ORIGINAL ARTICLE

Physical capacity in relation to low back, neck, or shoulder pain in a working population

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An appendix to this article is available on our website.

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Aims: To investigate the longitudinal relation between physical capacity (isokinetic lifting strength, static endurance of the back, neck, and shoulder muscles, and mobility of the spine) and low back, neck, and shoulder pain.

Methods: In this prospective cohort study, 1789 Dutch workers participated. At baseline, isokinetic lifting strength, static endurance of the back, neck, and shoulder muscles, and mobility of the spine were measured in the pain free workers, as well as potential confounders, including physical workload. Low back, neck, and shoulder pain were self-reported annually at baseline and three times during follow up.

Results: After adjustment for confounders, Poisson generalised estimation equations showed an increased risk of low back pain among workers in the lowest sex specific tertile of performance in the static back endurance tests compared to workers in the reference category (RR = 1.42; 95% CI 1.19 to 1.71), but this was not found for isokinetic trunk lifting strength or mobility of the spine. An increased risk of neck pain was shown for workers with low performance in tests of isokinetic neck/shoulder lifting strength (RR = 1.31; 95% CI 1.03 to 1.67) and static neck endurance (RR = 1.22; 95% CI 1.00 to 1.49). Among workers in the lowest tertiles of isokinetic neck/shoulder lifting strength or endurance of the shoulder muscles, no increased risk of shoulder pain was found.

Conclusions: The findings of this study suggest that low back or neck endurance were independent predictors of low back or neck pain, respectively, and that low lifting neck/shoulder strength was an independent predictor of neck pain. No association was found between lifting trunk strength, or mobility of the spine and the risk of low back pain, nor between lifting neck/shoulder strength or endurance of the shoulder muscles and the risk of shoulder pain.

Low back, neck, and shoulder pain are of multifactorial origin. Both physical and psychosocial factors can contribute to its development, as well as individual factors such as gender, age, and anthropometry.[1 2] The biomechanical load tolerance model assumes that musculoskeletal disorders can be explained by an imbalance between load and tolerance, which may become manifest as musculoskeletal symptoms and disorders. The term "load" describes physical stresses acting on the body or on anatomical structures within the body. These stresses include kinetic (motion), kinematic (force), oscillatory (vibration), and thermal energy sources, which can originate from the external environment (such as vibrating tools), or from actions of the individual (such as lifting objects). The term "tolerance" is used to describe the capacity of physical and physiological responses of the body to the load.[1]

The association between physical capacity and musculoskeletal disorders has been studied in the laboratory using in vitro and cadaver studies.[3 4] In epidemiological studies, only proxy measures of physical capacity can be used—for example, isokinetic lifting strength, endurance time of submaximal static muscle contraction, or joint mobility. Several longitudinal studies reported on the relation between physical capacity and the risk of low back pain. Low performance in tests of muscle strength,[5–8] endurance,[9–11] and mobility[7 12] were reported as risk factors for low back pain, although many other studies did not find these results.[7 9 12–24] Furthermore, very few longitudinal studies have examined the association between physical capacity and the risk of neck or shoulder pain.[5 25] Barnekow-Bergkvist *et al* reported on a decreased risk of neck/shoulder problems in males with high performance in a test of dynamic endurance,[5] but no association was found between muscle strength and the risk of neck or shoulder pain.[25]

The main objective of this prospective cohort study among a working population is to investigate if isokinetic lifting strength and static endurance of the back and neck/shoulder muscles, and mobility of the spine are predictors of low back, neck, or shoulder pain, independent of the physical workload.

METHODS

Design

The present study is part of the longitudinal study on musculoskeletal disorders, absenteeism, stress, and health (SMASH),[26–28] a large prospective cohort study among a working population with a follow up time of three years. Almost 1800 blue-collar and white-collar workers participated in this study. They were working in 34 companies located throughout the Netherlands. Data were collected on physical capacity, musculoskeletal disorders, and many potential confounding factors. The baseline measurements were carried out between January 1994 and May 1995 consisting of a comprehensive self-administered postal questionnaire, measurements of physical capacity, and assessment of physical load at the workplace. During follow up, three questionnaires were filled out about once every year with a range of 9–15 months at maximum due to differences in response time.

Abbreviations: GEE, generalised estimation equation; LMD, localised musculoskeletal discomfort

Study population

At baseline, 1789 (87%) of the 2064 workers who were invited to participate in SMASH completed the self-administered questionnaire. We excluded workers from the analyses if they had worked less than one year in their current job, worked less than 20 hours per week, or received sickness benefit or permanent disability pension at baseline (211 workers were excluded). Furthermore, we excluded workers from the analyses when data on outcome measures were missing in three or four questionnaires (107, 105, and 108 workers were excluded for low back, neck, and shoulder pain, respectively).

Just before testing physical capacity at baseline, we asked the workers for contraindications that might involve a health risk, or that might have an effect on the results of the tests. We excluded workers from the tests if they had cardiovascular diseases, or fever, or were pregnant (143, 204, and 211 workers were excluded, respectively). In addition, current localised musculoskeletal discomfort (LMD) was asked. The LMD score was used to obtain a rating of the perceived feelings of discomfort (pain, fatigue, tremor, etc) in any part of the body (ranging from no discomfort (zero) to worst imaginable discomfort (10)).[29] We excluded workers from the tests for the low back, neck, or shoulders if they reported an LMD score of at least four points in the matching body region. Finally, we included 1328, 1269, and 1259 workers in the analyses on low back, neck, and shoulder pain, respectively.

Assessment of outcome measures

Outcome measures were self-reported low back, neck, and shoulder pain. Data on musculoskeletal disorders were measured by an adapted Dutch version of the Nordic Questionnaire.[30] In the baseline and the three follow up questionnaires, subjects were asked about low back, neck, and shoulder pain ("Did you have pain in the past 12 months?") on a four point scale ("no", "sometimes", "regular", or "prolonged"). We dichotomised these variables by combining "no" with "sometimes" ("no pain"), and "regular" with "prolonged" ("pain"). If a pain-free episode was followed by an episode with low back, neck, or shoulder pain, we defined this as occurrence of an event. We did not consider pain at baseline as an event. However, if workers with pain at baseline recovered during follow up and experienced recurrence at a later follow up moment, we defined this as occurrence of an event. In addition, for some workers events occurred twice at follow up, if they reported pain in both the first and third follow up questionnaire, but were free of pain at baseline and at the second follow up moment. Furthermore, for workers with at random missing data on low back, neck, or shoulder pain in one or two questionnaires, potential transitions from "no pain" to "pain" were analysed in the same way as for workers without missing data, but transitions from a missing value to a non-missing value and vice versa were ignored.

Table 1 Characteristics of the study population, SMASH, 1994–97 (n = 1357)

Characteristics*	Total population†
Men	69.5
Age (mean (SD))‡	35.4 (8.8)
Working hours per week (mean (SD))‡	38.1 (5.1)
Years of employment in current job (mean (SD))‡	9.4 (7.6)
Type of occupation	
Blue-collar occupations	61.3
White-collar occupations	31.0
Caring occupations	7.7
Occurrence of low back pain during follow up§	
Follow up 1	8.9
Follow up 2	10.6
Follow up 3	6.9
Occurrence of neck pain during follow up§	
Follow up 1	5.8
Follow up 2	6.9
Follow up 3	3.7
Occurrence of shoulder pain during follow up§	
Follow up 1	7.2
Follow up 2	6.4
Follow up 3	5.8

*Unless otherwise indicated, baseline characteristics are given.
†Unless otherwise indicated, values are percentages (%).
‡SD, standard deviation.
§Regular or prolonged pain in the past 12 months and no or sometimes pain in the past 12 months in the previous questionnaire.

Assessment of physical capacity

At baseline, physiotherapists performed the different tests of isokinetic lifting power strength, submaximal endurance time of static contraction of the back, neck, and shoulder muscles, and mobility of the spine. Isokinetic lifting strength was measured with the Aristokin dynamometer (Lode BV Medical Technology, Groningen, the Netherlands), both from floor to hip level for the trunk muscles, and from hip to shoulder level for the neck/shoulder muscles. After practicing, in order to get familiar with the Aristokin, workers had to lift the box three times with maximum effort with a velocity of 40 cm/sec and a rest period of 30 seconds in between. Isokinetic lifting strength (in Newtons) was defined as the average outcome of the second and third lifts.

We defined static endurance as the number of seconds during which the workers could keep a position, while carrying a load. To test the static endurance of the back extensors, the Biering-Sørensen test[8] was used. Workers were lying prone on a table and had to keep their unsupported upper part of the body in a horizontal position with fixation of the buttocks and legs. We asked the LMD score at intervals of 15 seconds. The test was finished when the workers reached an LMD score of five in the back region, or a score of seven in another part of the body, or after four minutes at maximum. For the measurement of the static endurance of the neck extensors, the workers had to keep their head flexed at 45° in a sitting position, while carrying a helmet of 5 kg for males, or 2.5 kg for females. For the measurement of the static endurance of the shoulder elevators, workers had to keep their arms elevated at 90° in a sitting position, while carrying a load of 2.5 kg for males, or 1.5 kg for females. We obtained LMD at intervals of 30 seconds. The tests were finished at an LMD score of five in the neck/shoulder region, or a score of seven in another part of the body, or after seven minutes at maximum.

Lumbar flexion was measured by the Schöber test, that is the difference in the distance between 5 cm below and 10 cm above S1/S2 in a position of maximum flexion and in the neutral position.[31] Rotation of the spine was measured by the difference in the distance (in cm) between the incisura jugularis and L5 in a position of maximum rotation and in the neutral position. Both flexion and rotation were measured twice. In this study, we averaged the outcomes of those two measurements. Furthermore, we averaged left and right rotation, because of high correlation (Pearson correlation coefficient 0.74 ($p = 0.000$)).

Assessment of potential confounders

Potential confounding factors related to low back, neck, or shoulder pain were measured at baseline including age, length, body mass index, years of employment, number of working hours per week, education, physical workload, psychosocial workload,[32] physical load during leisure time,[33]

Table 2 Characteristics of the study population, SMASH, 1994–97 (n = 1357)

	Men median (min–max)	Women median (min–max)	Total median (min–max)
Isokinetic lifting strength back muscles (n)	551 (52 to 1358)	338 (39 to 724)	475 (39 to 1358)
Isokinetic lifting strength neck/shoulder muscles (n)	257 (38 to 563)	129 (15 to 272)	210 (15 to 563)
Static endurance back extensors (sec)	90 (5 to 240)	90 (6 to 240)	90 (5 to 240)
Static endurance neck flexors (sec)*	278 (7 to 420)	284 (30 to 420)	280 (7 to 420)
Static endurance shoulder elevators (sec)*	270 (48 to 420)	210 (27 to 420)	257 (27 to 420)
Flexion of the spine (cm)	7.0 (2.0 to 10.0)	6.5 (0.5 to 10.01)	7.0 (0.5 to 10.0)
Rotation of the spine (cm)	5.8 (1.5 to 12.8)	5.1 (1.4 to 11.5)	5.5 (1.4 to 12.8)

*Loads were different for men and women.

coping style,[34] and exposure to one or more life events.[35] Furthermore, we considered previous low back, neck, or shoulder pain, self-reported general health status, self-reported physical condition, and measures of physical capacity, apart from the independent variable, as potential confounders. Finally, comorbidity regarding other musculoskeletal disorders at baseline and during follow up was a potential confounder.

Physical load at work was assessed using video recordings and was self-reported. Four 10 or 14 minutes video recordings were taken randomly during a day of about half of the workers. They were assigned to groups with similar tasks. In each of these groups, about half of the videotapes were observed by trained research assistants and analysed for posture, movement, and force exertion. Data on psychosocial workload were collected by means of the Job Content Questionnaire, which measured all dimensions of the Demand-Control Support Model. Various items on the questionnaire were combined into dimensions as proposed by Karasek *et al*.[32] Physical load during leisure time included the average number of hours of sports participation per week during the past year, the number of years of sports participation in the past,[36] and the frequency of sports or heavy physical activities which causes sweating during the past four months.

The online appendix (see http://www.occenvmed.com/supplemental) lists all potential confounding factors for the analyses on low back, neck, and shoulder pain separately, which were associated with low back, neck, or shoulder pain with a p value of 0.25 or less. Mutually dependent confounding factors (Spearman correlation coefficients of $\geqslant 0.5$ or $\leqslant -0.5$) were excluded.

STATISTICAL ANALYSES

We have used Poisson generalised estimation equations (GEE) to analyse the association between isokinetic lifting strength, static endurance, and mobility of the spine at baseline as fixed variables and self-reported low back, neck, or shoulder pain at every follow up moment as dichotomous time variables.[37] For each of the three follow up moments, the transitions from a pain free episode to an episode with pain were measured. We performed the analyses with the statistical package Stata version 7.0 (Stata Corp, College Station, TX, USA).

In order to adjust for differences in performance in tests of physical capacity between men and women, we calculated sex specific tertiles, which were combined categories of both tertiles for men and women. We estimated univariate and multivariate risk ratios (RRs) and 95% confidence intervals (95% CIs) with the highest tertile as reference category. These RRs can be interpreted as the risk of occurrence of pain during follow up in workers with low or medium performance in tests of physical capacity compared to those with high performance, taking into account the dependency of the observations within one worker.[38]

We included follow up time both in univariate and multivariate analyses to adjust for the fact that the association between physical capacity at baseline and the risk of musculoskeletal disorders during follow up could be stronger after one year than after two or three years. Furthermore, we selected age as a confounder a priori. All other potential confounders were included in the univariate GEE models together with the dependent and independent variables. If the crude beta coefficients changed at least 10%, these confounders were included in the final multivariate

Table 3 Univariate and multivariate risk ratios (95% confidence intervals) of the association between sex specific tertiles of physical capacity and low back pain, SMASH, 1994–97 (n = 1328)

Physical capacity	Total events/total number at risk*	Crude RR (95% CI)†	Adjusted RR (95% CI)
Isokinetic lifting strength back muscles	High (86/1060)	1.00	1.00‡
	Moderate (98/1056)	0.99 (0.83 to 1.19)	1.01 (0.84 to 1.21)
	Low (96/1055)	1.06 (0.89 to 1.27)	1.09 (0.91 to 1.31)
Static endurance back extensors	High (87/1003)	1.00	1.00‡
	Moderate (85/991)	1.14 (0.93 to 1.39)	1.13 (0.93 to 1.38)
	Low (94/1010)	1.43 (1.19 to 1.71)	1.42 (1.19 to 1.71)
Flexion of the spine	High (94/1160)	1.00	1.00‡
	Moderate (99/1015)	1.08 (0.91 to 1.29)	1.09 (0.91 to 1.30)
	Low (129/1469)	1.10 (0.94 to 1.30)	1.12 (0.95 to 1.31)
Rotation of the spine	High (92/1179)	1.00	1.00§
	Moderate (119/1194)	1.09 (0.92 to 1.30)	0.99 (0.82 to 1.19)
	Low (111/1268)	1.18 (1.00 to 1.39)	1.10 (0.92 to 1.32)

*Summarisation of occurrence annually during follow up divided by a summarisation of all workers at risk annually during follow up.
†RR, risk ratio; CI, confidence interval. Including the covariate duration of follow up.
‡Adjusted for duration of follow up, and age.
§Adjusted for duration of follow up, age, and isokinetic lifting strength.

Table 4 Univariate and multivariate risk ratios (95% CIs) of the association between sex specific tertiles of physical capacity and neck pain, SMASH, 1994–97 (n = 1269)

Physical capacity	Total events/total number at risk*	Crude RR (95% CI)†	Adjusted RR (95% CI)
Isokinetic lifting strength neck/shoulder muscles	High (59/1030)	1.00	1.00‡
	Moderate (60/1084)	1.27 (0.99 to 1.64)	1.21 (0.94 to 1.55)
	Low (59/1039)	1.45 (1.14 to 1.84)	1.31 (1.03 to 1.67)
Static endurance neck flexors	High (47/1099)	1.00	1.00§
	Moderate (76/1174)	1.24 (0.97 to 1.59)	1.15 (0.94 to 1.40)
	Low (64/1152)	1.70 (1.34 to 2.14)	1.22 (1.00 to 1.49)

*Summarisation of occurrence annually during follow up divided by a summarisation of all workers at risk annually during follow up.
†RR, risk ratio; CI, confidence interval. Including the covariate duration of follow up.
‡Adjusted for duration of follow up, age, and length.
§Adjusted for duration of follow up, age, comorbidity of low back or shoulder pain, and previous neck pain.

models. All confounders were added as fixed variables to the models, except comorbidity regarding other musculoskeletal disorders during follow up, which was added as a time variable.

RESULTS

Characteristics of the study population

Tables 1 and 2 present descriptive statistics of the study population and performance in tests of physical capacity, both among males and females. Almost 70% of the workers were male and the mean age was 36 years. Employees worked 38 hours per week on average. Almost 70% of the workers had a blue-collar or caring profession and more than 30% had a white-collar job. During follow up, between 7% and 11% of the workers had a low back pain episode following a pain-free episode, between 4% and 7% of the workers had neck pain, and between 6% and 7% of the workers had shoulder pain.

For some measures, performance in tests of physical capacity was not distributed normally. Many workers were able to reach the maximum endurance time in the static neck and shoulder endurance tests. Therefore, tables 1 and 2 show median (minimum-maximum) performance. Median static endurance of the back and neck muscles and mobility of the spine were comparable in men and women, but median isokinetic lifting strength and median static endurance of the shoulder muscles were higher in men than in women.

Low back pain

Table 3 shows the results of the univariate and multivariate GEE analyses of the association between performance in tests of physical capacity of the low back and the risk of low back pain. Adjusted for age and follow up time, the risk ratio of low back pain was 1.42 (95% CI 1.19 to 1.71) among workers in the lowest tertile of static endurance of the back muscles compared to the reference. No increased risk of low back pain was found for workers with low isokinetic lifting strength or decreased mobility of the spine.

Neck pain

An increased risk of neck pain was shown among workers with low performance in the tests of isokinetic neck/shoulder lifting strength (adjusted RR = 1.31; 95% CI 1.03 to 1.67) and static endurance of the neck muscles (adjusted RR = 1.22; 95% CI 1.00 to 1.49) (see table 4).

Shoulder pain

Univariate analyses showed an increased risk of shoulder pain among workers in the lowest tertile of isokinetic lifting strength (crude RR 1.34; 95% CI 1.06 to 1.70). After adjustment for confounders, no relationships remained. No association was found between static endurance of the shoulder elevators and the risk of shoulder pain (see table 5).

DISCUSSION

Interpretation of the results

In the present study, we reported on the longitudinal association between physical capacity, measured by isokinetic lifting strength, static endurance, and mobility of the spine, and the risk of low back, neck, or shoulder pain.

Workers with low performance in the static back endurance test at baseline had an increased risk of low back pain during three years of follow up. We found no increased risks of low back pain among workers with decreased levels of isokinetic trunk lifting strength and mobility of the spine. Furthermore, workers with low performance in static endurance test of the neck muscles or the isokinetic neck/shoulder lifting test at baseline had an increased risk of neck

Table 5 Univariate and multivariate risk ratios (95% CIs) of the association between sex specific tertiles of physical capacity and shoulder pain, SMASH, 1994–97 (n = 1259)

Physical capacity	Total events/total number at risk*	Crude RR (95% CI)†	Adjusted RR (95% CI)
Isokinetic lifting strength neck/shoulder muscles	High (62/1030)	1.00	1.00‡
	Moderate (73/1070)	1.25 (0.98 to 1.59)	1.16 (0.91 to 1.46)
	Low (71/1028)	1.34 (1.06 to 1.70)	1.16 (0.92 to 1.46)
Static endurance shoulder elevators	High (77/1091)	1.00	1.00§
	Moderate (73/1097)	1.05 (0.83 to 1.32)	0.86 (0.69 to 1.07)
	Low (63/1091)	1.17 (0.93 to 1.46)	0.88 (0.71 to 1.11)

*Summarisation of occurrence annually during follow up divided by a summarisation of all workers at risk annually during follow up.
†RR, risk ratio; CI, confidence interval. Including the covariate duration of follow up.
‡Adjusted for duration of follow up, age, and length.
§Adjusted for duration of follow up, age, comorbidity of low back or neck pain, previous shoulder pain, and the number of sports participation in the past.

pain during follow up. Finally, we found no relationships between isokinetic neck/shoulder lifting strength and static endurance of the shoulder muscles and the risk of shoulder pain.

The associations found in this study cannot automatically be interpreted as direct causal relationships, because intermediate factors could have played a role. For example, physical capacity at baseline could have been decreased by musculoskeletal disorders in the past and/or could have been influenced by physical load at work and during leisure time in the past. It is plausible that higher physical load in the past would have led to higher physical capacity at baseline, due to training. Because in this study, several potential confounding factors were taken into account, such as previous musculoskeletal disorders, anthropometry, physical and psychosocial load at work, and physical load during leisure time, it can be concluded that low back or neck muscle endurance are independent predictors of low back or neck pain, respectively, and that low lifting neck/shoulder strength is an independent predictor of neck pain.

Comparisons with former research

In line with our results, three studies in the general population reported on low endurance as a risk factor for low back pain.[9–11] In two of these studies, the Biering-Sørensen test was used, as we used in our study.[9 11] Rissanen *et al*[10] reported on dynamic trunk extensor endurance using standardised arch-up tests and is therefore not comparable with the results of our study. On the other hand, the results of the present study for the static back endurance tests were contradictory to several studies that did not find a relation.[7 12 15–18 20 23] These differences can be explained by many factors. In contrast to our study, some of these studies reported on the relationship between dynamic endurance and low back pain.[18 20] In other studies, which used the Biering-Sørensen test, the study population was quite specific,[7 12 15–17 20 23] like (female) nurses[16 17] or spinning operators,[23] in contrast to our diverse study population.

Furthermore, in line with our results, several studies did not find an association between lifting strength and the risk of future low back pain.[3 9 13 15 18–22 24] However, the results of many of these studies are not comparable with our results, because isometric strength was measured, in contrast to our isokinetic strength test.[3 9 13 18 20 22 24] Four studies found low trunk strength as a significant risk factor of low back pain,[5–8] but these studies are not comparable with our results. Three of these studies used an isometric strength test,[5 6 8] and Takala *et al*[7] used a specific study population of forest industry workers.

About half of the studies reporting on the association between trunk mobility and low back pain found no association,[9 14 24] which is in line with our results, while half of the studies found decreased mobility of the spine as a risk factor of low back pain.[7 12] On the other hand, Biering-Sørensen *et al*[8] reported on a larger Schöber value as a predictor of first time low back pain in males.

Very few studies reported on the longitudinal relationship between physical capacity and the risk of neck or shoulder pain.[5 25] Our finding that low isokinetic lifting strength predicts neck pain is contradictory to the study of Hämäläinen *et al*,[25] in which no relation was found. It is difficult to compare these results directly with our results, because Hämäläinen *et al* used an isometric strength test instead of our isokinetic strength test and their study population of student fighter pilots was more specific. Our finding of low static endurance as a predictor of neck pain is in line with the study of Barnekow-Bergkvist *et al*,[5] although this study reported on dynamic endurance measured by a bench press.

Methodological considerations

Some methodological considerations can be made regarding this study. Firstly, we assumed that the association between physical capacity at baseline and the risk of low back, neck, or shoulder pain would be stronger after one year than after two or three years. Therefore, we included follow up time in the analyses as a potential confounder of this relationship. In addition, to examine if our assumption was correctly, we performed univariate analyses with inclusion of the interaction term physical capacity×follow up time, but found no interaction (data not shown). This means that it is plausible that the relation between performance in tests of physical capacity and the risk of low back or neck pain did not change substantially during follow up. In addition, because pain was asked for a relatively long period of 12 months, we assumed that the on average small differences in response time did not influence the outcome measure. Therefore, we did not adjust for these differences and used equal time points for all workers.

Secondly, the interpretation of performance in tests of physical capacity depends on several factors. One of these factors is the test-retest reliability and interrater reliability. These were investigated in four different pilot studies among healthy subjects (15 students and 18 workers). Two physiotherapists carried out the tests of physical capacity at two moments with one week in between. The average results of these pilot studies showed high test-retest reliability (Pearson correlation coefficient of more than 0.75 and a p value of the paired *t* test of more than 0.40), but moderate interrater reliability (Pearson correlation coefficient between 0.50 and 0.75 and a p value of the paired *t* test between 0.10 and 0.40) for the isokinetic neck/shoulder lifting test and the back endurance test. Test-retest reliability and interrater reliability were moderate for the other tests of physical capacity. This means that misclassification could not completely be excluded from our study. Furthermore, performance in tests of physical capacity might have been influenced by motivation, pain during testing, or kinesiophobia, leading to non-differential misclassification, resulting in an attenuation of the effects. To investigate the influence of motivation and pain on the performance in the isokinetic lifting tests and endurance tests in this study, we carried out analyses for a selection of workers who were evaluated by the physiotherapist as well motivated for the tests (on a three point scale) and did not report or show pain (n = 1151). Univariate risk ratios were comparable with those for the whole study population, which means that motivation or pain during testing did not play an important role in the performance of the tests and misclassification was not likely.

A third factor that could have influenced the results of the study was our choice to divide performance in tests of physical capacity into tertiles, because we did not have any physiological cut off point. Some measures were normally distributed while others were skewed. For example, many workers were able to reach the maximum endurance time in the static endurance tests, which means that no distinction could be made between workers with good performance and workers with very good performance. To investigate if underestimation of effects might be at hand among the normally distributed measures, due to inclusion of individuals with a ''normal'' physical capacity in the high and low tertiles, we calculated quartiles and combined the second and third one as the moderate category, but we found comparable results with those of tertiles. Furthermore, in general, physical capacity of men is higher than that of women. On average, men have larger body sizes, higher muscle forces, and higher aerobic capacity than women.[39] In the present study, the isokinetic lifting tests and the mobility tests of the spine were identical for men and women, whereas the loads used in the static endurance tests of the neck and shoulder muscles were heavier for men than for women. When calculating tertiles of the isokinetic lifting tests of the whole study population, as expected, most of the men were categorised into the highest tertile, while most of the women were categorised into the lowest tertile. Despite the fact that the static shoulder endurance test was specified by gender, most of the men were still categorised into the highest tertile, while most of the women were categorised into the lowest tertile. In this study, we have chosen to calculate sex specific tertiles for all measures of physical capacity, in order to adjust for the unequal distribution of men and women. A comment can be made on this choice, because in many occupations workload is comparable for men and women, which means that the capacity of a woman in the highest tertile could still be too low to give an appropriate response on the workload, while the capacity of a man in the lowest tertile (with a higher physical capacity than the woman) could be high enough to give an appropriate response on the same workload.

Finally, results for neck and shoulder pain might have been different when we had combined neck and shoulder pain as one outcome measure. Reasons to combine neck/shoulder pain are the facts that the trapezius muscles act on both the neck and the shoulder region, and that respondents find it difficult to discriminate between neck and shoulder pain. A reason to separate neck and shoulder pain is to get more insight into the difference in effect on either neck or shoulder pain. Despite lower statistical power, we separated neck and shoulder pain, because multivariate results were different (RRs were 1.31 and 1.16, respectively).

CONCLUSIONS

The results of the present study suggest that low back or neck muscle endurance were independent predictors of low back or neck pain, respectively, and that low lifting neck/shoulder strength was an independent predictor of neck pain. Isokinetic lifting trunk strength and mobility of the spine were not found as predictors of low back pain, nor were lifting neck/shoulder strength and endurance of the shoulder muscles found as predictors of shoulder pain.

Main messages

- Low static back endurance was an independent predictor of *low back pain*, but this was not found for isokinetic trunk lifting strength and mobility of the spine.
- Low static neck endurance and low isokinetic lifting strength of the neck/shoulder muscles were independent predictors of *neck pain*.
- No relation was found between isokinetic lifting strength or static endurance of the shoulder muscles and the risk of *shoulder pain*.

Policy implications

- Guidelines on work related factors should not only focus on the reduction of workload, but also on interventions to increase muscle strength of the neck/shoulder muscles and static endurance of the back and neck muscles.

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