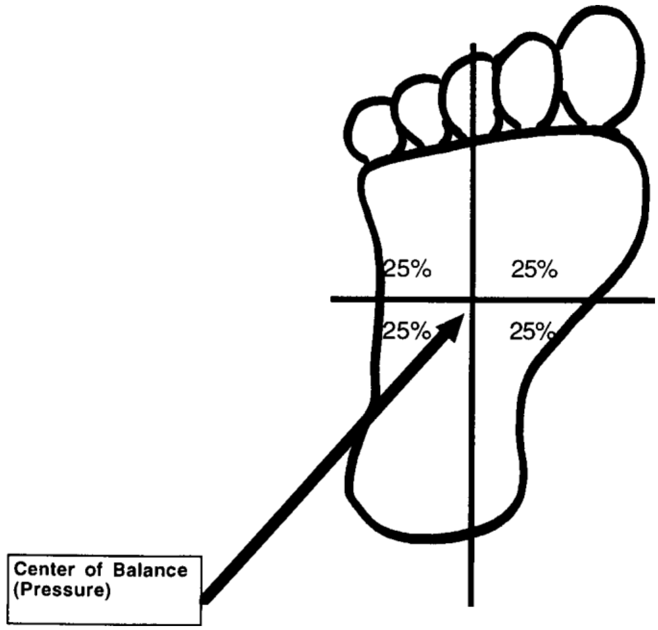


Fig 3: Visual representation of the center of balance for single-leg stance. "Normal" center of balance is the point on the foot where the ball and heel of each foot is partitioned into four quadrants, each quadrant comprised of 25% of the body weight.

RESULTS

The means and standard deviations for each testing condition are presented in the Table. ICCs, standard error of measurement (SEM), and confidence intervals (CI) are also presented in the Table. The mean values of postural sway ranged from .28 to 1.72 cm and from .65 to 1.70 cm for the double- and single-leg stance, respectively. ICCs ranged from poor (ICC = .06) to excellent (ICC = .90).

DISCUSSION

Measurement of balance has numerous potential applications in athletic training, such as determining the effect of injury, surgery, and external devices such as tape and braces on balance. It is important to establish the reliability of postural sway measurements for different testing conditions and testers. When evaluating an athlete for return to play, athletic trainers need to have confidence in the measuring devices used, as well as in the normative measures that are available to assist in these decisions. Our investigation addressed reliability of measurement and adds to the limited pool of normative data for static and dynamic balance testing conditions. The major finding of our study was that a wide range of reliability exists for static and dynamic testing conditions.

Double-Leg Testing Conditions

The lowest ICC was observed for double-leg stable platform with the eyes-closed condition. This may be because this was the first test performed with the eyes closed. The order of testing was not randomized. We intentionally arranged testing in a progression of least difficult, Double-Leg Static Eyes Open, to most difficult, Single-Leg Dynamic Nondominant Eyes Open, according to manufacturer's protocol.

The double-leg with static platform reliability coefficients for the eyes-open and eyes-closed conditions varied considerably (Double-Leg Static Eyes Open, ICC = .75 vs Double-Leg Static Eyes Closed, ICC = .06). The double-leg with dynamic platform coefficients were considerably better (Double-Leg Dynamic Eyes Open, ICC = .78 vs Double-Leg Dynamic Eyes Closed, ICC = .84). This finding was unexpected because the dynamic conditions would appear to be more challenging than the static conditions. Although we included a practice test before all test conditions, we can only speculate that this finding was related to a learning effect under the static and dynamic conditions.

Single-Leg Testing Conditions

Our ICCs for the single-leg conditions ranged from .41 to .90. ICCs provide unitless estimates of the reliability of measurement.[2] The SEM provides an estimate of the precision of measurement and is useful to determine if differences between scores are due to change or error.[2] For example, if the score for the Single-Leg Static Dominant Eyes Open condition was 0.64 cm with a SEM of .14 cm, we are 95% confident that there exists a band of error of ± .27 cm around this measurement. The .95 CI equals the mean of the sample ± 1.96 multiplied by the SEM (.95. CI = x ± 1.96 SEM).6 Likewise, if the score for the Single-Leg Dynamic Nondominant Eyes Open condition was .92 cm with a SEM of .06 cm, we are 95% confident that there exists a band of error ± .12 around this measurement. If the sway index was .92 cm on day 1 and .82 cm on day 2, the clinician can be 95% certain that the difference was due to error rather than to true change. In this example, a change greater than ± .12 cm would be necessary to attribute the difference to change rather than to error. Thus, the clinician must be conscious that the differences observed may exist due to measurement variance alone.

Postural Sway During Two Tests and Resulting Intraclass Correlation Coefficients (ICC), Standard Error of Measurements (SEM; cm), and Confidence Intervals (CI) for All Test Protocols

Protocols	Postural Sway (cm; Mean ± SD) Test 1	Test 2	ICC	SEM	95% CI
Double-Leg Static Eyes Open	.27 ± .12	.29 ± .10	.75	.06	.16-.40
Double-Leg Static Eyes Closed	.34 ± .08	.40 ± .37	.06	.26	.13-.87
Double-Leg Dynamic Eyes Open	.87 ± .39	.86 ± .38	.78	.18	.51-1.21
Double-Leg Dynamic Eyes Closed	1.81 ± .57	1.64 ± .77	.84	.27	1.20-2.22
Single-Leg Static Dominant Eyes Open	.60 ± .27	.57 ± .16	.57	.14	.31-.85
Single-Leg Static Dominant Eyes Closed	1.75 ± .47	1.66 ± .59	.57	.34	1.04-2.36
Single-Leg Static Nondominant Eyes Open	.71 ± .23	.59 ± .17	.41	.21	.24-1.06
Single-Leg Static Nondominant Eyes Closed	1.48 ± .39	1.48 ± .52	.49	.32	.86-2.10
Single-Leg Dynamic Dominant Eyes Open	1.05 ± .39	.92 ± .25	.63	.32	.36-1.60
Single-Leg Dynamic Nondominant Eyes Open	.91 ± .33	.91 ± .32	.90	.06	.79-1.04

Reliability coefficients for eyes-open vs eyes-closed conditions for single-leg testing (dominant leg) were identical (Single-Leg Static Dominant Eyes Open and Single-Leg Static Dominant Eyes Closed, ICC = .57). The coefficients for eyes-open vs eyes-closed conditions for single-leg testing (nondominant leg) were Single- Leg Static Nondominant Eyes Open, ICC = .41 vs Single-Leg Static Nondominant Eyes Closed, ICC = .49). This is important because the values reported above from our single-leg static testing conditions would be comparable to the eyes-open free- stance conditions used by Irrgang and Lephart.[7] Their protocol consisted of four test conditions that were randomly administered on the right lower extremity and consisted of Eyes Open Free Stance, Eyes Open Controlled Stance, Eyes Closed Free Stance, and Eyes Closed Controlled Stance. During free stance, the subjects were allowed to place their arms and their nonsupporting leg in any position they chose. During controlled stance, the subjects folded their arms across their chests and held their nonsupporting leg with their knees flexed to 90º.[7] Eyes-open and closed free-stance ICCs were calculated for within and between days. Within-day correlations were Eyes Open Free Stance, ICC = .82; Eyes Open Controlled Stance, ICC = .56; Eyes Closed Free Stance, ICC = .65; and Eyes Closed Controlled Stance, ICC = .72. Between-day correlation coefficients were Eyes Open Free Stance, ICC = .76; Eyes Open Controlled Stance, ICC = .47; Eyes Closed Free Stance, ICC =. 72; and Eyes Closed Controlled Stance, ICC =.63.[7] We asked our subjects to refrain from contacting the balancing extremity with the contralateral leg, and we put no restraints on the angle that the ipsilateral knee was held during each test. We found lower reliability coefficients for measures obtained during eyes open and eyes closed compared to those reported by Irrgang and Lephart.[7] This finding may be due to the influence of interexaminer testing, even though the test procedures were standardized.

Our reliability measures for the dynamic conditions were Single-Leg Dynamic Dominant Eyes Open, ICC = .63 and Single-Leg Dynamic Nondominant Eyes Open, ICC = .90. Although we would have expected the dynamic tests to be more difficult, the continual movement of the platform during the dynamic condition may have helped the subjects to remain centered on the force platform. As with the double-stance testing, the possibility of a learning effect must also be considered as a potential explanation.

RECOMMENDATIONS

Maintaining postural stability involves integrating multiple physical components. The wide range of reliability coefficients in our study is probably related to this multifaceted system. For example, concentration may be compromised due to extraneous factors such as visual or audible disturbances that may be present in the room. Also, variations in mental status may vary from test to test. Controlling for these disturbances may improve the reliability of measurement. Although every effort was made to control the test environment, our test setting was not completely isolated for this investigation.

We strongly recommend that assessment of balance occur in a completely isolated setting, while minimizing external influences. We noticed during the testing procedures that subjects had individual techniques for maintaining balance. For example, some subjects would count to themselves to remain focused on the task. Future research should examine different concentration techniques for maintaining or improving balance.

It has also been suggested that a learning effect may be present during the progression of testing conditions (Lebsack DL, et al; unpublished data, June 1994); our findings seem to support this notion. Future research should examine the learning curve associated with balance performance and determine when, if at all, a plateau occurs. It is unclear whether the ability to perform well on such measures relates specifically to dynamic joint function. Investigation of factors directly related to dynamic joint function offers an exciting challenge for further research.

CONCLUSION

We conclude that variability exists for the measure of postural sway for static and dynamic testing conditions. Athletic trainers need to recognize this variability when assessing the effects of balance deficits following injury. Currently, there is no established system of evaluating dynamic balance using field tests. The potential of incorporating measures obtained with devices such as the Chattecx Dynamic Balance System with future measures obtained using field tests may offer a solution for a more comprehensive evaluation of dynamic joint function. Secondly, the above values provide athletic trainers with a baseline (with respective confidence intervals) for future examination of postural sway parameters.

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