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TRUNK MUSCLE STRENGTH AND BACK MUSCLE ENDURANCE IN CONSTRUCTION WORKERS WITH AND WITHOUT LOW BACK DISORDERS

Eva Holmström,[1] Ulrich Moritz[2] and Magnus Andersson[1]

From [1]Bygghälsan, The Swedish Construction Industry's Organization for the Working Environment and Health, Malmö, Sweden and [2]Department of Physical Therapy, University of Lund, Lund, Sweden

ABSTRACT. The aim of this study was to test the hypothesis that male workers exposed to heavy work and with no lifetime history of a low back disorder (group A) have better trunk muscle strength and back muscle endurance compared to male workers with the same work exposure but with a probable (group B) or definite low back disorder (group C). Group A ($n=42$) was clinically negative on physical examination. Group B ($n=75$) was clinically negative or uncertain and group C ($n=86$) was clinically positive, with current or previous low back disorders occurring in both groups. Group A had a significantly higher mean intraindividual extension/flexion ratio, namely 1.29 versus 1.19, in group C. The mean values for maximum isometric trunk extension and flexion strength did not differ between the groups. The isometric trunk extensor endurance was significantly lower in group C than in both group A and group B.

Key words: construction worker, extension/flexion ratio, low back pain, low back trouble, maximum voluntary contraction, reliability, trunk extension torque, trunk muscle endurance, trunk muscle strength.

The relationship between trunk muscle strength and low back pain has been discussed by many authors (3). Cross-sectional studies have come to different conclusions concerning the importance of trunk muscle strength in relation to low back pain. Nicolaisen & Jörgensen (13) and Thorstensson & Arvidson (19) found no differences between subjects with or without low back trouble. Suzuki & Endo (18), however, reported decreased trunk muscle strength in patients suffering from backache for less than one month compared to controls. Pope et al. (16) noted that low back pain decreased strength of both trunk extensors and flexors. McNeill et al. (12) found low-back disorder patients to have significantly less trunk extension strength than healthy subjects. As for patients with sciatic pain, Riihimäki et al. (17) found a relationship with trunk extensor strength, but not trunk flexor strength, and only in retrospect.

In a prospective study Biering-Sörensen (4) could not prove isometric trunk muscle strength to be a predictor of low back trouble, nor could Riihimäki et al. (17) with regard to sciatic pain. Battie et al. (2) could not prove that reduced isometric lifting strength predicted industrial back problems. On the other hand, Chaffin et al. (6) concluded from their studies that both the incidence rate and severity of back injury increased when job demands exceeded the individual's lifting strength.

In both cross-sectional and prospective studies isometric back muscle endurance has been found to be related to low back pain. Nicolaisen & Jörgensen (13) found a correlation between a low degree of isometric endurance of trunk extensors and low back pain in both men and women. Biering-Sörensen (4) found in his study of a Danish population that good isometric endurance of the back muscles might prevent first-time occurrences of low back trouble in men.

The importance of a balance between the strength of trunk extensors and flexors in relation to low back pain seems to be unclear. Beimborn & Morrissey (3) stated in their review article that trunk extensors are the strongest of the trunk muscles and that the average trunk extension/flexion ratio is 1.3. Most authors have not found significant differences in ratios between low back pain patients and controls (4, 18). However, Hemborg (7) did find a significant difference in ratios, 1.54 versus 1.29, between construction workers with chronic low back pain compared to workers without low back pain. The increased ratio was due to a significant reduction of trunk flexor muscle strength. By contrast, Pope et al. (16) found trunk flexors to be stronger than extensors in both patients and controls.

Construction workers are exposed to heavy physi-

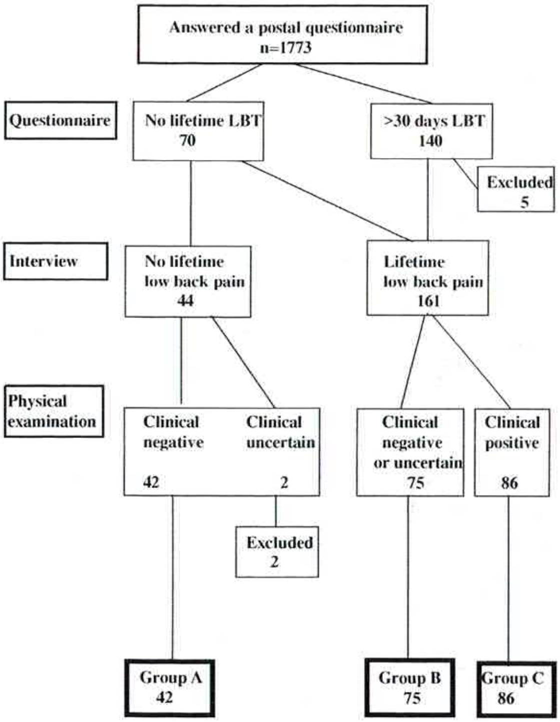

Fig. 1. The selection and allocation of subjects.

cal work-loads (5) and need both trunk muscle strength and endurance to manage their work. Low back trouble is the most prevalent musculoskeletal problem reported by construction workers (10, 15). Nevertheless, 12% of construction workers reported no lifetime low back trouble in a survey (10). It is not clear whether individual trunk muscle strength and particularly back muscle endurance are important factors in prevention of low back pain in connection with heavy work such as in the construction industry.

The aim of this investigation was to test the hypothesis that men without a low back disorder who are exposed to heavy work have better trunk muscle strength and back muscle endurance than men with a definite or probable low back disorder and to study the relationship between back muscle strength and endurance.

SUBJECTS

In an epidemiological survey 1 773 construction workers answered a questionnaire about musculoskeletal symptoms and their work environment (10). From those answering "no" to a question in the questionnaire about lifetime low back trouble, 70 male construction workers were randomly selected. From those answering "more than 30 days" to a question in the questionnaire about the duration of low back trouble during the past year, another 140 male workers were randomly chosen. According to answers given in a personal interview about lifetime low back pain and an assessment after a physical examination with pain-provoking tests, the workers were divided into three groups (Fig. 1). Group A consisted of 42 workers reporting no lifetime low back pain in the interview and who were clinically negative in the physical examination. Group B consisted of 75 workers who reported lifetime low back pain and who were clinically negative or uncertain, a probable low back disorder group. Group C consisted of 86 workers reporting lifetime low back pain and who were clinically positive, a definite low back disorder group. Four workers were excluded because they had not been in construction work during the past six months and one because of a neurological disease. Another two were excluded because they did not fulfil the criteria for any group.

The physical examination (9) comprised the following pain-provoking tests: active spinal mobility test, straight leg raising test, springing test, interspinal and paraspinal palpation, combined lumbar extension and lateral flexion in standing and passive lumbar flexion and extension in sidewise lying position. The criteria for classifying a person as "clini-

Table I. *Characteristics of the subjects*

Group A = no lifetime low back disorder. Group B = probable low back disorder. Group C = definite low back disorder

	Age			Height		Weight		Time in construction industry	
	Mean (years)	SD	Range	Mean (cm)	SD	Mean (kg)	SD	Mean (years)	SD
Group A ($n=42$)	43.7	10.4	22–64	174.8	5.9	79.1	12	19.8	10.5
Group B ($n=75$)	44.5	10.8	19–63	177	6.8	77.5	11.9	22.7	11.1
Group C ($n=86$)	44.1	11.3	19–64	177.8	6.5	82.1	12	19.7	11.9

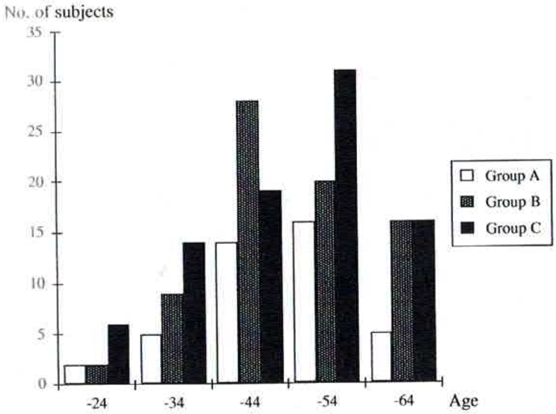

Fig. 2. Age distribution of the no lifetime low back disorder group (A), the probable low back disorder group (B) and the definite low back disorder group (C). Group A $n=42$, group B $n=75$ and group C $n=86$.

cally positive" for LBP were as follows: Pain must be provoked in the lower back and/or in one or both legs by the active spinal mobility test and/or the springing test in the lumbar spine, and by one or more of the other pain-provoking tests. Those assessed "uncertain" did not clearly report pain during the tests. The examination was conducted without the examiner's knowledge of the individuals' low back pain history and current status. The characteristics of the subjects in the different groups are summarized in Table I. The age distribution of the three groups is illustrated in Fig. 2. There was a significant difference in self-reported activity during leisure time between the groups, $\chi^2=12.84$ ($p<0.05$), but not concerning smoking habits. All the 13 main occupational categories of construction workers (10) were equally distributed in the three groups.

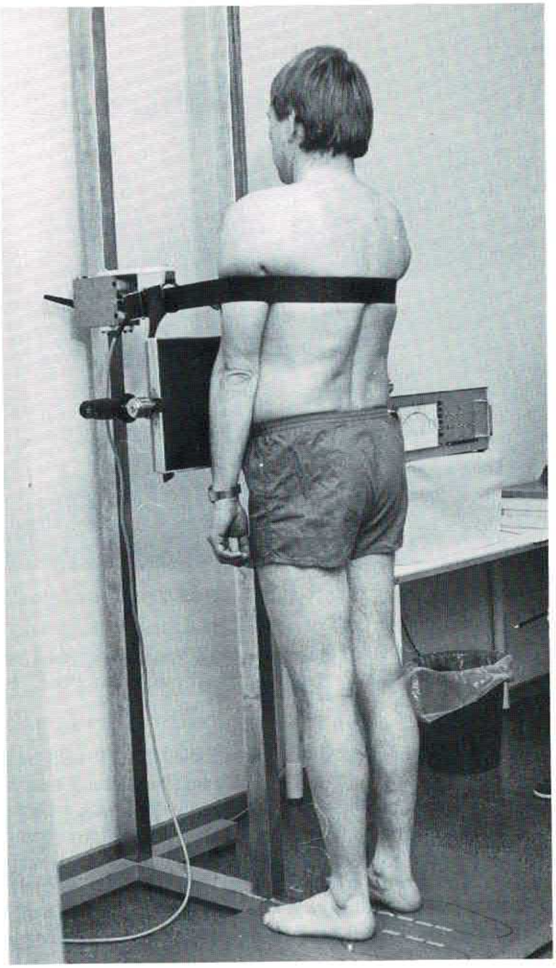

Fig. 3. Measurement of maximum isometric voluntary trunk extension.

MEASUREMENTS

The maximum voluntary isometric contraction (MVC) of the trunk flexors and extensors was measured with the subject standing in a special frame with a strap firmly placed around the chest and shoulders at the level of the insertion of the deltoid muscle (Fig. 3). The strap was connected to a strain gauge dynamometer. The equipment was calibrated every day against a spring dynamometer, from 25 kg to 100 kg. The pelvis was stabilized by an upholstered support adjustable in height. In this position the subjects performed maximum voluntary isometric backward extension and isometric forward flexion (1, 11, 14). They were all asked to successively increase their effort up to a maximum during each contraction. Three maximum voluntary contractions were performed and calculations were based on the median value. All tests provoking pain were excluded.

The maximum voluntary isometric endurance (MVE) of trunk extensors was determined with the subjects lying prone on a small bench with their legs and buttocks fixed and with the trunk unsupported (Fig. 4 *a*). The bench was angled 6° and a special cushion was placed under the pelvis to prevent discomfort. An adjustable arm with a photoelectric cell was fitted to the bench. The photocell was placed just under the horizontally positioned trunk in order to check the position (Fig. 4 *a*). The individuals were placed with the anterior superior iliac spine positioned exactly at the edge of the bench.

The length of time the subjects were able to maintain the unsupported trunk in horizontal position was measured in seconds (4, 13). The subjects were instructed to maintain the position to exhaustion. All tests were excluded if pain or other special circumstances were the cause of the stopping. Before starting the endurance test, the subjects supported their folded arms on a scale and the weight of the trunk was read off (Fig. 4 *b*). The distance between the anterior superior iliac spine and the centre of the shoulder joint was measured to calculate the torque of the trunk weight. When calculating maximum extension and flexion torque the length of the torque arm level measured in the endurance test was reduced by 0.1 m. The reduction of 0.1 m is explained by the more

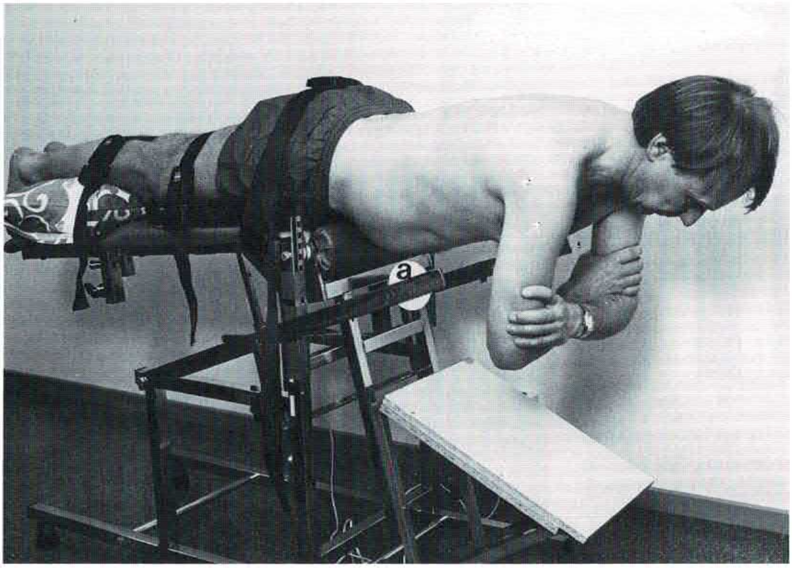

Fig. 4 a. Measurement of trunk extensor endurance. A photoelectric cell (*a*) was placed just under the trunk.

caudally attached strap during the MVC test compared to the centre of support for the trunk during the endurance test.

Reliability

The reliability of isometric trunk muscle strength tests and the isometric back muscle endurance test was determined in 15 construction workers without current low back trouble (mean age 36.3 years, SD ± 10.3). There was an intervening period of 4 weeks between the tests. The coefficients of variation for the three consecutive contractions of each strength test ranged between 4% and 7%. The reliability coefficients for the test–retest measurements were 0.94 for trunk extension strength ($n = 13$), 0.89 for trunk flexion strength ($n = 14$) and 0.91 for trunk extension endurance ($n = 15$).

Statistics

The hypothesis of a difference between mean values was tested using the *t*-test. Pearson's correlation coefficient was used to test the relationship between trunk muscle measurements and age. Spearman's rank-order correlation coefficient was computed to test the relationship between strength and endurance and categorial variables. To test the stability of the strength test and of the endurance test, the Spearman rank-order correlation coefficient and coefficient of variation were

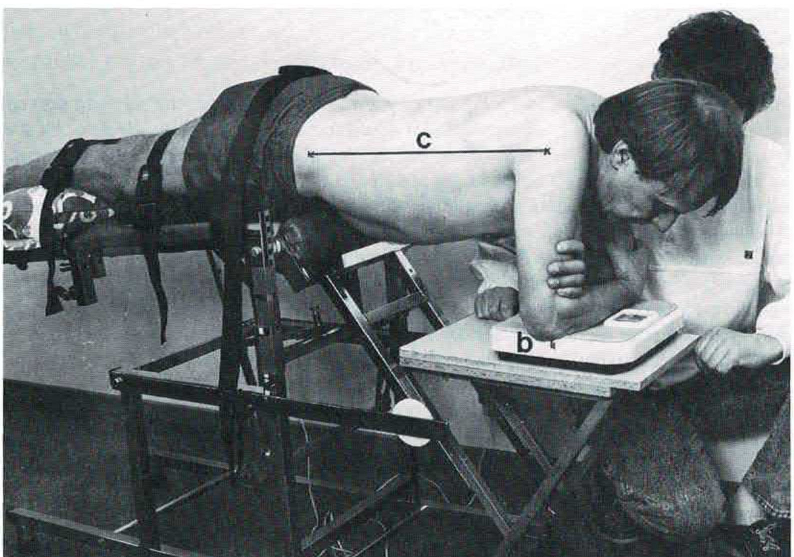

Fig. 4 b. Measurement of trunk weight (*b*) and torque arm level (*c*) in the endurance test position.

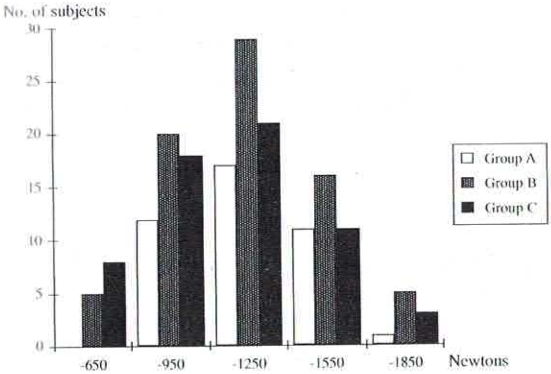

Fig. 5. The distribution of maximum trunk extensor strength in male workers with no lifetime (A), probable (B) and definite (C) low back disorders.

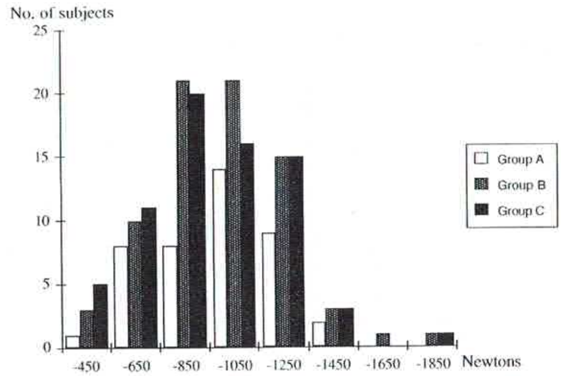

Fig. 6. The distribution of maximum trunk flexor strength in male workers with no lifetime (A), probable (B) and definite (C) low back disorders.

computed. The chi-square test was used to test differences between categorial variables. p-values $\leqslant 0.05$ were considered statistically significant.

RESULTS

Trunk muscle strength

The distribution of maximum trunk strength in group A, B and C is illustrated in Fig. 5 and 6. The maximum voluntary trunk extension torque was on average 418.8 Nm (SD ± 104.1) in group A, 418.5 Nm (SD ± 126.6) in group B and 394.6 (SD ± 129.2) in group C. The maximum voluntary trunk flexion torque was 327 Nm (SD ± 88.5) in group A, 342.5 Nm (SD ± 111.9) in group B and 335.5 Nm (SD ± 114.9) in group C. The results are summarized in Table II. No significant differences could be noted. The reduction of subjects performing the tests was due to the exclusion of all tests where pain was provoked.

The ratio between maximum trunk extension contraction and maximum trunk flexion contraction was calculated for each individual. The extensor muscles were stronger in all three groups. Group A showed the largest difference between extensor and flexor muscles with an extension/flexion ratio of 1.29. Group A differed significantly from group C but not from group B (Table II).

There was a significant negative correlation between age and maximum trunk extension torque in all three groups. The correlation coefficient was −0.34 ($p<0.05$) in group A, −0.36 ($p<0.001$) in group B and −0.56 ($p<0.001$) in group C. There was a significant negative correlation between age and maximum trunk flexion torque in the two low back disorder groups. The correlation coefficient was −0.31 ($p<0.01$) in group B and −0.53 ($p<0.001$) in group C. The correlation coefficient in group A was −0.27 (NS).

Table II. *Maximum voluntary isometric contraction of trunk muscles in male workers with no lifetime (group A), probable (group B) and definite (group C) low back disorders. n = 203*

	Maximum isometric trunk flexion torque				Maximum isometric trunk extension torque				Ext./flex. ratio			
	Mean (Nm)	SD	Range	*n*	Mean (Nm)	SD	Range	*n*	Mean	SD	Range	*n*
Group A	327	88.5	128–466	42	418.8	104.1	201–669	41	1.29[a]	0.24	0.88–1.9	41
Group B	342.5	111.9	129–738	75	418.5	126.6	153–745	75	1.26	0.29	0.6–2.2	75
Group C	335.5	114.9	111–681	71	394.6	129.2	139–681	61	1.19[a]	0.26	0.53–1.86	61

[a] Significant difference between group A and group C ($p \leqslant 0.05$).

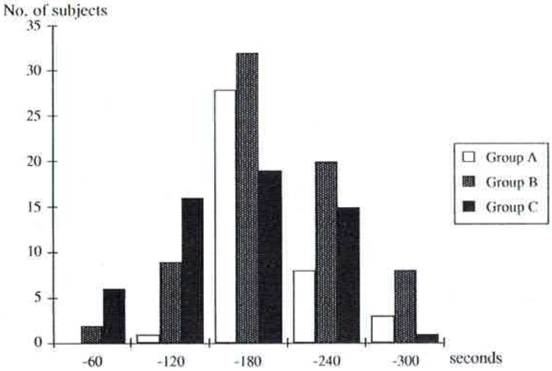

Fig. 7. The distribution of trunk extensor endurance time in male workers with no lifetime (A), probable (B) and definite (C) low back disorders.

Trunk extensor endurance

The distribution of maximum trunk extensor endurance time in groups A, B and C is shown in Fig. 7. The maximum voluntary isometric trunk extensor endurance averaged 171.5 sec (SD ± 34.2) in group A compared to 166.7 sec (SD ± 55.6) in group B and 137.5 sec (SD ± 57.1) in group C. The differences were significant both between groups A and C and between groups B and C with $p<0.01$. The results are summarized in Table III. The rather great reduction of subjects performing the endurance test was due to the exclusion of all tests where pain was provoked.

The mean torque of trunk weight was lowest in group A and highest in group C, but the differences were not significant (Table III). No significant correlation between torque of trunk weight and endurance time was noted in any of the groups. On the average, group A used 39.2% of MVC for trunk extensors during the endurance test, group B used 39.7% and group C 42.9%. The percentage of MVC for trunk extensors during the endurance test correlated significantly and negatively with endurance time in groups B and C with correlation coefficients of −0.29 ($p<0.05$) and −0.28 ($p<0.05$). In group A the correlation was positive but not significant. There was no significant correlation between age and endurance time in any of the groups.

No significant correlation between maximum isometric trunk extensor strength and maximum trunk extensor endurance was noted. The correlation coefficients were −0.19 in group A, 0.20 in group B and 0.14 in group C.

A significant correlation between endurance time and activity during leisure time was found only in group B with a correlation coefficient of 0.24 ($p<0.05$). No correlation was found between smoking habits and trunk extensor endurance in any of the groups. The correlation coefficient for the total group ($n=169$, missing = 36) was −0.08 (NS).

DISCUSSION

Different investigations have come to different conclusions concerning the importance of trunk muscle strength for low back disorders. Chaffin et al. (6) reported muscle strength as a predictor of the incidence and severity of back pain when individual strength and job requirements were taken into consideration. Battié et al. (2), using the same isometric lifting strength testing technique as Chaffin but without taking job requirements into consideration, could

Table III. *Isometric trunk extensor endurance, torque of trunk weight and torque of trunk weight as a percentage of maximum isometric extension torque in male workers with no lifetime (group A), probable (group B) and definite (group C) low back disorders.* $n=203$

	Isometric trunk extensor endurance				Torque of trunk weight				Torque of trunk weight as a percentage of maximum extension torque			
	Mean (sec)	SD	Range	*n*	Mean (Nm)	SD	Range	*n*	Mean (%)	SD	Range	*n*
Group A	171.5[a]	34.2	119–266	40	156.1	30.9	92–230	40	39.2	10.9	24–73	40
Group B	166.7[b]	55.6	28–291	71	152.8	27.3	98–260	75	39.7	12.9	23–92	70
Group C	137.5[a, b]	57.1	21–253	57	159.8	26.3	96–242	57	42.9	14.9	26–92	51

[a] Significant difference between group A and group C ($p \leq 0.01$).
[b] Significant difference between group B and group C ($p \leq 0.01$).

not predict individuals at risk for industrial back problems. However, the ratio in our study revealed an association between isometric trunk muscle strength and low back disorders. Group C showed a significantly lower extension/flexion ratio than group A. This is in accordance with the findings of McNeill et al. (12), who measured isometric trunk muscle strength in the upright position and calculated ratios. The lower ratio, found in our study, was due to a lower trunk extensor strength and a higher trunk flexor strength in group C. Biering-Sörensen (4), measuring in the same way, found no differences between subjects with and without back trouble. There are difficulties in interpreting the results. This can be due to the simplified way of classifying low back symptoms. Our series seemed to be a representative sample of construction workers. The workers in the three groups had been exposed to heavy construction work for about 20 years. The classification of low back pain was based on a physical examination with pain-provoking tests and the individuals' reports on history of low back symptoms. The 42 workers in group A had reported no lifetime low back pain in an interview and there were no findings on physical examination. The 86 workers in group C were intended to be the opposite extremes. They had reported current or previous low back pain in the interview and they were all classified as positive on physical examination.

In group A the maximum trunk extension torque was 419 Nm and the maximum trunk flexion torque was 327 Nm. That was about 20% higher than the strength values for normal males reported by Asmussen et al. (1). No significant differences were found on comparing mean values of trunk strength in groups A, B and C. Obviously, construction workers generally have better isometric trunk muscle strength than other men, irrespective of low back status.

Group C showed the shortest trunk extensor endurance time in our study and it differed significantly from that in both group A and group B. This is in accord with the findings of Nicolaisen & Jörgensen (13). In our study group A showed the longest endurance time, which was different from the results in Nicolaisen's study.

The torque of the trunk weight was somewhat, but not significantly, higher in group C than in the other groups. However, the correlation between torque of trunk weight and endurance time was not significant for any of the groups. Neither was the correlation between maximum trunk extensor strength and endurance time. The individuals in group C used a higher percentage of their maximum trunk extensor strength during the endurance test than the individuals in the other two groups, but only 8% of the variation in endurance time could be explained thereby.

In the physical examination lumbar structure was found to be delicate in group C and therefore pain could be suspected to be the cause of the reduced endurance time. That should not be the case, however, because all tests stopped because of pain were excluded. It is also reasonable to assume that pain also would have influenced maximum trunk extensor strength, but it did not.

The possible influence of intra-abdominal pressure during the endurance test was investigated in a pilot study (8). The intraabdominal pressure was 20 mmHg in one male and one female during the endurance test. This corresponded to the intraabdominal pressure in relaxed standing position and could not be of importance in the endurance test situation to stabilize the trunk.

The differences in endurance time could not be explained by differences in smoking habits or physical activity during leisure time. Relation between physical activity and endurance time was only found in group B and could only explain 6% of variation of the endurance time.

The reliability of the endurance test, with a correlation coefficient of 0.91, was about the same as that reported by Jörgensen & Nicolaisen (11).

CONCLUSIONS

The intraindividual maximum trunk extension/flexion ratio was significantly lower in workers with a definite low back disorder than in workers with no low back disorder. The mean values for maximum isometric trunk muscle strength did not differ between male workers with a no lifetime low back disorder and those with a probable or definite low back disorder. The isometric trunk extensor endurance time was significantly shorter in male workers with a definite low back disorder than in those with a no lifetime low back disorder and those with a probable low back disorder. On the average the workers used 39%–43% of their maximum trunk extensor strength during the endurance test.

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Address for offprints:

Eva Holmström, RPT
Bygghälsan
Höjagatan 21
S-212 33 Malmö
Sweden