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Muscle Strength in Adolescent Men and Future Musculoskeletal Pain:

A Cohort Study with 17 Years of Follow-up

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Abstract

Objectives

Musculoskeletal pain is highly prevalent throughout adulthood with a major impact on health, function and participation in the society. Still, the association between muscle strength and development of musculoskeletal pain is unclear. We aimed to study whether overall muscle strength in adolescent men is associated with self-reported musculoskeletal pain in adulthood.

Design

Cohort study with baseline data from the Swedish Conscription Register and outcome information from the random population-based Swedish Living Conditions Surveys.

Setting

Sweden, 1970-2005.

Participants

We studied 5492 men who at age 17-19 years tested their isometric muscle strength (hand grip, arm flexion, knee extension) during the compulsory conscription.

Outcome measures

The men were surveyed regarding self-reported musculoskeletal pain; mean follow-up time of 17 (range 1-35) years. Our primary outcome was a self-report of musculoskeletal pain, and secondary outcomes were a report of "severe pain", "pain in back/hips", "pain in neck/shoulders", or "pain in arms/legs", respectively. We categorized muscle strength into three groups; low, average, and high using the 25th to 75th percentile to define the reference category (average). We calculated incidence rate ratios using log binomial regression with adjustment for smoking, body mass index, education, and physical activity.

Results

In the adjusted model, men with low overall muscle strength had decreased risk of self-reported musculoskeletal pain (incidence rate ratio 0.93, 95% confidence interval 0.87-0.99). We observed no such association in men with high strength (0.99, 0.93-1.05). Furthermore, no statistically significant increase or decrease in risk was observed for any of the secondary outcomes.

Conclusion

In men, low overall isometric muscle strength in youth was not associated with an increased risk of future musculoskeletal pain. Contrarily, we observed a slightly decreased risk of self-reported musculoskeletal pain in adulthood. Residual confounding by adult occupational exposures, leisure time physical activity level and psychosocial factors may have impacted on results.

Article summary

Article focus

- We aimed to study whether overall muscle strength in youth is inversely associated with the development of musculoskeletal pain in adulthood.

Key messages

- In contradiction to our expectations, we observed a decreased risk of self-reported musculoskeletal pain in adult men with low overall isometric muscle strength in youth.
- Low muscle strength may potentially serve as a deselection criterion for activities with high risk of acute injuries or chronic physical overload, factors with negative impact on musculoskeletal health.

Strengths and limitations of study

- The main strengths of the study are a large sample, the use of three differents measures of muscle strength, and comparably long time to follow-up.
- The main limitations of the study are the following; the cohort does not include women, musculoskeletal pain only identified with one question per site, motivation for military service might influence measurement of muscle strength and the potential for unmeasured or residual confounding.

Introduction

Musculoskeletal disorders (MSDs), such as low back pain, osteoarthritis, and widespread pain, are highly prevalent in the adult population.[1-3] MSDs also contribute to a substantial burden of disease at middle and older ages.[4] Although pain emanating from the musculoskeletal system might be attributed to a wide range of diseases with diverse causal chains, many MSDs have common risk factors such as heavy occupational work load,[5 6] a high body mass index (BMI),[7-9] and a low socio-economy.[10-12] Although smoking in some studies have been identified as a risk factor for certain MSDs,[13 14] its main effect on musculoskeletal pain might be as an effect modifier of the pain sensation.[15] As physical work load is a risk factor for many MSDs,[16] a model in which muscle strength in the loaded parts of the body are protective for future disorders is appealing. Furthermore, physical exercise with focus on muscle strength is an important secondary and tertiary prevention of MSDs.[17 18] A handful of studies have hitherto longitudinally investigated the strength of isolated muscle groups in adulthood as a determinant of later MSDs.[19-22] However, in adult subjects, there is for the time being conflicting evidence of the value of muscle strength as a protective factor of musculoskeletal pain, such as neck/shoulder pain and low back pain.[19]

In the longer perspective, relatively little is known about the association of muscle strength in youth and later disease, including musculoskeletal pain.[23] Two studies have investigated the result of single muscle strength tests as determinants of musculoskeletal complaints decades later.[24 25] The first, using number of sit-ups during 30 seconds as a strength measure, found no association with later low back pain or tension neck in men. In women, the high strength group had a decreased odds ratio (OR) of tension neck.[24] The second study found a decreased OR for MSDs in men who either had a strong performance in isotonic bench press or in a isometric two hand lift test.[25] Neither of the two studies includes a measure of overall muscular capacity. In summary, although there is some evidence of an association between low muscle strength in youth and later risk of MSDs, the association between overall muscle strength in adolescence and later musculoskeletal pain has not

been studied. Furthermore, with a larger sample size, data on common risk factors, testing of three different muscle groups, and data on physical work capacity, we address some of the limitations of earlier studies.

Our aim in this study was to investigate the general muscle strength in adolescent males as a determinant of later self-reported musculoskeletal pain. We hypothesized that low general muscle strength in youth is associated with an increased risk of having musculoskeletal pain in adulthood.

Methods

We used two main two main criteria to identify the study cohort. First, the subjects should have performed mandatory conscription testing in Sweden between 1970-1994, with the exception of the years 1978 and 1985. Secondly, they should have been included in the Swedish Living Conditions Surveys any year between 1980 and 2005 when questions regarding musculoskeletal problems, smoking status, and physical activity were simultaneously included.

Furthermore, we excluded all men who were surveyed prior to the baseline testing or were younger than 17 years or older than 19 years at baseline (Table 1). We also excluded men with an existing musculoskeletal disorder (Diseases of the musculoskeletal system and connective tissue according to the International classification of disease version 8 or 9) and those who had missing data on variables included in the primary model (muscle strength, smoking, BMI, physical activity, level of education). In the final study sample we included 5492 men (figure 1). Data from the Swedish conscription testing has been previously used for research purposes.[26-28] During the period of the study sample testing, conscription was mandatory by law for all Swedish men. Specially trained employees at six regional conscription centers administrated the conscription tests during a two-day session that also included separate evaluations by a medical doctor and a psychologist. Only men with serious health complaints, were excused from conscription. The procedure included measurements of each subject's weight in underwear to the kilogram and height without shoes to the centimeter. Using height and weight, we calculated BMI as height/kg^2. Probably due to rare errors of data entry, there are unlikely extreme values in the dataset. Therefore, we excluded all subjects with registered extreme values on height (<150, >210 cm), weight (<40, >150 kg), or an extreme calculated value for BMI (<15, >60) (figure 1). The study was approved by the Ethical Review Board at Lund University and the manuscript was prepared according to the STROBE-statement.[29]

Muscle strength

The men performed three tests of isometric muscle strength during conscription; hand grip, elbow flexion, and knee extension. At the start of test period in 1970, the tests were performed as previously described [30] and remained unchanged in general throughout the test period. In summary, hand grip was measured with a 90° flexion at the elbow with the humerus in parallel to the torso. Knee extension was measured in a sitting position with 90° knee flexion and arms crossed over chest. The pelvis was fixed to the seat and a strap fastened above the lateral malleolus. Also, elbow flexion was measured in a sitting position with 90° flexion at the elbow and the humerus in parallel to the torso. A strap was fastened at the level of the radial styloid process.

We calculated a measure of general muscle strength by standardizing and combining the three tests of muscle strength. To avoid bias due to change of testing procedure over time, we categorized the cohort into five subgroups based on period of conscription (1970-1973, 1974-1977, 1979-1984, 1986-1990, 1990-1994) and for each subgroup calculated the relative muscle strength. We standardized the three tests of muscle strength [standardized value= (value−mean)/standard deviation] within each subgroup and used the mean of the three test scores as a proxy for general muscle strength. Using percentiles, we then categorized the cohort into three groups of muscle strength, where the 25th to 75th percentile defined the average category, the bottom 25th percentile configured the low category, and the top 25th percentile defined the high muscle strength category.

Survey of musculoskeletal pain

The Swedish Living Conditions Surveys (ULF) is a random population based survey conducted by Statistics Sweden, previously used for research purposes.[31-33] For the present study, we used data collected during a total of 10 years (1980, 1988, 1989, 1997-1999, 2002-2005). The surveys were generally performed as interviews in person by trained interviewers, with a minority of the interviews performed by phone. For men included in more than one survey, we used the last survey without relevant study data missing.

At follow-up, the men were asked three questions regarding any current musculoskeletal pain: 1) Do you have pain in neck or shoulders? 2) Do you have back-pain, hip-pain or sciatica? 3) Do you have ache, pain in hands, elbows, legs or knees? For each type of complaint one of three answers was possible: 1) Yes, severe 2) Yes, mild and 3) No. Our primary outcome was having reported either severe or mild musculoskeletal pain, whereas our secondary outcomes we defined as follows: 1) Having reported severe musculoskeletal pain 2) Having reported pain in back/hips 3) Having reported pain in shoulders/neck 4) Having reported pain in arms/legs. From the surveys, we also included data on self-reported current smoking status (yes/no), physical activity (practically none, now and then, regularly, regularly strenuous), and level of education (compulsory school or less, secondary education, higher education). Drop-outs from the survey, i.e. those who have declined participation, cannot be individually identified. However, of the men who were asked to be included in the relevant age-groups, 11.3-31.0% declined participation in the years of study. The mean rate of non-participation over the relevant years in the same group was 22.9%.

Statistical analyses

All analyses were performed with SAS 9.3 (SAS Institute Inc). We used logistic binomial regression to estimate incidence rate ratios (IRR) and control potential confounders. In the multivariate model (primary model), we included muscle strength, BMI, smoking status, physical activity and level of education.

To test whether cardiovascular aspects of physical capacity confounded our results, we used physical work capacity measured as $W_{max\ 6\ min}$ in a sensitivity analysis. For $W_{max\ 6\ min}$, the test result is an estimate of maximum work sustainable for 6 minutes[34] and is in young men correlated with maximum oxygen uptake (r=0.9). [35 36] Acceptable data quality on work capacity was available in the subsample of men performing the baseline testing in 1976-1982. Out of all men in the cohort conscripted during the time period, 1154 men (74.6 %) completed an acceptable physical work capacity test on a bicycle ergometer (i.e. heart rate >174 at the end of testing). We added the work capacity in relation to body weight as a continuous variable to the univariate model. Furthermore, we also performed two sensitivity analyses on the multivariate model with musculoskeletal pain as the dependent variable. In the first, we added test center to the model. For the second, to test whether our categorization of muscle strength influenced the results, we 1) treated the standardized muscle strength as a continuous variable 2) treated the standardized muscle strength as a categorical variable based on quintiles.

Results

The mean time to follow-up was 17 years (table 1). Men with low muscle strength did not have an increased risk, but rather a statistically significant decreased risk, for the primary outcome "Musculoskeletal pain" (table 2). To summarize the observations of the secondary outcomes, we did not observe any statistically significant risk increases for neither men with a low nor high muscle strength. Compared to the crude model, the multivariate model produced similar risk estimates.

Sensitivity analyses

Work capacity had a significant effect in the subsample analysis (p=0.04) whereas it had only minor effect on the risk estimates for a musculoskeletal problem, being 0.94 (0.82-1.08) and 1.02 (0.90-1.16) for low and high strength, respectively. The pattern of association in the secondary outcomes were in general somewhat strengthened when we adjusted for work capacity (data not shown). Using muscle strength as a continuous variable (hence assuming a linear relationship) did weaken the association with later musculoskeletal pain (p=0.22). When we instead used quintiles to categorize muscle strength, we observed no increased risk for the group with lowest strength compared to average strength (IRR=0.93, 95% confidence interval 0.85-1.01).

Discussion

Investigating the overall isometric muscle strength in adolescent men as a determinant of future musculoskeletal pain, we observed a decreased risk of self-reported musculoskeletal pain in men with low muscle strength. No such association was observed for men with high strength. We also found a similar, however not statistically significant, pattern for "pain in back/hips" and "pain in neck/shoulders", whereas no association was found for future problems in arms/legs. Noticeably the observed associations were in contradiction to our expectations.

Using a historical cohort design with prospective registration of exposure and the outcome, our study includes a large sample and thus allows better control for known confounders compared to previous studies. All covariates (muscle strength, BMI, smoking, education, physical activity) included in the multivariate model for musculoskeletal pain also had a significant association with the outcome. Furthermore, by controlling for work capacity, we aimed to isolate the direct effect of muscle strength from other aspects of physical capacity. However, the study also has important limitations. First and foremost, we have used strength data from military conscription testing. Although it provides a rich dataset from a structured environment, we do not know how the subject's motivation for military service may have biased the performance during the testing procedure. However, assuming there is no association between motivation at conscription testing and later risk of musculoskeletal pain (or the loss to follow-up) any bias would at most dilute our result. Nevertheless, stronger recruits are more likely to be assigned to positions with heavy load duty. Secondly, the conscription was mandatory for men only. As the pattern of physical activity and occupational exposure differ between men and women, any generalization of the results to women must be made with great caution. Third, the physical activity measurement consisted of a single question and did neither allow calculation of metabolic equivalent of task (MET) nor included occupational exposure. Also musculoskeletal pain is measured by questions that combine more than one site, decreasing the precision. However, the categories are fairly well demarcated anatomically save for the question regarding pain in arms/legs. Fourth, the covariates collected with musculoskeletal pain at follow-up (smoking, physical activity, level of education) are cross-sectional and might thus be mediators of reverse causation. However, the adjusted estimates are much in line with the crude estimates.

It has been suggested that there is a U-shaped association between physical activity and later back pain. [37 38] Furthermore, as former occupational exposure and certain sport participation are established risk factors for future MSDs,[16 39] it lends some evidence for a more general model, in which certain forms of physical activity is negative for the musculoskeletal health. Primarily, our observations do not support low muscle strength in youth as a risk factor for later musculoskeletal pain. Instead, we suggest that our results can be explained by muscle strength in youth being one selection criterion for future high risk activities with a negative influence on the musculoskeletal health, e.g. higher risk of joint injury due to sports participation or manual repetitive work load. This would also include more immediate exposure such as more physically demanding military service.[40] Although we have controlled for level of education, which might serve as a proxy for occupational exposure, there is potential for residual confounding as we did not have more appropriate data. In other words, individuals with low general muscle strength might to a certain degree be deselected for high risk activities compared to men with an average or high strength. However, the strength of an individual is associated with the muscle fiber type distribution, which have a large genetic component.[41] Type I fibers are more common in endurance athletes[42] whereas high type II percentage have been reported to be associated with isometric muscle strength[43] as well as low back pain.[44] Thus, we cannot exclude that the decreased risk observed in men with low strength is mediated by factors related to muscle fiber type.

Partly in contrast with a previous study,[25] we did not observe a negative effect of low muscle strength on the risk future of musculoskeletal problems in men. Although we in the present study only include measurements of isometric strength, the previous study observed associations with both an isometric strength measure (static two hand lift) and an isotonic strength measure (bench press). In a study on the same cohort, it is reported that the result in bench press, but not two hand lift, was associated with both future cardiovascular fitness and future physical activity,[45] potentially explaining part of the difference. As another study reported flexibility as a sit and reach test,[24] but not strength measured as sit-ups, to be negatively associated with future risk of back pain, it is possible that other aspects of muscular and musculoskeletal function is of greater importance of future risk of MSDs than isometric muscle strength.

The association between muscle strength and later musculoskeletal pain diminished when we used muscle strength as a continuous variable. This was not surprising, as the observed association was non linear in the primary model. It is to be expected that the test centers differ somewhat in their reported test results, as they were assigned adolescents based on geography. However, including test centers in the model did not have any effect on the overall association. When we included work capacity in the model, most risk estimates decreased in absolute values, furthering strengthening the observations in the primary model. By using the relative muscle strength during testing periods of five years, we partially address the potential systematic change in testing procedure over the years. Although the methods of measurements have not changed at large, minor adjustments cannot be excluded.

Although we found no increased risk of future musculoskeletal problems in men with low muscle strength in adolescence, future studies need to better quantify the occupational exposure and leisure time physical activity. Since the physical activity pattern and physical fitness profiles differ between men and women, further investigations are also needed to investigate if similar associations can be found in women.

We observed a decreased risk of self-reported musculoskeletal pain in adult men with low overall isometric muscle strength in youth. We hypothesize that low muscle strength *per se* is not protective of future musculoskeletal pain. Instead, low muscle strength might serve as a deselection criterion for professions or types of leisure time physical activity with higher risk of acute injuries or chronic physical overload, factors with negative impact on musculoskeletal health.

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Author contributions

ST proposed the study idea, collected data, designed the study, and drafted the manuscript. IP designed the study and provided input during manuscript preparation. CZ designed the study and performed the statistical analyses. ME designed the study, collected data, and provided input during manuscript preparation. All authors approved the final version of the manuscript.

Data sharing statement

No additional data to share.

Competing Interests

None

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Tables and Figures

Table 1: Description of study sample

Table 2: Risk estimates for the muscle strength in youth as a determinant of self-reported musculoskeletal pain in adulthood

Figure 1: The identification of the study sample and the loss to follow-up

Table 1 Description of study sample

Mean age at baseline (SD)	18.2 (0.5)
Mean time to follow-up (SD, range)	17.2 years (8.4, 1-35)
BMI (%)	
<18.5	477 (8.7)
18.5-24.9	4500 (81.9)
25-29.9	448 (8.2)
>30	67 (1.2)
Muscle Strength* (%)	
Low	1371 (25.0)
Average	2745 (50.0)
High	1371 (25.0)
Type of interview (%)	
In person	4351 (79.2)
By telephone	1141 (20.8)
Pain in back/hips (%)	
Yes	1647 (30.0)
Yes, severe	321 (5.8)
No	3843 (70.0)
Missing	2 (0.0)
Pain in neck/shoulders (%)	
Yes	1564 (28.5)
Yes, severe	247 (4.5)
No	3926 (71.5)
Missing	2 (0.0)
Pain in arms/legs (%)	
Yes	1243 (22.6)
Yes, severe	196 (3.6)
No	4246 (77.4)
Missing	3 (0.0)
Pain, independent of location (%)	
Yes	2850 (51.9)
Yes, severe	576 (10.0)
No	2639 (48.1)
Missing	3 (0.0)
Smoking status (%)	
Yes	827 (15.1)
No	4665 (84.9)
Level of education (%)	
Compulsory	582 (10.6)
Secondary	2891 (52.7)
Higher	2011 (36.7)
Physical Activity (%)	
Practically non	584 (10.6)
Now and then	1615 (29.4)
Regularly	2077 (37.8)
Regularly strenuous	1216 (22.2)

*= categorization based on quartiles

Table 2 Risk estimates for the muscle strength in youth as a determinant of self-reported musculoskeletal pain in adulthood

Outcomes	**Models**				
	Univariate			**Multivariate**[a]	
	Muscle strength			**Muscle strength**	
	Low (N=1371)	**Average** (N=2745)	**High** (N=1371)	**Low**	**High**
	IRR (N)	**Reference** (N)	**IRR** (N)	**IRR** (95% CI)	**IRR** (95% CI)
Musculoskeletal pain	0.92 (668)	1 (1457)	0.99 (722)	0.93 (0.87-0.99)	0.99 (0.93-1.05)
Severe musculoskeletal pain	0.96 (135)	1 (283)	1.12 (158)	0.96 (0.79-1.17)	1.08 (0.90-1.30)
Pain in back/hips	0.92 (384)	1 (832)	1.03 (429)	0.93 (0.84-1.04)	1.03 (0.94-1.14)
Pain in neck/shoulders	0.91 (366)	1 (799)	0.99 (397)	0.92 (0.83-1.03)	1.00 (0.90-1.10)
Pain in arms/legs	0.97 (297)	1 (616)	1.07 (330)	0.97 (0.85-1.10)	1.06 (0.94-1.19)

N= Number of cases
IRR= Incidence rate ratio
CI= Confidence interval
a= adjusted for smoking status, physical activity, education, body mass index

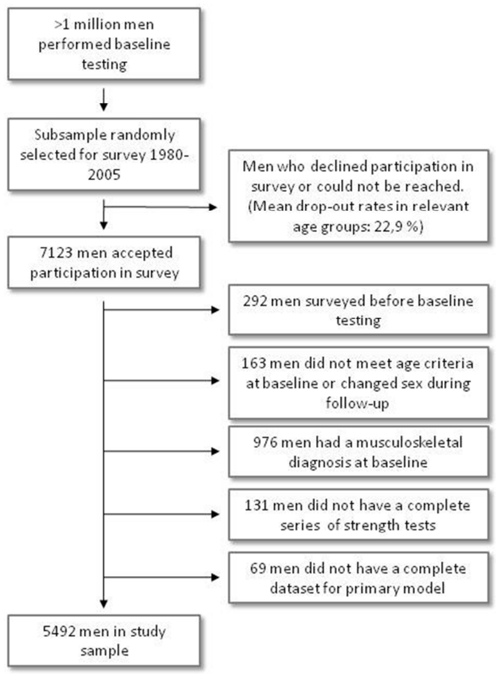

Figure 1: The identification of the study sample and the loss to follow-up
254x190mm (96 x 96 DPI)

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cohort studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2-3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5-6
Objectives	3	State specific objectives, including any prespecified hypotheses	6
Methods			
Study design	4	Present key elements of study design early in the paper	6+
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6-9
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	6-7
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	-
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-9
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*6-9*
Bias	9	Describe any efforts to address potential sources of bias	9
Study size	10	Explain how the study size was arrived at	Figure 1
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6-9
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	9
		(*b*) Describe any methods used to examine subgroups and interactions	9
		(*c*) Explain how missing data were addressed	-
		(*d*) If applicable, explain how loss to follow-up was addressed	-
		(*e*) Describe any sensitivity analyses	9
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Figure 1
		(b) Give reasons for non-participation at each stage	Figure 1
		(c) Consider use of a flow diagram	Figure 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Table 1
		(b) Indicate number of participants with missing data for each variable of interest	Table 1
		(c) Summarise follow-up time (eg, average and total amount)	Table 1
Outcome data	15*	Report numbers of outcome events or summary measures over time	Table 1
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Table 1
		(*b*) Report category boundaries when continuous variables were categorized	6-9
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	-
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	9
Discussion			
Key results	18	Summarise key results with reference to study objectives	10-11
Limitations			
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	13-14
Generalisability	21	Discuss the generalisability (external validity) of the study results	12-13
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	14

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

Muscle Strength in Adolescent Men and Future Musculoskeletal Pain: A Cohort Study with 17 Years of Follow-up

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Muscle Strength in Adolescent Men and Future Musculoskeletal Pain:

A Cohort Study with 17 Years of Follow-up

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Abstract

Objectives

Musculoskeletal pain is highly prevalent throughout adulthood with a major impact on health, function and participation in the society. Still, the association between muscle strength and development of musculoskeletal pain is unclear. We aimed to study whether overall muscle strength in adolescent men is associated with self-reported musculoskeletal pain in adulthood.

Design

Cohort study with baseline data from the Swedish Conscription Register and outcome information from the random population-based Swedish Living Conditions Surveys.

Setting

Sweden, 1970-2005.

Participants

We studied 5489 men who at age 17-19 years tested their isometric muscle strength (hand grip, arm flexion, knee extension) during the compulsory conscription.

Outcome measures

The men were surveyed regarding self-reported musculoskeletal pain; mean follow-up time of 17 (range 1-35) years. Our primary outcome was a self-report of musculoskeletal pain, and secondary outcomes were a report of "severe pain", "pain in back/hips", "pain in neck/shoulders", or "pain in arms/legs", respectively. We categorized muscle strength into three groups; low, average, and high using the 25th to 75th percentile to define the reference category (average). We estimated relative risks using log binomial regression with adjustment for smoking, body mass index, education, and physical activity.

Results

In the adjusted model, men with low overall muscle strength had decreased risk of self-reported musculoskeletal pain (0.93, 95% confidence interval 0.87-0.99). We observed no such association in men with high strength (0.99, 0.93-1.05). Furthermore, no statistically significant increase or decrease in risk was observed for any of the secondary outcomes.

Conclusion

In men, low overall isometric muscle strength in youth was not associated with an increased risk of future musculoskeletal pain. Contrarily, we observed a slightly decreased risk of self-reported musculoskeletal pain in adulthood. Residual confounding by adult occupational exposures, leisure time physical activity level and psychosocial factors may have impacted on results.

Article summary

Article focus

- We aimed to study whether overall muscle strength in youth is inversely associated with the development of musculoskeletal pain in adulthood.

Key messages

- In contradiction to our expectations, we observed a decreased risk of self-reported musculoskeletal pain in adult men with low overall isometric muscle strength in youth.
- We speculate that low muscle strength may serve as a deselection criterion for activities with high risk of acute injuries or chronic physical overload, factors with negative impact on musculoskeletal health.

Strengths and limitations of study

- The main strengths of the study are a large sample, the use of three differents measures of muscle strength, and comparably long time to follow-up.
- The main limitations of the study are the following; the cohort does not include women, musculoskeletal pain only identified with one question per site, motivation for military service might influence measurement of muscle strength, and the potential for unmeasured or residual confounding.

Introduction

Musculoskeletal disorders (MSDs), such as low back pain, osteoarthritis, and widespread pain, are highly prevalent in the adult population.[1-3] MSDs also contribute to a substantial burden of disease at middle and older ages.[4] Although pain emanating from the musculoskeletal system might be attributed to a wide range of diseases with diverse causal chains, many MSDs have common risk factors such as heavy occupational work load,[5 6] a high body mass index (BMI),[7-9] and a low socio-economy.[10-12] Although smoking in some studies have been identified as a risk factor for certain MSDs,[13 14] its main effect on musculoskeletal pain might be as an effect modifier of the pain sensation.[15] As physical work load is a risk factor for many MSDs,[16] a model in which the muscle strength in the loaded parts of the body are protective for future disorders is appealing. Furthermore, physical exercise with focus on muscle strength is an important secondary and tertiary prevention of MSDs.[17 18] A handful of studies have hitherto longitudinally investigated the strength of isolated muscle groups in adulthood as a determinant of later MSDs.[19-22] However, in adult subjects, there is for the time being conflicting evidence of the value of muscle strength as a protective factor of musculoskeletal pain, such as neck/shoulder pain and low back pain.[19]

In the longer perspective, relatively little is known about the association of muscle strength in youth and later disease, including musculoskeletal pain.[23] Two studies have investigated the result of single muscle strength tests as determinants of musculoskeletal complaints decades later.[24 25] The first, using number of sit-ups during 30 seconds as a strength measure, found no association with later low back pain or tension neck in men. In women, the high strength group had a decreased odds ratio (OR) of tension neck.[24] The second study found a decreased OR for MSDs in men who either had a strong performance in isotonic bench press or in a isometric two hand lift test.[25] Neither of the two studies includes a measure of overall muscular capacity. In summary, although there is some evidence of an association between low muscle strength in youth and later risk of MSDs, the association between overall muscle strength in adolescence and later musculoskeletal pain has not

been studied. Furthermore, with a larger sample size, data on common risk factors, testing of three different muscle groups, and data on physical work capacity, we address some of the limitations of earlier studies.

Our aim in this study was to investigate the general muscle strength in adolescent males as a determinant of later self-reported musculoskeletal pain. We hypothesized that low general muscle strength in youth is associated with an increased risk of having musculoskeletal pain in adulthood.

Methods

For this prospective register-based cohort study, we used two main criteria to identify the study sample. First, when typically aged 18, the subjects should have performed mandatory conscription testing in Sweden between 1970-1994, with the exception of the years 1978 and 1985. Secondly, they should have been included in the Swedish Living Conditions Surveys any year between 1980 and 2005 when questions regarding musculoskeletal problems, smoking status, and physical activity were simultaneously included.

Furthermore, we excluded all men who were surveyed prior to the baseline testing or were younger than 17 years or older than 19 years at baseline (Table 1). We also excluded men with an existing musculoskeletal disorder (Diseases of the musculoskeletal system and connective tissue according to the International classification of disease version 8 or 9) and those who had missing data on variables included in the primary model (muscle strength, smoking, BMI, physical activity, level of education). In the final study sample we included 5489 men (figure 1). Data from the Swedish conscription testing has been previously used for research purposes.[26-28] During the period of the study sample testing, conscription was mandatory by law for all Swedish men. Specially trained employees at six regional conscription offices administrated the conscription tests during a two-day session that also included separate evaluations by a medical doctor and a psychologist. Only men with serious health complaints, were excused from conscription. The procedure included measurements of each subject's weight in underwear to the kilogram and height without shoes to the centimeter. Using height and weight, we calculated BMI as height/kg^2. Probably due to rare errors of data entry, there are unlikely extreme values in the dataset. Therefore, we excluded all subjects with registered extreme values on height (<150, >210 cm), weight (<40, >150 kg), or an extreme calculated value for BMI (<15, >60) (figure 1). The study was approved by the Ethical Review Board at Lund University and the manuscript was prepared according to the STROBE-statement.[29]

Muscle strength

The men performed three tests of isometric muscle strength during conscription; hand grip, elbow flexion, and knee extension. At the start of test period in 1970, the tests were performed as previously described [30] and remained unchanged in general throughout the test period. In summary, hand grip strength on the preferred side was measured with 90° flexion at the elbow and the humerus in parallel to the torso. Knee extension was measured in a sitting position with 90° knee flexion and arms crossed over chest. The pelvis was fixed to the seat and a strap fastened above the lateral malleolus. Also, elbow flexion was measured in a sitting position with 90° flexion at the elbow and the humerus in parallel to the torso. A strap was fastened at the level of the radial styloid process.

We calculated a measure of general muscle strength by standardizing and combining the three tests of muscle strength. To avoid bias due to change of testing procedure over time, we categorized the cohort into five subgroups based on period of conscription (1970-1973, 1974-1977, 1979-1984, 1986-1990, 1990-1994) and for each subcohort calculated the relative muscle strength. We standardized the three tests of muscle strength [standardized value= (value−mean)/standard deviation] within each subgroup and used the mean of the three test scores as a proxy for general muscle strength. Using percentiles, we then categorized the cohort into three groups of muscle strength, where the 25th to 75th percentile defined the average category, the bottom 25th percentile configured the low category, and the top 25th percentile defined the high muscle strength category.

Survey of musculoskeletal pain

The Swedish Living Conditions Surveys (ULF) is a random population based survey conducted by Statistics Sweden, previously used for research purposes.[31-33] For the present study, we used data collected during a total of 10 years (1980, 1988, 1989, 1997-1999, 2002-2005). The surveys were generally performed as interviews in person by trained interviewers, with a minority of the interviews performed by phone. For men included in more than one survey, we used the last survey without relevant study data missing.

At follow-up, the men were asked three questions regarding any current musculoskeletal pain: 1) Do you have pain in neck or shoulders? 2) Do you have back-pain, hip-pain or sciatica? 3) Do you have ache, pain in hands, elbows, legs or knees? For each type of complaint one of three answers was possible: 1) Yes, severe 2) Yes, mild and 3) No. Our primary outcome was having reported either severe or mild musculoskeletal pain, whereas our secondary outcomes we defined as follows: 1) Having reported severe musculoskeletal pain 2) Having reported pain in back/hips 3) Having reported pain in shoulders/neck 4) Having reported pain in arms/legs. From the surveys, we also included data on self-reported current smoking status (yes/no), physical activity (practically none, now and then, regularly, regularly strenuous), and level of education (compulsory school or less, secondary education, higher education). Drop-outs from the survey, i.e. those who have declined participation, cannot be individually identified. However, during the years of survey used in this study, the participation rate in the survey among men in relevant age groups were 70.0-88.7%.

Statistical analyses

All analyses were performed with SAS 9.3 (SAS Institute Inc). We used logistic binomial regression to estimate relative risks (RR) and control potential confounders. In the multivariate model (primary model), we included muscle strength, BMI, smoking status, physical activity and level of education.

Sensitivity analyses

To test whether cardiovascular aspects of physical capacity confounded our results, we used physical work capacity measured as $W_{max\ 6\ min}$ in a sensitivity analysis. For $W_{max\ 6\ min}$, the test result is an estimate of maximum work sustainable for 6 minutes[34] and is in young men correlated with maximum oxygen uptake (r=0.9). [35 36] Acceptable data quality on work capacity was available in the subsample of men performing the baseline testing in 1976-1982. Out of all men in the cohort conscripted during the time period, 1154 men (74.6 %) completed an acceptable physical work capacity test on a bicycle ergometer (i.e. heart rate >174 at the end of testing). We added the work capacity in relation to body weight as a continuous variable to the univariate model. Furthermore, we also performed two sensitivity analyses on the multivariate model with musculoskeletal pain as the dependent variable. In the first, we added test center to the model. For the second, to test whether our categorization of muscle strength influenced the results, we 1) treated the standardized muscle strength as a continuous variable 2) treated the standardized muscle strength as a categorical variable based on quintiles.

Results

The mean time to follow-up was 17 years (table 1). Men with low muscle strength did not have an increased risk, but rather a statistically significant decreased risk, for the primary outcome "Musculoskeletal pain" (table 2). To summarize the observations of the secondary outcomes, we did not observe any statistically significant risk increases for neither men with a low nor high muscle strength. Compared to the crude model, the multivariate model produced similar risk estimates.

Sensitivity analyses

Work capacity had a significant effect in the subsample analysis (p=0.03) whereas it had only minor effect on the risk estimates for musculoskeletal pain, being 0.94 (95% confidence interval 0.82-1.08) and 1.02 (0.90-1.16) for low and high strength, respectively. The pattern of association in the secondary outcomes were in general somewhat strengthened when we adjusted for work capacity (data not shown). Using muscle strength as a continuous variable (hence assuming a linear relationship) did weaken the association with later musculoskeletal pain (p=0.23). When we instead used quintiles to categorize muscle strength, we observed no increased risk for the group with lowest strength compared to average strength (RR=0.93, 0.85-1.01).

Discussion

Investigating the overall isometric muscle strength in adolescent men as a determinant of future musculoskeletal pain, we observed a decreased risk of self-reported musculoskeletal pain in men with low muscle strength. No such association was observed for men with high strength. We also found a similar, however not statistically significant, pattern for "pain in back/hips" and "pain in neck/shoulders", whereas no association was found for future problems in arms/legs. Noticeably the observed associations were in contradiction to our expectations.

Using a historical cohort design with prospective registration of exposure and the outcome, our study includes a large sample and thus allows better control for known confounders compared to previous studies. All covariates (muscle strength, BMI, smoking, education, physical activity) included in the multivariate model for musculoskeletal pain also had a significant association with the outcome. Furthermore, by controlling for work capacity, we aimed to isolate the direct effect of muscle strength from other aspects of physical capacity. However, the study also has important limitations. First and foremost, we have used strength data from military conscription testing. Although it provides a rich dataset from a structured environment, we do not know how the subject's motivation for military service may have biased the performance during the testing procedure. However, assuming there is no association between motivation at conscription testing and later risk of musculoskeletal pain (or the loss to follow-up) any bias would at most dilute our result. Nevertheless, stronger recruits are more likely to be assigned to positions with heavy load duty. Secondly, the conscription was mandatory for men only. As the pattern of physical activity and occupational exposure differ between men and women, any generalization of the results to women must be made with great caution. Third, the physical activity measurement consisted of a single question and did neither allow calculation of metabolic equivalent of task (MET) nor included occupational exposure. Also musculoskeletal pain is measured by questions that combine more than one site, decreasing the precision. However, the categories are fairly well demarcated anatomically save for the question regarding pain in arms/legs. Fourth, the covariates collected with musculoskeletal pain at follow-up (smoking, physical activity, level of education) are cross-sectional and might thus be mediators of reverse causation. However, the adjusted estimates are much in line with the crude estimates.

It has previously been suggested that there is a U-shaped association between physical activity and later back pain. [37 38] Furthermore, as former occupational exposure and certain sport participation are established risk factors for future MSDs,[16 39] it lends some evidence for a more general model, in which certain forms of physical activity is negative for the musculoskeletal health. Primarily, our observations do not support low muscle strength in youth as a risk factor for later musculoskeletal pain. Instead, we speculate that our results can be explained by muscle strength in youth being one selection criterion for future high risk activities with a negative influence on the musculoskeletal health, e.g. higher risk of joint injury due to sports participation or manual repetitive work load. This would also include more immediate exposure such as more physically demanding military service.[40] Although we have controlled for level of education, which might serve as a proxy for occupational exposure, there is potential for residual confounding as we did not have more appropriate data. In other words, individuals with low general muscle strength might to a certain degree be deselected for high risk activities compared to men with an average or high strength. However, this is only one of many possible explanations. For example, the strength of an individual is associated with the muscle fiber type distribution, which have a large genetic component.[41] Type I fibers are more common in endurance athletes[42] whereas high type II percentage have been reported to be associated with isometric muscle strength[43] as well as low back pain.[44] Thus, our observations could potentially be explained by both social and biological factors.

Partly in contrast with a previous study,[25] we did not observe a negative effect of low muscle strength on the risk future of musculoskeletal problems in men. Although we in the present study only include measurements of isometric strength, the previous study observed associations with both an isometric strength measure (static two hand lift) and an isotonic strength measure (bench press). In a study on the same cohort, it is reported that the result in bench press, but not two hand lift, was associated with both future cardiovascular fitness and future physical activity,[45] potentially explaining part of the difference. Another study reported flexibility as a sit and reach test,[24] but not strength measured as sit-ups, to be negatively associated with future risk of back pain. Hence, it is possible that other aspects of muscular and musculoskeletal function is of greater importance of future risk of MSDs than isometric muscle strength.

The association between muscle strength and later musculoskeletal pain diminished when we used muscle strength as a continuous variable. This was not surprising, as the observed association was non linear in the primary model. It is to be expected that the test offices differ somewhat in their reported test results, as they were assigned adolescents based on geography. However, including test offices in the model did not have any effect on the overall association. When we included work capacity in the model, most risk estimates decreased in absolute values, furthering strengthening the observations in the primary model. By using the relative muscle strength during testing periods of five years, we partially address the potential systematic change in testing procedure over the years. Although the methods of measurements have not changed at large, minor adjustments cannot be excluded.

Although we found no increased risk of future musculoskeletal problems in men with low muscle strength in adolescence, future studies need to better quantify the occupational exposure and leisure time physical activity. Since the physical activity pattern and physical fitness profiles differ between men and women, further investigations are also needed to investigate if similar associations can be found in women.

In contrast to our hypothesis, we observed a decreased risk of self-reported musculoskeletal pain in adult men with low overall isometric muscle strength in youth. We speculate that low muscle strength *per se* is not protective of future musculoskeletal pain. Instead, low muscle strength might serve as a deselection criterion for professions or types of leisure time physical activity with higher risk of acute injuries or chronic physical overload, factors with negative impact on musculoskeletal health.

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Author contributions

ST proposed the study idea, collected data, designed the study, and drafted the manuscript. IP designed the study and provided input during manuscript preparation. CZ designed the study and performed the statistical analyses. ME designed the study, collected data, and provided input during manuscript preparation. All authors approved the final version of the manuscript.

Data sharing statement

There is no additional data to share.

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Tables and Figures

Table 1: Description of study sample

Table 2: Risk estimates for the muscle strength in youth as a determinant of self-reported musculoskeletal pain in adulthood

Figure 1: The identification of the study sample and the loss to follow-up

Table 1 Description of study sample

Number of men	5489
Mean age at baseline (SD)	18.2 (0.5)
Mean time to follow-up (SD, range)	17.2 years (8.4, 1-35)
Mean hand grip* (SD)	617 (98)
Mean elbow flexion* (SD)	385 (83)
Mean knee extension* (SD)	567 (116)
Muscle Strength (%)	
Low	1371 (25.0)
Average	2747 (50.0)
High	1371 (25.0)
BMI (%)	
<18.5	477 (8.7)
18.5-24.9	4498 (81.9)
25-29.9	448 (8.2)
>30	66 (1.2)
Type of interview (%)	
In person	4349 (79.2)
By telephone	1140 (20.8)
Pain in back/hips (%)	
Yes	1645 (30.0)
of which severe	321 (5.8)
No	3842 (70.0)
Missing	2 (0.0)
Pain in neck/shoulders (%)	
Yes	1562 (28.5)
of which severe	246 (4.5)
No	3925 (71.5)
Missing	2 (0.0)
Pain in arms/legs (%)	
Yes	1243 (22.6)
of which severe	196 (3.6)
No	4243 (77.3)
Missing	3 (0.0)
Pain, independent of location (%)	
Yes	2847 (51.9)
of which severe	576 (10.5)
No	2639 (48.1)
Missing	3 (0.0)
Smoking status (%)	
Yes	827 (15.1)
No	4662 (84.9)
Level of education (%)	
Compulsory	589 (10.7)
Secondary	2889 (52.6)
Higher	2011 (36.6)
Physical Activity (%)	
Practically non	583 (10.6)
Now and then	1613 (29.4)
Regularly	2077 (37.8)
Regularly strenuous	1216 (22.2)

* In Newton.

Table 2 Risk estimates for the muscle strength in youth as a determinant of self-reported musculoskeletal pain in adulthood

	Models				
	Univariate			**Multivariate**[a]	
	Muscle strength			**Muscle strength**	
	Low (N=1371)	**Average** (N=2747)	**High** (N=1371)	**Low**	**High**
Outcomes	**RR** (N)	**Reference** (N)	**RR** (N)	**RR** (95% CI)	**RR** (95% CI)
Musculoskeletal pain	0.92 (668)	1 (1457)	0.99 (722)	0.93 (0.87-0.99)	0.99 (0.93-1.05)
Severe musculoskeletal pain	0.96 (135)	1 (283)	1.12 (158)	0.96 (0.79-1.18)	1.07 (0.89-1.29)
Pain in back/hips	0.92 (384)	1 (832)	1.03 (429)	0.93 (0.84-1.03)	1.03 (0.94-1.13)
Pain in neck/shoulders	0.92 (366)	1 (799)	0.99 (397)	0.93 (0.83-1.03)	1.00 (0.90-1.10)
Pain in arms/legs	0.97 (297)	1 (616)	1.07 (330)	0.97 (0.86-1.10)	1.06 (0.94-1.19)

N= Number of cases
RR= Relative risk estimates
CI= Confidence interval
a= adjusted for smoking status, physical activity, education, body mass index

1

Muscle Strength in Adolescent Men and Future Musculoskeletal Pain:

A Cohort Study with 17 Years of Follow-up

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Abstract

Objectives

Musculoskeletal pain is highly prevalent throughout adulthood with a major impact on health, function and participation in the society. Still, the association between muscle strength and development of musculoskeletal pain is unclear. We aimed to study whether overall muscle strength in adolescent men is associated with self-reported musculoskeletal pain in adulthood.

Design

Cohort study with baseline data from the Swedish Conscription Register and outcome information from the random population-based Swedish Living Conditions Surveys.

Setting

Sweden, 1970-2005.

Participants

We studied 5489~~92~~ men who at age 17-19 years tested their isometric muscle strength (hand grip, arm flexion, knee extension) during the compulsory conscription.

Outcome measures

The men were surveyed regarding self-reported musculoskeletal pain; mean follow-up time of 17 (range 1-35) years. Our primary outcome was a self-report of musculoskeletal pain, and secondary outcomes were a report of "severe pain", "pain in back/hips", "pain in neck/shoulders", or "pain in arms/legs", respectively. We categorized muscle strength into three groups; low, average, and high using the 25th to 75th percentile to define the reference category (average). We ~~calculated incidence rate ratios~~estimated relative risks using log binomial regression with adjustment for smoking, body mass index, education, and physical activity.

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Results

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In the adjusted model, men with low overall muscle strength had decreased risk of self-reported musculoskeletal pain (~~incidence rate ratio~~ 0.93, 95% confidence interval 0.87-0.99). We observed no such association in men with high strength (0.99, 0.93-1.05). Furthermore, no statistically significant increase or decrease in risk was observed for any of the secondary outcomes.

Conclusion

In men, low overall isometric muscle strength in youth was not associated with an increased risk of future musculoskeletal pain. Contrarily, we observed a slightly decreased risk of self-reported musculoskeletal pain in adulthood. Residual confounding by adult occupational exposures, leisure time physical activity level and psychosocial factors may have impacted on results.

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Article summary

Article focus

- We aimed to study whether overall muscle strength in youth is inversely associated with the development of musculoskeletal pain in adulthood.

Key messages

- In contradiction to our expectations, we observed a decreased risk of self-reported musculoskeletal pain in adult men with low overall isometric muscle strength in youth.
- We speculate that lLow muscle strength may potentially serve as a deselection criterion for activities with high risk of acute injuries or chronic physical overload, factors with negative impact on musculoskeletal health.

Strengths and limitations of study

- The main strengths of the study are a large sample, the use of three differents measures of muscle strength, and comparably long time to follow-up.
- The main limitations of the study are the following; the cohort does not include women, musculoskeletal pain only identified with one question per site, motivation for military service might influence measurement of muscle strength, and the potential for unmeasured or residual confounding.

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Introduction

Musculoskeletal disorders (MSDs), such as low back pain, osteoarthritis, and widespread pain, are highly prevalent in the adult population.[1-3] MSDs also contribute to a substantial burden of disease at middle and older ages.[4] Although pain emanating from the musculoskeletal system might be attributed to a wide range of diseases with diverse causal chains, many MSDs have common risk factors such as heavy occupational work load,[5 6] a high body mass index (BMI),[7-9] and a low socio-economy.[10-12] Although smoking in some studies have been identified as a risk factor for certain MSDs,[13 14] its main effect on musculoskeletal pain might be as an effect modifier of the pain sensation.[15] As physical work load is a risk factor for many MSDs,[16] a model in which the muscle strength in the loaded parts of the body are protective for future disorders is appealing. Furthermore, physical exercise with focus on muscle strength is an important secondary and tertiary prevention of MSDs.[17 18] A handful of studies have hitherto longitudinally investigated the strength of isolated muscle groups in adulthood as a determinant of later MSDs.[19-22] However, in adult subjects, there is for the time being conflicting evidence of the value of muscle strength as a protective factor of musculoskeletal pain, such as neck/shoulder pain and low back pain.[19]

In the longer perspective, relatively little is known about the association of muscle strength in youth and later disease, including musculoskeletal pain.[23] Two studies have investigated the result of single muscle strength tests as determinants of musculoskeletal complaints decades later.[24 25] The first, using number of sit-ups during 30 seconds as a strength measure, found no association with later low back pain or tension neck in men. In women, the high strength group had a decreased odds ratio (OR) of tension neck.[24] The second study found a decreased OR for MSDs in men who either had a strong performance in isotonic bench press or in a isometric two hand lift test.[25] Neither of the two studies includes a measure of overall muscular capacity. In summary, although there is some evidence of an association between low muscle strength in youth and later risk of MSDs, the association between overall muscle strength in adolescence and later musculoskeletal pain has not

been studied. Furthermore, with a larger sample size, data on common risk factors, testing of three different muscle groups, and data on physical work capacity, we address some of the limitations of earlier studies.

Our aim in this study was to investigate the general muscle strength in adolescent males as a determinant of later self-reported musculoskeletal pain. We hypothesized that low general muscle strength in youth is associated with an increased risk of having musculoskeletal pain in adulthood.

Methods

For this prospective register-based cohort study, ~~W~~we used ~~two main~~ two main criteria to identify the study sample~~cohort~~. First, when typically aged 18, the subjects should have performed mandatory conscription testing in Sweden between 1970-1994, with the exception of the years 1978 and 1985. Secondly, they should have been included in the Swedish Living Conditions Surveys any year between 1980 and 2005 when questions regarding musculoskeletal problems, smoking status, and physical activity were simultaneously included.

Furthermore, we excluded all men who were surveyed prior to the baseline testing or were younger than 17 years or older than 19 years at baseline (Table 1). We also excluded men with an existing musculoskeletal disorder (Diseases of the musculoskeletal system and connective tissue according to the International classification of disease version 8 or 9) and those who had missing data on variables included in the primary model (muscle strength, smoking, BMI, physical activity, level of education). In the final study sample we included 5489~~92~~ men (figure 1). Data from the Swedish conscription testing has been previously used for research purposes.[26-28] During the period of the study sample testing, conscription was mandatory by law for all Swedish men. Specially trained employees at six regional conscription ~~center~~offices administrated the conscription tests during a two-day session that also included separate evaluations by a medical doctor and a psychologist. Only men with serious health complaints, were excused from conscription. The procedure included measurements of each subject's weight in underwear to the kilogram and height without shoes to the centimeter. Using height and weight, we calculated BMI as height/kg^2. Probably due to rare errors of data entry, there are unlikely extreme values in the dataset. Therefore, we excluded all subjects with registered extreme values on height (<150, >210 cm), weight (<40, >150 kg), or an extreme calculated value for BMI (<15, >60) (figure 1). The study was approved by the Ethical Review Board at Lund University and the manuscript was prepared according to the STROBE-statement.[29]

Muscle strength

The men performed three tests of isometric muscle strength during conscription; hand grip, elbow flexion, and knee extension. At the start of test period in 1970, the tests were performed as previously described [30] and remained unchanged in general throughout the test period. In summary, hand grip strength on the preferred side was measured with a 90° flexion at the elbow andwith the humerus in parallel to the torso. Knee extension was measured in a sitting position with 90° knee flexion and arms crossed over chest. The pelvis was fixed to the seat and a strap fastened above the lateral malleolus. Also, elbow flexion was measured in a sitting position with 90° flexion at the elbow and the humerus in parallel to the torso. A strap was fastened at the level of the radial styloid process.

We calculated a measure of general muscle strength by standardizing and combining the three tests of muscle strength. To avoid bias due to change of testing procedure over time, we categorized the cohort into five subgroups based on period of conscription (1970-1973, 1974-1977, 1979-1984, 1986-1990, 1990-1994) and for each subcohortgroup calculated the relative muscle strength. We standardized the three tests of muscle strength [standardized value= (value−mean)/standard deviation] within each subgroup and used the mean of the three test scores as a proxy for general muscle strength. Using percentiles, we then categorized the cohort into three groups of muscle strength, where the 25th to 75th percentile defined the average category, the bottom 25th percentile configured the low category, and the top 25th percentile defined the high muscle strength category.

Survey of musculoskeletal pain

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The Swedish Living Conditions Surveys (ULF) is a random population based survey conducted by Statistics Sweden, previously used for research purposes.[31-33] For the present study, we used data collected during a total of 10 years (1980, 1988, 1989, 1997-1999, 2002-2005). The surveys were generally performed as interviews in person by trained interviewers, with a minority of the interviews performed by phone. For men included in more than one survey, we used the last survey without relevant study data missing.

At follow-up, the men were asked three questions regarding any current musculoskeletal pain: 1) Do you have pain in neck or shoulders? 2) Do you have back-pain, hip-pain or sciatica? 3) Do you have ache, pain in hands, elbows, legs or knees? For each type of complaint one of three answers was possible: 1) Yes, severe 2) Yes, mild and 3) No. Our primary outcome was having reported either severe or mild musculoskeletal pain, whereas our secondary outcomes we defined as follows: 1) Having reported severe musculoskeletal pain 2) Having reported pain in back/hips 3) Having reported pain in shoulders/neck 4) Having reported pain in arms/legs. From the surveys, we also included data on self-reported current smoking status (yes/no), physical activity (practically none, now and then, regularly, regularly strenuous), and level of education (compulsory school or less, secondary education, higher education). Drop-outs from the survey, i.e. those who have declined participation, cannot be individually identified. However, during the years of survey used in this study, the participation rate in the survey among men in relevant age groups were 70.0-88.7%. ~~of the men who were asked to be included in the relevant age-groups, 11.3-31.0% declined participation in the years of study. The mean rate of non-participation over the relevant years in the same group was 22.9%.~~

Statistical analyses

All analyses were performed with SAS 9.3 (SAS Institute Inc). We used logistic binomial regression to estimate ~~incidence rate ratios~~relative risks (~~I~~RR) and control potential confounders. In the multivariate model (primary model), we included muscle strength, BMI, smoking status, physical activity and level of education.

Sensitivity analyses

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To test whether cardiovascular aspects of physical capacity confounded our results, we used physical work capacity measured as $W_{max\ 6\ min}$ in a sensitivity analysis. For $W_{max\ 6\ min}$, the test result is an estimate of maximum work sustainable for 6 minutes[34] and is in young men correlated with maximum oxygen uptake (r=0.9). [35 36] Acceptable data quality on work capacity was available in the subsample of men performing the baseline testing in 1976-1982. Out of all men in the cohort conscripted during the time period, 1154 men (74.6 %) completed an acceptable physical work capacity test on a bicycle ergometer (i.e. heart rate >174 at the end of testing). We added the work capacity in relation to body weight as a continuous variable to the univariate model. Furthermore, we also performed two sensitivity analyses on the multivariate model with musculoskeletal pain as the dependent variable. In the first, we added test center to the model. For the second, to test whether our categorization of muscle strength influenced the results, we 1) treated the standardized muscle strength as a continuous variable 2) treated the standardized muscle strength as a categorical variable based on quintiles.

Results

The mean time to follow-up was 17 years (table 1). Men with low muscle strength did not have an increased risk, but rather a statistically significant decreased risk, for the primary outcome "Musculoskeletal pain" (table 2). To summarize the observations of the secondary outcomes, we did not observe any statistically significant risk increases for neither men with a low nor high muscle strength. Compared to the crude model, the multivariate model produced similar risk estimates.

Sensitivity analyses

Work capacity had a significant effect in the subsample analysis (p=0.0~~4~~3) whereas it had only minor effect on the risk estimates for~~ a~~ musculoskeletal pain~~problem~~, being 0.94 (95% confidence interval 0.82-1.08) and 1.02 (0.90-1.16) for low and high strength, respectively. The pattern of association in the secondary outcomes were in general somewhat strengthened when we adjusted for work capacity (data not shown). Using muscle strength as a continuous variable (hence assuming a linear relationship) did weaken the association with later musculoskeletal pain (p=0.2~~2~~3). When we instead used quintiles to categorize muscle strength, we observed no increased risk for the group with lowest strength compared to average strength (~~I~~RR=0.93, ~~95% confidence interval ~~0.85-1.01).

Discussion

Investigating the overall isometric muscle strength in adolescent men as a determinant of future musculoskeletal pain, we observed a decreased risk of self-reported musculoskeletal pain in men with low muscle strength. No such association was observed for men with high strength. We also found a similar, however not statistically significant, pattern for "pain in back/hips" and "pain in neck/shoulders", whereas no association was found for future problems in arms/legs. Noticeably the observed associations were in contradiction to our expectations.

Using a historical cohort design with prospective registration of exposure and the outcome, our study includes a large sample and thus allows better control for known confounders compared to previous studies. All covariates (muscle strength, BMI, smoking, education, physical activity) included in the multivariate model for musculoskeletal pain also had a significant association with the outcome. Furthermore, by controlling for work capacity, we aimed to isolate the direct effect of muscle strength from other aspects of physical capacity. However, the study also has important limitations. First and foremost, we have used strength data from military conscription testing. Although it provides a rich dataset from a structured environment, we do not know how the subject's motivation for military service may have biased the performance during the testing procedure. However, assuming there is no association between motivation at conscription testing and later risk of musculoskeletal pain (or the loss to follow-up) any bias would at most dilute our result. Nevertheless, stronger recruits are more likely to be assigned to positions with heavy load duty. Secondly, the conscription was mandatory for men only. As the pattern of physical activity and occupational exposure differ between men and women, any generalization of the results to women must be made with great caution. Third, the physical activity measurement consisted of a single question and did neither allow calculation of metabolic equivalent of task (MET) nor included occupational exposure. Also musculoskeletal pain is measured by questions that combine more than one site, decreasing the precision. However, the categories are fairly well demarcated anatomically save for the question regarding pain in arms/legs. Fourth, the covariates collected with musculoskeletal pain at follow-up (smoking, physical activity, level of education) are cross-sectional and might thus be mediators of reverse causation. However, the adjusted estimates are much in line with the crude estimates.

It has previously been suggested that there is a U-shaped association between physical activity and later back pain. [37 38] Furthermore, as former occupational exposure and certain sport participation are established risk factors for future MSDs,[16 39] it lends some evidence for a more general model, in which certain forms of physical activity is negative for the musculoskeletal health. Primarily, our observations do not support low muscle strength in youth as a risk factor for later musculoskeletal pain. Instead, we speculatesuggest that our results can be explained by muscle strength in youth being one selection criterion for future high risk activities with a negative influence on the musculoskeletal health, e.g. higher risk of joint injury due to sports participation or manual repetitive work load. This would also include more immediate exposure such as more physically demanding military service.[40] Although we have controlled for level of education, which might serve as a proxy for occupational exposure, there is potential for residual confounding as we did not have more appropriate data. In other words, individuals with low general muscle strength might to a certain degree be deselected for high risk activities compared to men with an average or high strength. However, this is only one of many possible explanations. For example, the strength of an individual is associated with the muscle fiber type distribution, which have a large genetic component.[41] Type I fibers are more common in endurance athletes[42] whereas high type II percentage have been reported to be associated with isometric muscle strength[43] as well as low back pain.[44] Thus, our observations could potentially be explained by both social and biological factors.we cannot exclude that the decreased risk observed in men with low strength is mediated by factors related to muscle fiber type.

Partly in contrast with a previous study,[25] we did not observe a negative effect of low muscle strength on the risk future of musculoskeletal problems in men. Although we in the present study only include measurements of isometric strength, the previous study observed associations with both an isometric strength measure (static two hand lift) and an isotonic strength measure (bench press). In a study on the same cohort, it is reported that the result in bench press, but not two hand lift, was associated with both future cardiovascular fitness and future physical activity,[45] potentially explaining part of the difference. As another study reported flexibility as a sit and reach test,[24] but not strength measured as sit-ups, to be negatively associated with future risk of back pain., Hence, it is possible that other aspects of muscular and musculoskeletal function is of greater importance of future risk of MSDs than isometric muscle strength.

The association between muscle strength and later musculoskeletal pain diminished when we used muscle strength as a continuous variable. This was not surprising, as the observed association was non linear in the primary model. It is to be expected that the test offices~~centers~~ differ somewhat in their reported test results, as they were assigned adolescents based on geography. However, including test office~~center~~s in the model did not have any effect on the overall association. When we included work capacity in the model, most risk estimates decreased in absolute values, furthering strengthening the observations in the primary model. By using the relative muscle strength during testing periods of five years, we partially address the potential systematic change in testing procedure over the years. Although the methods of measurements have not changed at large, minor adjustments cannot be excluded.

Although we found no increased risk of future musculoskeletal problems in men with low muscle strength in adolescence, future studies need to better quantify the occupational exposure and leisure time physical activity. Since the physical activity pattern and physical fitness profiles differ between men and women, further investigations are also needed to investigate if similar associations can be found in women.

In contrast to our hypothesis, w~~W~~e observed a decreased risk of self-reported musculoskeletal pain in adult men with low overall isometric muscle strength in youth. We speculate~~hypothesize~~ that low muscle strength *per se* is not protective of future musculoskeletal pain. Instead, low muscle strength might serve as a deselection criterion for professions or types of leisure time physical activity with higher risk of acute injuries or chronic physical overload, factors with negative impact on musculoskeletal health.

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Author contributions

ST proposed the study idea, collected data, designed the study, and drafted the manuscript. IP designed the study and provided input during manuscript preparation. CZ designed the study and performed the statistical analyses. ME designed the study, collected data, and provided input during manuscript preparation. All authors approved the final version of the manuscript.

Data sharing statement

There is no additional data to share.

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Tables and Figures

Table 1: Description of study sample

Table 2: Risk estimates for the muscle strength in youth as a determinant of self-reported musculoskeletal pain in adulthood

Figure 1: The identification of the study sample and the loss to follow-up

Table 1 Description of study sample

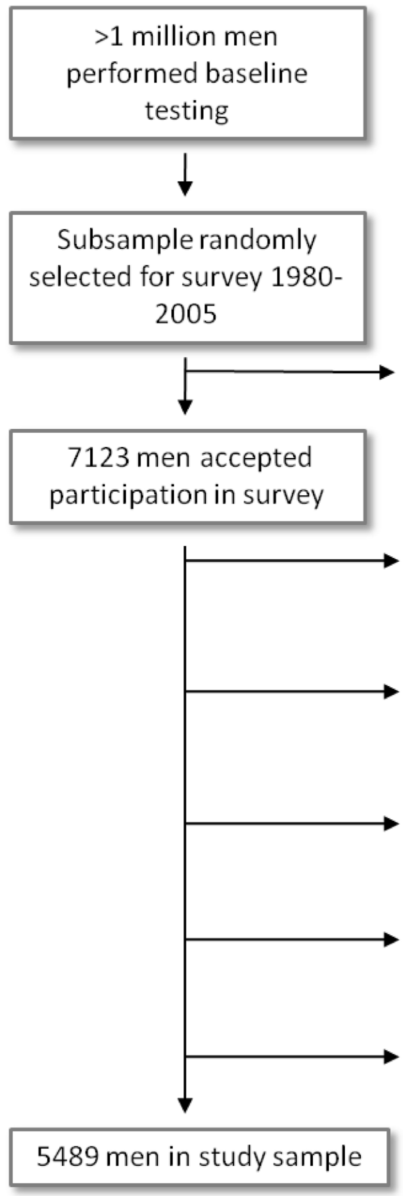
Number of men	5489
Mean age at baseline (SD)	18.2 (0.5)
Mean time to follow-up (SD, range)	17.2 years (8.4, 1-35)
Mean hand grip* (SD)	617 (98)
Mean elbow flexion* (SD)	385 (83)
Mean knee extension* (SD)	567 (116)
Muscle Strength (%)	
Low	1371 (25.0)
Average	2747 (50.0)
High	1371 (25.0)
BMI (%)	
<18.5	477 (8.7)
18.5-24.9	4498 (81.9)
25-29.9	448 (8.2)
>30	66 (1.2)
Type of interview (%)	
In person	4349 (79.2)
By telephone	1140 (20.8)
Pain in back/hips (%)	
Yes	1645 (30.0)
of which severe	321 (5.8)
No	3842 (70.0)
Missing	2 (0.0)
Pain in neck/shoulders (%)	
Yes	1562 (28.5)
of which severe	246 (4.5)
No	3925 (71.5)
Missing	2 (0.0)
Pain in arms/legs (%)	
Yes	1243 (22.6)
of which severe	196 (3.6)
No	4243 (77.3)
Missing	3 (0.0)
Pain, independent of location (%)	
Yes	2847 (51.9)
of which severe	576 (10.5)
No	2639 (48.1)
Missing	3 (0.0)
Smoking status (%)	
Yes	827 (15.1)
No	4662 (84.9)
Level of education (%)	
Compulsory	589 (10.7)
Secondary	2889 (52.6)
Higher	2011 (36.6)
Physical Activity (%)	
Practically non	583 (10.6)
Now and then	1613 (29.4)
Regularly	2077 (37.8)
Regularly strenuous	1216 (22.2)

* In Newton.

Table 2 Risk estimates for the muscle strength in youth as a determinant of self-reported musculoskeletal pain in adulthood

Outcomes	Models Univariate Muscle strength **Low** (N=1371) **IRR** (N)	**Average** (N=27475) **Reference** (N)	**High** (N=1371) **IRR** (N)	**Multivariate**[a] **Muscle strength** **Low** **IRR** (95% CI)	**High** **IRR** (95% CI)
Musculoskeletal pain	0.92 (668)	1 (1457)	0.99 (722)	0.93 (0.87-0.99)	0.99 (0.93-1.05)
Severe musculoskeletal pain	0.96 (135)	1 (283)	1.12 (158)	0.96 (0.79-1.187)	1.078 (0.8990-1.2930)
Pain in back/hips	0.92 (384)	1 (832)	1.03 (429)	0.93 (0.84-1.034)	1.03 (0.94-1.1314)
Pain in neck/shoulders	0.921 (366)	1 (799)	0.99 (397)	0.932 (0.83-1.03)	1.00 (0.90-1.10)
Pain in arms/legs	0.97 (297)	1 (616)	1.07 (330)	0.97 (0.865-1.10)	1.06 (0.94-1.19)

N= Number of cases
IRR= Incidence rate ratioRelative risk estimates
CI= Confidence interval
a= adjusted for smoking status, physical activity, education, body mass index



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STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cohort studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2-3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5-6
Objectives	3	State specific objectives, including any prespecified hypotheses	6
Methods			
Study design	4	Present key elements of study design early in the paper	6+
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6-9
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	6-7
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	-
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-9
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*6-9*
Bias	9	Describe any efforts to address potential sources of bias	9
Study size	10	Explain how the study size was arrived at	Figure 1
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6-9
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	9
		(*b*) Describe any methods used to examine subgroups and interactions	9
		(*c*) Explain how missing data were addressed	-
		(*d*) If applicable, explain how loss to follow-up was addressed	-
		(*e*) Describe any sensitivity analyses	9
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Figure 1
		(b) Give reasons for non-participation at each stage	Figure 1
		(c) Consider use of a flow diagram	Figure 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Table 1
		(b) Indicate number of participants with missing data for each variable of interest	Table 1
		(c) Summarise follow-up time (eg, average and total amount)	Table 1
Outcome data	15*	Report numbers of outcome events or summary measures over time	Table 1
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Table 1
		(*b*) Report category boundaries when continuous variables were categorized	6-9
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	-
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	9
Discussion			
Key results	18	Summarise key results with reference to study objectives	10-11
Limitations			
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	13-14
Generalisability	21	Discuss the generalisability (external validity) of the study results	12-13
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	14

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

Muscle Strength in Adolescent Men and Future Musculoskeletal Pain: A Cohort Study with 17 Years of Follow-up

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Muscle Strength in Adolescent Men and Future Musculoskeletal Pain:

A Cohort Study with 17 Years of Follow-up

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Abstract

Objectives

Musculoskeletal pain is highly prevalent throughout adulthood with a major impact on health, function and participation in the society. Still, the association between muscle strength and development of musculoskeletal pain is unclear. We aimed to study whether overall muscle strength in adolescent men is associated with self-reported musculoskeletal pain in adulthood.

Design

Cohort study with baseline data from the Swedish Conscription Register and outcome information from the random population-based Swedish Living Conditions Surveys.

Setting

Sweden, 1970-2005.

Participants

We studied 5489 men who at age 17-19 years tested their isometric muscle strength (hand grip, arm flexion, knee extension) during the compulsory conscription.

Outcome measures

The men were surveyed regarding self-reported musculoskeletal pain; mean follow-up time of 17 (range 1-35) years. Our primary outcome was a self-report of musculoskeletal pain, and secondary outcomes were a report of "severe pain", "pain in back/hips", "pain in neck/shoulders", or "pain in arms/legs", respectively. We categorized muscle strength into three groups; low, average, and high using the 25th to 75th percentile to define the reference category (average). We estimated relative risks using log binomial regression with adjustment for smoking, body mass index, education, and physical activity.

Results

In the adjusted model, men with low overall muscle strength had decreased risk of self-reported musculoskeletal pain (0.93, 95% confidence interval 0.87-0.99). We observed no such association in men with high strength (0.99, 0.93-1.05). Furthermore, no statistically significant increase or decrease in risk was observed for any of the secondary outcomes.

Conclusion

In men, low overall isometric muscle strength in youth was not associated with an increased risk of future musculoskeletal pain. Contrarily, we observed a slightly decreased risk of self-reported musculoskeletal pain in adulthood. Our results does not support a model in which low muscle strength is a risk factor for future musculoskeletal pain.

Article summary

Article focus

- We aimed to study whether overall muscle strength in youth is inversely associated with the development of musculoskeletal pain in adulthood.

Key messages

- In contradiction to our expectations, we observed a decreased risk of self-reported musculoskeletal pain in adult men with low overall isometric muscle strength in youth.The study does not provide evidence in support of a theoretical model in which low muscle strength in young men is associated with an increased risk of musculoskeletal pain later in life.

Strengths and limitations of study

- The main strengths of the study are a large sample, the independent evaluation of exposure and outcome, the combined use of three different measures of muscle strength, and the comparably long time to follow-up.
- The main limitations of the study are the following; the cohort does not include women, musculoskeletal pain only identified with one question per site, the motivation for military service might influence performance in muscle strength testing, and the potential for unmeasured or residual confounding.

Introduction

Musculoskeletal disorders (MSDs), such as low back pain, osteoarthritis, and widespread pain, are highly prevalent in the adult population.[1-3] MSDs also contribute to a substantial burden of disease at middle and older ages.[4] Although pain emanating from the musculoskeletal system might be attributed to a wide range of diseases with diverse causal chains, many MSDs have common risk factors such as heavy occupational work load,[5 6] a high body mass index (BMI),[7-9] and a low socio-economy.[10-12] Although smoking in some studies have been identified as a risk factor for certain MSDs,[13 14] its main effect on musculoskeletal pain might be as an effect modifier of the pain sensation.[15] As physical work load is a risk factor for many MSDs,[16] a model in which the muscle strength in the loaded parts of the body are protective for future disorders is appealing. This is also the main rationale of studies in the area; does general or demarcated muscle strength have a protective effect on future complaints in the adjacent structures? It is also known that physical exercise with focus on muscle strength is an important secondary and tertiary prevention of MSDs.[17 18] A handful of studies have hitherto investigated the strength of isolated muscle groups as a determinant of later MSDs in adulthood.[19-22] However, there is conflicting evidence of the value of muscle strength as a protective factor of musculoskeletal pain, such as neck/shoulder pain and low back pain in adult subjects.[19]

When considering muscle strength in youth as a potential risk factor in the longer perspective, its association with later disease of any kind is relatively unknown, including musculoskeletal pain.[23] At least two studies have investigated the result of single muscle strength tests as determinants of musculoskeletal complaints decades later.[24 25] The first study, using number of sit-ups during 30 seconds as a strength measure, found no association with later low back pain or tension neck in men. In women however, the high strength group had a decreased odds ratio (OR) of tension neck.[24] The second study found a decreased OR for MSDs in men who either had a strong performance in isotonic bench press or in a isometric two hand lift test.[25] Neither of the two studies includes a measure of overall muscular capacity. Hence, although there is some evidence of an association between low muscle strength in youth and later risk of MSDs, the association between overall muscle strength in adolescence and later musculoskeletal pain has never been studied. Furthermore, with a larger sample size, data on common risk factors, testing of three different muscle groups, and data on physical work capacity, we also address some of the limitations of earlier studies.

Our aim in this study was to investigate the general muscle strength in adolescent males as a determinant of later self-reported musculoskeletal pain. We hypothesized that low general muscle strength in youth is associated with an increased risk of having musculoskeletal pain in adulthood.

Methods

For this prospective register-based cohort study, we used two main inclusion criteria to identify the study sample. First, when typically aged 18, the subjects should have performed mandatory conscription testing in Sweden between 1970-1994, with the exception of the years 1978 and 1985. Second, they should have been included in the Swedish Living Conditions Surveys any year between 1980 and 2005 when questions regarding musculoskeletal problems, smoking status, and physical activity were simultaneously included.

We excluded all men who were surveyed prior to the baseline testing or were younger than 17 years or older than 19 years at baseline (Table 1). We also excluded men with an existing musculoskeletal disorder (Diseases of the musculoskeletal system and connective tissue according to the International classification of disease version 8 or 9) and those who had missing data on variables included in the primary model (muscle strength, smoking, BMI, physical activity, level of education). In the final study sample we included 5489 men (figure 1). The Swedish conscription register is well characterized and has been used for research purposes previously.[26-28] At the time of study sample testing, conscription was mandatory by law for all Swedish men. Specially trained employees at six regional conscription offices administrated the conscription tests during a two-day session. The procedure also included separate evaluations by a medical doctor and a psychologist. Only men with serious health complaints were excused from conscription. The procedure included measurements of each man's weight in underwear to the kilogram and height without shoes to the centimeter. Using height and weight, we calculated BMI as height/kg^2. Probably due to rare errors of data entry, there are unlikely extreme values in the dataset. Therefore, we excluded all subjects with registered extreme values on height (<150, >210 cm), weight (<40, >150 kg), or an extreme calculated value for BMI (<15, >60) (figure 1). The study was approved by the Ethical Review Board at Lund University and the manuscript was prepared according to the STROBE-statement.[29]

Muscle strength

The men performed three tests of isometric muscle strength during conscription; hand grip, elbow flexion, and knee extension. At the start of test period in 1970, the tests were performed as previously described [30] and remained unchanged in general throughout the test period. In summary, hand grip strength on the preferred side was measured with 90° flexion at the elbow and the humerus in parallel to the torso. Knee extension was measured in a sitting position with 90° knee flexion and arms crossed over chest. The pelvis was fixed to the seat and a strap fastened above the lateral malleolus. Also, elbow flexion was measured in a sitting position with 90° flexion at the elbow and the humerus in parallel to the torso. A strap was fastened at the level of the radial styloid process.

We calculated a measure of general muscle strength by standardizing and combining the three tests of muscle strength. To avoid bias due to change of testing procedure over time, we categorized the cohort into five subgroups based on period of conscription (1970-1973, 1974-1977, 1979-1984, 1986-1990, 1990-1994) and for each subcohort calculated the relative muscle strength. First, we standardized the three tests of muscle strength [standardized value= (value−mean)/standard deviation] within each subgroup and used the mean of the three test scores as a proxy for general muscle strength. Using percentiles, we then categorized the cohort into three groups of muscle strength, where the 25th to 75th percentile defined the average category, the bottom 25th percentile configured the low category, and the top 25th percentile defined the high muscle strength category.

Survey of musculoskeletal pain

The Swedish Living Conditions Surveys (ULF) is a random population based survey conducted by Statistics Sweden, previously used for research purposes.[31-33] For the present study, we used data collected during a total of 10 years (1980, 1988, 1989, 1997-1999, 2002-2005). The surveys were generally performed as interviews in person by trained interviewers, with a minority of the interviews performed by phone. For men included in more than one survey, we used the last survey without relevant study data missing.

At follow-up, the men were asked three questions regarding any current musculoskeletal pain: 1) Do you have pain in neck or shoulders? 2) Do you have back-pain, hip-pain or sciatica? 3) Do you have ache, pain in hands, elbows, legs or knees? For each type of complaint one of three answers was possible: 1) Yes, severe 2) Yes, mild and 3) No. Our primary outcome was having reported either severe or mild musculoskeletal pain, whereas our secondary outcomes we defined as follows: 1) Having reported severe musculoskeletal pain 2) Having reported pain in back/hips 3) Having reported pain in shoulders/neck 4) Having reported pain in arms/legs. From the surveys, we also included data on self-reported current smoking status (yes/no), physical activity (practically none, now and then, regularly, regularly strenuous), and level of education (compulsory school or less, secondary education, higher education). Drop-outs from the survey, i.e. those who have declined participation, cannot be individually identified. However, during the years of survey used in this study, the participation rate in the survey among men in relevant age groups were 70.0-88.7%.

Statistical analyses

All analyses were performed with SAS 9.3 (SAS Institute Inc). We used logistic binomial regression to estimate relative risks (RR) and control potential confounders. In the multivariate model (primary model), we included muscle strength, BMI, smoking status, physical activity and level of education.

Sensitivity analyses

To test whether cardiovascular aspects of physical capacity confounded our results, we used physical work capacity measured as W_{max6} in a sensitivity analysis. For W_{max6}, the test result is an estimate of maximum work sustainable for 6 minutes[34] and is in young men correlated with maximum oxygen uptake (r=0.9). [35 36] Acceptable data quality on work capacity was available in the subsample of men performing the baseline testing in 1976-1982. Out of all men in the cohort conscripted during the time period, 1154 men (74.6 %) completed an acceptable physical work capacity test on a bicycle ergometer (i.e. heart rate >174 at the end of testing). We added the work capacity in relation to body weight as a continuous variable to the univariate model. Furthermore, we also performed two sensitivity analyses on the multivariate model with musculoskeletal pain as the dependent variable. In the first, we added test center to the model. For the second, to test whether our categorization of muscle strength influenced the results, we used the standardized muscle strength both as a continuous variable and as a categorical variable based on quintiles.

Results

The mean time to follow-up was 17 years (table 1). Men with low muscle strength did not have an increased risk for the primary outcome "Musculoskeletal pain", but rather a statistically significant decreased risk(table 2). To summarize the observations of the secondary outcomes, we did not observe any statistically significant risk increases for neither men with a low nor high muscle strength. Compared to the crude model, the multivariate model produced similar risk estimates.

Sensitivity analyses

Work capacity had a significant effect in the subsample analysis (p=0.03) whereas it had only minor effect on the risk estimates for musculoskeletal pain, being 0.94 (95% confidence interval 0.82-1.08) and 1.02 (0.90-1.16) for low and high strength, respectively. The pattern of association in the secondary outcomes were in general somewhat strengthened when we adjusted for work capacity (data not shown). Using muscle strength as a continuous variable (hence assuming a linear relationship) did weaken the association with later musculoskeletal pain (p=0.23). When we instead used quintiles to categorize muscle strength, we observed no increased risk for the group with lowest strength compared to average strength (RR=0.93, 0.85-1.01).

Discussion

Investigating the general isometric muscle strength in adolescent men as a determinant of future musculoskeletal pain, we observed a decreased risk of self-reported musculoskeletal pain in men with low muscle strength. We also found a similar pattern, however not statistically significant, for "pain in back/hips" and "pain in neck/shoulders", whereas no association was found for future problems in arms/legs. Noticeably, the current study adds no support to a model in which low muscle strength in men is a risk factor for later musculoskeletal pain.

Using a historical cohort design with prospective registration of exposure and the outcome, the study includes a large sample and thus allows better control for known confounders compared to previous studies. All covariates (muscle strength, BMI, smoking, education, physical activity) included in the multivariate model for musculoskeletal pain also had a significant association with the outcome. Furthermore, by investigating the effects of physical work capacity in a sensitivity analysis, we aimed to isolate the direct effect of muscle strength from other aspects of physical capacity. However, the study also has important limitations. First and foremost, we have used strength data from military conscription testing. Although it provides a rich dataset from a structured environment, we do not know how the subjects' motivation for military service may have biased the performance during the testing procedure. However, assuming there is no association between motivation at conscription testing and later risk of musculoskeletal pain (or the loss to follow-up) any bias would at most dilute our result. Nevertheless, stronger recruits are more likely to be assigned to positions with heavy load duty. Secondly, the conscription was mandatory for men only. As the pattern of physical activity and occupational exposure differ between men and women, any generalization of the results to women must be made with great caution. Third, the physical activity measurement consisted of a single question and did neither allow calculation of metabolic equivalent of task (MET) nor included occupational exposure. Also musculoskeletal pain is measured by questions that combine more than one site, decreasing the precision. However, the categories are fairly well demarcated anatomically save for the question regarding pain in arms/legs. Fourth, the covariates collected with musculoskeletal pain at follow-up (smoking, physical activity, level of education) are cross-sectional and might thus be mediators of reverse causation. However, the adjusted estimates are much in line with the crude estimates.

Primarily, we do not suggest that low muscle strength in youth is a protective factor for later musculoskeletal pain. However, our observations could potentially be explained by both social and biological factors. First, as former occupational exposure[16] and certain sport participation[37] are established risk factors for future MSDs, it lends some evidence for a general model in which certain forms of physical activity is negative for the musculoskeletal health. It has also previously been suggested that there is a U-shaped association between physical activity and later back pain,[38 39] i.e that subjects with low and high levels of physical activity has an increased risk compared to the group with average activity. First, we speculate that our results may be explained by muscle strength in youth being one selection criterion for future high risk activities with a negative influence on the musculoskeletal health, e.g. higher risk of joint injury due to sports participation or manual repetitive work load. This would also include more immediate exposure in youth such as more physically demanding military service.[40] Although we have controlled for level of education, which we regard as a proxy for occupational exposure, there is potential for residual confounding. In other words, individuals with low general muscle strength might to a certain degree be deselected for high risk activities compared to stronger men.. A second potential explanation for our observation can be based on that, the strength of an individual is associated with the muscle fiber type distribution, which have a large genetic component.[41] Whereas type I fibers are more common in endurance athletes[42], a high type II percentage have been reported to be associated with both isometric muscle strength[43] as well as low back pain.[44]

It is important to note that our main result are not the significantly decreased risk of later musculoskeletal pain observed in men with low strength but the nonexistent risk increase in the same group. This is partly in contrast with one of the few previous studies in the area. Although we in the present study only include measurements of isometric strength, the previous study[25] reported associations with both an isometric strength measure (static two hand lift) and an isotonic strength measure (bench press). In another study on the same cohort, it is reported that the result in bench press, but not two hand lift, was associated with both future cardiovascular fitness and future physical activity,[45] potentially explaining part of the difference. Another study reported flexibility as a sit and reach test,[24] but not strength measured as sit-ups, to be negatively associated with future risk of back pain. Hence, it is possible that other aspects of muscular and musculoskeletal function is of greater importance of future risk of MSDs than the isometric muscle strength as such.

The association between muscle strength and later musculoskeletal pain diminished when we used muscle strength as a continuous variable. This was not surprising, as the observed association was non linear in the primary model. It is to be expected that the test offices differ somewhat in their reported test results, as they were assigned adolescents based on geography. However, including test offices in the model did not have any effect on the overall association. When we included work capacity in the model, most risk estimates decreased in absolute values, furthering strengthening the observations in the primary model. By using the relative muscle strength during testing periods of five years, we partially address the potential systematic change in testing procedure over the years. Although the methods of measurements have not changed at large, minor adjustments cannot be excluded.

In future studies, it would be of interest to investigate if low muscle strength serves as a deselection criterion for professions or types of leisure time physical activity with higher risk of acute injuries or chronic physical overload, factors with negative impact on musculoskeletal health.. Since the physical activity pattern and physical fitness profiles differ between men and women, further investigations are also needed to investigate if similar associations can be found in women.

In conclusion, we observed no increased risk of self-reported musculoskeletal pain in adult men with low overall isometric muscle strength in youth. Thus, this study add no support to a model in which muscle strength is a risk factor for future musculoskeletal pain in men.

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Author contributions

ST proposed the study idea, collected data, designed the study, and drafted the manuscript. IP designed the study and provided input during manuscript preparation. CZ designed the study and performed the statistical analyses. ME designed the study, collected data, and provided input during manuscript preparation. All authors approved the final version of the manuscript.

Data sharing statement

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Competing Interests

None

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Tables and Figures

Table 1: Description of study sample

Table 2: Risk estimates for the muscle strength in youth as a determinant of self-reported musculoskeletal pain in adulthood

Figure 1: The identification of the study sample and the loss to follow-up

Table 1 Description of study sample

Number of men	5489
Mean age at baseline (SD)	18.2 (0.5)
Mean time to follow-up (SD, range)	17.2 years (8.4, 1-35)
Mean hand grip* (SD)	617 (98)
Mean elbow flexion* (SD)	385 (83)
Mean knee extension* (SD)	567 (116)
Muscle Strength (%)	
Low	1371 (25.0)
Average	2747 (50.0)
High	1371 (25.0)
BMI (%)	
<18.5	477 (8.7)
18.5-24.9	4498 (81.9)
25-29.9	448 (8.2)
>30	66 (1.2)
Type of interview (%)	
In person	4349 (79.2)
By telephone	1140 (20.8)
Pain in back/hips (%)	
Yes	1645 (30.0)
of which severe	321 (5.8)
No	3842 (70.0)
Missing	2 (0.0)
Pain in neck/shoulders (%)	
Yes	1562 (28.5)
of which severe	246 (4.5)
No	3925 (71.5)
Missing	2 (0.0)
Pain in arms/legs (%)	
Yes	1243 (22.6)
of which severe	196 (3.6)
No	4243 (77.3)
Missing	3 (0.0)
Pain, independent of location (%)	
Yes	2847 (51.9)
of which severe	576 (10.5)
No	2639 (48.1)
Missing	3 (0.0)
Smoking status (%)	
Yes	827 (15.1)
No	4662 (84.9)
Level of education (%)	
Compulsory	589 (10.7)
Secondary	2889 (52.6)
Higher	2011 (36.6)
Physical Activity (%)	
Practically non	583 (10.6)
Now and then	1613 (29.4)
Regularly	2077 (37.8)
Regularly strenuous	1216 (22.2)

* In Newton.

Table 2 Risk estimates for the muscle strength in youth as a determinant of self-reported musculoskeletal pain in adulthood

	Models				
	Univariate			Multivariate[a]	
	Muscle strength			Muscle strength	
	Low (N=1371)	**Average** (N=2747)	**High** (N=1371)	**Low**	**High**
Outcomes	**RR** (N)	**Reference** (N)	**RR** (N)	**RR** (95% CI)	**RR** (95% CI)
Musculoskeletal pain	0.92 (668)	1 (1457)	0.99 (722)	0.93 (0.87-0.99)	0.99 (0.93-1.05)
Severe musculoskeletal pain	0.96 (135)	1 (283)	1.12 (158)	0.96 (0.79-1.18)	1.07 (0.89-1.29)
Pain in back/hips	0.92 (384)	1 (832)	1.03 (429)	0.93 (0.84-1.03)	1.03 (0.94-1.13)
Pain in neck/shoulders	0.92 (366)	1 (799)	0.99 (397)	0.93 (0.83-1.03)	1.00 (0.90-1.10)
Pain in arms/legs	0.97 (297)	1 (616)	1.07 (330)	0.97 (0.86-1.10)	1.06 (0.94-1.19)

N= Number of cases
RR= Relative risk estimates
CI= Confidence interval
a= adjusted for smoking status, physical activity, education, body mass index

Muscle Strength in Adolescent Men and Future Musculoskeletal Pain:

A Cohort Study with 17 Years of Follow-up

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Abstract

Objectives

Musculoskeletal pain is highly prevalent throughout adulthood with a major impact on health, function and participation in the society. Still, the association between muscle strength and development of musculoskeletal pain is unclear. We aimed to study whether overall muscle strength in adolescent men is associated with self-reported musculoskeletal pain in adulthood.

Design

Cohort study with baseline data from the Swedish Conscription Register and outcome information from the random population-based Swedish Living Conditions Surveys.

Setting

Sweden, 1970-2005.

Participants

We studied 5489 men who at age 17-19 years tested their isometric muscle strength (hand grip, arm flexion, knee extension) during the compulsory conscription.

Outcome measures

The men were surveyed regarding self-reported musculoskeletal pain; mean follow-up time of 17 (range 1-35) years. Our primary outcome was a self-report of musculoskeletal pain, and secondary outcomes were a report of "severe pain", "pain in back/hips", "pain in neck/shoulders", or "pain in arms/legs", respectively. We categorized muscle strength into three groups; low, average, and high using the 25th to 75th percentile to define the reference category (average). We estimated relative risks using log binomial regression with adjustment for smoking, body mass index, education, and physical activity.

Results

In the adjusted model, men with low overall muscle strength had decreased risk of self-reported musculoskeletal pain (0.93, 95% confidence interval 0.87-0.99). We observed no such association in men with high strength (0.99, 0.93-1.05). Furthermore, no statistically significant increase or decrease in risk was observed for any of the secondary outcomes.

Conclusion

In men, low overall isometric muscle strength in youth was not associated with an increased risk of future musculoskeletal pain. Contrarily, we observed a slightly decreased risk of self-reported musculoskeletal pain in adulthood. Our results does not support a model in which low muscle strength is a risk factor for future musculoskeletal pain. ~~Residual confounding by adult occupational exposures, leisure time physical activity level and psychosocial factors may have impacted on results.~~

Article summary

Article focus

- We aimed to study whether overall muscle strength in youth is inversely associated with the development of musculoskeletal pain in adulthood.

Key messages

- In contradiction to our expectations, we observed a decreased risk of self-reported musculoskeletal pain in adult men with low overall isometric muscle strength in youth.
- The study does not provide evidence in support of a theoretical model in which low muscle strength in young men is associated with an increased risk of musculoskeletal pain later in life.
- We speculate that low muscle strength may serve as a deselection criterion for activities with high risk of acute injuries or chronic physical overload, factors with negative impact on musculoskeletal health.

Strengths and limitations of study

- The main strengths of the study are a large sample, the independent evaluation of exposure and outcome, the combined use of three differents measures of muscle strength, and the comparably long time to follow-up.
- The main limitations of the study are the following; the cohort does not include women, musculoskeletal pain only identified with one question per site, the motivation for military service might influence measurementperformance in of muscle strength testing, ; and the potential for unmeasured or residual confounding.

Introduction

Musculoskeletal disorders (MSDs), such as low back pain, osteoarthritis, and widespread pain, are highly prevalent in the adult population.[1-3] MSDs also contribute to a substantial burden of disease at middle and older ages.[4] Although pain emanating from the musculoskeletal system might be attributed to a wide range of diseases with diverse causal chains, many MSDs have common risk factors such as heavy occupational work load,[5 6] a high body mass index (BMI),[7-9] and a low socio-economy.[10-12] Although smoking in some studies have been identified as a risk factor for certain MSDs,[13 14] its main effect on musculoskeletal pain might be as an effect modifier of the pain sensation.[15] As physical work load is a risk factor for many MSDs,[16] a model in which the muscle strength in the loaded parts of the body are protective for future disorders is appealing. This is also the main rationale of studies in the area; does general or demarcated muscle strength have a protective effect on future complaints in the adjacent structures? Furthermore, It is also known that physical exercise with focus on muscle strength is an important secondary and tertiary prevention of MSDs.[17 18] A handful of studies have hitherto longitudinally investigated the strength of isolated muscle groups as a determinant of later MSDs in adulthood as a determinant of later MSDs.[19-22] However, in adult subjects, there is for the time being conflicting evidence of the value of muscle strength as a protective factor of musculoskeletal pain, such as neck/shoulder pain and low back pain in adult subjects.[19]

When considering muscle strength in youth as a potential risk factor iIn the longer perspective, relatively little is known aboutits the association withof muscle strength in youth and later disease of any kind is relatively unknown, including musculoskeletal pain.[23] -At least Ttwo studies have investigated the result of single muscle strength tests as determinants of musculoskeletal complaints decades later.[24 25] The first study, using number of sit-ups during 30 seconds as a strength measure, found no association with later low back pain or tension neck in men. In women however, the high strength group had a decreased odds ratio (OR) of tension neck.[24] The second study found a decreased OR for MSDs in men who either had a strong performance in isotonic bench press or in a isometric two hand lift test.[25] Neither of the two studies includes a measure of overall muscular capacity. -Hence, although there is some evidence of an association between low muscle strength in youth and later risk of MSDs, the association between overall muscle strength in adolescence and later musculoskeletal pain has nevernot been studied. -Furthermore, with a larger sample size, data on common risk factors, testing of three different muscle groups, and data on physical work capacity, we also address some of the limitations of earlier studies.

Our aim in this study was to investigate the general muscle strength in adolescent males as a determinant of later self-reported musculoskeletal pain. We hypothesized that low general muscle strength in youth is associated with an increased risk of having musculoskeletal pain in adulthood.

Methods

For this prospective register-based cohort study, we used two main inclusion criteria to identify the study sample. First, when typically aged 18, the subjects should have performed mandatory conscription testing in Sweden between 1970-1994, with the exception of the years 1978 and 1985. Second, they should have been included in the Swedish Living Conditions Surveys any year between 1980 and 2005 when questions regarding musculoskeletal problems, smoking status, and physical activity were simultaneously included.

We excluded all men who were surveyed prior to the baseline testing or were younger than 17 years or older than 19 years at baseline (Table 1). We also excluded men with an existing musculoskeletal disorder (Diseases of the musculoskeletal system and connective tissue according to the International classification of disease version 8 or 9) and those who had missing data on variables included in the primary model (muscle strength, smoking, BMI, physical activity, level of education). In the final study sample we included 5489 men (figure 1). The Swedish conscription register is well characterized and has been used for research purposes previously.Data from the Swedish

~~conscription testing has been previously used for research purposes.~~[26-28] ~~During the period~~ At the time of ~~the~~ study sample testing, conscription was mandatory by law for all Swedish men. Specially trained employees at six regional conscription offices administrated the conscription tests during a two-day session. The procedure ~~that~~ also included separate evaluations by a medical doctor and a psychologist. Only men with serious health complaints~~,~~ were excused from conscription. The procedure included measurements of each man~~subject~~'s weight in underwear to the kilogram and height without shoes to the centimeter. Using height and weight, we calculated BMI as height/kg^2. Probably due to rare errors of data entry, there are unlikely extreme values in the dataset. Therefore, we excluded all subjects with registered extreme values on height (<150, >210 cm), weight (<40, >150 kg), or an extreme calculated value for BMI (<15, >60) (figure 1). The study was approved by the Ethical Review Board at Lund University and the manuscript was prepared according to the STROBE-statement.[29]

Muscle strength

The men performed three tests of isometric muscle strength during conscription; hand grip, elbow flexion, and knee extension. At the start of test period in 1970, the tests were performed as previously described [30] and remained unchanged in general throughout the test period. In summary, hand grip strength on the preferred side was measured with 90° flexion at the elbow and the humerus in parallel to the torso. Knee extension was measured in a sitting position with 90° knee flexion and arms crossed over chest. The pelvis was fixed to the seat and a strap fastened above the lateral malleolus. Also, elbow flexion was measured in a sitting position with 90° flexion at the elbow and the humerus in parallel to the torso. A strap was fastened at the level of the radial styloid process.

We calculated a measure of general muscle strength by standardizing and combining the three tests of muscle strength. To avoid bias due to change of testing procedure over time, we categorized the cohort into five subgroups based on period of conscription (1970-1973, 1974-1977, 1979-1984, 1986-1990, 1990-1994) and for each subcohort calculated the relative muscle strength. First, ~~W~~we standardized the three tests of muscle strength [standardized value= (value−mean)/standard deviation] within each subgroup and used the mean of the three test scores as a proxy for general muscle strength. Using percentiles, we then categorized the cohort into three groups of muscle strength, where the 25th to 75th percentile defined the average category, the bottom 25th percentile configured the low category, and the top 25th percentile defined the high muscle strength category.

Survey of musculoskeletal pain

The Swedish Living Conditions Surveys (ULF) is a random population based survey conducted by Statistics Sweden, previously used for research purposes.[31-33] For the present study, we used data collected during a total of 10 years (1980, 1988, 1989, 1997-1999, 2002-2005). The surveys were generally performed as interviews in person by trained interviewers, with a minority of the interviews performed by phone. For men included in more than one survey, we used the last survey without relevant study data missing.

At follow-up, the men were asked three questions regarding any current musculoskeletal pain: 1) Do you have pain in neck or shoulders? 2) Do you have back-pain, hip-pain or sciatica? 3) Do you have ache, pain in hands, elbows, legs or knees? For each type of complaint one of three answers was possible: 1) Yes, severe 2) Yes, mild and 3) No. Our primary outcome was having reported either severe or mild musculoskeletal pain, whereas our secondary outcomes we defined as follows: 1) Having reported severe musculoskeletal pain 2) Having reported pain in back/hips 3) Having reported pain in shoulders/neck 4) Having reported pain in arms/legs. From the surveys, we also included data on self-reported current smoking status (yes/no), physical activity (practically none, now and then, regularly, regularly strenuous), and level of education (compulsory school or less, secondary education, higher education). Drop-outs from the survey, i.e. those who have declined participation, cannot be individually identified. However, during the years of survey used in this study, the participation rate in the survey among men in relevant age groups were 70.0-88.7%.

Statistical analyses

All analyses were performed with SAS 9.3 (SAS Institute Inc). We used logistic binomial regression to estimate relative risks (RR) and control potential confounders. In the multivariate model (primary model), we included muscle strength, BMI, smoking status, physical activity and level of education.

Sensitivity analyses

To test whether cardiovascular aspects of physical capacity confounded our results, we used physical work capacity measured as $W_{max\ 6\ min}$ in a sensitivity analysis. For $W_{max\ 6\ min}$, the test result is an estimate of maximum work sustainable for 6 minutes[34] and is in young men correlated with maximum oxygen uptake (r=0.9). [35 36] Acceptable data quality on work capacity was available in the subsample of men performing the baseline testing in 1976-1982. Out of all men in the cohort conscripted during the time period, 1154 men (74.6 %) completed an acceptable physical work capacity test on a bicycle ergometer (i.e. heart rate >174 at the end of testing). We added the work capacity in relation to body weight as a continuous variable to the univariate model. Furthermore, we also performed two sensitivity analyses on the multivariate model with musculoskeletal pain as the dependent variable. In the first, we added test center to the model. For the second, to test whether our categorization of muscle strength influenced the results, we 1) treated used the standardized muscle strength both as a continuous variable and 2) treated the standardized muscle strength as a categorical variable based on quintiles.

Results

The mean time to follow-up was 17 years (table 1). Men with low muscle strength did not have an increased risk for the primary outcome "Musculoskeletal pain", but rather a statistically significant decreased risk, for the primary outcome "Musculoskeletal pain" (table 2). To summarize the observations of the secondary outcomes, we did not observe any statistically significant risk increases for neither men with a low nor high muscle strength. Compared to the crude model, the multivariate model produced similar risk estimates.

Sensitivity analyses

Work capacity had a significant effect in the subsample analysis (p=0.03) whereas it had only minor effect on the risk estimates for musculoskeletal pain, being 0.94 (95% confidence interval 0.82-1.08) and 1.02 (0.90-1.16) for low and high strength, respectively. The pattern of association in the secondary outcomes were in general somewhat strengthened when we adjusted for work capacity (data not shown). Using muscle strength as a continuous variable (hence assuming a linear relationship) did weaken the association with later musculoskeletal pain (p=0.23). When we instead used quintiles to categorize muscle strength, we observed no increased risk for the group with lowest strength compared to average strength (RR=0.93, 0.85-1.01).

Discussion

Investigating the generaloverall isometric muscle strength in adolescent men as a determinant of future musculoskeletal pain, we observed a decreased risk of self-reported musculoskeletal pain in men with low muscle strength. No such association was observed for men with high strength. We also found a similar pattern, however not statistically significant, pattern for "pain in back/hips" and "pain in neck/shoulders", whereas no association was found for future problems in arms/legs. Noticeably, the current study adds no support to a model in which low muscle strength in men is a risk factor for later musculoskeletal pain. the observed associations were in contradiction to our expectations.

Using a historical cohort design with prospective registration of exposure and the outcome, theour study includes a large sample and thus allows better control for known confounders compared to previous studies. All covariates (muscle strength, BMI, smoking, education, physical activity) included in the multivariate model for musculoskeletal pain also had a significant association with the outcome. Furthermore, by investigating the effects of controlling for physical work capacity in a sensitivity analysis, we aimed to isolate the direct effect of muscle strength from other aspects of physical capacity. However, the study also has important limitations. First and foremost, we have used strength data from military conscription testing. Although it provides a rich dataset from a structured environment, we do not know how the subject's' motivation for military service may have biased the performance during the testing procedure. However, assuming there is no association between motivation at conscription testing and later risk of musculoskeletal pain (or the loss to follow-up) any bias would at most dilute our result. Nevertheless, stronger recruits are more likely to be assigned to positions with heavy load duty. Secondly, the conscription was mandatory for men only. As the pattern of physical activity and occupational exposure differ between men and women, any generalization of the results to women must be made with great caution. Third, the physical activity measurement consisted of a single question and did neither allow calculation of metabolic equivalent of task (MET) nor included occupational exposure. Also musculoskeletal pain is measured by questions that combine more than one site, decreasing the precision. However, the categories are fairly well demarcated anatomically save for the question regarding pain in arms/legs. Fourth, the covariates collected with musculoskeletal pain at follow-up (smoking, physical activity, level of education) are cross-sectional and might thus be mediators of reverse causation. However, the adjusted estimates are much in line with the crude estimates.

Primarily, we do not suggest that low muscle strength in youth is a protective~~k~~ factor for later musculoskeletal pain. However, our observations could potentially be explained by both social and biological factors. ~~It has previously been suggested that there is a U-shaped association between physical activity and later back pain.[37 38] Furthermore, a~~First, as former occupational exposure[16] and certain sport participation[37] are established risk factors for future MSDs,[~~16~~ 39] it lends some evidence for a ~~more~~ general model~~,~~ in which certain forms of physical activity is negative for the musculoskeletal health. It has also previously been suggested that there is a U-shaped association between physical activity and later back pain,[38 39] i.e that subjects with low and high levels of physical activity has an increased risk compared to the group with average activity. ~~Primarily, our observations do not support low muscle strength in youth as a risk factor for later musculoskeletal pain.~~ First~~Instead~~, we speculate that our results ~~can~~ may be explained by muscle strength in youth being one selection criterion for future high risk activities with a negative influence on the musculoskeletal health, e.g. higher risk of joint injury due to sports participation or manual repetitive work load. This would also include more immediate exposure in youth such as more physically demanding military service.[40] Although we have controlled for level of education, which we regard as ~~might serve as~~ a proxy for occupational exposure, there is potential for residual confounding. ~~as we did not have more appropriate data.~~ In other words, individuals with low general muscle strength might to a certain degree be deselected for high risk activities compared to stronger men. ~~with an average or high strength~~. A second potential explanation for our observation can be based on that~~However, this is only one of many possible explanations. For example~~, the strength of an individual is associated with the muscle fiber type distribution, which have a large genetic component.[41] Whereas t~~T~~ype I fibers are more common in endurance athletes[42]~~, whereas~~ a high type II percentage have been reported to be associated with both isometric muscle strength[43] as well as low back pain.[44] ~~Thus, our observations could potentially be explained by both social and biological factors.~~

It is important to note that our main result are not the significantly decreased risk of later musculoskeletal pain observed in men with low strength but the nonexistent risk increase in the same group. This is Ppartly in contrast with one of the fewa previous studiesy in the area.,[25] we did not observe a negative effect of low muscle strength on the risk future of musculoskeletal problems in men. Although we in the present study only include measurements of isometric strength, the previous study [25] reportedobserved associations with both an isometric strength measure (static two hand lift) and an isotonic strength measure (bench press). In another study on the same cohort, it is reported that the result in bench press, but not two hand lift, was associated with both future cardiovascular fitness and future physical activity,[45] potentially explaining part of the difference. Another study reported flexibility as a sit and reach test,[24] but not strength measured as sit-ups, to be negatively associated with future risk of back pain. Hence, it is possible that other aspects of muscular and musculoskeletal function is of greater importance of future risk of MSDs than the isometric muscle strength as such.

The association between muscle strength and later musculoskeletal pain diminished when we used muscle strength as a continuous variable. This was not surprising, as the observed association was non linear in the primary model. It is to be expected that the test offices differ somewhat in their reported test results, as they were assigned adolescents based on geography. However, including test offices in the model did not have any effect on the overall association. When we included work capacity in the model, most risk estimates decreased in absolute values, furthering strengthening the observations in the primary model. By using the relative muscle strength during testing periods of five years, we partially address the potential systematic change in testing procedure over the years. Although the methods of measurements have not changed at large, minor adjustments cannot be excluded.

In future studies, it would be of interest to investigate if low muscle strength serves as a deselection criterion for professions or types of leisure time physical activity with higher risk of acute injuries or chronic physical overload, factors with negative impact on musculoskeletal health.~~Although we found no increased risk of future musculoskeletal problems in men with low muscle strength in adolescence, future studies need to better quantify the occupational exposure and leisure time physical activity~~. Since the physical activity pattern and physical fitness profiles differ between men and women, further investigations are also needed to investigate if similar associations can be found in women.

~~In contrast to our hypothesis~~In conclusion, we observed no~~a~~ in~~de~~creased risk of self-reported musculoskeletal pain in adult men with low overall isometric muscle strength in youth. Thus, this study add no support to a model in which muscle strength is a risk factor for future musculoskeletal pain in men. ~~We speculate that low muscle strength *per se* is not protective of future musculoskeletal pain. Instead, low muscle strength might serve as a deselection criterion for professions or types of leisure time physical activity with higher risk of acute injuries or chronic physical overload, factors with negative impact on musculoskeletal health.~~

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Author contributions

ST proposed the study idea, collected data, designed the study, and drafted the manuscript. IP designed the study and provided input during manuscript preparation. CZ designed the study and performed the statistical analyses. ME designed the study, collected data, and provided input during manuscript preparation. All authors approved the final version of the manuscript.

Data sharing statement

There is no additional data to share.

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Tables and Figures

Table 1: Description of study sample

Table 2: Risk estimates for the muscle strength in youth as a determinant of self-reported musculoskeletal pain in adulthood

Figure 1: The identification of the study sample and the loss to follow-up

Table 1 Description of study sample

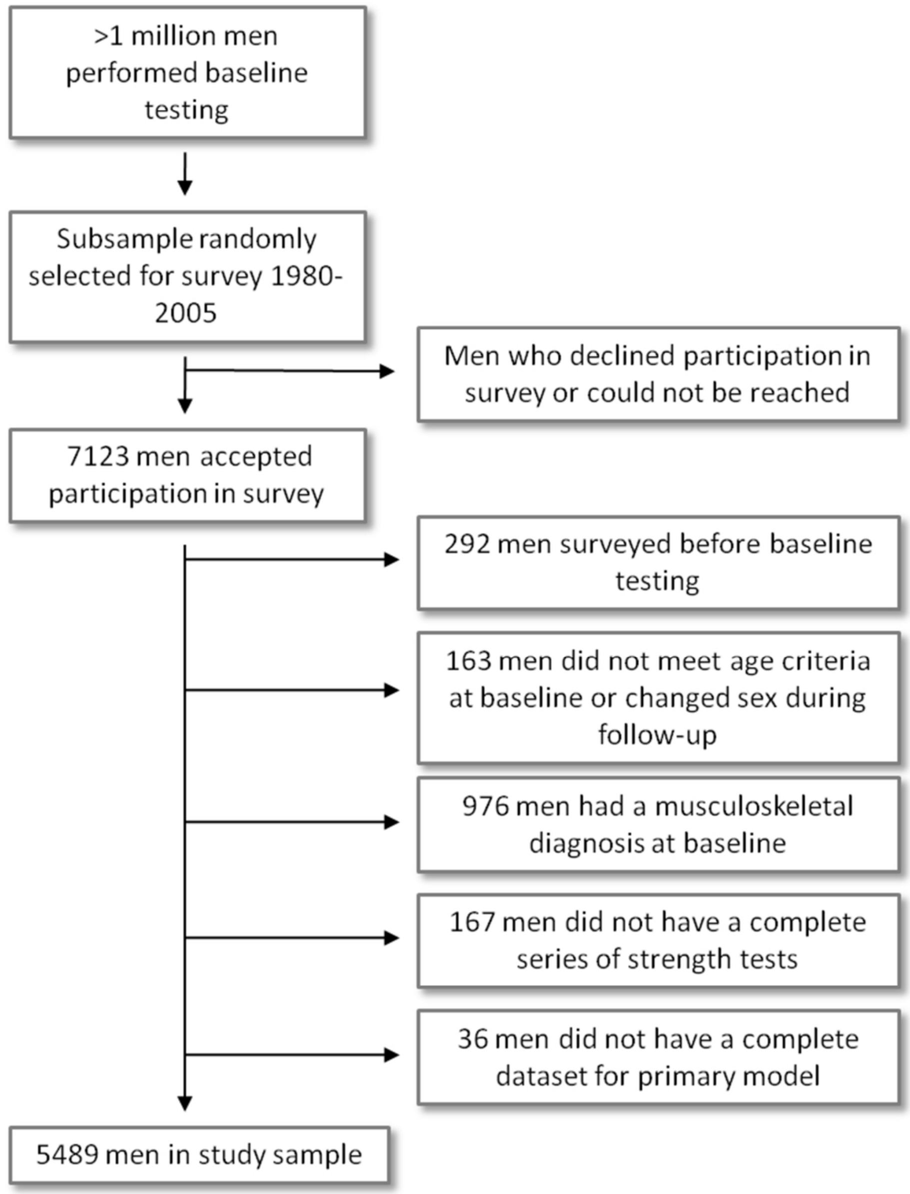
Number of men	5489
Mean age at baseline (SD)	18.2 (0.5)
Mean time to follow-up (SD, range)	17.2 years (8.4, 1-35)
Mean hand grip* (SD)	617 (98)
Mean elbow flexion* (SD)	385 (83)
Mean knee extension* (SD)	567 (116)
Muscle Strength (%)	
Low	1371 (25.0)
Average	2747 (50.0)
High	1371 (25.0)
BMI (%)	
<18.5	477 (8.7)
18.5-24.9	4498 (81.9)
25-29.9	448 (8.2)
>30	66 (1.2)
Type of interview (%)	
In person	4349 (79.2)
By telephone	1140 (20.8)
Pain in back/hips (%)	
Yes	1645 (30.0)
of which severe	321 (5.8)
No	3842 (70.0)
Missing	2 (0.0)
Pain in neck/shoulders (%)	
Yes	1562 (28.5)
of which severe	246 (4.5)
No	3925 (71.5)
Missing	2 (0.0)
Pain in arms/legs (%)	
Yes	1243 (22.6)
of which severe	196 (3.6)
No	4243 (77.3)
Missing	3 (0.0)
Pain, independent of location (%)	
Yes	2847 (51.9)
of which severe	576 (10.5)
No	2639 (48.1)
Missing	3 (0.0)
Smoking status (%)	
Yes	827 (15.1)
No	4662 (84.9)
Level of education (%)	
Compulsory	589 (10.7)
Secondary	2889 (52.6)
Higher	2011 (36.6)
Physical Activity (%)	
Practically non	583 (10.6)
Now and then	1613 (29.4)
Regularly	2077 (37.8)
Regularly strenuous	1216 (22.2)

* In Newton.

Table 2 Risk estimates for the muscle strength in youth as a determinant of self-reported musculoskeletal pain in adulthood

	Models				
	Univariate			Multivariate[a]	
	Muscle strength			Muscle strength	
	Low (N=1371)	**Average** (N=2747)	**High** (N=1371)	**Low**	**High**
Outcomes	**RR** (N)	**Reference** (N)	**RR** (N)	**RR** (95% CI)	**RR** (95% CI)
Musculoskeletal pain	0.92 (668)	1 (1457)	0.99 (722)	0.93 (0.87-0.99)	0.99 (0.93-1.05)
Severe musculoskeletal pain	0.96 (135)	1 (283)	1.12 (158)	0.96 (0.79-1.18)	1.07 (0.89-1.29)
Pain in back/hips	0.92 (384)	1 (832)	1.03 (429)	0.93 (0.84-1.03)	1.03 (0.94-1.13)
Pain in neck/shoulders	0.92 (366)	1 (799)	0.99 (397)	0.93 (0.83-1.03)	1.00 (0.90-1.10)
Pain in arms/legs	0.97 (297)	1 (616)	1.07 (330)	0.97 (0.86-1.10)	1.06 (0.94-1.19)

N= Number of cases
RR= Relative risk estimates
CI= Confidence interval
a= adjusted for smoking status, physical activity, education, body mass index



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STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cohort studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2-3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5-6
Objectives	3	State specific objectives, including any prespecified hypotheses	6
Methods			
Study design	4	Present key elements of study design early in the paper	6+
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6-9
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	6-7
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	-
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-9
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*6-9*
Bias	9	Describe any efforts to address potential sources of bias	9
Study size	10	Explain how the study size was arrived at	Figure 1
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6-9
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	9
		(*b*) Describe any methods used to examine subgroups and interactions	9
		(*c*) Explain how missing data were addressed	-
		(*d*) If applicable, explain how loss to follow-up was addressed	-
		(*e*) Describe any sensitivity analyses	9
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Figure 1
		(b) Give reasons for non-participation at each stage	Figure 1
		(c) Consider use of a flow diagram	Figure 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Table 1
		(b) Indicate number of participants with missing data for each variable of interest	Table 1
		(c) Summarise follow-up time (eg, average and total amount)	Table 1
Outcome data	15*	Report numbers of outcome events or summary measures over time	Table 1
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Table 1
		(*b*) Report category boundaries when continuous variables were categorized	6-9
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	-
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	9
Discussion			
Key results	18	Summarise key results with reference to study objectives	10-11
Limitations			
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	13-14
Generalisability	21	Discuss the generalisability (external validity) of the study results	12-13
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	14

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.