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Concurrent Determination of Reliability and Validity of Force Platform, Danesh Salar-e Iranian, Using Kistler's Platform in Measuring Static Balance of Men and Women Athletes; A Descriptive-Surveying Study

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Original Article

Abstract

Introduction: The aim of the current research was to concurrently determine the reliability and validity of force platform device, Danesh Salar-e Iranian, using Kistler's platform device in measuring the static balance of men and women athletes.

Materials and Methods: Participants consisted of 50 athletes (25 men and 25 women) from Isfahan City, Iran, who were selected using a purposive convenience sampling method. The research instrument included the force platform device of Danesh Salar-e Iranian model and Kistler's platform device. The subjects tried to keep their static balance on each of the force platforms for 40 seconds with eyes open and eyes closed. After 48-72 hours, test-retest was done under the same conditions as the first test. Each test repeated three times. To measure internal and time reliability, the within-group and between-group correlation tests were used. To measure the concurrent validity, the Pearson correlation test was used. The significance level was set at $P < 0.05$.

Results: Kistler's force platform in all parameters of open eyes ($P < 0.001$) and closed eyes ($P < 0.005$) and Danesh Salar-e Iranian force platform in most of the open eyes parameters ($P < 0.001$) have internal reliability. All open eyes parameters in the Kistler's platform ($P < 0.001$) and Danesh Salar-e Iranian's platform ($P < 0.030$) have shown significant repeatability. Kistler's platform has time stability in all closed eyes parameters ($P = 0.0001$) except total amplitude ($P = 0.36$). There were also significant correlations between all of the variables in the two devices ($P \leq 0.050$).

Conclusion: Danesh Salar-e Iranian force platform is a valid and reliable equipment to measure the static balance in men and women athletes in most parameters. Technical improvements of the equioment can increase the psychometric parameters of this tool, as well as its usability and effectiveness in the assessment of postural stability.

Keywords: Static balance, Validity, Reliability, Force platform, Athlete

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Introduction

Balance in humans is a physiological-mechanical state that holds the center of gravity within the range of the support surface. When the skeletal structure is in balance, the body's mechanical system performs most efficiently and minimal level of energy is expected to be consumed (1). Postural control and coordination are among the essential components of normal activity in individuals. In studies, coordination and balance are measured by observing the quality and speed of performing repetitive movements. Since balance and stance control are essential prerequisites for daily activities, investigation of movement control to train motor skills can be of interest to coaches, athletes, physiotherapists, and occupational therapists (2). Previous studies have addressed balance, postural

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control, and coordination in healthy (3), elderly (4), disabled (5), and athlete individuals (6).

Reliable tools and tests are essential for the specialists to identify postural control and maintaining balance. Various instruments have been designed to measure balance, including laboratory instruments including the force plate, the Biodex balance system (BBS), and the stabilometer. Among these tools, the force plate is one of the most common balance measuring devices (7). The balance measurement instruments currently used in the country are manufactured by other countries. For the sake of scientific independence and economic growth of the country, Iranian Danesh Salar-e Iranian company produced the force plate device for the first time in Iran. Since the use of any new tool requires determining the validity and reliability of the tool to be used correctly and reliably, its validity and reliability investigation is of particular importance.

Most previous studies have used the Pearson's correlation coefficient test as a reliability analysis test. The results of the linear correlation coefficient may indicate a linear relationship and not necessarily an agreement between the test and re-test. The intraclass correlation coefficient (ICC) has been selected as the most appropriate reliability test (8). It seems that the execution of the balance exercises varies from one session to another. Therefore, in the present study, the test-retest reliability was assessed using the data of the test performed on the same day (intra-session) and the data of the test performed on a different day (inter-session) to determine the performance reliability. In light of the above, the present study is conducted with the aim to determine the concurrent reliability and validity of the force plate manufactured by the Danesh Salar-e Iranian company with a force plate produced by Kistler Company, Switzerland, in measuring the static balance of male and female athletes.

Materials and Methods

This was a descriptive-survey study and a developmental one with regard to its type and goals. The statistical population of the study included male and female athletes of Isfahan, Iran, with the age range of 18-30 years who had at least one year of regular sport training in individual and team sports and participated in official competitions. The study sample consisted of 50 athletes (25 men and 25 women) who were selected through the purposive convenience sampling method. The study inclusion criteria included no structural postural problems, lack of lower extremity fractures over the past six months, no uncorrected visual impairments, no vestibular disorders, and no use of nerve medications, narcotics, alcohol, and any substance leading to dizziness or lack of focus and affecting balance. The exclusion criteria were any damage during the tests and the lack of timely attendance for the re-test.

To estimate the sample size required for the validation, the method described in the studies by Walter et al. (9) and Shieh (10), with $\beta = 0.20$ and $\alpha = 0.05$ and the desired ICC range between 0.70. and 0.90, was used. Using the formula, 20 individuals were estimated for each of the male and female groups of athletes, which for further validity, 25 individuals in each group and a total of 50 individuals were included in the study.

The study instruments consisted of a Kistler force plate device (9260aa6, Kistler Co., Switzerland) with dimensions of $60 \times 50 \times 5$ cm^3 placed at the Musculoskeletal Research Center, School of Rehabilitation Sciences, Isfahan University of Medical Sciences and Iranian force plate (DSI, Danesh Salar-e Iranian, Iran) with dimensions of $50 \times 40 \times 8$ cm^3. The force platform (force plate) measures and analyzes the body oscillations indirectly based on the static surface reaction to the forces exerted by changes in the center of gravity of the body, in order to measure the postural stability.

The basis of measurement in this device is the piezoelectric properties of materials which measures the ground reaction force (GRF) in the anterior-posterior, lateral, and vertical planes. A sampling frequency of 100 Hz was considered. The data were stored on a personal computer (PC) and then transferred to Excel 2007 software (version 2007, Microsoft, Office Excel, USA) to calculate the changes in the center of pressure (COP) of the body. The data were passed through the six-order 10-Hz low-pass Butterworth filter (11). The displacement of the anterior-posterior and lateral views of the COP was measured on the X and Y axes of the force plate, respectively.

To conduct the study, male and female athletes from different sport fields were first invited to participate in the introduction session and each participant was given a demographic characteristics questionnaire. The athletes who qualified in the inclusion criteria were selected to be examined. The study was approved with a code of ethics 23821402942033 by the Ethics Committee on Environmental Research, Isfahan (Khorasgan) Branch, Islamic Azad University, Isfahan, Iran. The ethical considerations were considered for all subjects, including knowledge of different stages of the study, the right to withdraw at each stage of the study, necessary care during exercise, and the right to receive information about themselves. Finally, the informed consent form was completed by the subjects and their anthropometric characteristics (height, weight, etc.) were measured and recorded. Prior to starting the main study, a pilot study was conducted on 5 patients and the examiner was introduced to possible problems.

At the beginning of the study and before beginning recording, the examiner explained the procedure of the tests to the participants. All subjects were then subjected to the static balance test in the same condition as follows. At first, the tests were run in a random sequence on one of the force plates, so that each subject stood on the force plate during 6 trials of 40 seconds. The mean of three trials of each subject for each position was calculated as a measure of his/her postural control performance. For this purpose, the subject was placed in the center of the force plate with bare and paired feet. The hands were hanging next to the body and the subject was immobile throughout the test. Postural oscillation was evaluated at two different positions of visual feedback. In the eyes-open mode, the subject was asked to gaze at a marker at a 2-meter distance from and at the same level of his or her eyes. The visual feedback in the eyes-closed mode was obtained from the subject using a blindfold on their eyes. So, he/she was asked to imagine looking at the marker. The participants performed 3 fixed standing trials with their eyes open and 3 trials with their eyes closed in a random sequence. Statistical analysis was not applied on the first and last 5 seconds of the test time to minimize the device and subject error. The subject then performed the same steps on the other force plate device. After completing the first period of tests on both devices, the subjects returned to the laboratory 48 to 72 hours later to perform the tests again. The tests were performed on both force plates under the same conditions as the first tests in a random manner. The location, method, time of day, and environmental conditions were the same for both test and retest. The information obtained from the 30-second useful test on the force plate was stored on the computer and the analysis was carried out based on calculating the changes in the COP of the feet over time. The variables included oscillation in the lateral view, oscillation in the anterior-posterior view, total oscillation, mean velocity in the lateral view, mean velocity in the anterior-posterior view, and total mean velocity in both eyes open and closed modes.

The intra-class and inter-class correlation tests were employed to measure the internal and temporal consistency of each force plate, respectively, and the Pearson's correlation coefficient test was used to assess the concurrent validity. Finally, data were analyzed in Excel 2007 and SPSS software (version 23, IBM Corporation, Armonk, NY, USA).

Since the correlation tests between the anterior-posterior oscillation velocity values in the eyes-open mode were not significant between the two force plate measurements ($P = 0.200$), a power analysis using G*Power software (version 3.1, University of Dusseldorf, Germany) was conducted to check whether the non-significance of the correlations was due to the low sample size (low study power). Setting the correlation coefficient to 0.15, significance level (alpha error) to 0.05, and study power (beta error-1) at the level of 0.8, the optimum sample size was calculated to be 37 individuals. Accordingly, the study power and sample size were in an acceptable level.

Results

The demographic characteristics of the subjects are presented in table 1.

Table 1. Demographic characteristics of participants

participant	n	Age (year)	Height (cm)	Weight (kg)	Sport history (year)
Total	50	23 ± 5	173 ± 9	22 ± 2	6 ± 3
Female	25	22 ± 5	165 ± 5	21 ± 1	6 ± 4
Male	25	22 ± 5	180 ± 6	23 ± 2	6 ± 3

Data are reported as mean ± standard deviation (SD).

The mean balance variables for each attempt on the Danesh Salar-e Iranian force plate and Kistler force plate are shown separately in table 2.

In order to examine the internal consistency of each device, the ICC test was performed separately, with the results presented in table 3.

As the findings in table 3 suggest, the Kistler force plate had internal consistency in all eyes open and closed indices and the Danesh Salar-e Iranian force plate had internal consistency in all eyes open indices (except for average velocity with $P = 0.020$) ($P < 0.050$). However, the Danesh Salar-e Iranian force plate had no internal consistency in all eyes open indices (except for total oscillation with $P = 0.001$) ($P > 0.050$). To test the temporal consistency of each device, the reliability test was performed in two time steps separately (Table 4).

Given the results reported in table 4, the two force plates showed temporal consistency in all eyes-open indices ($P < 0.050$). In addition, the Kistler force plate was of temporal consistency in all indices in the eyes-closed mode (except for total oscillation with

Table 2. Mean balance variables in the two force plates

Index			Kistler	Danesh Salar-e Iranian
Open eye	Sway (mm)	Lateral view	390.03 ± 189.77	402.57 ± 101.50
		Anterior-posterior view	459.63 ± 171.31	506.72 ± 162.30
		Total oscillation	431.99 ± 190.65	437.69 ± 105.62
	Average speed (mm/s)	Lateral view	13.00 ± 6.32	12.55 ± 3.60
		Anterior-posterior view	15.32 ± 5.71	14.41 ± 3.62
		Average total speed	14.39 ± 6.35	14.90 ± 4.62
Closed eye	Sway (mm)	Lateral view	15.05 ± 10.30	16.40 ± 4.20
		Anterior-posterior view	16.40 ± 6.89	15.71 ± 3.83
		Total oscillation	493.95 ± 99.98	505.24 ± 87.98
	Average speed (mm/s)	Lateral view	451.50 ± 309.05	462.60 ± 76.90
		Anterior-posterior view	16.40 ± 6.89	15.71 ± 3.83
		Average total speed	16.46 ± 7.35	17.32 ± 3.60

Data are reported as mean ± SD.

P = 0.060) (P < 0.050), whereas the Iranian force plate had not temporal consistency in all indices in the eyes-closed mode (except for total oscillation with P = 002) (P > 0.050). To determine the validity, the concurrent validity and Pearson's correlation coefficient test were used, the results of which are displayed in table 5.

The results of table 5 indicated that there was a significant correlation between the two force plates in all variables (P < 0.050) and the correlation coefficients in the indices varied from strong to weak. Therefore, the Danesh Salar-e Iranian device has concurrent validity at different intensities.

Discussion

The objective in this study was to determine the concurrent reliability and validity of Danesh Salar-e Iranian force plate with the Kistler force plate in measuring the static balance of male and female athletes. The findings revealed that the Iranian device was of internal and temporal consistency to measure the static balance of the male and female athletes in the eyes-open condition, but it lacked internal and temporal consistency in the eyes-closed condition. In other words, when vision information is not available, the internal consistency and temporal consistency of the force plate device are not verified. As the visual information decreases, the postural fluctuations increase one to three times (12). In the lack of the vision information, the body uses different strategies to maintain balance, with the ankle strategy being the first one.

Table 3. Intraclass correlation coefficient (ICC) for the two force plates

Index			Kistler					Danesh Salar-e Iranian				
			F-test (F = 99)		95% CI		ICC	F-test (F = 99)		95% CI		ICC
			P value	Value	Upper bound	Lower bound		P value	Value	Upper bound	Lower bound	
Open eye	Sway (mm)	Lateral view	0.001*	10.54	0.93	0.85	0.82-0.90	0.001*	2.25	0.70	0.34	0.38-0.55
		Anterior-posterior view	0.001*	5.51	0.87	0.73	0.69-0.81	0.001*	3.02	0.77	0.50	0.50-0.66
		Total oscillation	0.001*	2.18	0.69	0.31	0.37-0.54	0.001*	2.07	0.67	0.28	0.34-0.51
	Average speed (mm/s)	Lateral view	0.001*	1.54	0.93	0.85	0.82-0.90	0.001*	1.89	0.64	0.21	0.30-0.47
		Anterior-posterior view	0.001*	5.51	0.87	0.73	0.69-0.81	0.200	1.18	0.43	-0.25	0.08-0.15
		Average total speed	0.001*	2.18	0.69	0.31	0.37-0.54	0.001*	2.08	0.67	0.28	0.35-0.52
Closed eye	Sway (mm)	Lateral view	0.001*	3.24	0.79	0.54	0.52-0.69	0.330	1.08	0.38	-0.36	0.04-0.08
		Anterior-posterior view	0.001*	1.69	0.60	0.12	0.25-0.41	0.250	1.14	0.41	-0.29	0.06-0.12
		Total oscillation	0.001*	1.84	0.63	0.19	0.29-0.45	0.001*	2.13	0.68	0.30	0.36-0.53
	Average speed (mm/s)	Lateral view	0.001*	3.24	0.79	0.54	0.52-0.69	0.990	0.58	-0.14	-1.52	0.25-0.69
		Anterior-posterior view	0.001*	1.69	0.60	0.12	0.25-0.41	0.280	1.12	0.40	-0.32	0.05-0.10
		Average total speed	0.001*	1.84	0.63	0.19	0.29-0.45	0.790	0.84	0.20	-0.75	0.08-0.18

CI: Confidence interval; ICC: Intraclass correlation coefficient; P < 0.050*

Table 4. Reliability in two time steps for the two force plates

Index			Kistler					Danesh Salar-e Iranian				
			F-test (F = 99)		95% CI		ICC	F-test (F = 99)		95% CI		ICC
			P value	Value	Upper bound	Lower bound		P value	Value	Upper bound	Lower bound	
Open eye	Sway (mm)	Lateral view	0.001*	2.64	0.74	0.43	0.45-0.62	0.001*	2.00	0.66	0.25	0.33-0.50
		Anterior-posterior view	0.001*	2.32	0.71	0.36	0.39-0.56	0.001*	2.67	0.74	0.44	0.45-0.62
		Total oscillation	0.001*	2.37	0.71	0.37	0.40-0.57	0.001*	2.51	0.73	0.40	0.43-0.60
	Average speed (mm/s)	Lateral view	0.001*	2.64	0.74	0.43	0.45-0.62	0.027*	1.47	0.54	-0.01	0.19-0.32
		Anterior-posterior view	0.001*	2.32	0.71	0.36	0.39-0.56	0.001*	1.96	0.65	0.24	0.32-0.49
		Average total speed	0.001*	2.37	0.71	0.37	0.40-0.57	0.001*	2.13	0.68	0.30	0.36-0.53
Closed eye	Sway (mm)	Lateral view	0.001*	3.33	0.79	0.55	0.53-0.70	0.750	0.87	0.22	-0.70	0.06-0.14
		Anterior-posterior view	0.001*	3.27	0.79	0.54	0.53-0.69	0.240	1.14	0.41	-0.29	0.06-0.13
		Total oscillation	0.360	1.07	0.37	-0.38	0.03-0.06	0.002*	1.78	0.62	0.16	0.28-0.43
	Average speed (mm/s)	Lateral view	0.001*	3.33	0.79	0.55	0.53-0.70	0.660	0.91	0.26	-0.61	0.04-0.08
		Anterior-posterior view	0.001*	3.27	0.79	0.54	0.53-0.69	0.610	0.94	0.28	-0.57	0.03-0.06
		Average total speed	0.001*	3.04	0.77	0.51	0.50-0.67	0.910	0.76	0.11	-0.94	0.13-0.31

CI: Confidence interval; ICC: Intraclass correlation coefficient; P < 0.050*

This strategy and its associated muscle synergy are among the first patterns identified to control body oscillation in standing posture (2). The second strategy is the hip strategy which controls the center of gravity movement by creating rapid and wide movement in the hip (13). It is likely that the subjects in the present study used different strategies for maintaining balance in each attempt in the lack of vision. Therefore, the temporal and internal reproducibility of the device is questioned, and the results of the present study confirm this.

In accordance with the results of the present study, there was concurrent validity between the Kistler force plate and Danesh Salar-e Iranian force plate in some indices. There was a strong concurrent validity in the eyes-open mode for the whole oscillation range. Moreover, it was acceptable in the lateral oscillation range and moderate in the anterior-posterior oscillation range, although this validity was very weak in the eyes-closed condition and in case of the oscillation velocity, in the eyes-open mode. Factors such as group differences, test length, and sample size affect the concurrent validity coefficient (14). The sample size in this study (n = 50) could be one of the reasons for the significant correlation coefficient between the two devices. In the studies performed in this regard, the number of repetitions varied between 1 and 5. Santos et al. concluded with a study that long attempts with several measurements were required to achieve an acceptable reliability. However, they suggested that these long attempts may vary in different communities (15).

Table 5. Results of correlation coefficients between the two force plates

Index			Correlation coefficient	P value
Open eye	Sway (mm)	Lateral view	0.74	0.001*
		Anterior-posterior view	0.57	0.001*
		Total oscillation	0.89	0.001*
	Average speed (mm/s)	Lateral view	0.29	0.010*
		Anterior-posterior view	0.37	0.010*
		Average total speed	0.19	0.040*
Closed eye	Sway (mm)	Lateral view	0.30	0.010*
		Anterior-posterior view	0.11	0.050*
		Total oscillation	0.37	0.010*
	Average speed (mm/s)	Lateral view	0.54	0.001*
		Anterior-posterior view	0.17	0.030*
		Average total speed	0.75	0.001*

P < 0.050

Limitations

The time of data recording and the number of repetitions may be among the limitations of the present study that should be considered in future studies.

Recommendations

In the present study, the time duration of 30 seconds and 3 repetitions may be among the reasons for the low correlation between the concurrent validity of the two devices. Therefore, it is suggested that further time duration and repetitions be examined in future studies (15). Since dynamic balance measurement is also important for athletes, it is recommended to test the validity and reliability of the device in the dynamic balance test as well. Since the validity of the Danesh Salar-e Iranian force plate was verified in certain conditions and only for certain cases, it is advisable to use it alternatively in case of a limitation in the tools and only in the eyes-open conditions, and is should be used with caution when using results in the eyes-closed mode.

Conclusion

The results of the present study showed that Danesh Salar-e Iranian force plate device is a valid and reliable instrument for measuring static balance of male and female athletes in the eyes-open condition in most of the indices. In case of upgrading the tool, repeating the study, and obtaining the concurrent validity with good and strong correlation coefficients, this tool can be introduced to the scientific community.

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Authors' Contribution

Sara Alijani: Study support, executional, and scientific services, providing study equipment and samples, data collection, manuscript preparation, expert manuscript evaluation in scientific terms, final manuscript verification for submission to the journal, responsibility for maintaining the integrity of the study process from beginning to publishing, and responding to reviewers' comments; Zohreh Meshkati: Study design and ideation, study support, executional, and scientific services, providing study equipment and samples, analyzing and interpreting results, specialized statistics services, manuscript preparation, expert manuscript evaluation in scientific terms, final manuscript verification for submission to the journal, responsibility for maintaining the integrity of the study process from beginning to publication, and responding to the reviewers' comments; Ebrahim Sadeghi-Demneh: study support, executional, and scientific services, providing study equipment and samples, analyzing and interpreting results, specialized statistics services, manuscript preparation, expert manuscript evaluation in scientific terms, manuscript verification for submission to the journal, responsibility for maintaining the integrity of the study process from beginning to publication, and responding to the reviewers' comments.

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Conflict of Interest

The authors declare no conflict of interest.

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