Scand J Rehab Med 21:187–195, 1989

STANDING BALANCE IN HEALTHY SUBJECTS

Evaluation of a Quantitative Test Battery on a Force Platform

Charlotte Ekdahl,[1] Gun Britt Jarnlo[2] and Sven Ingmar Andersson[1]

From the [1]Department of Community Health Sciences, Lund University, S-240 10 Dalby and the [2]Department of Physical Therapy, Lund University, S-220 05 Lund, Sweden

ABSTRACT. A quantitative battery of tests for standing balance is needed in the assessment of functional impairments. The aims of the present study were to obtain stabilometric reference values for healthy females and males, 20–64 years of age, on a stable computerized force platform (AMTI) and to relate the balance data thus obtained to some traditional functional balance tests. Altogether, 152 subjects performed a series of tests. The test battery on the force platform comprised tests of standing with feet close together or on one leg while looking straight ahead or while blindfolded. Traditional functional balance tests were checked and various background data were collected through a questionnaire. Results of a separate test–retest reliability study of the test battery given on the force platform appeared promising, especially for the tests with eyes open. In the main study, results obtained on the force platform correlated significantly ($p<0.001$) with results of most of the functional tests. Women showed higher standing balance as compared with men. The results suggest the importance of relating the test-data not only to age but also to sex.

Key words: posture, equilibrium, stabilometry, functional capacity, normal subjects, reference values, sex factors, age factors.

INTRODUCTION

A quantitative and standardized test battery for standing balance is needed for the assessment of functional impairments in the elderly and in patients with various diseases. The standing balance involves physiological as well as psychological characteristics of the individual (30).

Several studies have reported postural sway in standing to be related to age (7, 12–14, 16, 19, 25, 28, 29) and sex (14, 17, 20, 22, 29), although various authors have failed to find significant relationships with age (5, 17) or with sex (5, 7, 27). Vision has been described as being an important stabilizing factor in standing upright (5, 10, 12–14, 18, 26, 27). Also, severe hearing loss has been shown to correlate with increased sway (17). Drugs with sedative properties may increase sway, although some studies indicate groups of subjects receiving such medication to not differ in amount of sway from groups receiving no medication (7, 22). Weight and height have been partly found to influence (13, 23) and partly to have no influence (4) on standing balance.

Since Romberg's observations more than a century ago, different quantitative tests of standing balance have been developed. Reviews of results concerning various systems for postural measurement have been presented (2, 4). In clinical practice and research, different functional balance tests have been used (6, 15, 26). Several technical arrangements to obtain more detailed quantitative measurements have been developed, for example Wright's ataxiameter (7, 22), stationary stable force platforms (3, 5, 8, 14, 17, 23, 27–29), and tilting platforms (11, 13, 20, 21).

Force platform variables, such as length of sway path and area, have been found useful for the quantification of body sway in patients with, for example, cerebellar lesions (9).

The present study aims at obtaining stabilometric reference values for age (20 to 64 years) and sex on a stable force platform (AMTI), and to relate the balance data thus obtained to traditional functional balance tests commonly used in clinical practice.

SUBJECTS AND METHODS

Subjects

The subjects in the main investigation were 152 volunteers (78 women and 74 men) divided into age groups as shown in Table I.

The criteria for participation were as follows: being 20–64 years of age, being employed by the University Hospital in Lund, feeling healthy, and having no subjectively experienced problems of maintaining standing balance. Subjects were excluded if they had a chronic (rheumatic, neurological or psychiatric) disease that might influence the results. Var-

Table I. *Age and sex groups*

Age (years)	Females	Males
20–29	13	12
30–39	11	12
40–44	10	10
45–49	10	10
50–54	11	10
55–59	13	10
60–64	10	10
Total	78	74

Table II. *Characteristics of the subjects*

Height (females/males)	165/177 cm
Mean range	154–187/160–196
Weight (females/males)	62/77 kg
Mean range	47–81/63–101
Sight (normal/slight impairment)	76/24%
Hearing (normal/slight impairment)	91/9 %
Workload (light/moderate/heavy)	22/61/17%
Leisure-activities (sitting/light/hard/elite)	14/66/17/3 %
Earlier major injuries (bilat./unilat./no)	8/19/73%
Medication (yes/no)	13/87%
Alcohol (regularly/seldom/never)	20/66/14%

ious characteristics of the subjects other than age are shown in Table II. The group of patients with regular medication (13%), comprised 10 subjects treated with anticontraceptive drugs, 7 with beta-blockers, 2 with antacid drugs and 1 with thyroid hormone medication.

In addition, a group of 10 other healthy volunteers, all of them physiotherapy students (5 women and 5 men; mean age =26.8 years, SD =6.5, range =23–45 years), were studied four times at one-week intervals in order to evaluate retest reliability for the measurements included in the study.

Methods

Functional tests. The functional tests, all performed on the floor, were given in the following order:

(i) Walking with ordinary shoes on as fast as possible for 30 meters in a hospital corridor, making one turn in the process. The time in seconds was noted.

(ii) Standing on one leg with the other slightly flexed, first the right and then the left, for 30 sec without shoes, looking straight ahead. Either *yes* (success) or *no* (failure) was recorded. Three trials on each leg were allowed. During the test, the subject was not allowed to move the foot from the initial position. Compensatory movements of arms and lifted leg were accepted.

(iii) Standing blindfolded under the same conditions as in (ii) for as long as possible. The highest value in seconds was noted.

(iv) Coordination test, performed in a standing position, requiring concomitant flexion of one arm and the opposite leg, alternating between right and left as fast as possible for 15 sec. The number of alternations was calculated.

Force platform. An AMTI force platform (Model OR6-5-1) was used to measure two force components in the lateral and sagittal planes concomitantly (1). The force platform was connected to a personal computer (IBM) via an analog/digital converter (DT2801-A). An AMTI SGA6-4 Signal Conditioner Amplifier was used in conjunction with the force platform. CAS (Computer Automated Stability Analysis) software calculated the mean position of the center of pressure relative to the platform coordinates, and plotted the sway data relative to this mean position. The following parameters were selected for the test battery: x, y = mean sway amplitude (cm) from the mean position in the lateral and sagittal directions, respectively; velocity = mean velocity (cm/sec) along the sway path; length = length of the sway path (cm); area = area included within sway path (cm^2).

The sampling interval for the 30-sec recordings was 0.1 sec. A 30-sec period was selected on the basis of the use to which the platform was later to be put in testing elderly persons and patients with various diseases.

Test battery on the force platform. The tests included in the battery were presented in the order of what was assumed to be increasing difficulty. All tests on the force platform were conducted for 3×30 sec. The following battery of tests, each to be performed without shoes, was given:

(v) Standing with the feet close together looking straight ahead and with the arms hanging (Test I);

(vi) Standing blindfolded in the same position as in (v) (Test II);

(vii) Standing on one leg, first the right and then the left, looking straight ahead. Compensatory movements of the arms and the lifted leg were accepted (Test III right, Test IV left);

(viii) Standing blindfolded in the same position as in (vii) (Tests V and VI).

The length of the sway path when standing on one leg and looking straight ahead was selected as a single test of standing balance. The results obtained from the second of the three recordings were used.

Questionnaire. The following variables were registered through a self-administered questionnaire: height, weight, sight (normal with glasses included if necessary/slight impairment), hearing (normal/slight impairment), profession, leisure-time activities, continuous medication including anticontraceptive drugs (yes/no), and earlier injuries of a major character (spine or legs) (bilateral/unilateral/no). The profession was recorded in terms of physical requirements (1 = mainly sitting, 2 = frequent movements but without heavy work-load, 3 = heavy work-load). Leisure-time activities were recorded according to Saltin and Grimby (24) on a four-point scale (1 = mainly sitting activities to 4 = regular participation in heavy sport activities at a high level of performance). Subjects were also asked about their habits of drinking alcohol (never/not every week/regularly every week).

Statistics. Pearson and Spearman correlations were calculated for interval and nominal/ordinal scale data, respectively. Analyses of variance (ANOVAs) were employed for data concerning sex and age in relation both to force platform

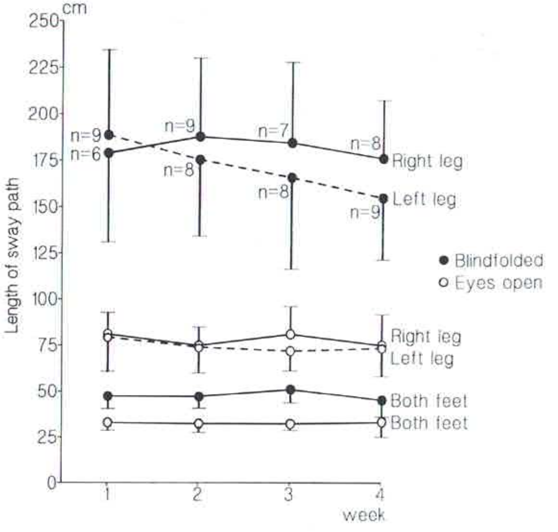

Fig. 1. Mean values and standard deviations for the test-battery on the force platform (second measurement) for the ten subjects included in the reliability study. Length of sway path at four different occasions.

measures (length of sway path) and to functional balance tests. A significance level of alpha =0.01 was chosen for the main study.

RESULTS

Tests on the force platform

Results concerning the test–retest reliability for the 10 subjects of the test-battery given on the force platform are shown in Fig. 1. All subjects managed to perform the tests involving standing with feet close together and of standing on one leg when looking straight ahead, but some were unable to carry out the task of standing on one leg blindfolded. The mean values for the group on the different tests varied relatively little from week to week, being especially constant for the tasks of standing on one leg and looking, and of standing with both feet together while looking or while blindfolded. The correlations between second recordings of length of sway path for weeks 1 and 4 were $r_S = 0.80$ ($p < 0.01$) and $r_S = 0.60$ ($p = 0.07$) for standing with feet together while looking straight ahead and while blindfolded, respectively. As to standing on one leg looking straight ahead, the corresponding values were $r_S = 0.65$ ($p < 0.05$) and $r_S = 0.72$ ($p < 0.05$) for the right and the left leg, respectively. Standing blindfolded on one leg did not reach significance in any case; $r_S = 0.37$ and 0.60 for the right and the left leg, respectively. Furthermore, the results indicated the second of the three 30-sec recordings on each test to in general yield a value about 5% higher than the mean value for the three recordings. Thus, for each test in the battery, the presented results refer to the second of the three recordings only.

In the main study, the numbers of subjects who managed to perform the various tests, as well as group means and standard deviations for velocity, length of sway path and area, are shown in Table III (males) and IV (females). All 152 subjects succeeded in performing the tests involving standing with feet together while looking straight ahead or while blindfolded. Furthermore, all but one of the subjects 20–54 years of age, managed to stand on one leg looking straight ahead, both left and right, for 30 sec. None of the men and only a few of the women over 50 years of age could perform the tests of standing blindfolded on one leg (Tables III and IV).

Separate ANOVAs were performed with regard to sex and age ($\leqslant 54/\geqslant 55$ years of age), using length of sway path (second measurement) of Tests I–IV as dependent variable. Results indicated sex and age differences to be present on Tests II–IV ($p < 0.01$). On Test I, p values were 0.02 for both age and sex. Males were found here to show greater sway than females, and older subjects to show greater sway than younger ones. Elimination of the 20 subjects who were treated with medication of any sort yielded essentially the same results.

Fig. 2 shows results of standing balance obtained

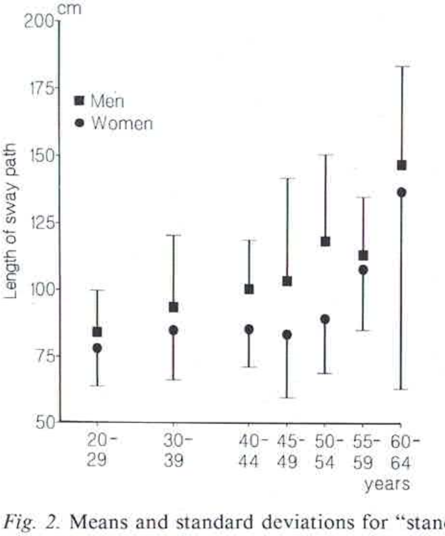

Fig. 2. Means and standard deviations for "standing on the left leg" while looking straight ahead on the force platform (length; second measurement) at various age groups.

Table III. *Means, standard deviations, and frequencies in the various age groups of males who succeeded i performing the tests (second measurement)*

For each of the six tests (I–VI), abbreviations refer to the following parameters: x, y = mean sway amplitude (cm), ve = velocit (cm/sec), le = length of sway path (cm), ar = area (cm^2).

		20–29 yrs n=12			30–39 yrs n=12			40–44 yrs n=10			45–49 yrs n=10			50–54 yrs n=10		
Test		*M*	SD	*n*	*M*	SD	*n*	*M*	SD	*n*	*M*	SD	*n*	*M*	SD	*n*
I	x	0.3	0.1	12	0.4	0.1	12	0.3	0.1	10	0.3	0.1	10	0.4	0.1	10
	y	0.3	0.1	12	0.4	0.1	12	0.4	0.1	10	0.4	0.1	10	0.4	0.1	10
	ve	1.3	0.3	12	1.4	0.5	12	1.4	0.2	10	1.3	0.3	10	1.6	0.4	10
	le	38.8	8.6	12	43.1	14.4	12	40.7	6.5	10	38.3	7.8	10	46.2	12.2	10
	ar	6.2	1.9	12	8.7	3.9	12	7.1	2.2	10	6.4	3.0	10	8.1	2.9	10
II	x	0.5	0.1	12	0.5	0.1	12	0.5	0.2	10	0.4	0.1	10	0.5	0.1	10
	y	0.5	0.2	12	0.4	0.2	12	0.6	0.3	10	0.4	0.1	10	0.4	0.1	10
	ve	2.0	0.6	12	2.3	0.7	12	2.3	0.8	10	2.1	0.9	10	2.5	1.1	10
	le	58.7	17.1	12	68.3	22.0	12	67.9	22.4	10	62.2	27.2	10	74.6	31.9	10
	ar	13.6	7.4	12	16.1	7.9	12	20.9	17.1	10	12.8	7.5	10	18.4	9.2	10
III	x	0.4	0.1	12	0.4	0.1	12	0.4	0.1	10	0.4	0.1	10	0.5	0.2	10
	y	0.6	0.2	12	0.5	0.2	12	0.6	0.3	10	0.6	0.2	10	0.6	0.2	10
	ve	3.3	0.9	12	3.1	0.8	12	3.4	0.8	10	3.4	1.4	10	4.3	1.5	10
	le	98.9	26.0	12	94.0	24.0	12	101.1	22.7	10	99.8	42.5	10	129.6	42.8	10
	ar	25.1	9.3	12	20.8	8.6	12	26.8	13.7	10	27.2	17.2	10	39.2	23.2	10
IV	x	0.4	0.1	12	0.4	0.1	12	0.4	0.1	10	0.4	0.1	10	0.5	0.1	10
	y	0.5	0.1	12	0.6	0.1	12	0.6	0.2	10	0.6	0.2	10	0.7	0.1	10
	ve	2.8	0.5	12	2.9	0.6	12	2.9	0.5	10	2.8	0.5	10	3.0	0.7	10
	le	84.1	15.7	12	93.6	26.9	12	100.5	18.3	10	103.0	38.5	10	118.4	32.5	10
	ar	19.2	5.3	12	23.7	9.9	12	26.1	12.6	10	28.0	15.6	10	36.3	17.0	10
V	x	0.8	0.1	7	0.9	0.2	4	1.1	0.3	3	1.0	0.1	2	.	.	0
	y	0.8	0.3	7	0.9	0.4	4	1.4	0.4	3	1.1	0.5	2	.	.	0
	ve	5.7	0.4	7	6.6	2.0	4	11.4	4.8	3	7.8	1.6	2	.	.	0
	le	171.9	12.6	7	199.2	60.4	4	340.3	145.0	3	235.1	49.1	2	.	.	0
	ar	71.8	28.9	7	97.8	64.4	4	216.6	131.3	3	134.3	71.6	2	.	.	0
VI	x	0.8	0.2	6	0.9	0.3	5	0.9	0.2	3	0.8	0.3	5	.	.	0
	y	1.0	0.4	6	0.9	0.3	5	0.9	0.0	3	1.0	0.2	5	.	.	0
	ve	5.9	1.4	6	6.6	2.0	5	8.0	1.3	3	7.8	1.5	5	.	.	0
	le	176.2	42.5	6	196.4	60.2	5	239.4	38.7	3	234.3	46.2	5	.	.	0
	ar	83.3	32.9	6	93.6	50.6	5	111.8	33.5	3	124.0	38.8	5	.	.	0

for standing on the left leg looking straight ahead (second measurement). A significant sex difference was found for this variable in the group as a whole (F=6.02, df=1, p=0.01), the mean value for females being lower (decreased sway) than for males, a result also found for each age group. The variables of velocity and area showed a similar pattern. The older subjects showed greater length of sway path than the younger.

Functional tests

All subjects up to 54 years of age were able to perform tests of standing on one leg looking straight ahead for 30 sec. The results for the various age and sex groups using traditional functional tests (standing blindfolded on one leg, coordination- and walking tests) are shown in Table V.

Separate ANOVAs were performed with regard to sex and age ($\leqslant 54/\geqslant 55$ years of age) with the functional balance tests described in Table V serving as dependent variables. The results showed significant age differences ($p<0.01$) on both the one-leg standing tests while blindfolded and the walking test, with impaired performance in the older subjects. No sig-

55–59 yrs $n=10$			60–64 yrs $n=10$		
M	SD	*n*	*M*	SD	*n*
0.3	0.1	10	0.4	0.1	10
0.3	0.1	10	0.4	0.1	10
1.3	0.3	10	1.8	0.6	10
39.6	7.5	10	55.1	17.2	10
6.1	2.3	10	10.4	6.7	10
0.4	0.1	10	0.6	0.2	10
0.4	0.1	10	0.6	0.2	10
1.9	0.5	10	3.4	1.2	10
57.6	14.6	10	105.5	36.7	10
11.7	4.7	10	31.1	14.0	10
0.4	0.1	9	0.5	0.1	8
0.6	0.1	9	0.5	0.1	8
3.9	0.7	9	4.7	1.3	8
116.9	20.4	9	144.2	40.2	8
31.9	12.9	9	36.6	16.0	8
0.5	0.1	8	0.6	0.1	8
0.6	0.1	8	0.5	0.1	8
3.6	0.7	8	4.5	2.1	8
113.3	21.8	8	147.1	36.9	8
30.0	10.5	8	39.4	12.4	8
.	.	0	.	.	0
.	.	0	.	.	0
.	.	0	.	.	0
.	.	0	.	.	0
.	.	0	.	.	0
.	.	0	.	.	0
.	.	0	.	.	0
.	.	0	.	.	0
.	.	0	.	.	0
.	.	0	.	.	0

nificant differences concerning sex were found. No significant age or sex differences were found on the coordination-test.

Correlations between stabilometric and functional test results

The correlations between traditional functional tests and force-platform measures for the total group are shown in Table VI. Both the measures of one-leg standing blindfolded and of walking 30 m and the force-platform measures (length, velocity, area) were significantly correlated (r_P ranging from 0.30 to 0.42, $p<0.001$). The coordination-test measure showed virtually zero correlations with the force-platform measures.

Correlations between stabilometric results and subjects' characteristics

Significant correlations were found between age and length of sway path on one-leg standing while looking straight ahead ($r_P=0.40$ for the right and 0.48 for the left leg, $p<0.001$ in both cases), indicating older subjects to show increased length of sway path than younger ones. No significant correlations were found between length of sway path and other characteristics of the subjects as described in Table II (height, weight, sight, hearing, workload, leisure-time activities, major injuries earlier, medication, and alcohol consumption), as calculated both for the total group (for height and weight, r_P ranging from 0.17 to 0.07) and separately for the two sexes (for height and weight, r_P ranging from 0.10 to -0.23).

Concerning earlier major unilateral injuries, a greater length of sway path was found for the injured leg than for the non-injured one.

DISCUSSION

Postural sway has been considered as part of standing balance, although there is no adequate consensus regarding how standing balance should be defined.

The reliability of the test battery carried out on the force platform may be regarded as acceptable, since the correlations-coefficients obtained were relatively high (r_S at least 0.60 for the two-leg standing tests and at least 0.65 for the one-leg tests of standing while looking straight ahead). Standing on one leg while looking straight ahead or while blindfolded seemed to be more difficult with the *right* leg than the *left*. This could possibly be interpreted as a learning effect or as a result of increased motivation, considering the fixed order of the tests given in the battery. Standing blindfolded on one leg appeared to be of almost a maximun level of difficulty, considering the high number of drop-outs. The relatively large number of drop-outs (4 out of 10) occurring during the initial week on the task of standing on the right leg while blindfolded may explain the relatively low mean sway value obtained. These results seem to accord, at least in part, with those of Black et al. (5), who found a significant improvement for the second trial on most of the tests they employed when studying postural sway in normal subjects.

Table IV. *Means, standard deviations, and frequencies in the various age groups of females who succeded i performing the tests (second measurement)*

For abbreviations, see Table III

Test		20–29 yrs $n=13$			30–39 yrs $n=11$			40–44 yrs $n=10$			45–49 yrs $n=10$			50–54 yrs $n=11$		
		M	SD	*n*	*M*	SD	*n*	*M*	SD	*n*	*M*	SD	*n*	*M*	SD	*n*
I	*x*	0.3	0.1	13	0.3	0.1	11	0.4	0.1	10	0.3	0.2	10	0.3	0.1	11
	y	0.4	0.2	13	0.3	0.1	11	0.5	0.2	10	0.4	0.1	10	0.3	0.1	11
	ve	1.2	0.2	13	1.2	0.2	11	1.5	0.6	10	1.2	0.3	10	1.2	0.3	11
	le	35.8	7.2	13	34.8	5.7	11	43.9	18.2	10	37.2	10.3	10	36.5	7.5	11
	ar	6.6	3.9	13	5.7	2.3	11	9.8	8.3	10	6.1	3.1	10	5.6	1.6	11
II	*x*	0.5	0.2	13	0.4	0.1	11	0.5	0.2	10	0.4	0.2	10	0.4	0.1	11
	y	0.5	0.1	13	0.4	0.1	11	0.4	0.1	10	0.4	0.1	10	0.4	0.2	11
	ve	1.8	0.4	13	1.9	0.5	11	1.7	0.3	10	1.6	0.4	10	1.7	0.6	11
	le	53.5	10.6	13	55.3	13.8	11	51.3	9.6	10	47.2	11.7	10	51.2	16.4	11
	ar	13.4	6.3	13	11.8	6.1	11	11.7	5.7	10	9.8	4.5	10	10.9	5.5	11
III	*x*	0.4	0.1	13	0.4	0.1	11	0.4	0.1	10	0.4	0.1	10	0.4	0.1	10
	y	0.5	0.1	13	0.6	0.2	11	0.6	0.1	10	0.5	0.2	10	0.5	0.1	10
	ve	2.6	0.5	13	3.0	0.7	11	2.8	0.5	10	2.8	0.5	10	2.6	0.6	10
	le	72.0	23.2	13	89.5	22.2	11	85.0	14.1	10	84.9	15.6	10	78.8	16.6	10
	ar	16.4	5.7	13	25.9	9.8	11	20.8	5.9	10	18.6	8.4	10	17.9	4.2	10
IV	*x*	0.4	0.1	13	0.4	0.1	11	0.4	0.1	10	0.4	0.1	10	0.4	0.1	11
	y	0.6	0.3	13	0.5	0.2	11	0.6	0.1	10	0.5	0.2	10	0.6	0.2	11
	ve	2.6	0.7	13	3.0	0.8	11	3.1	0.6	10	3.1	1.0	10	3.4	1.0	11
	le	78.1	14.3	13	85.0	17.7	11	85.5	14.3	10	83.6	14.3	10	89.5	20.5	11
	ar	19.9	8.5	13	19.2	7.0	11	20.5	4.3	10	20.1	7.9	10	25.3	9.6	11
V	*x*	0.8	0.2	7	0.8	0.2	4	0.8	0.0	2	0.8	0.1	3	0.6	.	1
	y	0.9	0.1	7	0.8	0.1	4	0.8	0.1	2	0.9	0.1	3	0.6	.	1
	ve	5.9	0.7	7	4.2	0.9	4	7.8	1.1	2	7.1	1.7	3	5.6	.	1
	le	176.0	19.7	7	216.9	26.0	4	233.4	32.0	2	199.7	68.0	3	166.6	.	1
	ar	75.4	15.8	7	94.0	27.2	4	92.2	24.9	2	88.1	28.4	3	50.2	.	1
VI	*x*	0.8	0.2	9	1.0	0.1	2	0.8	0.2	2	0.8	.	1	0.9	0.3	3
	y	0.9	0.2	9	1.1	0.0	2	0.8	0.2	2	0.7	.	1	1.0	0.3	3
	ve	6.2	1.4	9	8.1	1.2	2	7.9	1.8	2	5.8	.	1	8.2	3.4	3
	le	187.3	41.5	9	241.4	34.9	2	238.1	52.3	2	175.2	.	1	244.7	101.1	3
	ar	82.9	32.7	9	127.5	21.2	2	97.0	45.7	2	59.9	.	1	123.9	81.9	3

The order of the various tests in the test battery given on the force platform appeared to be that of increasing level of difficulty. Thus, for example, standing on one leg while looking straight ahead seemed to be more difficult than standing with feet together while blindfolded. It appeared to be normal for both women and men up to 54 years of age to be able to stand on one leg for 30 sec looking straight ahead, whereas the procedure of standing on one leg while blindfolded seemed to offer considerable problems at any age. None of the subjects in the age-interval 55–64 years could perform the tests of standing on the right or on the left leg blindfolded. For all age groups, the results obtained on the platform for those tests involving standing with feet together yielded a ratio of about 0.7 for sway while looking straight ahead versus while blindfolded. Throughout, the inter-subject variability was large in the oldest age group (60–64 years). Black et al. (5) also noted high inter-subject variances in subjects older than 50.

A single measure of standing balance, i.e., the second measurement of length of the sway path for one-leg standing, was selected for several reasons. It was argued, from a theoretical point of view, that the

55–59 yrs $n=13$			60–64 yrs $n=10$		
M	SD	*n*	*M*	SD	*n*
0.4	0.1	13	0.3	0.1	10
0.4	0.1	13	0.3	0.1	10
1.3	0.2	13	1.5	0.4	10
39.3	7.0	13	45.4	11.5	10
7.3	1.7	13	8.1	3.8	10
0.6	0.2	13	0.5	0.2	10
0.4	0.1	13	0.4	0.1	10
2.2	0.7	13	2.6	1.5	10
67.3	29.4	13	76.5	43.5	10
18.7	15.0	13	18.8	19.4	10
0.4	0.1	10	0.5	0.1	6
0.5	0.2	10	0.6	0.3	6
3.5	0.8	10	3.9	1.9	6
104.6	24.0	10	116.8	55.8	6
26.0	8.6	10	33.1	24.6	6
0.5	0.1	11	0.5	0.2	8
0.5	0.2	11	0.5	0.1	8
3.7	0.7	11	4.6	1.6	8
107.9	22.6	11	137.0	59.9	8
27.8	9.5	11	37.7	26.9	8
.	.	0	.	.	0
.	.	0	.	.	0
.	.	0	.	.	0
.	.	0	.	.	0
.	.	0	.	.	0
.	.	0	.	.	0
.	.	0	.	.	0
.	.	0	.	.	0
.	.	0	.	.	0
.	.	0	.	.	0

parameter of *length* would offer a greater potential than that of *area* in describing sway. Thus, for example, the length of the sway path appears to more adequately take account of the action which occurs than does area, since a large amount of sway may occur within a restricted area (1). One-leg standing tests were selected since these tests differentiate better than the two-leg tests. We considered the values on the first recording of each testing occasion to be less than ideal for inclusion in the test-battery because of the person being exposed there to an unfamilar situation. Similarly, results of the third recording in the series appeared to be especially influenced by learning or fatigue, making that recording also less than ideal. Recordings on the second testing occasion tended to vary less over subjects than the other two, as shown by the standard deviations of the results. Because of the risk of losing valuable information through drop-outs, mean values over the three recordings were found to be less suitable than those for a single testing occasion, particularly where in the higher age groups there were some subjects who failed at some point to maintain balance. Such a failure to succeed at the tests may explain the seemingly higher capacity of men in the 55–59 as compared with the 50–54 age group (cf. Fig. 2), which may simply refect the occurrence of drop-outs.

The results for the functional tests were similar to those obtained by Bohannon et al. (6), who argue that balance should be interpreted in light of the patient's age. In our study, the functional tests (all but the coordination test) discriminated significantly between younger and older subjects but not between women and men. Except for results on the coordination test, force platform results correlated significantly with the results of the functional tests. The correlation-coefficients there were never greater than 0.42, a value which explains no more than 18% of the variance. The findings thus suggest the functional balance tests, with the possible exception of the coordination test, to be of value in clinical practice.

The significant sex differences obtained on the force platform, indicating women to perform better than men, is seen to be in agreement with results of various other studies (14, 17), although some investigations have shown standing balance to be better in men than in women (20, 22). As sex differences were not evident in the functional test results, it might be argued that each of the two types of tests (functional and force platform tests) reveals information not revealed by the other. Thus, for example, it could be suggested that the traditional functional tests focus on time aspects, whereas the platform tests concern additional aspects more specifically related to certain postural sway parameters. Further studies, one could suggest, should consider the value of the functional and the force platform tests together in diagnosing well-known and defined lesions.

In earlier studies (13, 23), height and weight has been found to be of importance in analyzing sway results. We found, however, that neither height and weight, nor in fact work-load and leisure-time activities, correlated significantly with length of sway path

Table V. *Performance on the blindfolded one-leg standing tests and the walking test (means and standard deviations of time in seconds) and on the coordination test (means and standard deviations of number of alterations) for the various age and sex groups*

	Standing on one leg right, blindfolded			Standing on one leg left, blindfolded			Coordination test			Walking test		
Age (yrs)	*M*	SD	*n*	*M*	SD	*n*	*M*	SD	*n*	*M*	SD	*n*
Females												
20–29	39.5	33.4	13	44.0	51.3	13	40.4	7.1	13	13.1	1.5	13
30–39	22.6	17.4	11	26.8	20.7	11	34.2	9.8	11	15.0	1.9	11
40–44	24.7	17.7	10	21.3	14.1	10	34.1	10.9	9	15.1	1.9	10
45–49	20.1	19.2	10	29.2	23.8	10	31.9	6.0	10	15.5	2.1	10
50–54	28.9	29.0	11	25.0	16.0	11	35.6	9.5	11	16.1	2.2	10
55–59	13.0	14.4	12	13.8	15.8	12	28.7	12.9	13	16.8	3.3	13
60–64	9.1	10.7	10	3.4	2.3	10	27.8	12.6	10	18.6	1.9	10
Males												
20–29	42.7	33.7	12	29.3	19.2	12	38.7	7.6	12	12.8	2.2	12
30–39	32.4	33.9	12	30.3	18.3	12	31.8	7.6	11	14.1	1.9	12
40–44	22.2	16.1	10	25.3	14.8	10	36.5	12.8	10	14.6	2.0	10
45–49	25.4	25.1	10	34.8	32.5	10	33.5	6.6	10	14.5	2.7	10
50–54	6.9	7.9	10	9.4	7.0	10	33.6	7.3	10	19.7	11.2	10
55–59	13.2	8.7	10	13.2	8.6	10	32.7	3.8	10	16.2	1.7	10
60–64	6.7	4.1	10	7.0	4.2	10	40.5	11.1	10	15.5	3.2	10

Table VI. *Correlation coefficients (Pearson) between standing on one leg on the force platform looking straight ahead (length of sway path, velocity, and area; second measurement) and the functional tests (standing blindfolded on one leg, the walking test and the coordination test)*

	Right leg—force platform						Left leg—force platform					
	Length		Velocity		Area		Length		Velocity		Area	
Functional tests	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*
Right leg (blind-folded)	−0.41	0.0001	−0.42	0.0001	−0.36	0.0001	−0.37	0.0001	−0.36	0.0001	0.31	0.0001
Left leg (blind-folded	−0.39	0.0001	−0.41	0.0001	−0.37	0.0001	−0.39	0.0001	−0.38	0.0001	−0.35	0.0001
Walking (30 m)	0.34	0.0001	0.34	0.0001	0.30	0.0003	0.32	0.0001	0.31	0.0002	0.31	0.0002
Coordination test	−0.01	0.92	0.01	0.88	−0.00	0.99	−0.05	0.59	−0.03	0.71	−0.02	0.83

on the force platform. It is possible, as Juntunen et al. have noted (17), that other anthropometric dimensions such as center of gravity could be of relevance here.

In conclusion, the standing balance appears to be influenced by age, with impaired capacity for balance in older subjects, and also by sex, with women showing better function than men.

ACKNOWLEDGEMENTS

The authors thank Professor Ulrich Moritz, MD, head of the Department of Physical Therapy, University of Lund, Sweden, for his valuable suggestions and comments. The study was supported by grants from the Medical Faculty of the University of Lund and the Malmöhus County Council, Sweden.

REFERENCES

1. Advanced Mechanical Technology, Inc. Computerized biomechanics laboratory system users manual. Newton, Massachusetts, USA, July 1987.
2. Andres, R. O. & Anderson, D. J.: Designing a better postural measurement system. Am J Otolaryngol *1*: 197–206, 1980.
3. Barrett, R., Hyde, S. A. & Hark, W. B.: The design of a force platform for clinical use: a feasibility study of stabilography in evaluating the effect of orthotic intervention in Duchenne muscular dystrophy. J Med Eng Techn *11*: 68–73, 1987.
4. Begbie, G. H.: The assessment of imbalance. Physiotherapy *55*: 411–414, 1969.
5. Black, F. O., Wall, C., Rockette, H. E. & Kitch, R.: Normal subject postural sway during the Romberg test. Am J Otolaryngol *3*: 309–318, 1982.
6. Bohannon, R. W., Larkin, P. A., Cook, A. C., Gear, J. & Singer, J.: Decrease in timed balance test scores with aging. Phys Ther *64*: 1067–1070, 1984.
7. Brocklehurst, J. C., Robertson, D. & James-Groom, P.: Clinical correlates of sway in old age—sensory modalities. Age Ageing *11*: 1–10, 1982.
8. Crilly, R. G., Richardson, L. D., Roth, J. H., Vandervoort, A. A., Hayes, K. C. & Mackenzie, R. A.: Postural stability and Colles' fracture. Age Ageing *16*: 133–138, 1987.
9. Dichgans, J. & Mauritz, K.-H.: Patterns and mechanisms of postural instability in patients with cerebellar lesions. *In* Advances in neurology. Motor control mechanisms in health and disease (ed. J. E. Desmeth), *39*: 633–43. Raven Press, New York, 1983.
10. Dichgans, J., Mauritz, K.-H., Allum, J.-H.-J. & Brandt, T.: Postural sway in normals and atactic patients: Analysis of the stabilizing and destabilizing effects of vision. Agressologie *17C*: 15–23, 1976.
11. Diener, H. C., Dichgans, J., Bruzek, W. & Selinka, H.: Stabilization of human posture during induced oscillations of the body. Exp Brain Res *45*: 126–132, 1982.
12. Dornan, J., Fernie, G. R. & Holiday, P. J.: Visual input: its importance in the control of postural sway. Arch Phys Med Rehabil *59*: 586–591, 1978.
13. Era, P. & Heikkinen, E.: Postural sway during standing and unexpected disturbance of balance in random samples of men of different ages. J Gerontol *40*: 287–295, 1985.
14. Franchignoni, F. P., Vanni, G. & Savoini, C.: Analisi con sistema computerizzato degli effetti dell'età sul controllo posturale. Min Med *76*: 835–839, 1985.
15. Gabell, A. & Simons, M. A.: Balance coding. Physiotherapy *68*: 286–288, 1982.
16. Hasselkus, B. R. & Shambes, G. M.: Aging and postural sway in women. J Gerontol *30*: 661–667, 1975.
17. Juntunen, J., Ylikoski, J., Ojala, M., Matikainen, E., Ylikoski, M. & Vaheri, E.: Postural body sway and exposure to high-energy impulse noise. Lancet *ii*: 261–264, 1987.
18. Lee, D. N. & Lishman, J. R.: Visual proprioceptive control of stance. J Human Movement Studies *1*: 87–95, 1975.
19. Murray, M. P., Seireg, A. A. & Sepic, S. B.: Normal postural stability and steadiness: quantitative assessment. J Bone Joint Surg *57-A*: 510–516, 1975.
20. Mechling, R. W.: Objective assessment of postural balance through use of the variable resistance balance board. Phys Ther *66*: 685–688, 1986.
21. Nashner, N. M.: Adapting reflexes controlling the human posture. Exp Brain Res *26*: 59–72, 1976.
22. Overstall, P. W., Exton-Smith, A. N., Imms, F. J. & Johnson, A. L.: Falls in the elderly related to postural imbalance. Br Med J *i*: 261–264, 1977.
23. Ratliffe, K. T., Alba, B. M., Hallum, A. & Jewell, M. J.: Effects of approximation on postural sway in healthy subjects. Phys Ther *67*: 502–506, 1987.
24. Saltin, B. & Grimby, G.: Physiological analysis of middle-aged and old former athletes. Circulation *38*: 1104–1115, 1968.
25. Sheldon, J. H.: The effect of age on the control of sway. Geront Clin *5*: 129–138, 1963.
26. Stones, M. J. & Kozma, A.: Balance and age in the sighted and blind. Arch Phys Med Rehabil *68*: 85–89, 1987.
27. Stribley, R. F., Albers, J. W., Tourtellotte, W. W. & Cockrell, J. L.: A quantitative study of stance in normal subjects. Arch Phys Med Rehabil *55*: 74–80, 1974.
28. Vandervoort, A. A., Hayes, K. C. & Cape, R. D. T.: Postural sway in the elderly. *In* Congress in Applications of Biomechanics, Umeå, Sweden, Abstract p. 31, 1985.
29. Yoshida, K., Iwakura, H. & Inoue, F.: Motion analysis in the movement of standing up from and sitting down on a chair. Scand J Rehab Med *15*: 133–140, 1983.
30. Östlund, H.: A study of aim and strategy of stability control in quasistationary standing. Thesis. University of Lund, Sweden, 1979.

Address for offprints:
Charlotte Ekdahl, RPT
Department of Community Health Sciences
Lund University
S-240 10 Dalby
Sweden