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REPRODUCIBILITY OF NINE TESTS TO MEASURE SPINAL MOBILITY AND TRUNK MUSCLE STRENGTH

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ABSTRACT. The reproducibility of nine back function tests suitable for use in the occupational health service was determined in 30 male employees. The correlation of three tests made with a tape measure—forward bending, modified Schober, and side bending—was high in both intra- and inter-observer comparisons (r=0.82–0.96). Immediate repetition of the testing procedure improved the performance in the forward and side bending tests. The reproducibility was also good for the tests of dynamic (K=0.57–0.78) and endurance (r=0.90–0.96) strength of the abdominal muscles and quite good for the test of endurance strength of the back muscles (r=0.74–0.80). The differences between the examiners must be taken into account in the modified Schober test, and in testing the flexibility of the hip flexors and hamstrings and the endurance strength of the back muscles.

Key words: spinal mobility, muscle strength, function test, reproducibility, occupational health.

Low back troubles constitute a considerable part of the general morbidity in the population of working age. Not only physically heavy work, such as heavy lifting, repeated bending and twisting or forceful movements, but also prolonged sitting or standing especially in stooped postures make demands on the worker's trunk muscle strength, endurance and mobility (5, 6, 8, 10, 14, 17, 18, 19, 26, 32, 33, 34).

Assessment of working capacity including back function is an everyday task in the occupational health service. This requires a standardized examination program to measure back function. The procedure should be safe, inexpensive, and quick and easy for a physician or a physiotherapist to carry out. The methods should be reproducible and it would be valuable if they could predict an elevated risk of future low back pain.

The reproducibility of certain back function tests has been examined before (1, 2, 3, 7, 11, 20, 21, 22) but the variation in a tested subject during the examinations due to e.g. stretching and/or learning, has seldom been taken into account (4, 12, 15).

The purpose of this study was to determine the reproducibility of nine noninvasive tests that are probably simple to learn and use in ordinary practice to measure spinal mobility and trunk muscle strength.

SUBJECTS AND METHODS

The examinations were carried out in the occupational health service of a big shipyard during ordinary working hours. Each examination lasted about 20 min. Thirty male employees (14 planners, 6 welders, 10 plumbers), aged 35–44 years, were examined three times by three experienced physiotherapists (A, B, C) during one day. They were examined for the fourth time by one of them (A) a week later.

The intra-observer reproducibility was determined according to the measurements 1 (A_1) and 4 (A_2). The inter-observer reproducibility was determined according to the measurements made by B and C. To find out the influence of the testing order (the period), one half of the tested subjects were examined the second time by B and the third time by C while the other half were examined the second time by C and the third time by B (measurements 2 and 3).

The physiotherapists had practised together for one day before the examinations. They worked according to detailed instructions on how to tell the subjects to perform the tests and how to measure the performances. The tests were carried out in the same order and the performances restricted by pain were excluded. All skin markings were erased carefully after each examination.

Forward bending, the modified Schober test, flexibility of the hip flexors and hamstrings, side bending and rotation were used to measure mobility. The dynamic strength of the abdominal muscles was measured by a sit-up test; endurance strength tests were used both for the abdominal and back muscles (Appendix).

Statistical analysis

Cohen's kappa (K) was used in determining the reproducibility of the dynamic strength test of the abdominal muscles and the Wilcoxon signed rank test in determining the significance of the differences in the levels of the measurements due either to the examiners or the testing order.

The Pearson correlation coefficient (r) was used to determine the reproducibility of the other tests.

Table I. *Correlation coefficients (r) and Cohen's kappa (K) of the tests in the intra-observer and inter-observer comparisons*

Test	Intra-observer r	Inter-observer r
Forward bending (mm)	0.93	0.96
M-Schober (mm)	0.88	0.87
Hip flexors dx (°)	0.68	0.82
Hip flexors sin (°)	0.78	0.64
Hamstrings dx (°)	0.80	0.55
Hamstrings sin (°)	0.81	0.52
Sidebending dx (mm)	0.87	0.84
Sidebending sin (mm)	0.82	0.88
Rotation dx (°)	0.42	0.35
Rotation sin (°)	0.24	0.37
Abdominals, dynamic (stages 1–6)	0.57 (K)	0.78 (K)
Abdominals, endurance (s)	0.93	0.90
Back muscles, endurance (s)	0.74	0.80

The paired *t*-test was used to determine the significance of the differences between the means of the measurements made by the same examiner (A_1 and A_2).

Analysis of variance with repeated measures was used in the two-period crossover study in determining the significance of the differences between the means of the measurements made by different examiners (B and C) as well as measurements 2 and 3; handling order was used as the grouping factor and period as the within factor.

RESULTS

The distribution of all the test results was wide. Strong correlation coefficients ($r>0.80$) were found in the measurements made with a tape measure, e.g. in forward bending, modified Schober test and side bending, in both the intra- and inter-observer comparisons (Table I). The correlation coefficients were good in the measurements of the flexibility of the hip flexors ($r=0.68$–0.70) and hamstrings ($r=0.80$–0.81) in the intra-observer comparisons but weaker when done by different examiners ($r=0.64$–0.82 and 0.52–0.55 respectively). The method of measuring rotation proved to have weak reproducibility ($r<0.50$). The reproducibility proved to be good for the tests of dynamic strength ($K>0.50$) and endurance strength of the abdominal muscles ($r>0.90$), while the test of endurance strength of the back muscles showed poorer reproducibility ($r=0.74$–0.80).

The systematic errors in the measurements were defined by comparing the means of the test results. The means of the right and left sides were used in testing hip flexors and hamstrings as well as side bending and rotation. The differences in the means of the measurements made by the same examiner with

Table II. *Measurements made by examiner A with one week's interval (intra-observer comparisons)*

Test	Examiner	N	Mean		SD	Range
Forward bending (mm)	A_1	30	−7.53	***	78.23	−203–185
	A_2	30	−29.30		86.99	−212–241
M-Schober (mm)	A_1	29	73.10	NS	11.76	55–97
	A_2	30	71.20		13.10	49–101
Hip flexors (°)	A_1	30	0.63	**	7.24	−16–12.5
	A_2	30	4.10		8.46	−13–16
Hamstrings (°)	A_1	30	80.35	***	7.63	65–93.5
	A_2	30	84.50		8.13	65–100
Side bending (mm)	A_1	30	201.00	NS	40.17	107.5–259
	A_2	30	204.88		35.36	117.5–287
Rotation (°)	A_1	30	57.17	**	7.95	39–72
	A_2	30	52.53		7.93	33–70
Abdominals, endurance (s)	A_1	30	55.27	NS	76.43	0–240
	A_2	30	64.03		85.70	0–240
Back muscles, endurance (s)	A_1	29	134.31	NS	51.12	32–240
	A_2	29	135.24		51.27	26–240

* $p<0.05$, ** $p<0.01$, *** $p<0.001$, NS=non significant.

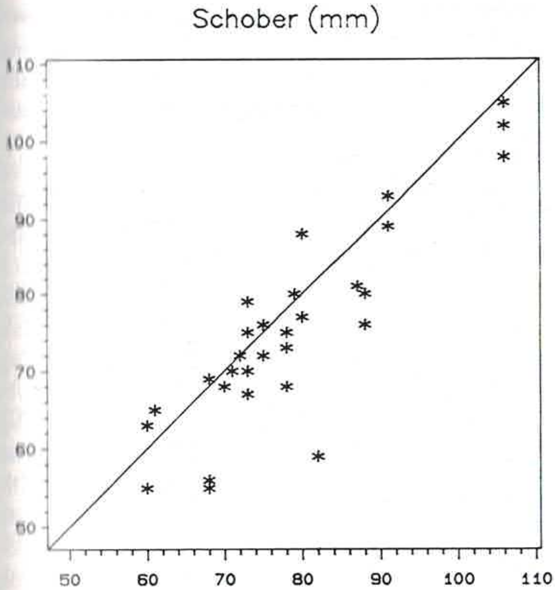

Fig. 1. Measurements in the modified Schober tests (mm) made by examiners B (on *x*-axis) and C (on *y*-axis).

one week's interval (Table II) were significant in testing forward bending ($t=3.72$, $p<0.001$), flexibility of the hip flexors ($t=-3.43$, $p<0.01$) and hamstrings ($t=-5.28$, $p<0.001$).

The differences in the means of the measurements made by different examiners (Table III) were significant in the modified Schober test ($F=8.02$, df=(1.28), $p<0.01$), in the test of the flexibility of the hip flexors ($F=6.77$, df=(1.28), $p<0.05$) and hamstrings ($F=36.01$, df=(1.28), $p<0.001$) as well as in the test of endurance strength of the back muscles ($F=9.36$, df=(1.25), $p<0.01$).

The test results of the dynamic strength of the abdominal muscles were distributed quite evenly in all categories and there were no significant differences in the stages of the measurements made either by the same examiner or the two different examiners.

As to the possible systematic effect of the period, i.e. the differences between the measurements 2 and 3, a significant improvement of the results was found in the two tests of forward bending ($F=6.70$, df=(1.27), $p<0.05$) and side bending ($F=6.28$, df=(1.27), $p<0.05$).

DISCUSSION

The correlation coefficients proved to be over 0.80 in the tests of active spinal mobility made with a tape measure and in the test of the endurance strength of the abdominal muscles. However, the good correlation coefficient does not guarantee that the results of two measurements are almost the same (35). The results may be dispersed systematically on the same

Table III. *Measurements made by examiners B and C (inter-observer comparisons)*

Test	Examiner	*N*	Mean		SD	Range
Forward bending (mm)	B	29	−32.28	NS	85.98	−203–197
	C	30	−26.90		86.76	−197–212
M-Schober (mm)	B	30	78.60	**	12.44	60–106
	C	30	75.20		12.98	55–105
Hip flexors (°)	B	30	9.15	*	8.41	−10–26
	C	30	6.63		8.03	−8–19
Hamstrings (°)	B	30	87.63	***	8.05	70–102.5
	C	30	79.83		6.95	64–91.5
Side bending (mm)	B	30	210.50	NS	36.44	123–298
	C	29	211.64		27.49	156–282.5
Rotation (°)	B	30	55.85	NS	7.07	39–70
	C	30	56.17		8.80	36–84
Abdominals, endurance (s)	B	30	61.17	NS	73.68	0–240
	C	29	52.86		65.32	0–240
Back muscles, endurance (s)	B	28	96.61	**	37.40	26–157
	C	29	83.17		36.98	18–166

* $p<0.05$, ** $p<0.01$, *** $p<0.001$, NS=non significant.

side of the straight $x=y$ in spite of the good r-value. This can be seen in Fig. 1 where the results of the modified Schober test measured by B are on the x-axis and those by C on the y-axis. This is due to systematic differences between the examiners, e.g. inspiring the subjects to give a maximum performance.

The repetition of the whole set of tests may also cause a systematic improvement in the results of a single test probably because the tissues stretch more when warmed, or because the subject learns to do the test better during repeated performances. This effect was evident in testing forward and side bending in immediate repetition, and this finding is in agreement with Frost's et al. study (4).

The influence of immediate repetition of the testing procedure was eliminated by changing the testing order, and the differences between two examiners could thus be differentiated from the variation in a tested subject. The differences between the examiners were significant in the modified Schober test and in testing the flexibility of the hip flexors and hamstrings as well as in testing the endurance strength of the back muscles.

The differences in the means of the results measured by the same examiner were significant in the tests of forward bending and flexibility of the hip flexors and hamstrings due to the variation in either the examiner or the tested subjects.

Variation in the starting position of a test may contribute to errors. However, habitual standing posture has been shown to be well reproducible (21, 35).

In addition to the variation in the subjects in performing the tests and the differences between the examiners many other factors may have an effect on the reproducibility. In this study, the surroundings were the same during all the examinations. The measures were all of the same kind but they were not calibrated and their errors were not recorded.

The individual properties of the subjects, such as motivation, fatigue, or feeling of pain, affect the test results. The subjects participated voluntarily in the study. They were informed that the aim of the comparison was to investigate the reproducibility of the back function tests. Thus, their motivation to perform the tests to the best of their ability was probably high. Possible diseases or anomalies of joints, tendons or muscles were not taken into account although the performances restricted by pain were excluded.

There are various ways of examining the mobility of the spine. The present methods of measuring forward and side bending proved to be accurate, reproducible, and easy and quick to use. Forward bending has also ben examined by measuring the distance from the middle finger to the floor with a tape measure (4, 7). In Gill's et al. study (7) the reproducibility proved to be poorer than in ours, but the influence of repeated performances was not considered. On the other hand, Frost et al. (4) took the effect into account, and the correlation coefficients of forward bending were strong in intra- and inter-observer comparisons, but those of side bending were weaker than in this study. Also Mellin (20) studied side bending with the method we used and found it well reproducible. As to side bending, it has also been examined by measuring the distance between the fingers and the end of the fibula (15) with a tape measure. The method has been considered reproducible but it demands accuracy in defining the bony landmarks. Reproducibility has proved to be poorer in measuring side bending with the skin distraction method (24, 27) although Million et al. (23) found it, as well as goniometer measurements, reproducible when made by the same examiner.

The modified Schober test proved not only to be easy and quick to carry out but also to have strong reproducibility made by the same examiner, which is in agreement with other studies (7, 23).

Better inter-examiner agreement might be achieved by an even more accurate definition of the bony landmarks (2). In some studies measurements of spinal flexion made with a goniometer (23, 29) or with a kyphometer (35) proved to be even more reproducible.

The methods of measuring the flexibility of the hip flexors and hamstrings were less accurate. The measurements were made with goniometers, which are considered easy to use, but the equipment requires an exact definition of its placement (29) and a careful measurement technique (3).

When the flexibility of the hip flexors is measured it is difficult to fix the pelvis always in the same place, the tested leg may not be relaxed enough or the other leg may not be fixed in place properly each time.

In measuring the flexibility of the hamstrings it is important to eliminate abduction and rotation of the tested leg and flexion of the knee. Tightness of the hip flexors may cause inaccuracy and, because of the complicated test procedure, it may be difficult to repeat the test in the same way. Frost et al. (4) also described these difficulties in making the measurements with a tape measure; then the reproducibility was even weaker than in the present study. Keeley et al. (12) made the measurements with an inclinometer, and found the method to have a strong reproducibility. In that study, the tested leg was raised to the point where the unfixed contralateral thigh was beginning to move. However, the results of this testing procedure might be affected by, e.g., tightness of the contralateral hip flexors.

The method of measuring rotation was poorly reproducible. The technique should be more precise. The inclinometer was small and difficult to read accurately. In addition, the magnetism of the surroundings may affect the results as pointed out by Mellin (22) who also stressed the importance of practice in using the instrument. Keeley et al. (12), using a different method than the one used in this study, found the inclinometers reliable in measuring hamstring flexibility but less reliable in measuring rotation. Rotation has also proved to be difficult to beasure with a tape measure (4).

The strength of the abdominal and back muscles has mostly been measured by various technical equipment, which is rarely available in ordinary practice. The reproducibility of the tests of dynamic and endurance strength of the abdominal muscles proved to be strong. One curl-up has been considered enough to describe the dynamic capability of the abdominal muscles (1, 28). In the present study, the dynamic abdominal muscle strength was assessed with the test technique used by Janda (9), however, applied so as to better distinguish mild muscle weakness as well. The procedure may be strange to adopt and the subject was thus allowed to do the test twice. In some studies the test has been done with a support at the feet (31) but the results may be misleading because even those with weaker muscles may reach higher stages due to strong hip flexors. On the other hand, when subjects with strong muscles are examined one curl-up does not determine the level of the ability of the muscles.

The present method of measuring the endurance strength of the abdominal muscles has not, to our knowledge, been described before. The reproducibility of the test was good but the testing procedure was troublesome and time-consuming.

The test for the endurance strength of the back muscles has also been used by Biering-Sørensen (1) and its reproducibility has been proved to be even better (11, 25) than in the current study. No special equipment was needed but the procedure was time-consuming.

The results of tested subjects in this kind of function tests are not directly comparable to each other. Many individual properties, e.g. age, anthropometry, obesity and sex may have some effect on the results. In the present study, all the measurements were made on working men, aged 35–44 years. Further investigations are needed to determine the normal variation and the reproducibility of the tests in examining patients and women and men of different ages, and to determine the prognostic value of the tests for future low back pain and disability syndromes.

In conclusion, the tests used in this study are easy to use and require no expensive equipment. However, the tests must be done very carefully and according to detailed instructions. The accuracy of the testing procedure is most important. Well-standardized tests proved to have the strongest reproducibility.

Individual variation in the tested subjects during immediately repeated procedures must be considered in testing forward and side bending. The modified Schober test, the tests of measuring the flexibility of the hip flexors and hamstrings, and those of the endurance strength of the back muscles are exposed to significant errors between examiners. The differences between the means of repeated measurements made by the same examiner are significant in testing forward bending and flexibility of the hip flexors and hamstrings. Inaccuracy in testing the hip flexors and hamstrings might be difficult to reduce. A more accurate method of measuring rotation should be developed.

This study is part of a large intervention project of reducing back diseases by means of labour protection and occupational health care, supported by The Finnish Work Environment Fund.

APPENDIX

Test Arrangements

Forward bending

The subject stands on a 250 mm high platform with his feet together and toes touching the meterboard. He is asked to bend slowly and evenly forwards and downwards as far as possible, with the knees, arms and fingers fully extended, hands sliding along the meterboard and fingers pushing the meterbar downwards. The upper edge of the meterbar shows the millimeters which are registered and subtracted from 650 mm (the standing level) for the final result (Fig. 2).

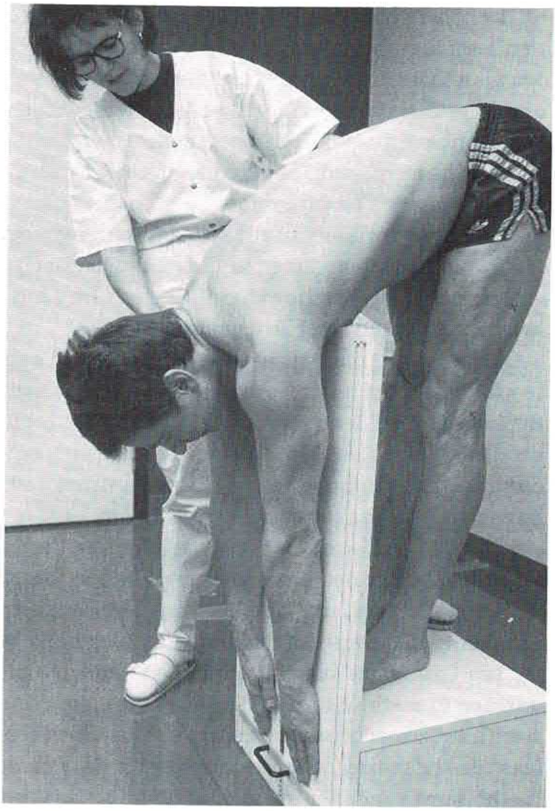

Fig. 2. Measurement of forward bending.

Schober's test, modified by Macrae & Wright (16)

The subject stands with his feet together, toes on the drawn line. The dimples of Venus are connected with a line by a ruler and a pen perpendicular to the skin (0-level). Two points on the spine are marked with one measurement: 100 mm above and 50 mm below the 0-level. The subject is then asked to bend forward as far as possible, with his knees fully extended and fingers stretching towards his toes. The distance between the marked points is measured in millimeters. The final result is the measurement minus 150 mm.

Flexibility of the hip flexor muscles (9, 13)

The tested subject sits on the examination table with his legs hanging over the edge of the table. The hydrogoniometer (MIE Medical Research, UK Pat. 8401841) is placed and zeroed on the midline of the thigh just above the patella. The subject is asked to lie down so that the ischial tuberosities are just on the edge of the table, the tested leg hanging freely over the edge. The other leg is bent and held by his hands near to the body so that the pelvis is tilted backwards and the lumbar lordosis is eliminated. The correct posture is checked by pushing the knee maximally against the body. The measurement of the hydrogoniometer is registered to an accuracy of one degree. The level below zero is signed negative.

Flexibility of the hamstring muscles (30)

In this passive straight leg raising test the subject lies supine. The hydrogoniometer is placed and zeroed on the midline of the thigh just above the patella of the tested leg. In the presence of strong lumbar lordosis or tightness of the hip flexors, a small pillow has been placed under the knee of the untested leg, so that the lower back is flat on the table. The examiner puts her leg on the untested leg to stabilize it and raises the tested leg slowly and evenly, knee fully extended, avoiding abduction and rotation, until tightness or pain restricts the movement. The angle is registered to an accuracy of one degree.

Side bending

The subject stands upright with his knees fully extended, feet 200 mm apart on the footprints painted on the floor, heels, back and head touching the wall, shoulders relaxed, arms and fingers straight. The points of the tips of the middle fingers are marked on the skin on the midline of the thighs. The subject is asked to bend the body to the side as far as possible so that the head, back and heels still touch the wall and the feet are flat on the floor. The hands slide downwards along the thigh and the tip of the middle finger on the midline of the thigh is marked. The distance between the points is measured in millimeters.

Rotation of the trunk

The subject sits on a chair without a backrest, with his thighs apart, feet flat on the floor on the footprints and back straight. A stick with a Myrin inclinometer is placed on his shoulders so that the meter is on the cervical spine. The stick is held from behind at both ends. The meter is stabilized and zeroed at the horizontal site. The pelvis of the subject is fixed by the examiner. He is asked to rotate the upper body slowly and evenly to the side as far as possible and to stop the movement when the pelvis begins to rotate. The measurement of the inclinometer is registered to an accuracy of one degree.

Dynamic strength of the abdominal muscles

The subject lies supine with knees at a 90° angle measured by the angle measurer. He is asked to curl

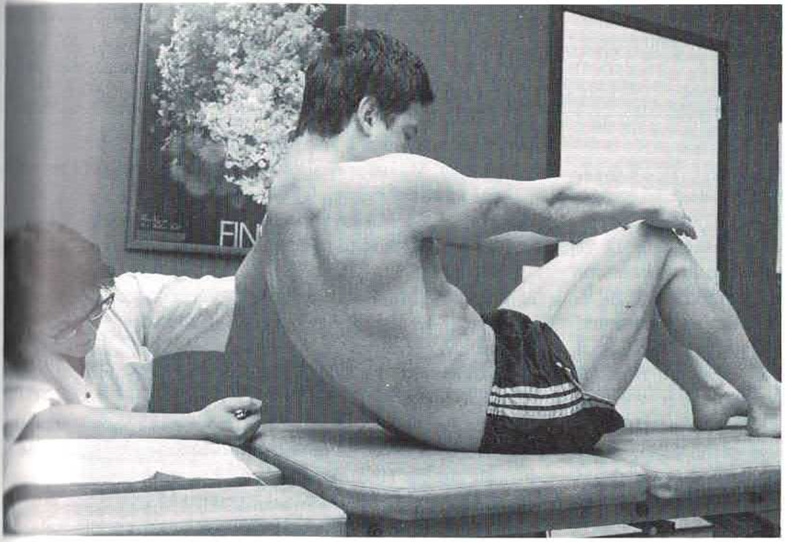

Fig. 3. Measurement of endurance strength of the abdominal muscles.

up with a round back as far as possible with feet flat on the surface of the table without support. The performance is not accepted if it is done with jerks, speed, straight back or if the heels rise from the surface of the table. The subject is allowed to perform the test twice. The performance is classified into six stages according to the position of the upper limbs and the distance of the different parts of the back from the table as follows:

1) with hands behind the neck, the elbows may be directed forwards during the performance and the curl-up is done until the low back rises from the table,

2) with arms crossed on the chest, the curl-up is done until the low back rises from the table,

3) with arms straight towards the knees, the curl-up is done until the low back rises from the table,

4) with arms straight towards the knees, the curl-up is done until only the middle back rises from the table,

5) with arms straight towards the knees, the curl-up is done until the shoulder blades rise from the table,

6) with arms straight towards the knees, only the head rises from the table.

Endurance strength of the abdominal muscles

The crests of the ilia of the tested subject are determined and a line between them is drawn with a pen and a ruler. The subject then lies down supine with knees at an angle of 90° measured by the angle measurer and feet flat on the table without support. He is asked to curl up with arms straight towards his knees until the drawn line can be seen. If necessary, he is helped to get into this posture, which should be held for a maximum of 240 sec. The time is given every 30 sec. The posture is checked during testing and if lost, the test is stopped (Fig. 3).

Endurance strength of the back muscles (1)

The subject lies prone on the examination table so that the upper body down to the crista iliaca is outside off the table. The rest of the body and the lower limbs are attached to the table by three belts at the hips, lower part of the thighs and lower part of the legs. A small pillow is placed under the ankles as support. The arms are crossed on the chest. The subject is asked to hold his upper body and head horizontal for a maximum of 240 sec. The time is given every 30 sec. If the posture is lost and cannot be corrected when remarked on by the examiner, or if there are signs of exhaustion, pain or cramp in the leg, the test is stopped.

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