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TRUNK STRENGTH, BACK MUSCLE ENDURANCE AND LOW-BACK TROUBLE

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ABSTRACT. The strength and endurance of the trunk muscles was studied in relation to the extent of earlier low-back trouble (LBT) in a homogeneous, and occupationally active group. Twenty-four female and 53 male postmen with an occupational senority of more than 2 years took part in the investigation. The cumulative lifetime prevalence, the one-year and the point prevalence of LBT were 67 %, 62 %, and 4 % in females and 55 %, 52 %, and 0 % in males. The rates are higher than in a representative Danish population 40 years old. Anthropometrical measurements and isometric strength (MVC) in trunk flexors and extensors were recorded. The flexibility of the spine, hip and knee joints, the fingertip–floor distance, and the restricted extension of the knee were evaluated. The isometric endurance in the trunk extensors was measured by two methods: 1) prone with the unsupported trunk in a horizontal position and the legs and hips fixated to a couch; and 2) standing, at 60 % MVC. The participants were divided into three groups according to the extent of *previous* LBT, Group I: LBT to a degree that made work impossible, Group II: LBT experienced but not to such a degree that work was hindered, and Group III: LBT never experienced. The main findings were that the isometric endurance time of the trunk extensors was shorter in group I than in II and III, while the trunk muscle strength, anthropometrical measures and joint flexibility were independent of the persons' earlier low-back episodes. Differences in the distribution of ST and FT muscle fibres are suggested as an explanation of the endurance difference. According to this the Group I persons have more fatigable FT fibres and are therefore more sensitive towards postural stress and muscle fatigue in postural muscles. A sex-related difference in the endurance time at the same relative muscle contraction was demonstrated. The explanation for this is probably that the intramuscular pressure is related to absolute strength. Therefore 60 % MVC might represent a larger hindrance to the blood flow in males and critical levels of anaerobicity will be reached more quickly than in females.

Key words: low-back trouble, MVC, isometric endurance, trunk flexors, trunk extensors, spine flexibility

Several attempts have been made to study trunk strength in various groups of patients with low-back pain, compared with that of more or less matched groups of normal subjects (1, 2, 8, 13, 23, 25). Most of the studies could demonstrate a reduction in the strength of the flexors and extensors of the trunk compared with normal values, and the authors suggest that the strength reduction must play a part in the development of low-back trouble (LBT).

In some of these investigations the patients were examined at a time when they were unfit to participate in their normal activities. The reference groups were in some cases chosen from patients with no LBT but undergoing treatment for other diseases. It is not clear, therefore, whether the trunk strength reduction in the patients with LBT was due to a limitation caused by pain, or to an actual decrease in the muscular strength.

In a general population with no acute low-back pain it was found that the trunk muscles tended to be weaker among those who experienced recurrence of LBT during a follow-up year compared with those without recurrence. Persons with first-time LBT during the follow-up year, however, did not have a trunk strength differing from that of those without LBT. Thus, the results from trunk strength measurements seem to be of little value as a predictor of LBT (9, 10).

Knowledge of the relationship between LBT and back muscle endurance is sparse and partly conflicting (9, 10). The endurance capacity of the muscles is an expression of their fatigability. Therefore, one may imagine that individuals with a low endurance of the back muscles are more exposed to postural stress that may lead to incorrect loading of the spine, and consequent LBT.

The purpose of the present investigation was primarily to study muscle strength and endurance of the trunk in relation to the extent of previous LBT in a homogeneous, active occupational group, viz. postmen. In addition a number of commonly used low-back related physical measures were obtained for use in comparisons with other studies of LBT.

MATERIAL AND METHODS

A total of 77 Danish postmen took part in the investigation: 24 females (median age 40.5 years (22–61 years)) and 53 males (median age 48.0 years (27–60 years)). Their occupational seniority was more than 2 years, on average 9.2 years for the females and 20.4 years for the males. At the time of the investigation none of the subjects was on the sick list and only one (a woman) had low-back symptoms. The investigation consisted of two parts.

Questionnaire

A questionnaire dealing with the experience of LBT and personal data (age and length of occupation) was filled in immediately before the laboratory examination. On the basis of this, both the men and the women were divided into three groups.

I. Those who once in their working life had experienced LBT to a degree that made it impossible for them to work.
II. Those who had experienced LBT, but not to a degree which made them unfit for work.
III. Those who had never experienced LBT.

The delimitation of the low-back region is, in accordance with recommendations published by an expert group appointed by the Nordic Council (3, 4), the area between the 12th rib and the gluteal folds.

Laboratory examination

In a laboratory examination, the following anthropometrical and physiological measurements were made.

Body height (cm).

Sitting height (cm): vertical distance from floor to crown of the head with the subject in a sitting upright position minus 46 cm (chair-height).

Body weight (kg).

Fat-free body mass (kg) was calculated from the formula $0.184 \times SF_{abd} + 0.145 \times SF_{knee}$, where SF_{abd} and SF_{knee} are the skinfold thickness (mm) on the abdominal wall and just above the patella, measured with skinfold caliper (15).

The weight-to-height ratio was expressed as the *Ponderal index* calculated by the formula $\sqrt[3]{W} \times h^{-1} \times 1000$ (35).

The maximal isometric strength (MVC) of the trunk flexors and extensors was measured standing, with a strap around the shoulders connected to a strain-gauge dynamometer fixated to the wall. In this position the subject performed maximal attempted backward extensions (front against dynamometer) and forward flexions (back against dynamometer) of the trunk (5), in both cases with the pelvis pressed against the wall. The duration of the contraction was 3–5 s. The measures are expressed in Newtons and as a percentage of standard values (6).

The isometric endurance of the trunk extensors was measured in two ways with an interval of more than one hour to ensure complete restitution. *Method 1:* The length of time (s) (max 240 s) the subject was able to maintain the unsupported upper part of the body (above the upper border of the iliac crest) horizontal, when placed prone on a couch with legs and buttocks fixated (10, 13). *Method 2:* The length of time (s) the subject was able to sustain a 60% MVC extensor contraction of the trunk muscles against a dynamometer (see above).

Fingertip–floor distance (FFD) (cm) was measured with a tape measure vertically from the tips of the middlefingers to the floor while the subject—without shoes—was bending maximally forward with the feet together and the knees straight (7, 10).

Modified Schober test (mm) for spinal flexion. An ink mark corresponding to the intersection between the midsagittal line and a line in level with the upper limit of the posterior part of the iliac crest and two ink marks respectively 5 cm below and 10 cm above this mark were drawn on the standing subjects. The distance between the lower and the upper mark was subsequently measured during a maximal forward flexion of the trunk. The increase of this distance above 15 cm was recorded in mm (22).

Restricted extension in the knee joint (degrees) representing the length of the hamstring muscles was measured, with the subject supine and the hips flexed 90°, as the angle between the longitudinal axis of tibia and the vertical, when the subject performed a maximal knee-extension (32). The angle determination was performed with a goniometer with an accuracy of five degrees. As the differences between the measures from the right and left leg were minimal, only the right leg results are tabulated.

Statistics: Conventional parametric statistics were used. A significance level of 0.05 was adopted.

RESULTS

The prevalence rates for LBT, namely the cumulative lifetime prevalence, the one-year period- and the point prevalence (on the day of examination) were 67%, 62% and 4% in females and 55%, 52% and 0% in males.

Our main results are given in Tables I–III. There was no statistically significant difference between groups II and III for any variable.

From Table I it appears that the females in group I (previous back troubles) were older and heavier than those in the two remaining groups of females. Since the ponderal index and weight were similar in the three groups of females, the greater weight in group I was due to the larger fat-free body mass, including bones and muscles. For men, only an age difference was found, i.e. the group I men were oldest.

The remaining anthropometric data of our subjects (height, sitting height, and weight) were in accordance with corresponding values in a recent representative survey of Danes (10).

Both the abdominal and the back muscle strength were similar in the three groups of males and females (Table II). Even when the strength measures

Table I

		Age (yrs)	Seniority (yrs)	Height (cm)	Sitting--height (cm)	Weight (kg)	Fat-free body mass (kg)	Ponderal index
Females								
Group I	$\bar{x}$	50^+	14.5^+	165	89°	69*	60*	24.8
n=6	SD	7.0	6.3	3.5	1.9	5.3	4.9	0.8
	SE	2.9	2.6	1.4	0.8	2.2	2.0	0.3
Group II	$\bar{x}$	42	9.0	162	85	61	53	24.3
n=10	SD	10.6	4.5	6.8	2.6	6.9	5.6	0.9
	SE	3.3	1.4	2.1	0.8	2.2	1.8	0.3
Group III	$\bar{x}$	35	5.5	164	86	60	51	23.9
n=8	SD	12.6	4.1	6.4	3.7	7.1	6.5	0.8
	SE	4.4	1.5	2.3	1.3	2.5	2.3	0.3
Males								
Group I	$\bar{x}$	50*	21.7	177	91	80	72	24.4
n=11	SD	6.7	9.9	8.6	5.0	9.0	8.4	1.1
	SE	2.1	3.0	2.6	1.5	2.7	2.5	0.3
Group II	$\bar{x}$	43	19.7	175	91	75	66	24.2
n=18	SD	9.3	10.3	5.3	1.9	9.3	8.4	1.0
	SE	2.2	2.4	1.2	0.4	2.2	2.0	0.2
Group III	$\bar{x}$	44	19.8	175	91	79	68	24.6
n=24	SD	7.6	9.0	6.8	3.9	12.8	10.9	1.0
	SE	1.5	1.8	1.4	0.8	2.6	2.2	0.2

Statistically significant difference from Group I to: 1) Groups II and III*, 2) Group III $^+$, 3) Group II $^{\circ}$.

Table II

		MVC trunk flexors		MVC trunk extensors		Ext/flex ratio	Isometric endurance of trunk extensors	
		N	%	*N*	%		Method 1(s)	Method 2(s)
Females								
Group I	$\bar{x}$	331	91	459	87	1.40	146*	63
n=6	SD	65.5	19.3	91.6	13.2	0.16	61.6	36.3
	SE	26.8	7.9	37.4	5.4	0.07	27.5	14.8
Group II	$\bar{x}$	375	99	448	83	1.19	227	69
n=10	SD	97.0	24.8	159.8	27.5	0.24	37.1	19.5
	SE	30.7	7.9	50.5	8.7	0.08	11.7	6.2
Group III	$\bar{x}$	397	100	511	92	1.37	219	80
n=8	SD	131.2	25.3	173.6	26.7	0.62	33.0	45.7
	SE	46.4	8.9	61.4	9.4	0.22	11.7	16.2
Males								
Group I	$\bar{x}$	559	87	687	78	1.24	148(*)	35*
n=11	SD	84.8	15.6	95.5	14.0	0.19	61.2	23.9
	SE	25.6	4.7	28.8	4.2	0.06	18.5	7.2
Group II	$\bar{x}$	552	86	677	77	1.24	194	61
n=18	SD	124.4	18.6	149.7	16.0	0.17	59.9	36.9
	SE	29.3	4.4	35.3	3.8	0.04	14.1	8.7
Group III	$\bar{x}$	582	90	668	75	1.15	184	54
n=24	SD	136.4	18.6	168.6	17.5	0.16	59.0	22.7
	SE	27.8	3.9	34.4	3.6	0.03	12.0	4.6

Statistically significant difference from Group I to: Groups II and III*; (*) see text.

Table III

		FFD (cm)	Mod. Schober (mm)	Restricted extension, right knee (degrees)
Females				
Group I	$\bar{x}$	6.0	51	23
n=6	SD	7.7	8.6	7.5
	SE	3.1	3.5	3.1
Group II	$\bar{x}$	0.6	54	14
n=10	SD	–	5.7	11.6
	SE	–	1.8	3.7
Group III	$\bar{x}$	3.0	60	19
n=8	SD	6.3	12.2	9.2
	SE	2.2	4.3	3.2
Males				
Group I	$\bar{x}$	10.0	59	30
n=11	SD	10.2	7.4	11.1
	SE	3.1	2.2	3.3
Group II	$\bar{x}$	5.0	59	31
n=18	SD	7.2	13.2	12.7
	SE	1.7	3.1	3.0
Group III	$\bar{x}$	7.0	55	24
n=24	SD	9.3	11.5	12.2
	SE	1.9	2.3	2.5

were compared with standards adjusted for age, height and sex (6), no differences could be demonstrated correlating to the state of previous low-back complaints. The relatively low values for muscle strength in the males were significant only from the females in the extensor muscles of those who had never experienced LBT (group III).

In consequence of the similarity in the absolute trunk muscle strength in the three groups, the extension/flexion ratio (Table II) is not influenced by the participants' degree of LBT in the past. This indicates that no isolated muscle strength reduction was present in the trunk extensors due to earlier attacks of low-back illness.

The isometric endurance capacity of the back muscles is presented in Table II. It can be seen that group I had a significantly smaller endurance capacity in the back muscles, evaluated by either of the two methods used. In females the results with method 1 were significantly different when group I are compared with groups II and III (146 vs 227 and 219 s). With method 2 the results in group I are also lower than those in groups II and III, but the differences are not statistically significant (see Discussion p. 6). In males, only results with method 2 from group I (35 s), were significantly different from those of groups II and III (61 and 54 s). With method 1, however, the results from groups I–III were 148 s, 194 s, and 184 s respectively, which is close to a significant difference between groups I and II ($p<0.06$) and shows a trend to a significant difference between groups I and III ($p<0.11$). Thus, muscle strength was not influenced by 'the health conditions' of the lower back, whereas muscular endurance capacity of the trunk extensors seemed to be reduced in persons with serious attacks of LBT earlier in life.

A sex difference for endurance time has been found previously (10, 28, 29, 31), which we are now able to confirm for groups without earlier complaints when the weight-independent method 2 is applied (females 80 s, males 54 s). With method 1, however, only a trend can be demonstrated ($p<0.1$).

The results from the clinical investigation are given in Table III. There is a trend towards a larger fingertip–floor distance (FFD) in group I compared with the other two groups in both the males and the females. This trend was not seen, however, in the modified Schober test or in the length of the hamstring muscles.

These clinical measures furthermore, seem to indicate that the flexibility of the spine, and of the hip and knee joints of the postmen was more restricted than that of a representative group of Danes (10).

In order to evaluate the FFD as an indicator of flexibility of the vertebral column we plotted the results from modified Schober, which is a reliable measure of flexibility (22), and the restricted extension of the right knee against FFD in Figs. 1 and 2.

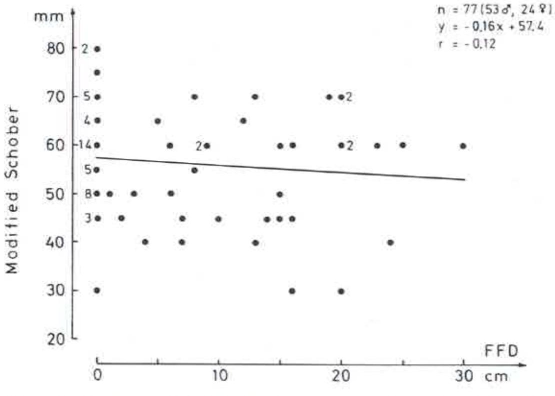

Fig. 1. The modified Schober scores for spinal flexion (mm), plotted against fingertip–floor distance (cm).

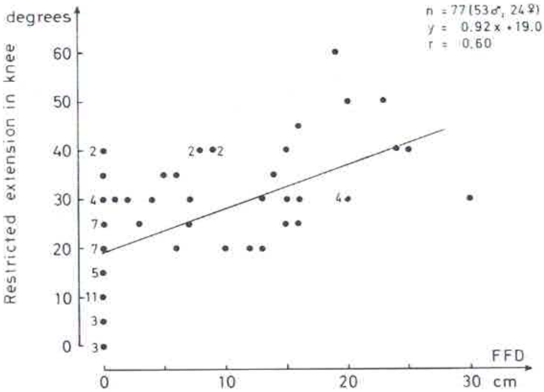

Fig. 2. Restricted extension in the right knee joint (degrees) as a measure of the hamstring muscle length, plotted against fingertip–floor distance (cm).

It is obvious that there was no correlation between FFD and the modified Schober test ($r=0.12$), whereas a quite good correlation was found between FFD and the length of the hamstring muscles ($r=0.60$). The FFD is therefore a poor test of flexibility of the vertebral column, though often used for this purpose (7, 10). The FFD is rather an expression of the tightness of the hamstrings.

DISCUSSION

The prevalence rates of LBT in our subjects were in agreement with similar rates from a larger population of postmen ($n=353$) (26). When the rates were compared with those from a representative 40-year-old population, the one-year period prevalence was higher in our subjects (9). The most striking differences were found in the females, whose lifetime and one-year prevalences were 67% vs 52% and 62% vs 38%, possibly attributable to either a social selection of the women recruited for the job of postman, or to the fact that the postman's job is more strenuous than the average female occupation.

When the absolute strength measurements from the back- and abdominal muscles are compared with gender-, age-, and dimension-related standards obtained 20 years ago with an identical method, a secular reduction in the muscle strength seems evident. The strength reduction is greatest in the males, and more marked in the back muscles than in the abdominal muscles. This tallies with the 7–8% reduction in children's trunk strength over a 25-year period (1956–1981) reported by Heebøll-Nielsen (14), and with a similar decrease in the back strength of elderly men (12). The reduced trunk muscle strength can possibly be ascribed to changes in the pattern of physical activity as well at working and in leisure time. Since it is postulated (1, 2, 8, 13, 23, 27) that weak trunk muscles are one of the risk factors for low-back disorders, the above-mentioned strength reduction could influence the rate of lumbar problems in a negative way.

From a study of in-patients with severe back disorders (1) it appears that back muscle strength of the patients is less than that of matched groups of normals. Since the patients' general muscle strength is reduced to the same extent as their back muscle strength, it is possible that the reduction is caused by the low level physical activity during the bedrest. When outpatients with low-back disorders were compared with normal persons, no difference in the back muscle strength of the two groups could be demonstrated (23). Our results from occupationally active people support these findings, as we were unable to demonstrate any back strength difference, either in females or in males when the three groups—previously absent owing to back complaints, with earlier back complaints, and without earlier back complaints—are compared. Thus, from retrospective studies on back muscle strength and LBT, the strength *per se* is of no prognostic value for subsequent development of low-back pain. This viewpoint is strongly supported in a 12-month prospective study with a group of 920 persons (9).

Very few data concerning the endurance capacity of the back muscles are to be found in the literature (10, 17, 28). The 60% MVC isometric endurance times varying from 63 s to 80 s in females and from 35 s to 61 s in males are, however, in agreement with the few existing results. The relative large endurance capacity in the back muscles compared with other muscle groups (see e.g. Rohmert (33) and Monod (24)) is partly explained by the fibre composition of the back muscles (16), i.e. a large proportion of slow-twitch oxidative fibres (type I). Moreover, it seems that the back muscles are able to mobilize a larger blood perfusion at a given relative contraction (% MVC) than are other muscle groups (11).

The sex difference in the back muscle endurance, with highest scores for the females, is difficult to explain. Similar observations have been reported previously from experiments with human limb muscles and trunk extensors (10, 28, 29, 31). Oxytocin has been suggested as a candidate because of its increasing effect on the blood perfusion of the contracting muscles (31). But since this effect and the blood concentration of oxytocin is not sex-dependent (18, 20, 21), this hormone can be omitted as a possibility. Therefore, it might be expected that differences in muscle fibre distribution in males and females could be part of the explanation. This is not the case, however, (34). A third possibility could be the influence of the sex homones. It has been shown that the endurance capacity is larger in 1) post-menopausal women than in younger women (29), and 2) in the first days of the menstrual cycle in women not taking oral contraceptives (30). In these periods of life the blood concentrations of estrogen and progesterone are relatively low. It is therefore possible that the sex-hormones or their regulatory hormones, through an unknown mechanism, can influence the endurance capacity and thus partly explain the observed sex difference.

In our opinion, however, the sex difference in muscular endurance can most likely be explained by differences in the intramuscular pressure (IMP) and in differences in muscle blood flow in males and females at the same relative strength level, e.g. 60% MVC. The rationale behind the explanation is: IMP is related to absolute strength (36) and a certain relative muscle load represents different, absolute loads and intramuscular pressures in males and females. Since no sex-difference is present in blood pressure, a certain submaximal muscle contraction, e.g. 60% MVC, represents a greater hindrance to the muscle blood flow in males than in females. Therefore, critical levels of anaerobicity might first be achieved in the males.

The 'IMP theory' cannot explain our most striking finding, i.e. that persons with earlier serious attacks of LBT have, compared with normals, less endurance capacity but similar strength in their trunk extensors. A tentative explanation of this difference could be that the patients' back muscles are dominated by easily fatigable muscle fibres, e.g. FT fibres. Such individuals will consequently be more exposed to postural stress, viz. muscular fatigue and probably impaired coordination of the postural muscles. The disturbance of the normal muscle coordination leads eventually to mechanical 'failure-loads' in the spine which in turn might be responsible for LBT.

This point of view is supported by the observation that a large isometric endurance of the trunk extensors seems to prevent first-time occurrence of LBT (10). It is possible, however, that LBT could induce changes in the trunk extensors, resulting in an impaired endurance capacity, but there is not evidence for this at the moment.

The unexpected moderate reduction in endurance time for the group I women in method 2 might be explained by the fact that they are older. Age *per se* increases the endurance time and that might mask a possible endurance-reducing effect of LBT (29).

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