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

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**Abstract**

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, 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.

Poisson GEE showed an increased risk of low back pain among workers in the lowest sex-specific tertile of static back endurance compared to workers in the reference category (risk ratio (RR) 1.42; 95% confidence interval (95% CI) 1.19-1.71), 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 neck/shoulder lifting strength (RR = 1.31; 95% CI 1.03-1.67) and low static neck endurance (RR = 1.22; 95% CI 1.00-1.49). Among workers with low lifting strength or low static endurance of the shoulder muscles, no increased risk of shoulder pain was found. 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.

*Keywords: cohort studies, muscle strength, endurance, low back pain, neck pain*

## 1. Introduction

Low back, neck, and shoulder pain are of multi-factorial 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].

Several longitudinal studies reported on the relation between physical capacity and the risk of low back pain. Low performance in tests of muscle strength [3-5] endurance [6,9] and mobility were reported as risk factors for low back pain, although many other studies did not find these results [3,6-8]. Barnekow-Bergkvist et al reported on a decreased risk of neck/shoulder problems in males with high performance in a test of dynamic endurance [3], but no association was found between muscle strength and the risk of neck or shoulder pain.

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.

## 2. Methods

### *2.1 Design*

The present study is part of the longitudinal study on musculoskeletal disorders, absenteeism, stress, and health (SMASH) [9-11], a large prospective cohort study among a working population with a follow-up time of three years. Almost 1800 Dutch blue-collar and white-collar workers participated in this study. Data were collected on physical capacity, musculoskeletal disorders, and many potential confounding factors. The baseline measurements were carried out between 1994 and 1995 consisting of a self-administered postal questionnaire, measurements of physical capacity, and assessment of physical load at the workplace. During follow-up, three questionnaires were filled out once every year.

### *2.2. 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. Localised Musculoskeletal Discomfort (LMD) was asked, which 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)) [12]. We excluded workers from the tests for the low back, neck, or shoulder 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.

### *2.3. Assessment of outcome measure*

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 [13]. In the baseline and the three follow-up questionnaires, low back, neck, and shoulder pain were asked ("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.

### *2.4. Assessment of physical capacity*

At baseline, physiotherapists performed the different tests of isokinetic lifting power strength, sub-maximal 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, both from flour to hip level for the trunk muscles, and from hip to shoulder level for the neck/shoulder muscles. 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 [5] 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 4 minutes at maximum. For the measurement of the static endurance of the neck extensors, the workers had to keep their head flexed at 45 degrees in a sitting position, while carrying a helmet of 5 kilograms for males, or 2.5 kilograms for females. For the measurement of the static endurance of the shoulder elevators, workers had to keep their arms elevated at 90 degrees in a sitting position, while carrying a load of 2.5 kilograms for males, or 1.5 kilograms 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 7 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)).

### *2.5. 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 [14], physical load during leisure time, coping style, and exposure to one or more life events. 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, co-morbidity regarding other musculoskeletal disorders at baseline and during follow -up was a potential confounder.

### *2.6. 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. For each of the three follow-up moments, the transitions from a pain free episode to an episode with pain were measured. 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. 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 percent, these confounders were included in the final multivariate models.

## 3. Results

### *3.1.Charateristics of the study population*

Almost 70% of the workers were male and the mean age was 36 years. Employees worked 38 hours per week on average. 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.

### 3.2. Low back pain

Table 1 shows the relation 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 1.19-1.71) 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.

Table 1
Univariate and multivariate risk ratios (95% confidence intervals) of the association between sex-specific tertiles of physical capacity and low back pain, SMASH, 1994 1997 (n = 1328)

| Physical capacity | Crude RR (95% CI) [a] | Adjusted RR (95% CI) |
|---|---|---|
| Isokinetic lifting strength back muscles | 1.00 | 1.00 [b] |
| | 0.99 (0.83-1.19) | 1.01 (0.84-1.21) |
| | 1.06 (0.89-1.27) | 1.09 (0.91-1.31) |
| Static endurance back extensors | 1.00 | 1.00 [b] |
| | 1.14 (0.93-1.39) | 1.13 (0.93-1.38) |
| | 1.43 (1.19-1.71) | 1.42 (1.19-1.71) |
| Flexion of the spine | | 1.00 [b] |
| | 1.08 )0.91-1.29) | 1.09 (0.91-1.30) |
| | 1.10 (0.94-1.30) | 1.12 (0.95-1.31) |
| Rotation of the spine | | 1.00 [c] |
| | 1.09 (0.92-1.30) | 0.99 (0.82-1.19) |
| | 1.18 (1.00-1.39) | 1.10 (0.92-1.32) |

[a] RR, risk ratio; CI, confidence interval. Including the covariate duration of follow-up.
[b] Adjusted for duration of follow-up, and age.
[c] Adjusted for duration of follow-up, age, and isokinetic lifting strength.

### 3.2. 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: 1.03-1.67) and static endurance of the neck muscles (adjusted RR = 1.22; 95% CI 1.00-1.49) (see Table 2).

Table 2
Univariate and multivariate risk ratios (95% confidence intervals) of the association between sex-specific tertiles of physical capacity and neck pain, SMASH, 1994-1997 (n = 1269)

| Physical capacity | Crude RR (95% CI) [a] | Adjusted RR (95% CI) |
|---|---|---|
| Isokinetic lifting strength neck/shoulder muscles | 1.00 | 1.00 [b] |
| | 1.27 (0.99-1.64) | 1.21 (0.94-1.55) |
| | 1.45 (1.14-1.84) | 1.31 (1.03-1.67) |
| Static endurance neck flexors | 1.00 | 1.00 [c] |
| | 1.24 (0.97-1.59) | 1.15 (0.94-1.40) |
| | 1.70 (1.34-2.14) | 1.22 (1.00-1.49) |

[a] RR, risk ratio; CI, confidence interval. Including the covariate duration of follow-up.
[b] Adjusted for duration of follow-up, age, and length.
[c] Adjusted for duration of follow-up, age, co-morbidity of low back or shoulder pain, and previous neck pain.

### 3.3 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 1.06-1.70). 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 3).

Table 3
Univariate and multivariate risk ratios (95% confidence intervals) of the association between sex-specific tertiles of physical capacity and neck pain, SMASH, 1994-1997 (n = 1269)

| Physical capacity | Crude RR (95% CI) [a] | Adjusted RR (95% CI) |
|---|---|---|
| Isokinetic lifting strength neck/shoulder muscles | 1.00 | 1.00 [b] |
| | 1.25 (0.98-1.59) | 1.16 (0.91-1.46) |
| | 1.34 (1.06-1.70) | 1.16 (0.92-1.46) |
| Static endurance shoulder elevators | 1.00 | 1.00 [c] |
| | 1.05 (0.83-1.32) | 0.86 (0.69-1.07) |
| | 1.17 (0.93-1.46) | 0.88 (0.71-1.11) |

[a] RR, risk ratio; CI, confidence interval. Including the covariate duration of follow-up.
[b] Adjusted for duration of follow-up, age, and length.
[c] Adjusted for duration of follow-up, age, co-morbidity of low back or neck pain, previous shoulder pain, and the number of sports participation in the past.

## 4. Discussion

### *4.1. Interpretation of the results*

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.

### *4.2. 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.

Secondly, the interpretation of performance in tests of physical capacity depends on several factors. One of these factors is the test-retest reliability and inter-rater 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 inter-rater 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 inter-rater reliability were moderate for the other tests of physical capacity. This means that misclassification could not completely be excluded from our study.

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 24 men is higher than that of women. 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 women in the highest tertile could still be too low to give an appropriate response on the workload, while the capacity of a men in the lowest tertile (with a higher physical capacity than the women) 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 in 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).

## 5. Conclusion

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.

## Refernces


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