Swedish Agency for Work Environment Expertise

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Systematic literature review 2025:8

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Foreword

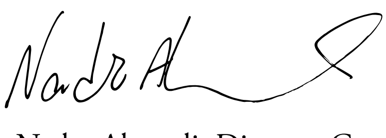
Prolonged or sustained heavy physical strain at work is estimated to be a significant cause of work-related deaths and previous research has linked this type of strain to up to a third of all work-related deaths. We also know that heavy physical strain occurs to varying degrees in many workplaces. For example, 2019 statistics from the Swedish Work Environment Authority show that 50 percent of women and 45 percent of men reported being physically fatigued after work at least one day a week in the last 3 months, and in some occupations it was as high as 80 percent. The negative effect of heavy work may be perceived as contradictory, as physical strain can also be linked to positive health effects in some situations, such as leisure-time physical activity. But here, research clearly shows that this type of prolonged strain at work can instead pose health risks.

With this in mind, and in an effort to ensure that no one dies as a result of their work, we have produced this review. We have chosen to compile knowledge from Nordic research on the extent to which, and in what way, long-term physically demanding work affects the risk of work-related deaths and cardiovascular disease, as high loads on these systems can cause serious health risks and death.

The authors of the systematic review are Professor Mikael Forsman at the Institute of Environmental Medicine, Karolinska Institutet and the School of Chemistry, Biotechnology and Health, KTH Royal Institute of Technology, Andreas Lundin PhD, at the Department of Global Public Health, Karolinska Institutet, Associate Professor Jenny Salander, and Professor Maria Albin at the Institute of Environmental Medicine, Karolinska Institutet. Mid Sweden University has contributed with literature and information searches and Professor David Hallman at the University of Gävle has, on behalf of the Agency, quality reviewed the systematic reviews whose viewpoints have contributed to the quality of the report. The responsible process manager at the Swedish Work Environment Authority has been Thomas Nessen, PhD. The Agency's communicator has been Lasse Nivér. The authors of the review have chosen their own theoretical and methodological starting points and are responsible for the results and conclusions presented in the review. I would like to thank both our external researchers and quality reviewers as well as employees at the authority who have contributed to producing this valuable systematic review, and a special thank you to Carl Lind at the Swedish Work Environment Authority for his contribution and support.

The review is published on the agency's website and in the "Systematic Reviews" series.

Gävle, September 2025



Nader Ahmadi, Director-General

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Summary

Creating healthy workplaces is an important part of promoting health. It can never be acceptable for anyone to die at or because of their work. Working life should offer everyone the opportunity for development and good health during, and as far as possible after, their working life.

Physically demanding work usually involves high energy expenditure, an elevated heart rate, and consequently a high cardiovascular strain. Heavy work can also involve repeated heavy lifting, which may also lead to a significant increase in heart rate over the course of a working day. Some studies indicate that such demanding work may contribute to cardiovascular disease, which remains the leading cause of death in Sweden.

Sustained heavy physical workload has been estimated to cause over 1,500 deaths per year, mainly among men. This figure represents a substantial proportion of the annual number of work-related deaths in Sweden. However, the estimate is somewhat uncertain, as it is based on an analysis of international studies. That analysis found an overall increased risk of work-related death among men exposed to sustained physically heavy or strenuous work, but no such association was observed among women.

Purpose

The purpose of this systematic review was to compile existing knowledge on the link between long-term or sustained physically demanding work and work-related mortality as well as cardiovascular disease, from a Nordic perspective. Another aim was, if such a link could be established, to highlight certain work-related risk factors associated with physically demanding work that may contribute to work-related mortality.

Methodology

To identify suitable publications for this systematic review, articles or reports were sought in English or a Scandinavian language that addressed working life in combination with physical exertion, with outcomes related to cardiovascular disease and/or mortality. At least one author and the study population had to be from a Nordic country. The literature searches yielded 1,889 articles with titles and abstracts.

The abstracts of all 1,889 articles were reviewed independently by two reviewers. A total of 109 abstracts were deemed relevant. After reviewing the full texts of these articles, 32 were found to be relevant for the report. Quality assessment was carried out using SBU's checklist for observational studies (SBU is the

Swedish Agency for Health Technology Assessment and Assessment of Social Services, a governmental authority that evaluates healthcare and social service interventions based on scientific evidence).

Results

The 32 included articles were relevant to the aim and research questions, all demonstrating sufficiently high quality (that is, a low or moderate risk of bias) in the reported risk estimates for allcause mortality or cardiovascular disease associated with high physical workload.

Risk of mortality from all causes

A total of 16 prospective cohort studies were identified concerning increased risk of work-related mortality, regardless of cause of death:

- In six studies, the findings indicated increased mortality associated with physically demanding work. Five of these found a statistically significant increase in mortality among those most highly exposed to physical workload. Four studies also observed that risk increased gradually from low to high levels of exposure, while one found a more U-shaped association (that is, the highest risk was seen in both the lowest and highest exposure groups compared to the intermediate group). In one study, the relationship became clear only when workload was evaluated in relation to the individual's own physical capacity. In the sixth study, the risk was considered elevated in both of the highest exposure groups (though not statistically significant in the highest group), and a statistically significant increase in risk was seen with increased exposure.
- Four studies found a protective effect of physically demanding work compared with predominantly sedentary work.
- Six studies found neither statistically significant increased nor decreased risk.

In those studies that identified an increased risk, the magnitude was low to moderate (relative risk 1.1–1.8, corresponding to an increased risk of 10 to 80 percent) in the highest exposure group. As indicated above, the results were partly contradictory across the studies (see *Discussion* section below).

An individual's vulnerability to physically demanding work may vary according to physical capacity and medical risk factors. Two studies investigated how the beneficial effects of leisure-time physical activity were influenced by the level of physical activity at work. One of these studies found that leisure-time physical activity was protective in all categories of physically demanding work, but in the group with the highest physical workload, leisure-time activity could not compensate for the risks associated with heavy occupational strain.

Risk of Incidence and mortality from cardiovascular disease

A total of 27 studies were identified in this area: 23 prospective cohort studies and 4 case-control studies.

- For the broad category of cardiovascular disease (without subdivision by specific diagnoses), three out of nine studies reported a statistically significant increased risk of cardiovascular disease at high levels of occupational physical workload. In addition, the risk increased with higher levels of exposure (dose-response). In contrast, three studies found that the risk was statistically significantly lower with high physical workload.
- For the subcategory of ischemic heart disease, three out of eight studies observed a statistically significant increase with dose-response, while one study found a statistically significant lower risk in the group with the highest exposure, also in a dose-response manner.
- For myocardial infarction, a subset of ischemic heart disease, three out of six studies identified a statistically significant increased risk; two of these observed an increasing risk with higher workload levels. One study reported a decreased risk with high occupational physical workload.
- Of two studies examining stroke in relation to occupational physical workload, one observed a decreased risk for ischemic stroke associated with higher workload, in a dose-response fashion, while the other found no statistically significant differences between the groups.
- One study on heart failure found a lower risk in physically demanding jobs compared with less physically demanding ones.

In studies that identified an increased risk of cardiovascular disease of any kind, the risk increase was generally low to moderate (relative risk 1.1–1.7) in the highest exposure group. As with the risk of work-related mortality from any cause, the relationship between occupational physical workload and cardiovascular disease was influenced by the individual's physical capacity (relative aerobic workload). In one study, the risk increase was estimated at 30 percent for every 10 percent increase in relative aerobic workload. In two studies, the risk of coronary artery disease with heavy physical work was particularly high among individuals with elevated blood pressure. Another study reported a higher risk of cardiovascular disease from physically demanding work among individuals with metabolic syndrome.

Discussion

Several of the individual Nordic studies included in this systematic review found that physically demanding work was associated with either higher or lower mortality, while other studies observed no statistically significant differences. This is consistent with findings from international reviews that included studies without geographic limitations; there is a statistically significant higher mortality among men in physically demanding occupations, but no differences in mortality between women in physically demanding and lighter jobs.

Similarly, studies investigating cardiovascular disease as an outcome showed conflicting results. In some studies, heavy work was significantly associated with both lower and higher risk, while other studies found no significant differences between those with physically strenuous jobs and those with lighter work.

When an increased risk was observed in relation to physically demanding work, it was generally low to moderate (relative risk 1.1–1.8), both for mortality from all causes and for cardiovascular disease. Since these are common outcomes, even such moderate risk increases are meaningful for individuals and contribute to health inequalities between occupational groups.

The existing studies, regarding both mortality and cardiovascular disease, support that the match between the physical demands of work and the individual's capacity plays a major role: a work-load that is far too high for an individual increases the risk. Only one study has quantified work-load in relation to individual capacity, but several have found that the negative effect of heavy physical work appears to be stronger among those with low physical fitness, and weaker among those with good fitness or those who are physically active in their leisure time. The observed excess risks are most consistent for men, whereas the studies yield more divergent results for women. Although there are substantial underlying differences in cardiovascular risk between men and women, the authors of the report consider it unlikely that the observed differences in risk associated with physically demanding work are biologically determined. It is more likely that these differences are due to disparities in the type of work men and women perform, but this remains to be investigated.

Limitations in the current state of knowledge:

- The most significant limitation concerns how high and very high physical workload is defined in existing studies. The issue pertains both to the data used and to its categorization; different studies use two to four categories, and even the highest category may include moderate workload.
- Estimates of exposure are based on self-reports and indirect methods, which may be too imprecise. Few studies employ objective and potentially more accurate methods for measuring exposure.
- It is also urgent to further investigate whether the risk is affected by the type of physical workload; manual handling and its biomechanical strain (such as heavy lifting) versus more dynamic, aerobic-demanding work (such as stair climbing).
- One factor that can distort risk estimation is the routine adjustment for educational level, even though low educational attainment is strongly associated with physically demanding work. In most cases, this tends to underestimate the risk.
- The limitations in current knowledge are particularly pronounced for women; more studies are needed with a sufficient number of women exposed to high physical workload.

Conclusions

The following findings have emerged from this systematic review:

- Heavy physical work does not provide the same positive health effects as leisure-time physical activity.
- The evidence regarding the association between heavy physical work and mortality (from all causes) is inconsistent, but the majority of findings suggest that such work is associated with a slightly to moderately increased risk of mortality (observed relative risk 1.1–1.8).
- The increased mortality associated with heavy physical work is probably explained in part by an elevated risk of ischemic heart disease. Researchers have proposed several mechanisms by which physically demanding work can increase the risk of cardiovascular disease.
- The relationship between the physical demands of work and the individual's physical capacity influences the risk associated with heavy physical occupation. Ensuring that the physical demands of work are matched to the individual's capacity may become increasingly important in working life. This is because it is becoming more common for individuals to enter the workforce with reduced physical capacity and to continue working until an older age.
- There is a need for measures to reduce the workload in jobs that are currently physically demanding. The challenges associated with heavy physical work are particularly pronounced as physical capacity declines due to normal, physiological ageing. As far as possible, jobs should be designed so that they can be carried out throughout an individual's working life without resulting in excessive strain. In cases where this is difficult to achieve, better matching might be accomplished by offering employees opportunities for work-adapted physical training during working hours. Additionally, middle-aged and older employees could be offered planned professional development for tasks that are less physically demanding.

Contents

1. Introduction

Sustained heavy physical strain at work has been estimated to cause over 1,500 deaths per year in Sweden. These deaths occur mainly among men, and account for a significant proportion of the annual number of work-related deaths (1). Work-related deaths or work-related cardiovascular disease refer to deaths or illnesses that can be attributed to work. However, the authors of that review (1) characterized the association as somewhat uncertain. The calculation was based on Coenen et al. (2) who, in a meta-analysis of international studies, found that the combined results showed an excess risk of death when the work involved exposure to sustained physically heavy or strenuous work (high level of occupational physical activity) for men, but this increased risk was not seen for women. Several research studies suggest that, unlike leisure-time physical activity, prolonged high levels of cardiovascular strain at work are not protective and may pose serious health risks. If heavy workloads increase the risk of premature death, this risk can be prevented by interventions at work and in the work environment.

At present, there is a lack of systematically compiled knowledge that sheds light from a Nordic perspective on whether, and to what extent, prolonged or sustained physically heavy or strenuous work causes work-related deaths or cardiovascular disease, and how the risks of the negative consequences can be reduced in working life.

Heavy physical strain in working life has a geographical variation (between countries), for example related to occupational safety (legislation and regulations) and the degree of mechanisation. The review has therefore been limited to the Nordic countries; but in the chapter *Discussion,* the results are related to meta-analyses that have not had geographical delimitations.

Prolonged or sustained heavy or strenuous physical work

Physically demanding work often involves high energy expenditure, with an elevated heart rate over a long period of time, and thus high stress on the heart and blood vessels. It can be dynamic work without external loads, such as cycling, walking, climbing stairs and cleaning. But it can also be static work that raises blood pressure as in manual handling, for example, with repeated heavy lifting that occurs in construction work, warehouse work and garbage collection, among others. The two types of heavy physical work that simultaneously stress several parts of the body, dynamic work without external loads and manual handling, can occur in combination.

Prolonged or sustained work means that this work can be assumed to last for a long period of time, so that the average workload and average heart rate during the individual's normal working day are elevated.

When physically demanding or strenuous work is discussed in the report, it refers to prolonged or sustained physically demanding or strenuous work as explained above.

Sometimes the term 'heavy physical work' includes all work that causes high mechanical stress on muscles and joints, such as assembly work and patient transfers. However, this review focuses on loads (often referred to as whole-body loads), which, in addition to loads on joints and muscles, also place strain on the respiratory and circulatory systems. As described above, even mechanical strain, if prolonged or sustained, can require high energy metabolism and place high demands on the body's ability to absorb oxygen.

It is not possible to remain at 100 percent of one's oxygen uptake capacity for a full working day. The International Labour Organization (ILO) has suggested (3, 4) that the average load should not exceed 30-35 percent of the individual oxygen uptake capacity (lower for heavy lifting). Several studies have used 33 percent of an individual's capacity over an 8-hour working day as a risk level for heavy physical work (5).

Several factors distinguish between high physical strain at work and at leisure. According to the above, high workload is when an increased level of activity is sustained over a long period of time. The level is such that it can be sustained for a long time. High physical strain in leisure time, for example a run or a strength training session, is usually at a higher level but for a shorter time. How these factors may explain the differences in health effects between loads is further described in the chapter Discussion.

Cardiovascular disease

Cardiovascular disease is an umbrella term encompassing a variety of conditions, and it remains the leading cause of death in Sweden (6). Heart attacks are the main cause of heart-related deaths. In 2022, 23,200 cases of acute myocardial infarction occurred in Sweden, of which 4,700 were fatal (7).

Cardiovascular disease as a main group can be divided into four different subgroups:

- heart disease
- stroke
- diseases of arteries
- hypertension.

Heart disease can be further divided into the groups:

- cardiac arrhythmia
- ischemic heart disease
- other specified heart disease.

Ischemic heart disease can then be divided into:

- sudden cardiac death
- myocardial infarction
- coronary heart disease
- symptoms of angina.

The focus of this review has been on cardiovascular disease as a collective term, ischemic heart disease, and myocardial infarction. Ischemic heart disease is one of the most common forms of cardiovascular disease, and myocardial infarction is one of the most severe and common forms of ischemic disease. The diagnostic criteria for these diseases are clear and they can be followed with high reliability in national registries (of hospitalisations and deaths) in Sweden as in many other countries. This means that they can be well studied in observational epidemiological studies.

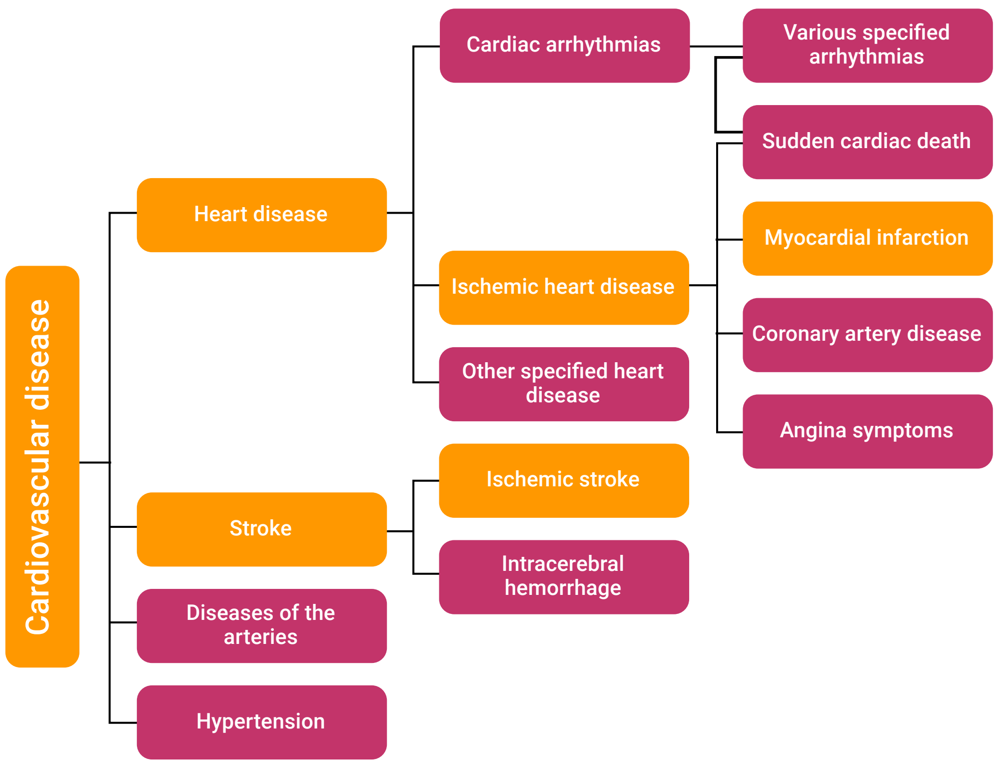

Figure 1. Overview of cardiovascular disease as a collective term and its various underlying conditions. The diagnoses illustrated by the yellow box are included in the questions in this re-port. Heart failure is counted here as ischemic heart disease.

Purpose

The purpose of the review was to summarise the knowledge of observed effects and associations between prolonged or sustained heavy physical work and work-related deaths and cardiovascular disease, in the Nordic countries.

The aim of the project was to make knowledge available that can be of practical use for work environment management in environments where heavy physical work occurs, if a load-dependent risk of cardiovascular disease or premature death is found. The review can then also contribute to the Swedish Work Environment Authority's work on regulations by highlighting some sources of risk in working life, which are linked to heavy physical work and which can cause work-related mortality.

Review questions

1. Is there an association between prolonged or sustained heavy or strenuous physical work and work-related mortality and cardiovascular disease? If so, how large is the observed increase in risk? What are the gender differences?
2. In a job involving prolonged or sustained heavy or strenuous physical work, what additional work or individual characteristics may increase or decrease the risk of work-related mortality and cardiovascular disease?

2. Method

The methodology used in the review follows the guidelines for a systematic review, which involves systematically searching for, evaluating and synthesising research (8). The material sought was peer-reviewed publications, without age limits, in English or one of the Scandinavian languages, in international journals. The material should be from the Nordic countries.

In the selection, a number of delimitations were made in terms of population, exposure and observed disease or death (Population, Exposure, Outcome - PEO). The studies were to cover the working population in the Nordic countries exposed to physically demanding work, and include observations in the following areas:

- mortality (regardless of cause of death), or shortened life expectancy
- cardiovascular disease incidence and death (see Figure 1)
- original studies with a longitudinal aspect (cohort studies and case-control studies).

When several studies were conducted on the same population, the most recent or most informative follow-up was included.

The following were not included:

- studies of the working population outside the Nordic countries
- the onset of peripheral artery disease ('intermittent claudication, deep vein thrombosis), hypertension, or pre-eclampsia[1]
- case studies, case series, experimental studies, mechanistic studies, clinical studies with risk factor change as outcome (for example, thickened heart muscle wall) without manifest disease (however, some such studies are referred to in the discussion section)
- studies that do not estimate the risk related to physically demanding work
- review articles (although the most recent reviews are included in the discussion chapter).

Information specialists at the Mid Sweden University's library assisted in developing search strings (see Appendix 3). They also carried out the literature search. The search strings were set based on the review questions and typical articles already produced in the field. Searches were made for articles that contained working life in combination with physical strain, and outcomes in the form of cardiovascular disease and/or mortality. At least one author had to be from one of the Nordic countries (the populations had to be from the Nordic countries, but it was not possible to include this in the search terms; the country to which the literature referred had to be examined after the literature searches).

1 The choice of included diagnoses was mainly based on an assessment of their respective importance for total mortality and the possibility of finding a sufficient number of Nordic studies of good quality.

Searches were conducted in the Scopus, Pubmed and Psycinfo databases. They resulted in 1,888 articles with titles and abstracts.

The abstracts of the 1,888 articles were independently reviewed by two reviewers. The inclusion criteria were based on PEO: that the abstract showed that the study was an original work and was based on a working population (population, P), mentioned exposure to heavy work (E) and had as outcome death or cardiovascular disease (observations, O). Initially, 252 abstracts were double-reviewed by both reviewers and the consistency of the assessments was discussed. After this, the remaining abstracts were divided between the reviewers who decided on inclusion/exclusion. In case of doubt, the article was included for full-text review. The full-text review was based on double review. When the assessments, relevance and quality assessment according to The Swedish Agency for Health Technology Assessment and Assessment of Social Services (SBU)'s criteria template differed, or in case of doubt, the differences were discussed until consensus was reached. Data extraction was done by the two reviewers separately. A total of 107 abstracts were considered relevant. Of the 107 relevant abstracts, 99 could be retrieved in full text. The remaining 9 were searched manually, but without success. They were all older publications, which are not available digitally.

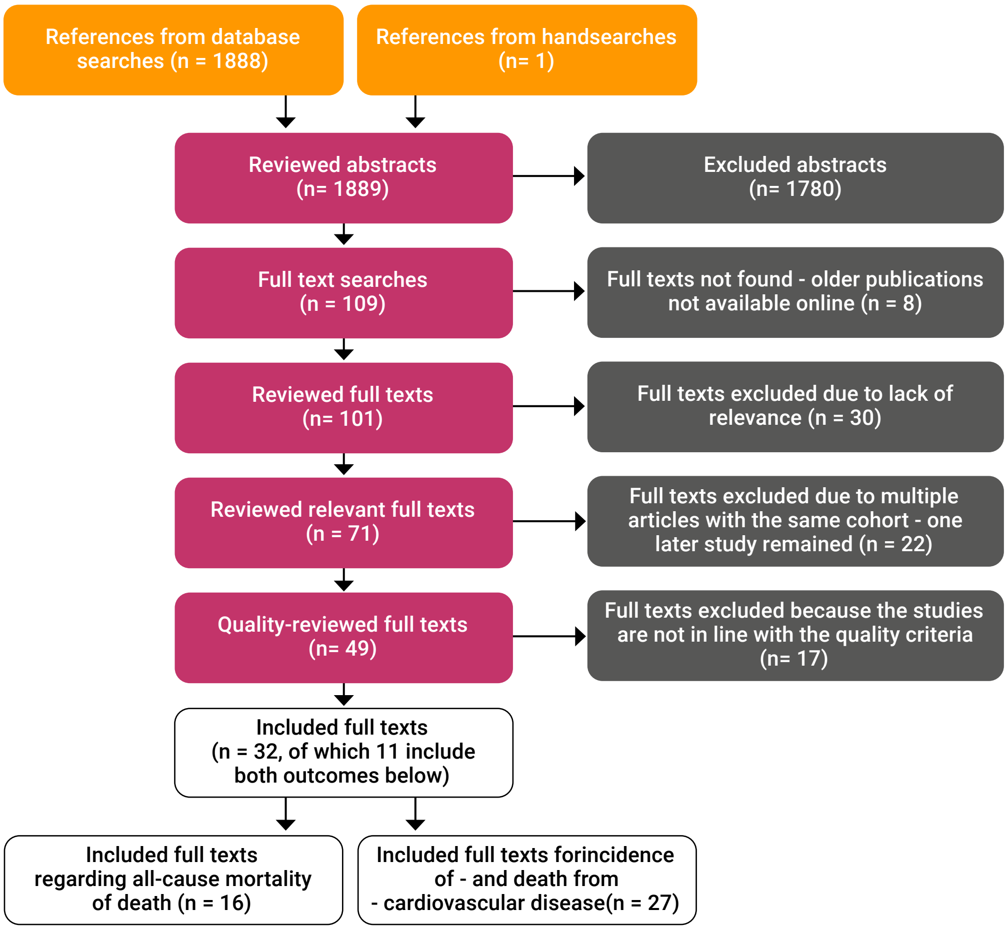

Figure 2 Selection of articles based on the database searches and one article identified from literature reviews (top right). A total of 1,889 abstracts were reviewed. 32 articles remained after the reviews.

A quality review was conducted using the SBU template for quality review of observational studies (57). The template was implemented in an Excel sheet. Studies with medium or high quality according to the quality criteria were included in the final summary of results. In accordance with the template, the quality review was done based on the questions of the review, that is the assessment of high risk of bias applies specifically to these and not generally. Studies excluded due to low quality (mainly high risk of bias) are listed together with full-text articles excluded for other reasons in Appendix 2. Among studies of medium or high quality, a further assessment was made of whether the studies had sufficient contrast in the analysis between work with 'high sustained physical strain' and other work.

Data were extracted from the articles systematically, and information from each article was recorded in a six-column Word table with the headings:

- publication, including author, title, year
- study population and study design
- exposure assessment, and how the exposure was determined
- covariates and variable for stratification
- outcome variables, and how they were determined
- outcomes, including dose-response; possible differences (if data are available) by other factors at work (for example, control of work situation); individual factors (including gender, age, leisure-time physical activity, and presence of chronic disease).

Appendices show two completed tables with extracted data from the reviewed full-text articles, which were included in the final analysis: appendix 1a (Cardiovascular disease and death caused by cardiovascular disease) and 1b (All-cause mortality). As shown in Figure 2, 11 articles that had results in both outcome areas are included in both appendices.

Inclusion and exclusion criteria

Population and study design

Only studies conducted in the Nordic countries were included in the report. The reason for this was that these best reflect conditions in Sweden and are thus more valid for describing a Swedish context. Only studies of the working population were included.

Furthermore, the studies needed to:

- report risk estimates for heavy physical work with confidence intervals or p-values
- be cohort studies or case-control studies
- not be limited to populations with a certain disease when the follow-up started

- have at least 100 cases in a case-control study or at least 100 events in a cohort study
- have at least 10 years of follow-up (as the follow-up time in the cohort often varies, the average or median should be at least 10 years).

Cardiovascular disease and death

A requirement for a study to be included in the review was that the study covered cardiovascular disease as a whole, heart disease, stroke, ischemic heart disease, ischemic stroke, myocardial infarction (see Figure 1) or death (from any cause).

Physically heavy work

Another requirement for inclusion in the report was that the study included different levels of heavy physical work, and that risk estimates were developed for cardiovascular disease or death, for a group with high levels of heavy physical work or physical activity at work.

Several studies have used the same study population, so the results are not independent. Therefore, the results from the most recent/most comprehensive follow-up are presented. After relevance and quality checks, 32 articles remained, see Figure 2.

Synthesis of the results

A narrative synthesis of the results was performed, including medium and high-quality studies with their extracted results (see Appendix 1a and 1b). As a first step, the number of studies showing statistically significant associations in the positive or negative direction, as well as statistically inconclusive studies, were reported. The magnitude and precision of the risk estimates were then illustrated in figures, organised by year of publication. This provided a visual representation of the evolution of the risk estimates, but also an idea of the risk of publication bias, a source of error that arises because non-significant results tend not to be published to the same extent. One sign that publication bias may be a problem for the field is often considered to be that studies with high risk estimates and low precision are an important part of the overall publication. No meta-analysis was conducted, but the main results are discussed, in the discussion chapter of the knowledge synthesis, in relation to recently published meta-analyses conducted without geographical delineation.

3. Results

Hard work and death regardless of the cause of death

Description of included studies

A total of 16 studies of sufficiently high quality, that is low or medium risk of bias, were identified that reported risk estimates for death from all causes in heavy work (9-24).

All were prospective cohort studies, in other words different exposure groups were followed over time to compare risks. All studies were population-based, except one which was based on employment in one city, Helsinki (12). Five of the studies were based on populations from Finland (with Finnish populations), five were from Denmark, four from Norway and two from Sweden. Twelve of the studies included both sexes, while four of the studies included only men. See Appendix 1b.

Exposure assessments

Regarding the exposure data, none of the studies included technical measurements (for example pulse measurements, which would have been a very reliable method compared to the commonly used and relatively unreliable self-assessments) of exposure. Only one study had detailed interview data on exposure (19). Three studies instead summarised different dimensions of physical strain (such as heavy lifting and excessive movement) into an index. In two of the studies this was done at the occupational group level (including office workers, teachers, painters, concrete workers, fitters) using a job-exposure matrix (12, 20), and in one study based on individual questionnaire responses (17). Otherwise, the estimate of physical exposure at work was based on a question in a questionnaire answered by the individual at baseline, that is when the individuals become participants in the study. Only two studies (12, 23) took into account whether exposure changed during the follow-up period. Ervasti et al. (12) also studied the risk in relation to the number of years exposed.

Follow-up time

The follow-up time in the studies was in most cases over 20 years, and the shortest time was 10 years (12). The group with the highest physical workload was compared in 11 of the studies with mainly sedentary work (9-11, 13, 14, 16, 18, 21-24), in three of the studies with the quartile with the lowest physical workload based on an index with different dimensions (12, 17, 20), and in one study with the group with walking work with lifting (15). One study compared the degree of the individual's physical capacity required in the work (19)[2].

Other factors

The studies also addressed other factors that may influence mortality in a studied group. For example, in addition to age and sex, all studies also took into account cardiovascular disease and sometimes other diseases at the start of the follow-up, as well as socioeconomic factors such as educational level. All but two of the studies (12, 20) also had individual data that allowed the statistical analysis to take into account lifestyle factors (such as smoking, alcohol, leisure-time physical activity) and individual risk factors for cardiovascular disease in particular (blood pressure, blood lipids, et cetera.).

Results of the studies

Results from 16 studies on all-cause mortality

- Five studies found increased mortality in the highest exposure group, four of which also found a gradually increasing risk with increasing physical load and one found a more U-shaped relationship (higher in both the lowest and highest groups than in the intermediate group; (14). In one of the studies (18), the effect was only clear when the physical load was put in relation to the individual's own physical ability. In another study (11), the risk was estimated to be elevated in the two highest exposure groups (not statistically significant in the highest) and there was a significant dose-response relationship.
    - In the studies that identified an increase in risk, this was low to moderate (relative risk 1.1-1.8) in the highest exposed group.
- Four studies found a protective effect of physically demanding work compared to mainly sedentary work.
- Six studies found neither a significantly lower nor higher risk. However, one of these (22) found a suggestion that the effect of physical load could be related to year of birth such that it was protective for men born before 1940, but a risk factor for men born after 1950 (HR=1.38; 95% CI 1.00 - 1.89).

The results of the different studies were as shown in the text box above partially contradictory. Inconsistencies between studies may be due to differences in, among other things, the quality of the exposure classification and the extent to which it was divided into sufficient levels to allow a possible effect in a highly

2 The article by Krause et al (19) studied 1,891 men in eastern Finland who were working at the time of the first survey. They answered survey questions about the time they had worked in the past year (full-time/part-time, absenteeism) and were interviewed about the time (in 15-minute units) they spent during a typical working day doing the following: sitting, standing, walking on level ground, walking on uneven ground, climbing stairs, performing other activities. Absolute energy expenditure (kcal/day) was calculated from reference data for such tasks. The men participating in the study performed a maximal work test and oxygen uptake capacity was determined. The propor-tion of the individual's physical capacity used at work was calculated from the work tasks and test results, as relative aerobic workload (%VO_2-max). The group was followed for 22 years. In the most adjusted model (19 factors), there was no significant increase in risk in relation to absolute energy expenditure (HR 1.03; 95 percent confidence interval 0.98-1.09). On the other hand, when workload was related to individual capacity, a 10 percent increase in relative aerobic workload was estimated to increase total mortality by 15 percent (95 percent confidence interval 7 percent to 24 percent). This corresponded to an estimated absolute risk of 225 extra deaths per 100,000 people per year. When the group was divided according to whether the relative aerobic workload was below or above 33 percent, total mortality was 30 percent (95 percent confidence interval 7 percent to 57 percent) higher in the high load group compared to the low load group.

exposed group to be discerned. As the comparison was made between physically demanding work and sedentary work, the results were mixed. In contrast, the results were consistent in those studies that instead compared (i) the quartile with the highest and lowest probability of heavy physical strain in different dimensions (12, 17, 20), (ii) moderate physical strain with heavy manual work (which then represented heavy physical strain) (15), or (iii) the proportion of the individual's physical ability required in the work (19). In these studies, an increased mortality was found in the highest exposed group and a gradual increase with increasing strain. This was true in all these studies except the one by Hermansen et al. (15) where the relationship was u-shaped (higher even for sitting work compared to the intermediate group).

Inconsistencies may also be due to the extent to which other factors that may influence the results were taken into account. In (15, 17) there was a comprehensive statistical adjustment for possible confounders such as social factors and individual risk factors, while (19) also adjusted for psychosocial factors at work. A couple of studies adjusted only for age and educational level (12, 20).

A total of six studies found an increasing risk of premature death with increasing exposure when looking at the whole study population of women and men together. Of these studies, three also reported separate risk estimates for women and men. These studies (12, 17, 20) found statistically significant risk increases among men, but not among women.[3]

There is also information to be gained from aggregating the risk estimates of individual studies. This is true whether or not they were statistically significant, as such a compilation provides an overview of whether there was a general tendency to estimate the risk as elevated or not. The fact that a study does not show statistically significant associations does not mean that there are no associations. They may still exist, but it may require a larger population or, for example, greater contrast between low- and high-exposure individuals to statistically ensure the association. The studies' risk estimates are illustrated in Figures 3-6 with their most adjusted model, for the highest exposed group in each study. The risk on the x-axis is the relative risk (or a proxy measure) to the risk of the least exposed group. The relative risk is interpreted as 'times greater', that is a relative risk of 2 means twice the risk compared to the comparison group. A relative risk below 1 means a risk lower than the comparison group. Figures 3-5 show that studies that either studied the risk for men and women together (Figure 3), or men separately (Figure 4), predominantly indicate an increased risk in the highest exposed group. This is not the case for studies that looked at women separately (Figure 6). In general, studies conducted in recent years tend to be more predominantly in favor of an increased risk.

3 One of the studies (17) first divided the exposure level of the study participants into quartiles and then stratified according to sex, in other words the highest quartile exposure is comparable for women and men. The other two studies (12, 20) first divided the participants by sex and then divided the exposure level into quartiles, i.e. exposure in the highest quartile was not the same for men and women.

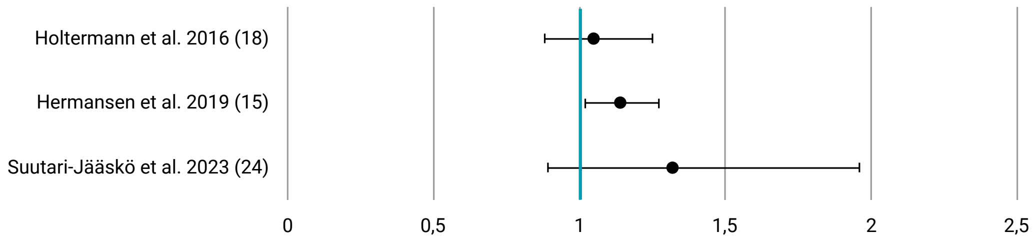

Figure 3. Heavy physical work and all-cause mortality. Pooled analyses including both men and women. Sorted by year of publication. Risk estimate from the most adjusted model with 95 percent confidence interval for the high-est exposed group.

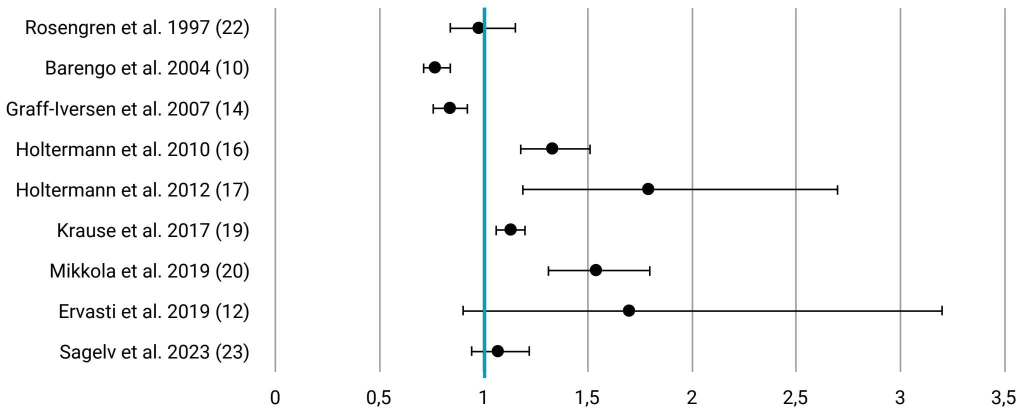

Figure 4. All-cause mortality, men. Studies in descending order of publication date. Risk estimate (with 95 percent confidence interval) for the highest exposed group in the most adjusted model. The comparison group is mainly sedentary workers except for Ervasti et al. 2019 (12), Holtermann et al. 2012 (17) and Mikkola et al. 2019 (20) (comparing with the 25 percent lowest exposed in the study) and Krause et al. 2017 (19) (relative aerobic work-load). Petersen et al. (2012) (21) studied the effect of heavy lifting and physical activity on work with reciprocal adjustment. In these analyses, the RRs were 1.00 and 1.02 respectively (non-significant). Franzon et al. 2015 (13) studied survival at age 85 for people with low physical activity and found a RR of 0.94 (non-significant).

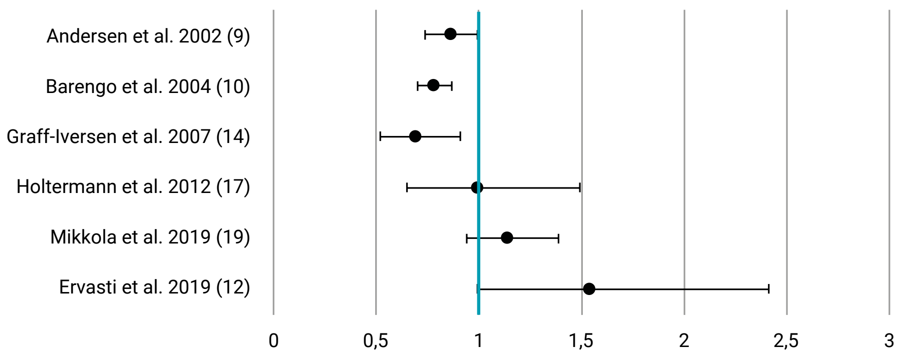

Figure 5. All-cause mortality, women. Studies in descending order of publication date. Risk estimate (with 95 percent confidence interval) for the highest exposed group in the most adjusted model. Petersen et al (2012) (21) studied the effect of heavy lifting and physical activity on work with mutual adjustment. In these analyses, the RRs were 0.95 and 0.94 respectively (non-significant).

Individual's physical capacity and medical risk factors

An individual's vulnerability to heavy physical workload may vary depending on physical capacity and medical risk factors. Krause et al. (19) found a clear risk associated with heavy physical work only when the load was related to the physical capacity of the individual. The results found by Holtermann et al. point in the same direction, (16) as an increased risk with high physical load was discovered only in those with low or moderate leisure-time physical activity, but not in those with high such activity.

Two studies investigated the influence of physical activity at work on the positive effect of leisure-time physical activity on life expectancy. Holtermann et al. (25) found that leisure-time physical activity was protective in all categories of physically demanding work, but in the group with very high physical demands at work, leisure-time physical activity could not compensate for the risk posed by the heavy work. They noted that the level of leisure-time physical activity was comparatively low both in the sedentary work group and in the very heavy physical workload group. Sagelv et al. (23) also found, overall, a protective effect of high leisure-time physical activity.

Most studies have included only those individuals who were not suffering from cardiovascular disease at baseline. However, three studies included those with initial disease and examined whether cardiovascular disease or metabolic syndrome resulted in a higher relative risk with heavy physical work. Holtermann et al. (26) did not find a higher risk in those with hypertension at baseline. Krause et al. (19) found a difference between those with and without ischemic heart disease, so that the additional risk of death for each 10 percent increase in relative aerobic workload (% VO2max) was calculated to be 225 additional deaths per 100,000 persons per year, respectively. Moe et al. (27) compared the effect of physical workload among people with and without metabolic syndrome[4]. Among those with metabolic syndrome, there was a u-shaped association with a significant increase in risk both in the lowest exposed (mainly sitting) group and among those with heavy physical work. No effect of physical load was seen in those without metabolic syndrome.

Heavy work and cardiovascular disease

Description of included studies

A total of 27 studies were identified, including 23 prospective cohort studies and 4 case-control studies, which reported on the risk of cardiovascular disease associated with high physical load (see Appendix 1a). Some studies examined the risk of developing cardiovascular disease, while others examined the risk of death from such disease. The studies were mainly population-based, except for two that were based on employment in a particular sector (industrial workers and

4 Metabolic syndrome is a group of factors that increase the risk of cardiovascular disease and type 2 diabetes. It includes abdominal obesity, dyslipidemia, elevated blood pressure and diabetes/reduced sensitivity to insulin.

Country	Number of articles in the analysis after full-text review, distributed by sex in the study population		
	Both sexes	Women	Men
Denmark, 7 studies	4	1	2
Finland, 9 studies	7	0	2
Norway, 5 studies	4	0	1
Sweden, 6 studies	3	0	3

Table 1. Distribution between the Nordic countries of the articles included in the analysis with estimates of the risk of cardiovascular disease at high physical load.

nurses, respectively). The distribution of the studies across the Nordic countries and the gender included is shown in Table 1.

Exposure assessments

Only 1 study had detailed interview data on exposure (19). The estimation of physical occupational exposure in the majority of studies was based on a questionnaire question completed by the individual at baseline, usually about exposure in the previous 12 months. Seven studies based the estimate on the job title assessed by an expert or linked to a job-exposure matrix. Only a few studies took into account whether the exposure changed during the follow-up period, as well as the duration of the exposure.

Factors included

With few exceptions, the studies also took into account socio-economic factors and previous diseases in addition to age and gender. Most studies also took into account lifestyle and cardiovascular disease risk factors at baseline.

The studies covered the whole group of cardiovascular diseases (see Figure 1) (10, 11, 14, 15, 18, 20, 23, 24, 28); the ischemic heart disease/coronary heart disease subgroup (16, 19, 22, 29-32); myocardial infarction (33-37); stroke (38, 39); and heart failure (40).

In some cases, studies looked only at death from the above mentioned diagnoses, while others looked at the risk of contracting the disease (usually through recorded hospitalisation) regardless of whether the person died from the disease.

Results of the studies

Results from 27 studies on cardiovascular disease incidence and death

- For the whole cardiovascular disease group, three studies (out of nine) reported a statistically significant risk of the whole cardiovascular disease group at high physical workload. The risk also increased with the degree of strain (dose-response). On the contrary, three studies found that the risk was lower at high physical workload.
- When analysing the ischemic heart disease subgroup, three studies (out of eight) found a statistically significant increase with dose-response, while 1 study found a statistically significant lower risk for the highest exposed group with dose-response.
- For myocardial infarction (a subset of ischemic heart disease), three (out of six) studies found a statistically significant risk, two of which found that the risk increased with increasing workload. One study reported lower risk with high physical workload.
- Of two studies of stroke in relation to heavy physical work, one study showed a lower risk of stroke in the highest exposed group (30) with the risk gradually decreasing with increasing exposure. One study showed small and non-significant differences between the groups (42).
- A study of heart failure (43) found a lower risk in physically heavy jobs compared to light ones.

All cardiovascular diseases

Among the studies that used *all* cardiovascular diseases as the basis for their analysis (nine studies), three (18, 20, 24) found a statistically significant increase in risk in the highest exposed group (see first bullet point in text box). In these studies there was also a gradual increase with increasing exposure. These studies were concerned only with death (as opposed to morbidity) from cardiovascular disease. In contrast, three other studies, also of cardiovascular death, found a lower risk in the highest exposed group (10, 11, 14). Three studies found no statistically significant difference between the highest and lowest exposed groups.

Figures 6-8 provide graphical summaries of the results that include the risk estimate for the highest exposed group in the studies. These figures show that in studies based on a pooled analysis that includes both men and women (Figure 6), the risk estimate in all studies is higher than 1.0, that is they indicate that heavy physical work increases the risk of cardiovascular disease. Support for an association has increased in studies in recent years. However, the correlations are not seen when other studies that have chosen to analyze the risk for men (Figure 7) and women (Figure 8) separately are combined. In these, the direction is almost negative (decreased risk) for both men and women.

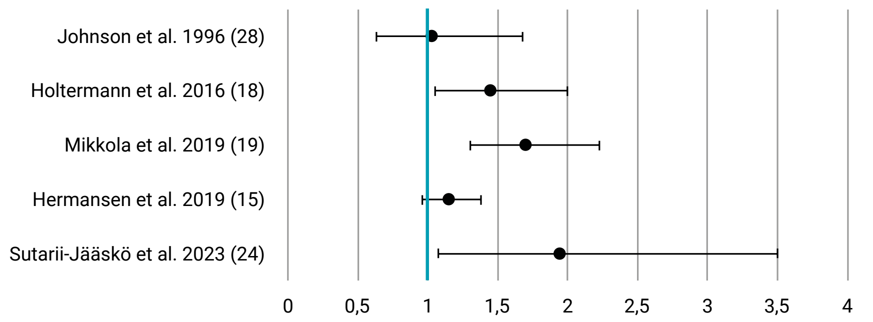

Figure 6. Cardiovascular disease, regardless of outcome, with total population including both men and women. The risk estimate (with 95 percent confidence intervals) is taken from the most adjusted model and refers to the highest exposed group.

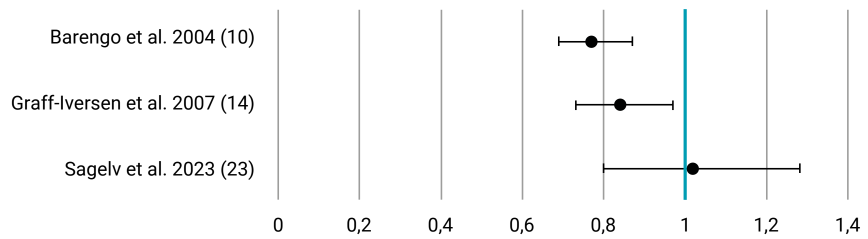

Figure 7. Cardiovascular disease, regardless of outcome, including only studies with separate analyses for men. The risk estimate (with 95 percent confidence interval) is taken from the most adjusted model and refers to the highest exposed group. The study by Dalene et al. (11) could not be included in the figure because they calculated the effect on survival time. They found longer survival for heavy work than for sitting work.

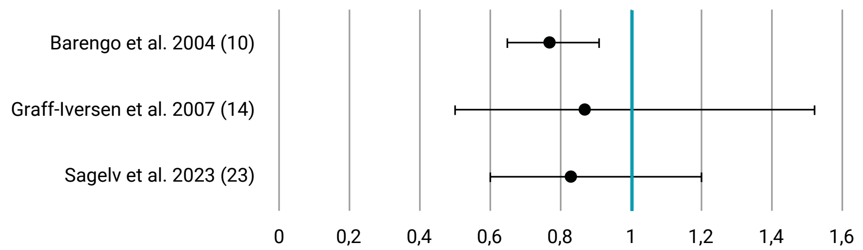

Figure 8. Cardiovascular disease, regardless of outcome, including only studies with separate analyses for women. The risk estimate (with 95 percent confidence interval) is taken from the most adjusted model and refers to the highest exposed group. The study by Dalene et al. (11) could not be included in the figure because they calculated the effect on survival time. They found no significant difference in survival between heavy work and sitting work.

Ischemic heart disease/coronary heart disease

The ischemic heart disease/coronary heart disease subgroup was examined in eight studies (see Figure 9). Of these, four studies showed a statistically significant increased risk in the highest exposed group (16, 19, 29), three of which showed a gradual increase with increasing exposure. Of these, two studied death from ischemic heart disease/coronary artery disease and two studied hospitalization for these diseases regardless of outcome. One study (incidence) showed a reduced risk (31). The other studies did not find statistically significant risks (22, 30, 32), but one of them (32) was very close to being significant (HR 1.29, 95 percent confidence interval 0.99-1.60, where an interval completely above 1 would imply a statistically significant increase in risk).

As shown in Figure 9, the overall pattern suggests that there is an excess risk of ischemic heart disease associated with heavy physical work. There are considerably fewer studies (seven studies) looking at ischemic heart disease compared to studies looking at cardiovascular disease as a whole (26 studies), but despite this the results are more consistent between studies looking at men and women together and those looking at the groups separately. As with the whole cardiovascular disease group, studies on ischemic heart disease in recent years tend to be more supportive of an increased risk.

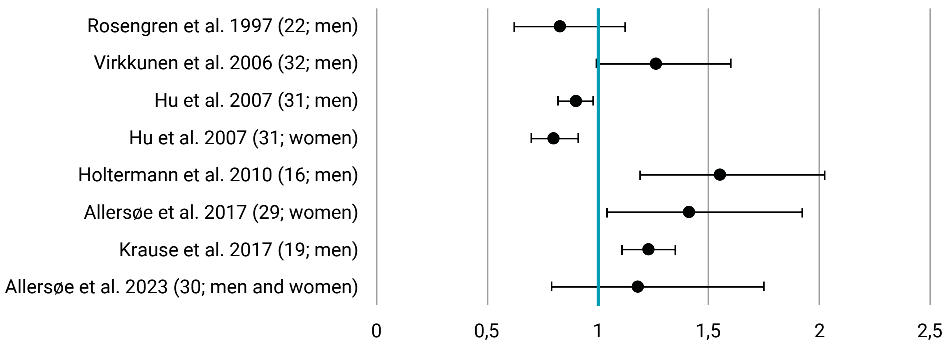

Figure 9. Ischemic heart disease regardless of outcome, studies are sorted by year of publication. The risk estimate for the highest exposed group in the most adjusted model is given with a 95 percent confidence interval. Krause et al (19) refers to risk per 10 percent increase in aerobic workload. Petersen et al. (21) divided physical load into heavy lifting and other physical activity at work, with mutual adjustment, and has therefore not been included in the figure. Petersen et al. (21) found a risk increase for men in relation to heavy lifting (RR = 1.52, 95 percent CI 1.15-2.02), but no significant increase in relation to high physical activity at work. No excess risks were observed for women.

Myocardial infarction

The more specific diagnosis of myocardial infarction was studied in six studies (one of which had two different exposure dimensions). Of these, three showed a statistically significant excess risk in the highest exposure group (33, 34, 41), with a gradual increase in risk with increased exposure in two of the studies (33, 34), especially if the exposure included heavy lifting. One study, on the contrary, showed a lower risk (35) that decreased gradually with increased exposure.

Two studies (36, 37) showed small and non-significant differences between the highest and lowest exposed groups. As shown in Figure 10, the studies related to myocardial infarction are less consistent than for the larger group of ischemic heart disease, but they still slightly outweigh, in recent years, the evidence of an association between heavy physical work and an increased risk.

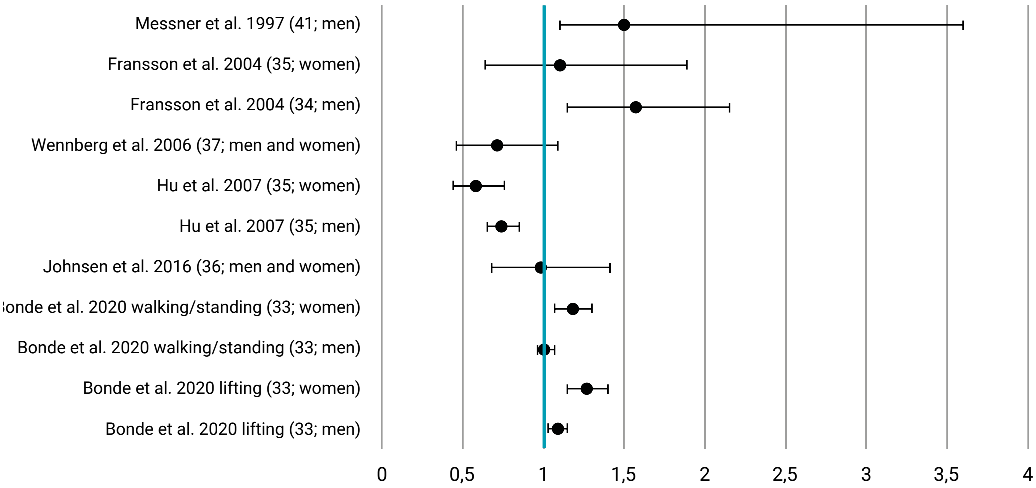

Figure 10. Myocardial infarction regardless of outcome, pooled analyses including both men and women. Sorted by year of publication. Risk estimate from the most adjusted model with 95 percent confidence interval for the highest exposed group.

The evidence base for assessing potential sex differences in the risk of cardiovascular disease is very limited; usually sex differences have been illustrated by stratified (sex-disaggregated) analysis. Of the 17 studies that included both men and women, five identified an increased risk in relation to high physical load, but two of them did not report risk estimates by sex. Of the remaining three studies that found an increase in risk in either sex, one study found an increased risk with dose-response for men, but not for women (20), and one study found an association mainly among women (33); an excess risk for work involving heavy lifting. In a case-control study (34), where less than a third of the included cases were women, there was a significantly increased risk in men in relation to heavy lifting and an estimated risk of the same order of magnitude for women, although not statistically significant.

Physical capacity of the individual and other risk factors

Some studies have examined whether the association between physically demanding work and cardiovascular disease is influenced by other factors in the work situation, the fit between the individual's ability and the physical demands, and the individual's risk factors for cardiovascular disease.

Allesøe et al. (29) found in a study of nurses that physically demanding work was associated with an increased risk of ischemic heart disease only among those with a low influence in their job, while the increase in risk was not significant among those with a high influence. However, when interaction tests were performed, testing across the whole group whether the effect of physically demanding work differs by level of influence, no statistically significant differences were found.

Krause et al. (19) found a clear association (in both strength and significance, in other words, a high increase in risk) between physical workload and death from cardiovascular disease, but this association was only apparent after relating it to the physical capacity of the individual (relative aerobic workload). The increase in risk was calculated to be 30 percent (95 percent confidence interval 14 percent to 49 percent) for every 10 percent increase in relative aerobic workload. An increased risk was seen for those working above, compared to those working below, 33 percent of their aerobic capacity.

Virkkunen et al. (42) and Allesøe et al. (43) found that the risk of coronary heart disease in heavy physical work was particularly high for those with hypertension (43). Moe et al. (27) found a higher risk of cardiovascular disease during heavy physical work in people with metabolic syndrome (which includes hypertension) compared to people without metabolic syndrome. Krause et al. (19) found a weaker association between heavy physical work and cardiovascular death in those who already had cardiovascular disease at baseline, compared to those who did not. However, the final analysis adjusted for a large number of other risk factors, including blood pressure, so the findings cannot be directly compared.

4. Discussion

This chapter discusses the main results of this review of Nordic studies in comparison with recent international reviews. In addition, knowledge of mechanisms that could explain an association between physically demanding work and increased mortality (regardless of cause) and cardiovascular disease is briefly summarised. Finally, gaps in the state of knowledge are described.

Results in relation to other reviews

Heavy physical work was found in the individual Nordic studies included in this review to be associated with both higher and lower mortality, while some studies found no effect on mortality. This is consistent with the findings of international reviews that included studies without geographical delineation. Coenen et al. found in a review study from 2018 (2) that most studies did not show any significant correlations, but by statistically combining the risk estimates from the individual studies in a so-called meta-regression, they showed that men in heavy jobs had a statistically significant higher risk of dying than those in light jobs. For women, on the other hand, no significant excess risks (or sub-risks) could be found using meta-regression. A recent meta-analysis with the same lead author refined the analysis of mortality differences between heavy and light jobs by making greater use of original individual-level data when pooling studies (44). The findings of that study were similar to those of Coenen et al. (2) with a statistically significant higher mortality rate for men in physically heavy jobs, but no differences in mortality rates for women in heavy and light jobs.

Even for studies that had cardiovascular disease as an outcome, results were conflicting between individual studies. Some studies found that heavy work was statistically significantly associated with both lower and higher risk, but there were also studies that found no significant excess risk for individuals with heavy work. An international review study pooled the risk estimates for cardiovascular mortality associated with heavy work from individual studies using meta-analysis regression, and found no differences related to job heaviness for either men or women (45). The same review study also examined the association between heavy work and ischemic heart disease, which is a more specific outcome than the broader category of cardiovascular disease. They found no statistically significant higher risk for those with heavy jobs, but highlighted a nine percent elevated risk (HR 1.09) for those with heavy jobs as a possible signal of excess risk. Similarly, the present review of Nordic studies shows both studies with a significantly higher risk of ischemic heart disease and studies with a significantly lower risk, but with a preponderance of studies indicating an excess risk.

An earlier Swedish review of work-related deaths (1), which included a review of the state of knowledge regarding mortality in relation to heavy physical work, concluded that there was some uncertainty about the relationship but that heavy work is a factor that should be included in calculations of the magnitude of work-related mortality. The review calculated the number of deaths in 2017 that were estimated to have been caused by heavy physical work. The calculation was based on the weighted risk increase from the review by Coenen and colleagues (2), which was 18 percent for men, and the data from the work environment survey on the prevalence of heavy physical work among men (20 percent). In total, 1,549 deaths in 2017 were estimated to have been caused by heavy physical work. In a later update, in 2023, of work-related deaths in Sweden, Järvholm (3) estimated that the situation had not changed.

Physical capacity of the individual and other factors

The existing studies suggest that the match between workload and individual capacity is essential. Only one, very well conducted, study has calculated workload in relation to individual capacity (19), but several studies have found that the negative effect of heavy physical work appears to be stronger in those with poor physical fitness and weaker in those with good fitness and who are physically active in their leisure time.

Not many studies have examined the interaction between physically demanding work and other occupational exposures, such as a poor social and organisational work environment, noise and air pollution. It is worth mentioning that one study investigated the association with job influence in nurses and found that the negative effect of heavy physical work was only present in those who lacked influence.

Regarding individual vulnerability factors in terms of pre-existing disease, a couple of studies suggest that those with hypertension (high blood pressure) are at a higher risk of heart disease than others if they have heavy work. One study looked at whether the risk of heavy work was affected by whether the individual had metabolic syndrome. This study found that for those with metabolic syndrome, the risk was higher for both sedentary work and heavy physical work compared to light physical work.

The observed higher risks associated with heavy physical work are most consistent for men. For women, some studies show that there is an excess risk, but there are also about as many that show no excess risk. While there are certainly significant underlying differences in cardiovascular disease risk between men and women, the observed differences in risk associated with heavy physical work are unlikely to be biological. It is more likely that they are due to differences in men's and women's work, but this remains to be investigated (see also the section *Limitations in the state of knowledge*).

How heavy physical work can damage the heart

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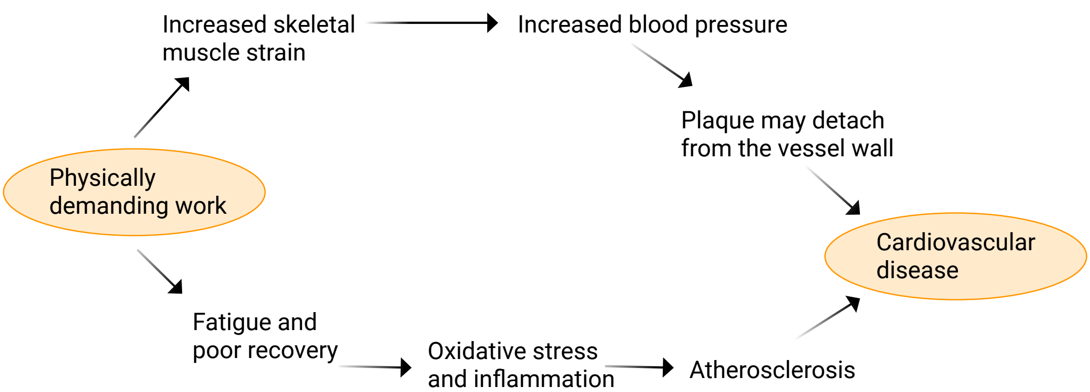

Figure 11. Impact of sustained heavy physical work on the cardiovascular system, via two possible physiological mechanisms. The upper one is a direct effect, via an increase in blood pressure. The lower one is more indirect, via inflammation, for example, and comes with some delay. Both mechanisms can exist in combination.

Limitations in the state of knowledge

See also chapter 6. *Knowledge gaps* for further discussion related to the state of knowledge. The main limitation in the state of knowledge is the operationalisation of how high to very high physical load is ”measured”. The limitation lies partly in the data used (which are usually self-reported) and partly in their categorisation. Most studies differentiate between strain in two to four categories, where the highest category may also include more moderate strain. Effective interventions require further knowledge of the risk at different measured or estimated levels, especially for highly exposed groups. In the longer term, objective technical methods (heart rate or activity measurements) may be used for categorisation, which would improve precision and provide a better basis for regulation (for example in the form of limit values). At present, it is difficult and expensive to carry out measurements in a sufficiently large population (which is needed to give the study sufficient statistical power).

It is also important to study whether the type of physical workload affects the risk of cardiovascular disease and work-related deaths. Medical studies examining cause and effect suggest that there is a difference between manual handling and its biomechanical load (such as heavy lifting) and more dynamic, pulse-demanding work (for example climbing stairs), but these dimensions of physically demanding work have rarely been separated in longitudinal studies. A few studies found effects of heavy lifting in particular. The risks associated with the type of heavy physical workload are also important for understanding the inconsistencies between studies, for example between women and men, different countries/regions, over calendar time, and precisely between vigorous and pulse-raising work, but above all for guiding interventions.

There is a risk that the degree of strength in the association between exposure and death or disease has been over- or underestimated. Studies have generally not taken into account the duration of exposure or changes in exposure over the follow-up period, which should generally weaken any associations. Another factor that may distort risk estimates is the routine failure to take into account and adjust for educational attainment in the analyses, despite the fact that low educational attainment is strongly associated with heavy physical work, particularly in men (which would underestimate heavy work). A further factor is that relatively little account is taken of the fact that heavy physical work often co-occurs with other negative work environment factors, such as noise and low job control (which would overestimate the effect of heavy work).

The limitations of the state of knowledge are particularly high for women; more studies with a sufficient number of women with high physical demands are needed.

Several studies have used 30-35 percent of an individual’s average capacity over a working day as a threshold for increased risk. But it is unclear above what level an increased risk actually exists. It is also important to know the role of variation and breaks during the working day in the association between heavy work and cardiovascular disease.

Only two studies have examined the impact of heavy physical work on stroke risk. Since there is evidence that heavy physical work increases blood pressure and initiates inflammation, which are general risk factors not only for heart disease but also for stroke, more studies are urgently needed.

Link to working life

In which occupations and sectors do a high proportion of workers have sustained physically demanding work? In Denmark, a list of such occupations has been produced (51). Men's occupations in the high exposure group include construction jobs such as carpenters, bricklayers, painters and plumbers, as well as general manual work such as operators in the food, assembly and plastics industries. It also often includes garbage collectors, meat cutters and forestry workers using chainsaws. Women's occupations with high physical demands include cleaners, and (as for men) food, assembly and plastics industry operators. One occupation that appears on women's list, but not on men's, is hand packers, people who fill, seal and label packages, a job that is often highly repetitive.

In smaller studies, cardiovascular load is often measured by heart rate measurements, which with today's technology is easier and cheaper than before. It is then possible to calculate the load on the cardiovascular system in relation to the individual's aerobic capacity. A recommendation that is often used is that during an entire working day, on average, one should not exceed 30-35 percent of one's own capacity (52). Percent of own capacity means percent of oxygen uptake capacity. In studies where heart rate has been measured during work, the percentage is calculated from the average heart rate of the working day in relation to the individual's resting and maximum heart rate. For example, if a worker has an average heart rate of 90 beats/minute during the day, a resting heart rate of 60 beats/minute and a maximum heart rate of 160 beats/minute, the relative heart rate load is 30 percent. In other words, the person is at 30 percent of their own oxygen uptake capacity. According to the recommendation, the load depends on both external demands and the individual's own capacity; in occupations that are on average below the recommended level, there are still normally individuals who are above it. Studies by Forsman and colleagues have shown that, for example, home care workers can be above the recommended level if the individual has a relatively low capacity (53). As the retirement age increases, it is also likely that more people in, for example, cleaning, construction and home care will be above the recommendation. It would be reasonable to expect that improved matching between occupations with physically demanding heavy work and the individual's capacity to be effective. This is difficult to achieve, but successful cases of work-based training periods have been described (54).

International reviews and Swedish studies show a decline in physical capacity of the population over time. The most pronounced decline over the last 20 years was seen for manual occupations and occupations with low formal qualification requirements (51). The calculations were based on oxygen uptake capacity from half a million health profile surveys (55). This trend has been projected to continue. Based on the same material of health profile surveys and estimated physical demands in different occupations, it was estimated that 25-50 percent of those employed in occupations with high pulse load (high aerobic demands) do not have a physical capacity that allows them to maintain good occupational health and not exceed 30 percent of maximum oxygen uptake capacity over an eight-hour working day (56).

Results of importance for occupational health and safety and other preventive measures in the workplace

Although the causal link between sustained heavy physical work and increased risk of cardiovascular disease or death cannot be considered fully established, there are findings in this review that suggest that some interventions would be valuable. These include:

- Efforts to further reduce the burden of jobs that are currently heavy. The conclusion is based partly on the relationships described, and partly on the fact that the physical capacity of the workforce is becoming more variable. This is both because more people are working into old age and because physical capacity tends to decline even in younger age groups.
- Increasing the individual's control in jobs or work situations with high physical demands.
- Matching the demands of the job to the physical capabilities of the individual.
- Interventions that promote physical activity outside the activity required by the job itself (for example, exercise during working hours).
- Access to occupational health care for those with persistent heavy physical strain. This is because there is a real risk that the demands of the job may exceed individual capacity in old age or chronic illness. It then becomes important to adapt the demands of the job or help the individual to change career.

5. Conclusions

The present review of the evidence suggests that heavy physical work does not have the same positive health effects as leisure-time physical activity.

Furthermore, the results of the included Nordic studies show that people with heavy physical work have an increased mortality rate (regardless of the cause of death). The increase in risk remains even after taking into account other important risk factors that could give rise to the statistical association shown. The research findings are not consistent, but the conclusion is supported by a synthesis of the body of research in this area (and recently published meta-analyses) which suggests that heavy work can cause work-related death.

The increased mortality associated with heavy physical work can probably be partly explained by an increased risk of ischemic heart disease. There are proposed mechanisms (that is causal links, see discussion chapter "*How heavy physical work can damage the heart*") for how heavy physical work can increase the risk of cardiovascular disease that are partially supported by observations in exposed people (increased blood pressure, increased inflammation, increased fatigue which reduces leisure time physical activity).

In addition, the relationship between the physical demands of work and the physical capacity of the individual is important. In one study, the increase in risk was most pronounced when related to relative aerobic workload, and several other studies found that the risk of heavy physical work was lower when physical fitness was good and when leisure-time physical activity was good. Ensuring that the physical demands of work are matched to an individual's capacity may become a growing issue in the world of work. This is because there is a trend for individuals to have increasingly lower physical capacity when they enter the workforce and because individuals work into older age (physical capacity declines with age).

Another conclusion from this review is that, although the state of knowledge is still partly unclear (see *Gaps in Knowledge,* below), basic principles of occupational physiology should be able to guide us. According to a commonly used rule of thumb, the load should not exceed about 30 percent (lower for heavy lifting) of the individual's maximum oxygen uptake capacity. Data from health checks in Sweden suggest that a significant proportion of the workforce in several manual occupations have jobs that require more than 30 percent of the workers' maximum capacity. Work should be varied, with opportunities for adequate breaks and recovery. It also seems to be important to be able to control how heavy work is performed.

To reduce the risk of premature death and cardiovascular dusease, efforts to reduce the strain of work that is currently physically demanding are needed. The problem with heavy physical work becomes particularly pronounced when physical capacity declines due to normal physiological ageing. As far as possible, jobs should be designed in such a way that they can normally be performed throughout working life without overloading the individual. Where this is difficult to achieve, consideration could be given to whether a better match could be achieved by offering the individual the opportunity for work-related physical exercise during working hours. Middle-aged and older employees could also be offered planned professional development for less physically demanding tasks.

6. Knowledge gaps

In the work on this review, a number of areas where there are limitations in the state of knowledge have been identified. These gaps in knowledge are briefly described below.

There are shortcomings in the estimates of physically demanding work

The main weakness in the evidence is in the ”measurement or estimation” of how hard the individuals work. In many cases, this is very rough, with few scale steps, and for statistical calculation reasons it has been aggregated into broad categories. Furthermore, a couple of studies use job-exposure matrices, in which measurements or estimates of exposure, in this case to heavy work, are set at the same level for everyone in each occupation. The advantage of such matrices is that the data are not (directly) self-reported. The matrices also make it possible to indirectly follow exposure over a longer period; however, it is assumed that everyone in an occupation has the same exposure, which is a generalization that leads to significant misclassification. Both types of imprecision (non-systematic misclassification) usually tend to underestimate the relationship between exposure and outcome.

Most studies have used self-reported physical workload (often in the last 12 months) to estimate exposure. It is unclear to what extent this results in systematic versus non-systematic error estimation. Systematic error estimation leads to bias in the associations.

Only one study has used detailed information on how the work is typically performed when calculating individual physical load, and also related this to the individual's capacity. No study has been based on technical measurements of the physical load. This is otherwise an advantageous method because such measurements have a high-precision point estimate and do not rely on self-assessment. They also provide a clear basis for risk assessment and intervention. Representativeness over a longer period needs to be included in the assessment, and for cardiovascular disease a sufficient follow-up period and a large number of exposed workers are also needed. Further development of exposure methodology for sustained heavy physical work is thus important to assess possible differences in risk associated with the type of sustained heavy physical work as well as the intensity, duration, frequency and variation of the work over time. In this way, a remaining urgent knowledge gap can be filled.

It is unclear whether different types of heavy physical load are associated with different levels of risk

A key knowledge gap for workplace interventions is whether there is a difference in risk between different types of heavy physical load. There is no clear answer to this in the literature reviewed here. Only a couple of studies have attempted to shed light on this and found associations with repeated heavy lifting in particular. Other studies have generally combined different types of load (walking, walking upstairs or uphill, lifting, et cetera.) and then found associations.

The recommendation used has not been evaluated

Another important question is whether the already accepted rule of thumb to avoid loads above 30 percent of maximum physical capacity is sufficient to avoid the negative effects, or whether even average loads below 30 percent of physical capacity may pose a risk of cardiovascular disease and death. The rule of thumb is often used, but has not been prospectively evaluated. However, any threshold development needs to take into account other health effects. Furthermore, it is important to further study the importance of individuals being able to control their work, take breaks and get sufficient rest.

There is a lack of knowledge about gender differences

There are no studies that examine in more detail whether there is a difference in risk between men and women at the same relative aerobic loads, especially at high loads, in jobs often held by men.

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8. Appendix

Appendix 1a. Cardiovascular disease and death caused by cardiovascular disease

Extracted data from the analyzed full-text articles

	Publication	Study design and population	Assessment of physical workload	Covariates and variables for stratification	Outcome variables	Results
1	Allesøe K, Holtermann A, Rugulies R, Aadahl M, Boyle E, Søgaard K. Does influence at work modify the relation between high occupational physical activity and risk of heart disease in women? Int Arch Occup Environ Health. 2017;90(5): 433-42	Danish Nurses study 1993, age 45-64 year old females member of nurses association. Free from IHD at baseline. Followed in registers through 2013. N = 12,093.	Self-report single item: (i) Mainly sedentary work without any physical exertion (sedentary OPA), (ii) work that to a large extent is carried out standing or walking, but is otherwise not physically exerting (moderate OPA), (iii) standing or walking work that involves some lifting or carrying (demanding OPA), (iv) heavy or fast and physically exerting work (strenuous OPA).	adjusted for age and risk factors for IHD (family history of IHD, diabetes, BMI, smoking and alcohol consumption), leisure time physical activity, work pressure, work hours and shift work and mutually adjusted for OPA and influence at work main strata influence at work	IHD cases were defined as hospitalization for myocardial infarction (ICD-8: 410 or ICD-10: I21–23), other acute or chronic IHD (ICD-8: 411 or 412 or ICD-10: I24 or I25), angina (ICD-8: 413 or ICD-10: I20) or lector-cardiographically diagnosed heart disease (ICD-8: 414).	HR, 95% CI Sedentary 1.01 0.81–1.27 Moderate (ref) Demanding 1.22 1.03–1.44 Strenuous 1.41 1.04–1.92 In strata of low influence significant risks, in strata of high influence ns.
2	Allesøe K, Aadahl M, Jacobsen RK, Kårhus LL, Mortensen OS, Korshøj M. Prospective relationship between occupational physical activity and risk of ischaemic heart disease: are men and women differently affected? Eur J Prev Cardiol. 2023;30(9):858-67	Random regional survey (western Copenhagen region), Monica, linked with registers: 1399 women 1706 men aged 30–61 years follow-up 1982-2016	Self-report single item: 1: Mainly sedentary: desk work, assemble small parts, and the like (sedentary) 2: Work involving some walking but no carrying heavy items: light industrial work, non- sedentary office work, inspection, kitchen work, housework, teaching, and the like (light) 3: Mainly walking, work involving climbing stairs, and some lifting: mail delivery, construction work, move heavy furniture, and the like (moderate, some lifting) 4: Physically demanding work with heavy lifting: excavation work, forestry, concrete work, and the like (strenuous, heavy lifting).	Age, sex, leisure time physical activity, family history of heart disease, diabetes, body mass index (BMI), serum cholesterol, high density lipoprotein (HDL), triglycerides, smoking, alcohol consumption, self-reported fitness, working hours, civil status, and socioeconomic status (SES). Main strata: sex	First IHD. IHD cases were defined as hospitalisation for myocardial infarction (410 in ICD-8 and I21–23 in ICD-10), other acute or chronic IHD (411–412 in ICD-8 and I24–25 in ICD-10), angina (413 in ICD-8 and I20 in ICD-10), or electrocardiographically diagnosed heart disease (414 in ICD-8).	Moderate and strenuous significantly higher HR compared with sedentary in age adjusted model. (strenuous HRageadj .1.00 to 2.22 1.18, strenuous HRage sex adjusted 0.79 to 1.75). Sex strata: (ref sedentary = no increased HR for women. For men, moderate: 1.42 (1.01 to 1.98); strenuous 1.46 (0.93 to 2.29).
3	Barengo NC, Hu G, Lakka TA, Pekkarinen H, Nissinen A, Tuomilehto J. Low physical activity as a predictor for total and cardiovascular disease mortality in middle-aged men and women in Finland. EUR HEART J. 2004;25(24): 2204-11	Random regional surveys. eastern and south-western Finland FINMONICA. 5,853 15,853 men and 16,824 women Aged 30–59 years. Free from cardiovascular heart disease (CHD), stroke, heart failure, cancer. Follow-up median 20 years	Self-report single item: (i) high: lots of walking and lifting at work, taking the stairs or walking uphill (for example industrial work, farm work and forestry); (ii) moderate: walking quite a lot at work without lifting or carrying heavy objects; (iii) low: mostly sedentary work without much walking (for example, working in an office).	Final model adjusted for adjusted for age, study year, body mass index, systolic blood pressure, Age, study year, education, smoking status, systolic blood pressure, cholesterol level, BMI and two other types of physical activity. Stratified by sex.	All cause mortality and cardiovascular mortality, the International Classification of Diseases (ICD). Used codes: ICD-9: 390–459 (I00–I99).	Cardiovascular mortality Men: Light occupational physical activity (REF). Men: Moderate 0.75 (0.64–0.87) Active 0.77 (0.69–0.87) Women: Moderate 0.73 (0.60–0.88) Active 0.77 (0.65–0.91)

	Publication	Study design and population	Assessment of physical workload	Covariates and variables for stratification	Outcome variables	Results
4	Bonde JPE, Flachs EM, Madsen IEH, Petersen SB, Andersen JH, Hansen J, et al. Acute myocardial infarction in relation to physical activities at work: A nationwide follow-up study based on job-exposure matrices. SCAND J WORK ENVIRON HEALTH. 2020;46(3):268-77	Danish residents (registers), who in 1995 at an age of 31–50 were gainfully employed. Free from IHD at baseline. Followed 1996–2016 n = 1.15 million	Job exposure based on occupation codes. Expert-rated JEM on lifting. Previous year and calendar specific cumulative exposures: lifting cumulative corresponding to the pack-year concept of smoking. One ton-year was defined as lifting one ton per day for one year. Values grouped by the sex-specific 25th, 50th, 75th and 90th percentiles	Age, cohabitation, education, employment status, social position, smoking (JEM), body mass index (JEM) and leisure-time physical activity (JEM).	Death and hospitalization AMI (ICD-10 principal Diagnosis I21)	IRR Total load lifted per day the previous year, kg/day. MEN ns Women: >0–390 >390–1050 >1050–3500 Between 1.12 and 1.16 Cumulative (years): Men: 0–≤3.1 >3.1–11.7 >11.7–25.6 >25.6–45.2 >45.2–126.6 (RR 1.09, CI 1,03, 1,15) Significant risk between 1.06 and 1.09 For women: ton tes >0.5–1.5 >5.1–12.4 >12.4–22.0 >22.0–118.0 RR 1,27 (CI 1,15-1,40) Significant, increase from 1.06 to 1.27
5	Dalene KE, Tarp J, Selmer RM, Ariansen IKH, Nystad W, Coenen P,Anderssen SA, Jostein Steene-Johannessen J, Ekelund U. Occupational physical activity and longevity in working men and women in Norway: a prospective cohort study. Lancet Public Health. 2021;6(6): 386-395	Norwegian population-based health examination surveys. 18-65 year olds. 213,079 men 224,299 women Baseline 1974-2002. Follow-up: death or end of 2018.	Self-report single item: sedentary work (eg, desk work or work including assembling of minor parts), work characterised by some walking (eg, light industrial work), non-sedentary office work, inspection, etc), work characterised by walking and lifting (eg, mail delivery and construction work), or work characterised by heavy manual labour (eg, digging and shovelling).	Age, sex, education, income, ethnicity, prevalent cardiovascular disease, smoking, leisure-time physical activity, body-mass index	Cardiovascular mortality: cardiovascular disease International Classification of Diseases (ICD)-8 codes 390–444·1, 444·3–458, 782·4; ICD-9 codes 390–459; ICD-10 codes I00–I99.	Cardiovascular mortality Difference in restricted mean survival time, years longer (95% CI) Men: Sedentary (ref) Walking 0.2 (0.0 to 0.4) Walking and lifting 0.2 (−0.1 to 0.4) Heavy labour 0.5 (0.2 to 0.7) Women: Sedentary (ref) Walking −0.1 (−0.2 – 0.1) Walking and lifting −0.4 (−0.8 - −0.1) Heavy labour −0.4 (−1.0 - 0-2)
6	Fransson E, De Faire U, Ahlbom A, Reuterwall C, Hallqvist J, Alfredsson L. The risk of acute myocardial infarction: Interactions of types of physical activity. Epidemiology. 2004;15(5):573-82	Case-control study Stockholm county (SHEEP). 1992–1994. Cases: 1204 men 550 women age 45–70 years, experienced their first MI during the study period (MI free at baseline). The controls: 1538 men 777 women were randomly selected from the study base, matched on sex, age, and hospital catchment area.	Perceived Occupational Physical Activity 15-category scale (0–14) in which 0–1 was defined as very, very light and 13–14 was defined as very, very demanding. In the analysis, 5 categories were constructed: very light (0–2), light (3–5), moderate (6–8), strenuous (9–11), very strenuous (12–14). The categories of strenuous and very strenuous were combined into one. Repetitive Lifting Did they lift or carry more than 5 kg for at least 2 hours per working day. Heavy Lifting Did they lift or carry more than 20 kg (women) or 30 kg (men) at least 5 times per working day.	Age, hospital catchment area, smoking, socioeconomic status, fiber intake, and alcohol consumption.	Myocardial infarction identified from the coronary and intensive-care units at the internal medicine departments at all the emergency hospitals within the Stockholm County area, the hospital discharge register for the Stockholm County area, and through death certificates	MI Odds Ratio (95% CI) Men: Very light (ref) Light 1.27 (1.01–1.60) Moderate 1.46 (1.10–1.93) Strenuous or very strenuous 1.57 (1.15–2.15) Women:Very light (ref) Light 0.93 (0.59–1.46) Moderate 0.88 (0.54–1.45) Strenuous or very strenuous 1.10 (0.64–1.89) Repetitive Men 1.23 (1.00–1.51), non-fatal 1.22 (0.98–1.52) Women 1.29 (0.87–1.91) non-fatal 1.49 (0.99–2.25) Heavy lifting Men 1.14 (0.90–1.43) non-fatal 1.27 (1.00–1.60) Women 1.46 (0.87–2.43) non-fatal 1.56 (0.91–2.67)

	Publication	Study design and population	Assessment of physical workload	Covariates and variables for stratification	Outcome variables	Results
7	Graff-Iversen S, Selmer R, Skurtveit S, Sørensen M. Occupational physical activity, overweight, and mortality: A follow-up study of 47,405 norwegian women and men. Res Q Exerc Sport. 2007;78(3):151-61	Norwegian regional population based surveys 1974–78: 23,884 men 23,521 women Free from self-reported CVD or disability pension at baseline. Follow-up until 2000 (25 years)	1. Sedentary work 2. Light occupational physical activity work, education 3. Moderately heavy occupational physical activity 4. Heavy occupational physical activity	Age, county, smoking, serum total cholesterol, education and income.	Mortality, from registers CVD was defined as ICD-8 codes 394–459; ICD-9: 390–459; or ICD-10: I00–I99. CHD, was defined as ICD-8 codes 410–413; ICD-9: 410–414; or ICD-10: I20–I25	CVD odds ratio (CI) Men Sedentary (ref) Light 1.04 0.91–1.19 Moderate 0.89 0.77–1.03 Heavy 0.84 0.73–0.97 Women Sedentary (ref) Light 1.19 0.89–1.60 Moderate 1.21 0.86–1.73 Heavy 0.87 0.50–1.52
8	Hermansen R, Jacobsen BK, Løchen M-L, Morseth B. Leisure time and occupational physical activity, resting heart rate and mortality in the Arctic region of Norway: The Finnmark Study. Eur J Prev Cardiol. 2019;26(15): 1636-44	Norwegian regional population-based survey linked to register (Finnmark 3) age 20-62 1987–1988: 8951 men 8746 women Follow-up 1987-2003	Self reported: Mostly sedentary, Walking (e.g. shop assistant, light industrial work, education), Walking and lifting (e.g. mailman, heavy industrial work, construction work) Heavy manual labour' (e.g. forestry work, heavy agriculture work, heavy construction work).	Age, sex, smoking status, BMI, self-reported angina pectoris, myocardial infarction, cerebral insult, diabetes, anti-hypertensive medication and leisure time physical activity stratified for sami/non-sami	CVD death (ICD)-9: 390–459 codes and ICD-10: I00–I99	Cardiovascular mortality Mostly sedentary 1.17 (1.02–1.34) Walking 1.09 (0.95–1.25) Walking and lifting (ref) Heavy manual labour 1.15 (0.96–1.38)
9	Holtermann A, Mortensen OS, Burr H, Søgaard K, Gyntelberg F, Suadicani P. Physical demands at work, physical fitness, and 30-year ischaemic heart disease and all-cause mortality in the Copenhagen Male Study. 2010;36(5):366-372	Danish regional population based survey in Copenhagen (Copenhagen Male Study) age 40-59 1970-71. With No history of CVD. 30 year follow-up (1970-2001) n = 4943	Sel report, summary score of two questions: Physical activity during work Holtermann 2013 (1=low, 2=moderate, 3–4=high) And strenuous work: "Do you perform strenuous work" 1=seldom or never, 2=occasionally, and 3=often. Added scores: 2 "low", 3 or 4 "moderate", 5 or 6 "high physical work demands".	Age, body mass index, alcohol use, smoking, leisure time physical activity, physical fitness Stratified for physical fitness	All cause mortality and Death from ischaemic heart disease (IHD) ICD-8: 410–14, ICD-10: I20–I25.	HR 95% CI IHD mortality Low (REF) Medium 1.26 (1.02–1.56) High 1.55 (1.19–2.02) Stratified analysis: Mortality: moderate and high only significant in strata of moderate PA IHD: High significant only in strata of low and moderate PA. Moderate significant only in moderate PA.
10	Holtermann A, Marott JL, Gyntelberg F, Søgaard K, Mortensen OS, Prescott E, et al. Self-reported occupational physical activity and cardiorespiratory fitness: Importance for cardiovascular disease and all-cause mortality. SCAND J WORK ENVIRON HEALTH. 2016;42(4):291-8	Danish regional population-based survey in Copenhagen (Copenhagen City Heart Study) 1991-1994 age 20–67. Follow-up in registers until 2013. Symptom free at basline. 2190 men 2534 women	Self-reported single item: (i) Mainly sedentary and do not walk much (ii) You walk around quite a bit at your workplace but do not have to carry heavy items (iii) Most of the time you walk, and you often have to walk upstairs and lift various items. (iv) You have heavy physical work. You carry heavy burdens and carry out physically strenuous work 1=low, score 2=moderate, and score 3–4=high.	Age, sex, smoking BMI, diabetes, income, alcohol and leisure PA.	All cause mortality, and CVD death defined as ICD-8: 390–458 and ICD-10: I00–I99.	Hjärta CVD mortality HR 95% CI Low (ref) Moderate 1.16 (0.83-1.63) High 1.45 (1.05-2.00) Död All mortality Low (ref) Moderate 0.89 (0.74-1.06) High 1.05 (0.88-1.25)

	Publication	Study design and population	Assessment of physical workload	Covariates and variables for stratification	Outcome variables	Results
11	Holtermann A, Mortensen OS, Burr H, Søgaard K, Gyntelberg F, Suadicani P. Physical work demands and physical fitness in low social classes-30-year ischemic heart disease and all-cause mortality in the copenhagen male study. J Occup Environ Med. 2011;53(11): 1221-7	Danish regional population based survey in Copenhagen (Copenhagen Male Study) age 40-59 1970-71. With No history of CVD. 30 year follow-up (1970-2001) 4921 men	As in Holtermann 2010d	BMI, systolic BP, diastolic BP, diabetes (treatment for), hypertension (treatment of), alcohol use, smoking (current, never, previous), leisure time physical activity. Strata: subset of low class and strata of physical fitness.	All cause mortality and Death from ischaemic heart disease (IHD) ICD-8:410–14, ICD-10: I20–I25.	HR 95% CI In low classes IHD Mortality Significant only in strata of high physical fitness: Low (ref) Medium 0.63 (0.42–0.95) High 0.80 (0.52–1.24)
12	Hu G, Sarti C, Jousilahti P, Silventoinen K, Barengo NC, Tuomilehto J. Leisure time, occupational, and commuting physical activity and the risk of stroke. Stroke. 2005;36(9): 1994-9	Finland, consecutive regional general population surveys 1972 and 1997. Age 25-64 yrs with no history of coronary heart disease, stroke, or cancer, at baseline Follow-up through 2003 N = 47,721	Self-report single item: (1) Light (physically very easy, sitting office work, eg, secretary) (2) Moderate (standing and walking, eg, store assistant, light industrial worker) (3) Active (walking and lifting, or heavy manual labor, eg, industrial or farm work).	Adjusted for age, area, and study year; BMI, SBP, cholesterol, education, smoking, alcohol consumption, and diabetes; 2 other types of physical activity. Stratified for else adjusted for sex.	Death or hospitalization Stroke (430 to 438 and I60–I66)	HR 95% CI Total stroke Light (ref) Moderate 0.94 (0.85–1.04) Active 0.89 (0.81–0.98) [similar men and women] Subarachnoid Hemorrhagic Stroke and Intracerebral Hemorrhagic Stroke -Not significant. Ischemic Stroke Light (ref) Moderate 0.90 (0.80–1.01) Active 0.88 (0.80–0.98)
13	Hu G, Tuomilehto J, Borodulin K, Jousilahti P. The joint associations of occupational, commuting, and leisure-time physical activity, and the Framingham risk score on the 10-year risk of coronary heart disease. EUR HEART J. 2007a;28(4): 492-8	Random regional samples in Finland, age 25–64 1972, 1977, 1982, 1987, 1992, and 1997. Free from CVD and Stroke. Followed-up in registers, mean time 18.9 yrs. N = 47,840	Self-report single item: (i) 'low'was physically very easy, sitting office work, e.g. secretary; (ii) 'moderate' was work including standing and walking, e.g. store assistant, light industrial worker; (iii) 'high' was work including walking and lifting, or heavy manual labor, e.g. industrial or farm work.	Age, study year, education, alcohol consumption, and smoking status, body mass index, systolic blood pressure, cholesterol, and history of diabetes. Also adjusted for commuting and leisure-time physical activity.	Combined fatal and non fatal: ICD-8 to ICD-10 non-fatal myocardial infarction (410–411 and I21–I22, I24) fatal cases of CHD (410–414 and I20–I25)	HR (95%CI) death and nonfatal Low (ref) Men: Low (ref) Moderate 0.87 (0.78–0.97) High 0.90 (0.82–0.98) Women: Moderate 0.75 (0.66–0.86) High 0.80 (0.70–0.91)

	Publication	Study design and population	Assessment of physical workload	Covariates and variables for stratification	Outcome variables	Results
14	Hu G, Tuomilehto J, Borodulin K, Jousilahti P. The joint associations of occupational, commuting, and leisure-time physical activity, and the Framingham risk score on the 10-year risk of coronary heart disease. EUR HEART J. 2007b;28(4): 492-8	Random regional samples in Finland, age 25–64 1972, 1977, 1982, 1987, 1992, and 1997. Free from CVD and Stroke. Followed up in registers 10 years from the baseline N = 41,053	Self-report single item: (i) 'low' was physically very easy, sitting office work, e.g. secretary; (ii) 'moderate' was work including standing and walking, e.g. store assistant, light industrial worker; (iii) 'high' was work including walking and lifting, or heavy manual labour, e.g. industrial or farm work.	Model 1, adjusted for study year and age in the analyses for any one of three types of physical activity and adjusted for study year in the analysis of FRS; Model 2, adjusted for study year, education, BMI, alcohol consumption, family history of CHD, and FRS (in the analyses for any one of three types of physical activity) or leisure-time physical activity (in the analysis of FRS); model 3, adjusted for study year, education, BMI, alcohol consumption, family history of CHD, occupational, commuting, and leisure-time physical activity, as well as FRS.	The Eighth, Ninth,and Tenth Revisions of the International Classification of Diseases (ICD) were used to identify non-fatal myocardial infarction (410–411 and I21–I22, I24) and fatal cases of CHD (410–414 and I20–I25).	First event, fatal or non-fatal. Low (ref) Men: Moderate 0.66 (0.55–0.79) High 0.74 (0.65–0.85) Women: Moderate 0.53 (0.40–0.70) High 0.58 (0.44–0.76)
15	Håheim LL, Holme I, Hjermann I, Leren P. Risk factors of stroke incidence and mortalit : A 12-year follow-up of the oslo study. Stroke. 1993;24(10): 1484-9	Screening program participants in OSLO age 40-49 in 1971-72 n = 14 403 (with relevant exposure data) Follow-up until 1984	Physical activity at work: sedentary, moderate, intermediate, or great.	Only bivariate risk measures, since no significant risks with occupational PA	Mortality and stroke incidence and stroke mortality ICD:430 through 438).	RR, 95% CI Sedentary (ref) Stroke incidence: Moderate 0.66 (0.34, 1.23) Intermediate+ great 1.62 (0.95, 2.75) Stroke mortality: Moderate 0.98 (0.33, 2.69) Intermediate+great 1.38 (0.46, 3.81)
16	Johnsen AM, Alfredsson L, Knutsson A, Westerholm PJM, Fransson EI. Association between occupational physical activity and myocardial infarction: A prospective cohort study. BMJ Open. 2016;6(10)	Prospective cohort (WOLF) 9961 Employees: 6849 men 3112 women mean age 42.7 yrs. having no history of myocardial infarction. Mean follow-up 13 yrs. Cox's regression.	Questionnaire about occupational physical activity (OPA): OPA1: Seated for more than half of their working day and no lifting or carrying OPA2 Standing or walking for more than half of their working day but with no lifting or carrying OPA3 Lifting or carrying either 5 kg for at least 2 hours of their working day, or heavy lifting (20 kg for women and 30 kg for men) at least five times per working day.	Model 1, adjusted for age. Model 2, adjusted for age and sex. Model 3, adjusted for age, sex and socioeconomic status. Model 4, adjusted for age, sex, socioeconomic status and lifestyle factors (smoking, leisure time physical activity, alcohol, fruit and vegetable consumption). Model 5, adjusted for age, sex and lifestyle factors.	National patient-register and register of death. Diagnosis 'acute myocardial infarction', I21 International Classification of Diseases, 10th Revision (ICD-10) or 410 (ICD-9).	Cardiovascular mortality, HR (95% CI), for OPA 2 and 3 versus OPA1(reference), restricted to those working 35 h/w or more OPA2: Model 2: 1.27 (0.94-1.75) Model 4: 1.14 (0.80-1.61) Model 5: 1.20 (0.86-1.69) OPA3: Model 2: 1.04 (0.75-1.75) Model 4: 0.87 (0.57-1.32) Model 5: 0.98 (0.68-1.41)

	Publication	Study design and population	Assessment of physical workload	Covariates and variables for stratification	Outcome variables	Results
17	Johnson JV, Stewart W, Hall EM, Fredlund P, Theorell T. Long-term psychosocial work environment and cardiovascular mortality among Swedish men. AM J PUBLIC HEALTH. 1996;86(3):324-31	Nested population-based nested case-control study: 12,517 currently or previously employed Swedish men 25 to 74 years of age. From the Swedish population (1977, 1979, 1980, 1981), Incidence density sampling: 5 controls per case	Occupational code (3-digit) linked to JEM based on SCB survey: physical job demands (a 5-item indicator measuring the physical burdensomeness of the job),	Relative risk estimates were adjusted for age, year last worked, survey year, smoking, exercise, education, social class, and nationality.	Mortality was obtained by linking study group records to the National Death Registry for the years 1977 through 1990. Cardiovascular mortality was analyzed by combining all deaths for arteriosclerotic heart disease, cerebro-vascular disease, and peripheral vascular disease (all years were standardized to International Classification of Diseases [8th edition; ICD] codes, 400 through 404, 410 through 414, 427, 430 through 436, and 440 through 445).	CVD mortality, RR (95% CI) from conditional regression, by cumulative exposure* period. Fully adjusted model. Highest physical work demands (4th quartile) versus lowest (1st quartile): 5y:1.24 (0.76,1.57) 10y: 1.15 (0.70,1.88), 15y: 1.05 (0.64,1.72) 20y:1.14 (0.70,1.86) 25y: 1.22 (0.76,1.96) 26+y: 1.03 (0.63,1.68) * Duration of exposure period before the date of the survey or most recent occupation.
18	Krause N, Arah OA, Kauhanen J. Physical activity and 22-year all-cause and coronary heart disease mortality. AM J IND MED. 2017;60(11):976-90	Prospective population-based study in Eastern Finland "Kuopio Ischemic Heart Disease (KIHD) Risk Factor Study": 1891 men aged 42, 48, 54, or 60 years, baseline examination 1984-1989	Interview: a typical workday. Subjects were asked, in increments of 15 min, how long they had performed the following activities at work: sitting, standing, walking on level ground, walking on uneven ground, climbing stairs, or any other activities. The 12 months test-retest correlation of 0.69 for the OPA interview indicated good reliability.36 Lifetime job stability claimed to be high in region. Absolute energy expenditure at work (in kcal/day) was assessed from baseline interview data on time spent in various activities at their current job during a typical workday and reference data on the energy requirements (kcal/ kg/hour) of these activities. Also, Relative Aerobic Strain, RAS (%VO2max) a relative EE measure that expresses the physical demands of work in terms of energy needed to perform the job as a percentage of the individual worker's aerobic cardiorespiratory fitness or maximal work capacity, and percent oxygen uptake reserve.	Adjustments Model 1: None Model 2: Age Model 3: Age and technical factors (Age, Participant in placebo/treatment group of lipid lowering drug trial), Biological factors (Blood glucose, Plasma fibrinogen, BMI, LDL-and HDL -cholesterol, Systolic blood pressure. Lipid-lowering/ antihypertensive medication); Behavioral factors (Alcohol consumption, pack-years of cigarette smoking, leisure-time physical activity) ; Socio-economic status (personal income); Psychosocial job factors (social support, mental strain, deadlines)) Model 4: Model 3+adjustment for IHD at baseline (Fully adjusted)	Outcomes: Record linkage to national cause of death registry. CHD includes ICD9 codes 410-414	CHD mortality (HR, 95% CI): Absolute energy expenditure (Unit 500 kcal/day) Age-adjusted: 1.12 (1.04-1.21) Fully adjusted: 1.05 (0.96-1.13) Relative aerobic strain (Unit 10%) Age-adjusted: 1.34 (1.24-1.45) Fully adjusted: 1.23 (1.11-1.35) Percent oxygen uptake reserve (Unit 10% Age-adjusted: 1.25 (1.17-1.34) Fully adjusted: 1.17 (1.08-1.27) Interaction was indicated between CVD death and IHD at base-line (RERI-significant). Stratification on IHD provided slightly higher RRs for no IHD at baseline.

	Publication	Study design and population	Assessment of physical workload	Covariates and variables for stratification	Outcome variables	Results
19	Messner T, Sihm H. Psycho-social risk factors for ischaemic heart disease among men in the subarctic area. Int J Circumpolar Health. 1997;56(1-2):12-20	Hospital-based case-control study: 219 male patients aged 35 to 64 years admitted to Kiruna District Hospital, with a first acute myocardial infarction between 1973 and 1985, were compared to 438 age-matched male controls without coronary heart disease.	To be retrieved	Diabetes, hypertension, smoking, and family history	Hospital record of first AMI	Heavy physical work (OR 1.5, 95% CI 1.1-3.6)
20	Mikkola TM, Von Bonsdorff MB, Salonen MK, Kautiainen H, Ala-Mursula L, Solovieva S, et al. Physical heaviness of work and sitting at work as predictors of mortality: A 26-year follow-up of the Helsinki Birth Cohort Study. BMJ Open. 2019;9(5)	Population-based birth cohort (Helsinki Birth Cohort Study): 5210 men 4725 women occupational code at baseline 1970 (ages 45–57 years), and 25 yrs of follow-up (2015)	Occupational physical heaviness of work assessed by a Job Exposure Matrix (JEM) based on occupational code (4-digit) at baseline. JEM was based on national representative survey, with question: Does your current job involve heavy physical work, in which you have to lift or carry heavy items, to dig, shovel or pound?' (yes/no). Similar question for sedentary work. Exposure categorized into quartiles by prevalence (of yes), separately for men and women.	Basic: Age Adjusted: Age, education	Cause of death (national registry). For CVD 400–499 in the ICD Ninth Revision and I00–I99 in the ICD 10th Revision	The HRs for men in the highest quartile of physical heaviness of work compared with men in the lowest quartile were 1.70 (1.30–2.23) for cardiovascular mortality and 3.18 (1.75–5.78) for external cause mortality (adjusted for age and years of education). Dose-response for deaths from CVD (quartiles I to IV) Men: p<0.01 Women: p=0.16 Point estimates not given, but illustrated in Figure 1.
21	Moe B, Mork PJ, Holtermann A, Nilsen TIL. Occupational physical activity, metabolic syndrome and risk of death from all causes and cardiovascular disease in the HUNT 2 cohort study. Occup Environ Med. 2013;70(2):86-90	Population-based prospective cohort, Norway, HUNT Study (1995– 1997; N=37300 men and women 20 yrs and older, free of diabetes and CVD) linked to national registries, average follow-up 12.4 yrs. Men with metabolic syndrome n=3529, without metabolic syndrome n=15411 Women with metabolic syndrome n= 2143, without metabolic syndrome 16217	Questionnaire: 'How would you describe your work?', with four mutually exclusive response options: (1) mostly sedentary (eg, at a desk, on an assembly line) (2) much walking (eg, delivery work, light industrial work, teaching) (3) much walking and lifting (eg, postman, nurse, construction work) (4) heavy physical work (eg, forestry work, heavy agricultural work, heavy construction work). The second and third category were merged into one group of 'much walking/lifting at work'	Cox proportional Hazards, adjusted for age (as the time scale), sex (men, women), leisure-time physical activity (no light or hard activity, smoking status (never, former, current, unknown), alcohol consumption (never, not the last 4 weeks, 1–3 units the last 4 weeks, more than 4 units the last 4 weeks, unknown) and education (13 years, unknown).	Mortality. Cardiovascular disease was defined by ICD-9: 390-459 and ICD-10: I00-I99.	Results (HR, 95% CI) for occupational physical activity are stratified by metabolic syndrome, with those without metabolic syndrome as the reference group (fully adjusted model): Cardiovascular diseases Without metabolic syndrome: Mostly sedentary 1.19 (0.84 to 1.70) Much walking/lifting 1.00 (ref) Much heavy physical work 1.20 (0.82 to 1.77) With metabolic syndrome: Mostly sedentary 2.74 (1.82 to 4.12) Much walking/lifting 1.79 (1.20 to 2.66) Much heavy physical work 3.02 (1.93 to 4.75)

	Publication	Study design and population	Assessment of physical workload	Covariates and variables for stratification	Outcome variables	Results
22	Rosengren A, Wilhelmsen L. Physical activity protects against coronary death and deaths from all causes in middle-aged men: Evidence from a 20-year follow-up of the primary prevention study in Goteborg. ANN EPIDEMIOL. 1997;7(1):69-75	Prospective population-based cohort: Multifactor Prevention Study, Gothenburg: 7142 men 47 to 55 yrs at baseline in 1970-1973 and without symptomatic CHD. 20 yrs follow-up	Postal questionnaire: physical activity at work was graded from 1 to 4. Grade 1 Mainly sedentary (n=2052) Grade 2 Predominantly walking on one level but no heavy lifting (n=2814), Grade 3 Mainly walking, including climbing stairs, or walking uphill or lifting heavy objects (n=1556), Grade 4 Heavy physical labor (n=651)	Basic: Age Full: Age, smoking, diastolic blood pressure, serum cholesterol, body mass index, diabetes, alcohol abuse, and low occupational class	Mortality from coronary heart disease and all causes	Coronary heart disease mortality, heavy physical labor versus mainly sedentary: Basic: RR=1.05 (0.83-1.32) Fully adjusted: RR=0.83 (0.62-1.12)
23	Sagelv EH, Dalene KE, Eggen AE, Ekelund U, Fimland MS, Heitmann KA, et al. Occupational physical activity and risk of mortality in women and men: the Tromsø Study 1986-2021. Br J Sports Med. 2023;58(2):81-8	Prospective population-based study: 29605 subjects aged 20–65 years from the Tromsø Study surveys Tromsø3-Tromsø7 (1986–2016), four decades of follow-up (updated covariates every 6-8 y)	Questionnaire: low (sedentary), moderate (walking work), high (walking+liftingwork) or very high (heavy manual labour)	Cox/Fine and Gray regressions (subdistributed HR, SHR, to take competing risks from other causes of death) Stratification by sex and by birth cohort. Interaction analyses with leisure time physical activity. Adjusted for age, body mass index, smoking, education, diet, alcohol and leisure time physical activity	Mortality in CVD, all causes and cancer CVD ICD codes: : ICD-8 codes 390–444.1, 444.3–458, 782.4), ICD-9 codes (390–459) and ICD-10 codes (I00–I99);	CVD In men, compared with low occupational physical activity (OPA): Moderate OPA: SHR: 0.95, 95% CI 0.80 to 1.14 High OPA: SHR 0.68, 95% CI 0.54 to 0.84) Very high OPA: SHR 1.02, 95% CI 0.80 to 1.28
24	Suutari-Jääskö A, Parkkila K, Perkiömäki J, Huikuri H, Kesäniemi YA, Ukkola OH. Leisure time and occupational physical activity, overall and cardiovascular mortality: a 24-year follow-up in the OPERA study. Ann Med. 2023;55(2)	Cohort (OPERA) population-based study (Finland). Base-line 1991-1993: N=1045 (40–59 yrs 519 with hypertension, and their age- and sex-matched controls (n=526), follow-up until 2020. Internal comparisons, Kaplan-Meier and Cox's regression	Occupation was self-reported. Each reported occupation was manually coded to three occupational physical activity categories: "no activity" contained study subjects whose occupations did not include any or little activity, such as office work; "mild" was formed by those whose work included mainly working while standing, moving from one place to another such as cleaner, mechanic, salesman etc. "heavy" was formed by those who were in physically demanding professions such as lumberjacking, loader, etc. including heavy exercise (mainly standing, lifting, etc.)	Age, sex, smoking pack years, HTA, LDL cholesterol, BMI, and alcohol consumption	Fatal CV events included a major coronary heart disease (CHD) event and stroke (excluding subarachnoid haemorrhage). CHD as a cause of death included I20-I25, I46, R96, R98 (ICD-10/410-414, 798 (not 7980 A) (ICD-8/9)) as an underlying cause for death or immediate causes of death and I21 or I22 (ICD-10)/410 (ICD-8/9) as first to third contributing cause of death. Stroke (excluding SAH) included I61, I63 (not I636), I64 (ICD-10)/431, 4330 A, 4331 A, 4339 A, 4340 A, 4341 A, 4349 A, 436 (ICD-9)/431 (except 43101, 43191), 433, 434, 436 (ICD-8)	CVD mortality by occupational physical activity status group: No activity (n = 427) 1 (Ref); Mild (n = 544) 1.401 (0.938; 2.092); Heavy (n = 73) 1.943 (1.077; 3.503)

	Publication	Study design and population	Assessment of physical workload	Covariates and variables for stratification	Outcome variables	Results
25	Wang Y, Tuomilehto J, Jousilahti P, Antikainen R, Mhnen M, Katzmarzyk PT, et al. Occupational, commuting, and leisure-time physical activity in relation to heart failure among finnish men and women. J Am Coll Cardiol. 2010;56(14): 1140-8	Finnish population, in 1972, 1977, 1982, 1987, 1992, 1997, and 2002. 25 to 74 yrs. Free from heart failure at baseline. Follow-up of mean 18.4 yrs 28,334 men 29,874 women	Self-report single item. 3 categories: 1) Low: physically very easy, sitting office work (e.g., secretary); 2) Moderate: work including standing and walking (e.g., store assistant, light industrial worker); 3) High: work including walking and lifting or heavy manual labor (e.g., industrial or farm work).	Age, study year, education, smoking, alcohol consumption, history of myocardial infarction, history of valvular heart disease, history of diabetes, systolic blood pressure, total cholesterol, history of using antihyper-tensive drugs, history of lung disease, body mass index, and other 2 types of physical activity	The International Classification of Diseases (ICD) codes 427.00 and 427.10 (ICD-8th edition); 428, 4029B (hypertensive heart disease with HF), and 4148A-X (ischemic HF with chronic CHD) (ICD-9th edition); and I50, I11.0 (hypertensi-ve heart disease with HF), I13.0, and I13.2 (hypertensive heart and renal disease with HF) (ICD-10th edition) Outome: hospitaliza-tion or HF medicine with these diagnoses.	HR 95% CI Total Low (ref) Moderate 0.85 (0.77–0.93) High 0.87 (0.80–0.94) Men: Low (ref) Moderate 0.90 (0.78–1.03) High 0.83 (0.73–0.93) Women: Low (ref) Moderate 0.80 (0.70–0.92) High 0.92 (0.82–1.05)
26	Wennberg P, Lindahl B, Hallmans G, Mess-ner T, Weinehall L, Johansson L, et al. The effects of commuting activity and occupational and leisure time physical activity on risk of myocardial infarction. Eur J Prev Cardiol. 2006;13(6):924-30	Swedish study, pooled incident case-referent study Västerbottens Intervention Program (VIP) and the WHO MONICA study in northern Sweden. 583 MI cases 2098 referents	Self-report, different between the survey's Individuals stating seden-tary work or almost never physically demanding work were categorized as low occupational physical activity. and Individuals stating highly physically demanding work or often physically demanding work were categorized as high occupational physical activity. Remaining individuals presented a middle group categorized as moderate occupational physical activity.	Commuting activity, occupational and leisure time physical activity in the same model. Also smoking, body mass index, cholesterol, diabetes, hypertension and level of educational attainment	MONICA criteria MI for non-fatal MI For fatal also CHD (ICD-9 codes 410–414, 429.2, ICD-10 codes I20–I25).	OR 95% CI Total Low (ref) Moderate 0.81 (0.60–1.09) High 0.71 (0.46–1.09) Men: Low (ref) Moderate 0.70 (0.50–0.98) High 0.67 (0.42–1.08) Women: Low (ref) Moderate 1.19 (0.59–2.39) High 0.84 (0.29–2.50)
27	Virkkunen H, Härmä M, Kauppinen T, Tenkanen L. The triad of shift work, occupational noise, and physical workload and risk of coronary heart disease. Occup Environ Med. 2006;63(6):378-86	Finnish occupational cohort. The Helsinki Heart Study (HHS) Men, 40-56 yrs, at baseline. Followed-up 13 yrs. N = 1804	Job exposure matrix (FINJEM). The exposure metric used in the analyses was the product of the proportion of the exposed and the mean level of exposure in that occupation. In the analyses this variable was categorized into tertiles.	Systolic blood pressure total serum cholesterol; smoking, BMI	CH: ICD-9 codes 410–414 and ICD-10 codes I20–I25	HR 94% CI In strata of follow-up periods. To 91 Tert1 (ref) Tert2 0.85 (0.50–1.42) Tert3 1.10 (0.71–1.68) To 95 Tert1 (ref) Tert2 0.85 (0.58–1.24) Tert3 1.11 (0.82–1.50) To 95 Tert1 (ref) Tert2 0.96 (0.71–1.29) Tert3 1.26 (0.99–1.60)

	Publication	Study design and population	Assessment of physical workload	Covariates and variables for stratification	Outcome variables	Results
	Petersen CB, Eriksen L, Tolstrup JS, Søgaard K, Grønbæk M, Holtermann A. Occupational heavy lifting and risk of ischemic heart disease and all-cause mortality. BMC Public Health. 2012;12:1-9.	Cohort (Danish National Health Interview Surveys); Random, national representative sample. 6,692 working men and 5,921 working women aged 16–85 years without cardiovascular disease at baseline.	Self reports in survey, two questions: Q1 (Heavy lifting): Exposed to lifting or carrying heavy burdens (minimum 10 kg) at work more than 2 days a week?" (yes/no) Q2 (Occupational physical activity in general): "Which description most precisely covers your level of physical activity at work?" 1) Mainly sedentary ;2) quite a bit of standing or walking; 3) Standing and walking most of the time with quite a bit of carrying or lifting heavy burdens; 4) Work that requires vigorous or strenuous physical activity. Q2 was dichotomized 1+2 (low physical activity) vs. 3+4 (high physical activity)	Stratified by gender. Adjusted for age, education, alcohol consumption, smoking status, stress, and physical activity in leisure time. Mutually adjusted for heavy lifting, and occupational physical activity, respectively	IHD (ICD-8 codes 410–414 and ICD-10 codes I20-I25) incidence (fatal and non-fatal), deaths updated until 2008-12-31, and hospitalizations until 2010-05-04.	Men: Heavy lifting 1.52 (1.15 - 2.02) General occupational physical activity 0.50 (0.37 - 0.68) Women: Heavy lifting 0.81 (0.50 - 1.56) General occupational physical activity 1.55 (0.98 - 2.44)

Appendix 1b. Death from any cause

Extracted data from the analyzed full-text articles

Publication	Study design and population	Assessment of physical workload	Covariates and variables for stratification	Outcome variables	Results
Andersen LB, Schnohr P, Scroll M, Hein HO. Dødelighed associeret med fysisk aktivitet i fritiden, på arbejdet, sport og cykling til arbejde [Mortality associated with physical activity in leisure time, at work, in sports and cycling to work]. Ugeskr Laeger. 2002 Mar 11;164(11):1501-6. Danish.	Population-based (Glostrup cohorts: 13375 women and 17265 men, mean follow-up 14.5 y	Questionnaire: 1) Sitting, 2 walking, 3 walking with occasional lifts, 4 heavy manual work	Cox regression Model 1: Age Model 2: Educational level Model 3: CHD risk factors	National registries (all-cause mortality)	All-cause mortality Women: Model 1: Occupational activity level 2 versus 1: 0.86 (0.77-0.96) Activity level 3-4 vs 1: 0.86 (0.74-0.99) Full adjustment: Reported as "no change" In highest physical activity group significant protection (p<0.05) Men: No difference in age-adjusted death rates with level of occupational physical activity, only after adjustment for education a tendence towards a decrease in mortality was seen (estimates not presented)
Barengo NC, Hu G, Lakka TA, Pekkarinen H, Nissinen A, Tuomilehto J. Low physical activity as a predictor for total and cardiovascular disease mortality in middle-aged men and women in Finland. EUR HEART J. 2004;25(24):2204-11	Random regional surveys. eastern and south-western Finland FINMONICA. 5,853 15,853 men and 16,824 women Aged 30–59 years. Free from cardiovascular heart disease (CHD), stroke, heart failure, cancer. Follow-up median 20 years	Self-report single item: (i) high: lots of walking and lifting at work, taking the stairs or walking uphill (for example industrial work, farm work and forestry); (ii) moderate: walking quite a lot at work without lifting or carrying heavy objects; (iii) low: mostly sedentary work without much walking (for example, working in an office).	Final model adjusted for adjusted for age, study year, body mass index, systolic blood pressure, Age, study year, education, smoking status, systolic blood pressure, cholesterol level, BMI and two other types of physical activity. Stratified by sex.	All cause mortality and cardiovascular mortality, the International Classification of Diseases (ICD). Used codes: ICD-9: 390–459 (I00–I99).	All cause mortality Light occupational physical activity (Ref). Men: Moderate 0.75 (0.68–0.83) Active 0.77 (0.71–0.84) Women: Moderate 0.79 (0.70–0.89) Active 0.78 (0.70–0.87)
Dalene KE, Tarp J, Selmer RM, Ariansen IKH, Nystad W, Coenen P, Anderssen SA, Jostein Steene-Johannessen J, Ekelund U. Occupational physical activity and longevity in working men and women in Norway: a prospective cohort study. Lancet Public Health. 2021;6(6): 386-395	Norwegian population-based health examination surveys. 18-65 year olds. 213,079 men 224,299 women Baseline 1974-2002. Follow-up: death or end of 2018.	Self-report single item: sedentary work (eg, desk work or work including assembling of minor parts), work characterised by some walking (eg, light industrial work), non-sedentary office work, inspection, etc), work characterised by walking and lifting (eg, mail delivery and construction work), or work characterised by heavy manual labour (eg, digging and shovelling).	Age, sex, education, income, ethnicity, prevalent cardiovascular disease, smoking, leisure-time physical activity, body-mass index	Cardiovascular mortality: cardiovascular disease International Classification of Diseases (ICD)-8 codes 390–444·1, 444·3–458, 782·4; ICD-9 codes 390–459; ICD-10 codes I00–I99.	Overall mortality: Sedentary (ref) Men: [yrs longer (CI)] Walking 0.4 (−0.1 to 1.0) Walking and lifting 0.8 (0.3-1.3) Heavy labour 1.7 (1.2-2.3) Women: [yrs longer] Walking 0.2 (0.0–0.3) Walking and lifting −0.1 (−0.4 to 0.3) Heavy labour 0.3 (−0.3 to 0.9)

Publication	Study design and population	Assessment of physical workload	Covariates and variables for stratification	Outcome variables	Results
Ervasti J, Pietiläinen O, Rahkonen O, Lahelma E, Kouvonen A, Lallukka T, Mänty M. Long-term exposure to heavy physical work, disability pension due to musculoskeletal disorders and all-cause mortality: 20-year follow-up-introducing Helsinki Health Study job exposure matrix. Int Arch Occup Environ Health. 2019 Apr;92(3):337-345.	all employees of the City of Helsinki, Finland, who had annual data of exposure for 8–10 years (1996–2005, n=18387; Men (n=2870) Women (n=15,517)). Follow-up 20016-2015	Survey-based (not self-reported) JEM, based on reported heavy physical effort or heavy lifting and carrying present in work. The scale was: 0 (does not occur); 1 (occurs, but does not bother); 2 (occurs, and bothers to a moderate degree); 3 (occurs and bothers to a large degree). Value 0 was categorized as "unexposed", and all the other values as "exposed". The JEM estimate was calculated as the prevalence of exposure (as percentage) in each 3-digit-occupational title. Mean annual exposure was calculated (permitted to change over time)	Cox proportional hazards models. The interaction test indicated effect modification by sex, and the analyses were stratified by sex. The results were presented as subhazard ratios (SHR) Adjustment for age, educational level, and chronic diseases (before start of follow-up)	National registries	All-cause mortality Lowest quartile, 1 (Ref) 2nd quartile Men:0.87 (0.52–1.46) Women: 1.24 (0.87–1.75) 3rd quartile Men: 2.29 (1.23–4.24) Women: 1.16 (0.79–1.71) Highest quartile Men: 1.70 (0.90–3.20) Women: 1.54 (0.99–2.41) Linear exposure variable, increase in risk(SHR) per 10% increase in heavy physical effort: Men: 1.13 (95% CI 1.04–1.22) Women: 1.03 (0.98–1.09)
Graff-Iversen S, Selmer R, Skurtveit S, Sørensen M. Occupational physical activity, overweight, and mortality: A follow-up study of 47,405 norwegian women and men. Res Q Exerc Sport. 2007;78(3):-151-61	Norwegian regional population based surveys 1974–78: 23,884 men 23,521 women Free from self-reported CVD or disability pension at baseline. Follow-up until 2000 (25 years)	1. Sedentary work 2. Light occupational physical activity work, education 3. Moderately heavy occupational physical activity 4. Heavy occupational physical activity	Age, county, smoking, serum total cholesterol, education and income.	Mortality, from registers CVD was defined as ICD-8 codes 394–459; ICD-9: 390–459; or ICD-10: I00–I99. CHD, was defined as ICD-8 codes 410–413; ICD-9: 410–414; or ICD-10: I20–I25	Mortality Sedentary (ref) Men Light 1.01 0.92–1.10 Moderate 0.95 0.87–1.05 Heavy 0.84 0.76–0.92 Women Light 1.01 0.88–1.17 Moderate 1.07 0.90–1.27 Heavy 0.69 0.52–0.91
Hermansen R, Jacobsen BK, Løchen M-L, Morseth B. Leisure time and occupational physical activity, resting heart rate and mortality in the Arctic region of Norway: The Finnmark Study. Eur J Prev Cardiol. 2019;26(15):1636-44	Norwegian regional population-based survey linked to register (Finnmark 3) age 20-62 1987–1988: 8951 men 8746 women Follow-up 1987-2003	Self reported: Mostly sedentary, Walking (e.g. shop assistant, light industrial work, education), Walking and lifting (e.g. mailman, heavy industrial work, construction work) Heavy manual labour' (e.g. forestry work, heavy agriculture work, heavy construction work).	Age, sex, smoking status, BMI, self-reported angina pectoris, myocardial infarction, cerebral insult, diabetes, anti-hypertensive medication and leisure time physical activity stratified for sami/non-sami	CVD death (ICD)-9: 390–459 codes and ICD-10: I00–I99	All cause mortality Walking and lifting (ref) HR (95%CI) Mostly sedentary 1.13 (1.04–1.22) Walking 1.08 (1.00–1.17) Walking and lifting (ref) Heavy manual labour 1.14 (1.02–1.27)
Holtermann A, Mortensen OS, Burr H, Søgaard K, Gyntelberg F, Suadicani P. Physical demands at work, physical fitness, and 30-year ischaemic heart disease and all-cause mortality in the Copenhagen male study. SCAND J WORK ENVIRON HEALTH. 2010;36(5):357-65	Danish regional population based survey in Copenhagen (Copenhagen Male Study) age 40-59 1970-71. With No history of CVD. 30 year follow-up (1970-2001) n = 4943 men	Self report, summary score of two questions: Physical activity during work Holtermann 2013 (1=low, 2=moderate, 3–4=high) And strenuous work: "Do you perform strenuous work" 1=seldom or never, 2=occasionally, and 3=often. Added scores: 2 "low", 3 or 4 "moderate", 5 or 6 "high physical work demands".	Age, body mass index, alcohol use, smoking , leisure time physical activity, physical fitness Stratified for physical fitness	All cause mortality and Death from ischaemic heart disease (IHD) ICD-8:410–14, ICD-10: I20–I25.	HR 95% CI IHD mortality Low (Ref) Medium 1.26 (1.02–1.56) High 1.55 (1.19–2.02) Stratified analysis: Mortality: moderate and high only significant in strata of moderate PA IHD: High significant only in strata of low and moderate PA. Moderate significant only in moderate PA.

Publication	Study design and population	Assessment of physical workload	Covariates and variables for stratification	Outcome variables	Results
Holtermann A, Mortensen OS, Burr H, Søgaard K, Gyntelberg F, Suadicani P. Physical work demands and physical fitness in low social classes-30-year ischemic heart disease and all-cause mortality in the Copenhagen male study. J Occup Environ Med. 2011;53(11):1221-7 XX SKALL ÄNDRAS TILL: Holtermann A, Burr H, Hansen JV, Krause N, Søgaard K, Mortensen OS. Occupational physical activity and mortality among Danish workers. International Archives of Occupational and Environmental Health. 2012;85(3):305-10.	Danish regional population based survey in Copenhagen (Copenhagen Male Study) age 40-59 1970-71. With No history of CVD. 30 year follow-up (1970-2001) N = 4921 men	As in Holtermann 2010	BMI, systolic BP, diastolic BP, diabetes (treatment for), hypertension (treatment of), alcohol use, smoking (current, never, previous), leisure time physical activity. Strata: subset of low class and strata of physical fitness.	All cause mortality and Death from ischaemic heart disease (IHD) ICD-8: 410–14, ICD-10: I20–I25.	HR 95% CI In low classes IHD Mortality Significant only in strata of high physical fitness: Low (ref) Medium 0.63 (0.42–0.95) High 0.80 (0.52–1.24)
Holtermann A, Marott JL, Gyntelberg F, Søgaard K, Mortensen OS, Prescott E, et al. Self-reported occupational physical activity and cardiorespiratory fitness: Importance for cardiovascular disease and all-cause mortality. SCAND J WORK ENVIRON HEALTH. 2016;42(4):291-8	Danish regional population-based survey in Copenhagen (Copenhagen City Heart Study) 1991-1994 age 20–67. Follow-up in registers until 2013. Symptom free at basline. 2190 men 2534 women	Self-reported single item: (i) Mainly sedentary and do not walk much (ii) You walk around quite a bit at your workplace but do not have to carry heavy items (iii) Most of the time you walk, and you often have to walk upstairs and lift various items. (iv) You have heavy physical work. You carry heavy burdens and carry out physically strenuous work 1=low, score 2=moderate, and score 3–4=high.	Age, sex, smoking BMI, diabetes, income, alcohol and leisure PA.	All cause mortality, and CVD death defined as ICD-8: 390–458 and ICD-10: I00–I99.	All mortality Low (ref) Moderate 0.89 (0.74-1.06) High 1.05 (0.88-1.25)

Publication	Study design and population	Assessment of physical workload	Covariates and variables for stratification	Outcome variables	Results
Krause N, Arah OA, Kauhanen J. Physical activity and 22-year all-cause and coronary heart disease mortality. AM J IND MED. 2017;60(11):976-90	Prospective population-based study in Eastern Finland "Kuopio Ischemic Heart Disease (KIHD) Risk Factor Study": 1891 men, aged 42, 48, 54, or 60 years, baseline examination 1984-1989	Interview: a typical workday. Subjects were asked, in increments of 15 min, how long they had performed the following activities at work: sitting, standing, walking on level ground, walking on uneven ground, climbing stairs, or any other activities. The 12 months test-retest correlation of 0.69 for the OPA interview indicated good reliability.36 Lifetime job stability claimed to be high in region. Absolute energy expenditure at work (in kcal/day) was assessed from baseline interview data on time spent in various activities at their current job during a typical workday and reference data on the energy requirements (kcal/ kg/hour) of these activities. Also, Relative Aerobic Strain, RAS (%VO2max) a relative EE measure that expresses the physical demands of work in terms of energy needed to perform the job as a percentage of the individual worker's aerobic cardiorespiratory fitness or maximal work capacity, and percent oxygen uptake reserve.	Adjustments Model 1: None Model 2: Age Model 3: Age and technical factors (Age, Participant in placebo/treatment group of lipid lowering drug trial), Biological factors (Blood glucose, Plasma fibrinogen, BMI, LDL-and HDL -cholesterol, Systolic blood pressure. Lipid-lowering/ antihypertensive medication); Behavioral factors (Alcohol consumption, pack-years of cigarette smoking, leisure-time physical activity) ; Socio-economic status (personal income); Psychosocial job factors (social support, mental strain, deadlines)) Model 4: Model 3+adjustment for IHD at baseline (Fully adjusted)	Outcomes: Record linkage to national cause of death registry. CHD includes ICD9 codes 410-414	CHD mortality (HR, 95% CI): Absolute energy expenditure (Unit 500 kcal/ day) Age-adjusted: 1.12 (1.04-1.21) Fully adjusted: 1.05 (0.96-1.13) Relative aerobic strain (Unit 10%) Age-adjusted: 1.34 (1.24-1.45) Fully adjusted: 1.23 (1.11-1.35) Percent oxygen uptake reserve (Unit 10%) Age-adjusted: 1.25 (1.17-1.34) Fully adjusted: 1.17 (1.08-1.27) Interaction was indicated between CVD death and IHD at base-line (RERI-significant). Stratification on IHD provided slightly higher RRs for no IHD at baseline.
Mikkola TM, Von Bonsdorff MB, Salonen MK, Kautiainen H, Ala-Mursula L, Solovieva S, et al. Physical heaviness of work and sitting at work as predictors of mortality: A 26-year follow-up of the Helsinki Birth Cohort Study. BMJ Open. 2019;9(5)	Population-based birth cohort (Helsinki Birth Cohort Study): 5210 men 4725 women occupational code at baseline 1970 (ages 45–57 years), and 25 yrs of follow-up (2015)	Occupational physical heaviness of work assessed by a Job Exposure Matrix (JEM) based on occupational code (4-digit) at baseline. JEM was based on national representative survey, with question: Does your current job involve heavy physical work, in which you have to lift or carry heavy items, to dig, shovel or pound?' (yes/ no). Similar question for sedentary work. Exposure categorized into quartiles by prevalence (of yes), separately for men and women.	Basic: Age Adjusted: Age, education	Cause of death (national registry). For CVD 400–499 in the ICD Ninth Revision and I00–I99 in the ICD 10th Revision	All-cause mortality Men: The HRs for men in the highest quartile of physical heaviness of work compared with men in the lowest quartile were 1.54 (1.31–1.80), Women: 4th quartile vs 1st: 1.14 (0.94 to 1.39) Dose-response by likelihood of heavy physical work (quartiles) I: 1.00 (Ref) Men II 1.18 (1.00 - 1.39) III 1.36 (1.16 to 1.58) IV 1.54 (1.31 to 1.80) P for trend <0.001 Women: II 0.97 (0.78 to 1.19) III 1.07 (0.87 to 1.31) IV 1.14 (0.94 to 1.39) p for trend 0.36

Publication	Study design and population	Assessment of physical workload	Covariates and variables for stratification	Outcome variables	Results
Rosengren A, Wilhelmsen L. Physical activity protects against coronary death and deaths from all causes in middle-aged men. Evidence from a 20-year follow-up of the primary prevention study in Göteborg. Ann Epidemiol. 1997 Jan;7(1):69-75.	Prospective population-based cohort: Multifactor Prevention Study, Gothenburg: 7142 men 47 to 55 yrs at baseline in 1970-1973 and without symptomatic CHD. 20 yrs follow-up	Postal questionnaire: physical activity at work was graded from 1 to 4. Grade 1 Mainly sedentary (n=2052) Grade 2 Predominantly walking on one level but no heavy lifting (n=2814), Grade 3 Mainly walking, including climbing stairs, or walking uphill or lifting heavy objects (n=1556), Grade 4 Heavy physical labor (n=651)	Basic: Age Full: Age, smoking, diastolic blood pressure, serum cholesterol, body mass index, diabetes, alcohol abuse, and low occupational class	Mortality from coronary heart disease and all causes	All cause mortality Heavy physical labour vs mainly sedentary: Basic: RR=1.23 (1.09-1.38) Fully adjusted: RR=0.98 (0.84-1.15)
Sagelv EH, Dalene KE, Eggen AE, Ekelund U, Fimland MS, Heitmann KA, Holtermann A, Johansen KR, Løchen ML, Morseth B, Wilsgaard T. Occupational physical activity and risk of mortality in women and men: the Tromsø Study 1986-2021. Br J Sports Med. 2024 Jan 3;58(2):81-88.	Prospective population-based study: 29605 subjects aged 20–65 years from the Tromsø Study surveys Tromsø3-Tromsø7 (1986–2016), four decades of follow-up (updated covariates every 6-8 y)	Questionnaire: low (sedentary), moderate (walking work), high (walking+liftingwork) or very high (heavy manual labour)	Cox/Fine and Gray regressions (subdistributed HR, SHR, to take competing risks from other causes of death) Stratification by sex and by birth cohort. Interaction analyses with leisure time physical activity. Adjusted for age, body mass index, smoking, education, diet, alcohol and leisure time physical activity	Mortality in CVD, all causes and cancer CVD ICD codes: ICD-8 codes 390–444.1, 444.3–458, 782.4), ICD-9 codes (390–459) and ICD-10 codes (I00–I99);	All causes mortality Men: Low occupational physical activity (OPA) (Ref) Moderate OPA,HR (95% CI) 0.98, (0.89-1.08) High OPA: 0.83, (0.74-0.92) Very high OPA 1.07 (0.94-1.22) Women: There was no association between OPA and mortality in women. Possible cohort effect by birth year for all-cause mortality in men (interaction p=0.06), where high OPA was associated with lower mortality risk in those born before 1940 (HR 0.82, 95% CI 0.71 to 0.96), whereas very high OPA was associated with higher mortality risk in those born after 1950 (HR 1.38, 95CI 1.00 to 1.89) (online supplemental table 13). For women, inconclusive.

Publication	Study design and population	Assessment of physical workload	Covariates and variables for stratification	Outcome variables	Results
Suutari-Jääskö A, Parkkila K, Perkiömäki J, Huikuri H, Kesäniemi YA, Ukkola OH. Leisure time and occupational physical activity, overall and cardiovascular mortality: a 24-year follow-up in the OPERA study. Ann Med. 2023;55(2)	Cohort (OPERA) population-based study (Finland). Base-line 1991-1993: N=1045 (40–59 yrs 519 with hypertension, and their age- and sex-matched controls (n=526), follow-up until 2020. Internal comparisons, Kaplan-Meier and Cox's regression	Occupation was self-reported. Each reported occupation was manually coded to three occupational physical activity categories: first"no activity" contained study subjects whose occupations did not include any or little activity, such as office work; second group "mild" was formed by those whose work included mainly working while standing, moving from one place to another such as cleaner, mechanic, salesman etc. The third group "heavy" was formed by those who were in physically demanding professions such as lumberjacking, loader, etc. including heavy exercise (mainly standing, lifting, etc.)	Age, sex, smoking pack years, HTA, LDL cholesterol, BMI, and alcohol consumption	Fatal CV events included a major coronary heart disease (CHD) event and stroke (excluding subarachnoid haemorrhage). CHD as a cause of death included I20-I25, I46, R96, R98 (ICD-10/410-414, 798 (not 7980 A) (ICD-8/9)) as an underlying cause for death or immediate causes of death and I21 or I22 (ICD-10)/410 (ICD-8/9) as first to third contributing cause of death. Stroke (excluding SAH) included I61, I63 (not I636), I64 (ICD-10)/431, 4330 A, 4331 A, 4339 A, 4340 A, 4341 A, 4349 A, 436 (ICD-9)/431 (except 43101, 43191), 433, 434, 436 (ICD-8)	CVD mortality by occupational physical activity status group: No activity (n = 427) 1 (reference); Mild (n = 544) 1.401 (0.938; 2.092); Heavy (n = 73) 1.943 (1.077; 3.503)
Petersen CB, Eriksen L, Tolstrup JS, Søgaard K, Grønbæk M, Holtermann A. Occupational heavy lifting and risk of ischemic heart disease and all-cause mortality. BMC Public Health. 2012;12:1-9.	Cohort (Danish National Health Interview Surveys); Random, national representative sample. 6,692 working men and 5,921 working women aged 16–85 years without cardiovascular disease at baseline.	Self reports in survey, two questions: Q1 (Heavy lifting): Exposed to lifting or carrying heavy burdens (minimum 10 kg) at work more than 2 days a week?" (yes/no) Q2 (Occupational physical activity in general): "Which description most precisely covers your level of physical activity at work?" 1) Mainly sedentary ;2) quite a bit of standing or walking; 3) Standing and walking most of the time with quite a bit of carrying or lifting heavy burdens; 4) Work that requires vigorous or strenuous physical activity. Q2 was dichotomized 1+2 (low physical activity) vs. 3+4 (high physical activity)	Stratified by gender. Adjusted for age, education, alcohol consumption, smoking status, stress, and physical activity in leisure time. Mutually adjusted for heavy lifting, and occupational physical activity, respectively	Data on all-cause mortality were obtained from the Danish Civil Registration System updated until 2010-05-04	Men: Heavy lifting 1.00 (0.74 -1.35) General occupational physical activity 1.02 (0.75 -1.39) Women: Heavy lifting 0.95 (0.59 - 1.53) General occupational physical activity 0.94 (0.60 -1.50)

Publication	Study design and population	Assessment of physical workload	Covariates and variables for stratification	Outcome variables	Results
Franzon K, Zethelius B, Cederholm T, Kilander L. Modifiable midlife risk factors, independent aging, and survival in older men: Report on long-term follow-up of the Uppsala longitudinal study of adult men cohort. J Am Geriatr Soc. 2015;63(5):877-85	Uppsala Longitudinal Study on Adult Men (ULSAM). All men born from 1920 to 1924 and living in Uppsala, Sweden were invited. At baseline, participants were 50 (range 48.6–51.1) years old, 2322 men (82%) participated. Last follow-up at mean age 88.	Questionnaire: Work-time PA was categorized into four groups: chiefly sedentary, mostly standing or walking, heavy lifting (>10 kg), and physically demanding work-Low work-time PA included sedentary and moderate PA.	Age, BMI, educational level, smoking	survival to age 85	Low physical work activity (survival vs non-survival) 0.94 (0.76–1.16) .59
Holtermann A, Burr H, Hansen JV, Krause N, Søgaard K, Mortensen OS. Occupational physical activity and mortality among Danish workers. Int Arch Occup Environ Health. 2012;85(3):305-10.					

Appendix 2. Summary of excluded full-text articles and reasons

	Publication	Orsak
1	Cillekenøe K, Søgaard K, Aadahl M, Boyle E, Holtermann A. Are hypertensive women at additional risk of ischaemic heart disease from physically demanding work? Eur J Prev Cardiol. 2016;23(10):1054-61	Samma population återfinns i en senare likartad artikel.
2	Clays E, Casini A, Van Herck K, De Bacquer D, Kittel F, De Backer G, Holtermann A. Do psychosocial job resources buffer the relation between physical work demands and coronary heart disease? A prospective study among men. Int Arch Occup Environ Health. 2016;89(8):1299-1307	Population utanför Skandinavien
3	Ferrario MM, Roncaioli M, Veronesi G, Holtermann A, Clays E, Borchini R, et al. Differing associations for sport versus occupational physical activity and cardiovascular risk. Heart. 2018;104(14):1165-72.	Population utanför Skandinavien
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7	Holme I, Helgeland A, Hjermann I, Leren P, Lund-Larsen PG. Physical activity at work and at leisure in relation to coronary risk factors and social class: a 4-year mortality follow-up the oslo study. ACTA MED SCAND. 1981;209(1-6):277-83.	Ej i linje med kvalitets-kraven
8	Holtermann A, Marott JL, Gyntelberg F, Søgaard K, Suadicani P, Mortensen OS, et al. Does the benefit on survival from leisure time physical activity depend on physical activity at work? A prospective cohort study. PLoS ONE. 2013;8(1).	Samma population återfinns i en senare likartad artikel.
9	Holtermann A, Mortensen OS, Burr H, Søgaard K, Gyntelberg F, Suadicani P. Fitness, work, and leisure-time physical activity and ischaemic heart disease and all-cause mortality among men with pre-existing cardiovascular disease. SCAND J WORK ENVIRON HEALTH. 2010;36(5):366-72.	Samma population återfinns i en senare likartad artikel.
10	Holtermann A, Mortensen OS, Burr H, Søgaard K, Gyntelberg F, Suadicani P. Physical work demands, hypertension status, and risk of ischemic heart disease and all-cause mortality in the Copenhagen Male Study. SCAND J WORK ENVIRON HEALTH. 2010;36(6):466-72.	Samma population återfinns i en senare likartad artikel.
11	Holtermann A, Mortensen OS, Burr H, Søgaard K, Gyntelberg F, Suadicani P. The interplay between physical activity at work and during leisure time - Risk of ischemic heart disease and all-cause mortality in middle-aged Caucasian men. SCAND J WORK ENVIRON HEALTH. 2009;35(6):466-74.	Ej i linje med kvalitets-kraven
12	Holtermann A, Burr H, Hansen JV, Krause N, Søgaard K, Mortensen OS. Occupational physical activity and mortality among Danish workers. Int Arch Occup Environ Health. 2012;85(3):305-10	Otillräckligt exponerings-klassificering
13	Hu G, Eriksson J, Barengo NC, Lakka TA, Valle TT, Nissinen A, et al. Occupational, commuting, and leisure-time physical activity in relation to total and cardiovascular mortality among finnish subjects with type 2 diabetes. CIRCULATION. 2004;110(6):666-73	Fel focus
14	Hu G, Jousilahti P, Antikainen R, Tuomilehto J. Occupational, commuting, and leisure-time physical activity in relation to cardiovascular mortality among finnish subjects with hypertension. Am J Hypertens. 2007;20(12):1242-50.	Fel fokus
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16	Karvonen MJ. Physical activity in work and leisure time in relation to cardiovascular diseases. ANN CLIN RES. 1982;14(Suppl. 34):118-23.	Samma population återfinns i en senare likartad artikel.
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18	Lapidus L, Bengtsson C. Socioeconomic factors and physical activity in relation to cardiovascular disease and death. A 12 year follow up of participants in a population study of women in Gothenburg, Sweden. BR HEART J. 1986;55(3):295-301.	Ej i linje med kvalitets-kraven
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20	Menotti A, Keys A, Blackburn H, Karvonen M, Punsar S, Nissinen A, et al. Blood pressure changes as predictors of future mortality in the seven countries study. J HUM HYPERTENS. 1991;5(3):137-44.	Population utanför Skandinavien

	Publication	Orsak
21	Menotti A, Keys A, Kromhout D, Blackburn H, Aravanis C, Bloemberg B, et al. Inter-cohort differences in coronary heart disease mortality in the 25-year follow-up of the seven countries study. Eur J Epidemiol. 1993;9(5):527-36.	Population utanför Skandinavien
22	Nyberg A, Alfredsson L, Theorell T, Westerlund H, Vahtera J, Kivimäki M. Managerial leadership and ischaemic heart disease among employees: The Swedish WOLF study. Occup Environ Med. 2009;66(1):51-5.	Fel fokus
23	Orsini N, Bellocco R, Bottai M, Pagano M, Michaelsson K, Wolk A. Combined effects of obesity and physical activity in predicting mortality among men. J Intern Med (GBR). 2008;264(5):442-51.	Fel fokus
24	Punsar S, Karvonen MJ. Physical activity and coronary heart disease in populations from East and West Finland. ADV CARDIOL. 1976;Vol. 18:196-207.	Ej i linje med kvalitets-kraven
25	Rosengren A, Anderson K, Wilhelmsen L. Risk of coronary heart disease in middle-aged male bus and tram drivers compared to men in other occupations: A prospective study. INT J EPIDEMIOL. 1991;20(1):82-7.	Samma population återfinns i en senare likartad artikel.
26	Salonen J, Puska P, Tuomilehto J. Physical activity and risk of myocardial infarction, cerebral stroke and death: A longitudinal study in eastern Finland. AM J EPIDEMIOL. 1982;115(4):526-37.	Alltför kort uppföljningstid
27	Salonen JT, Slater JS, Tuomilehto J, Rauramaa R. Leisure time and occupational physical activity: Risk of death from ischemic heart disease. AM J EPIDEMIOL. 1988;127(1):87-94.	Alltför kort uppföljningstid
28	Siltanen P, Romo M, Haapakoski J. The influence of previous physical activity on survival and reinfarction after first myocardial infarction. ACTA MED SCAND. 1982;212(668 S):34-48.	Fel fokus
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30	Suadicani P, Hein HO, Gyntelberg F. Socioeconomic status and ischaemic heart disease mortality in midd-le-aged men: Importance of the duration of follow-up. The Copenhagen male study. INT J EPIDEMIOL. 2001;30(2):248-55.	Samma population återfinns i en senare likartad artikel.
31	Toivanen S, Hemström Ö. Income differences in cardiovascular disease: Is the contribution from work similar in prevalence versus mortality outcomes? Int J Behav Med. 2006;13(1):89-100.	Alltför kort uppföljningstid
32	Tuomi K, Toikkanen J, Eskelinen L, Backman AL, Ilmarinen J, Jarvinen Klockars EM. Mortality, disability and changes in occupation among aging municipal employees. SCAND J WORK ENVIRON HEALTH. 1991;17(SUPPL. 1):58-66.	Alltför kort uppföljningstid
33	Aase A, Almås R. The diffusion of cardiovascular disease in the Norwegian farming community: A comnination of morbidity and mortality data. Soc Sci Med. 1989;29(8):1027-33.	Fel focus
34	Ahlman K, Koskela RS, Kuikka P, Koponen M, Annanmäki M. Mortality among sulfide ore miners. AM J IND MED. 1991;19(5):603-17.	Fel focus
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36	Holtermann A.; Mortensen O.S.; Burr H.; Søgaard K.; Gyntelberg F.; Suadicani P. Physical work demands, hypertension status, and risk of ischemic heart disease and all-cause mortality in the Copenhagen Male Study 2010 Scandinavian Journal of Work, Environment and Health	Fel fokus
37	Jensen G, Nyboe J, Appleyard M, Schnohr P. Risk factors for acute myocardial infarction in Copenhagen II: Smoking, alcohol intake, physical activity, obesity, oral contraception, diabetes, lipids, and blood pressure. EUR HEART J. 1991;12(3):298-308.	Alltför kort uppfölj-ningstid
38	Johansson S, Bergstrand R, Ulvenstam G, Vedin A, Wilhelmsson C, Wedel H, et al. Sex differences in preinfarction characteristics and longterm survival among patients with myocardial infarction. AM J EPIDEMIOL. 1984;119(4):610-23.	Fel fokus
39	Johansson M, Johansson L, Wennberg P, Lind M. Physical activity and risk of first-time venous thromboembolism. Eur J Prev Cardiol. 2019;26(11):1181-7.	Fel fokus
40	Berglund K, Almroth M, Falkstedt D, Hemmingsson T, Kjellberg K. The impact of cardiorespiratory fitness and physical workload on disability pension–a cohort study of Swedish men. Int Arch Occup Environ Health. 2024;97(1):45-55.	Ej i linje med kvalitets-kraven
41	Kuster RP, von Rosen P, Grooten WJA, Dohrn IM, Hagströmer M. Self-reported and device-measured physical activity in leisure time and at work and associations with cardiovascular events—a prospective study of the physical activity paradox. Int J Environ Res Public Health. 2021;18(22).	Ej i linje med kvalitetskraven
42	Korshøj M, Skaarup KG, Lassen MCH, Johansen ND, Marott JL, Schnohr P, et al. Association between exposure to heavy occupational lifting and cardiac structure and function: a cross-sectional analysis from the Copenhagen City Heart Study. Int J Card Imaging. 2022;38(3):521-32.	Fel fokus utfall är avvikelse i hjärtat vid ultraljud
43	Robroek SJW, Järvholm B, Van Der Beek AJ, Proper KI, Wahlström J, Burdorf A. Influence of obesity and physical workload on disability benefits among construction workers followed up for 37 years. Occup Environ Med. 2017;74(9):621-7.	Ej i linje med kvalitetskraven
44	Wang A, Arah OA, Kauhanen J, Krause N. Effects of leisure-time and occupational physical activities on 20-year incidence of acute myocardial infarction: Mediation and interaction. SCAND J WORK ENVIRON HEALTH. 2016;42(5):423-34.	Samma population återfinns i en senare likartad artikel.

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46	Krause N, Brand RJ, Arah OA, Kauhanen J. Occupational physical activity and 20-year incidence of acute myocardial infarction: Results from the kuopio ischemic heart disease risk factor study. SCAND J WORK ENVIRON HEALTH. 2015;41(2):124-39.	Samma population återfinns i en senare likartad artikel.
47	Fransson E, Knutsson A, Westerholm P, Alfredsson L. Indications of recall bias found in a retrospective study of physical activity and myocardial infarction. J Clin Epidemiol. 2008;61(8):840-7.	Allt för få fall
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52	Cillekens B, Lang M, Van Mechelen W, Verhagen E, Huysmans MA, Holtermann A, et al. How does occupational physical activity influence health? An umbrella review of 23 health outcomes across 158 observational studies. Br J Sports Med. 2020;54(24):1474-81.	Ej originalarbete
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55	Hannerz H, Holtermann A. Heavy lifting at work and risk of ischemic heart disease: Protocol for a register-based prospective cohort study. JMIR Res Prot. 2014;3(3).	Ej originalarbete
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57	Bo Andersen L, Schnohr P, Schroll M, Ole Hein H. All-cause mortality associated with physical activity during leisure time, work, sports, and cycling to work. Arch Intern Med. 2000;160(11):1621-8.	Samma population
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59	Falkstedt D, Hemmingsson T, Albin M, Bodin T, Ahlbom A, Selander J, et al. Disability pensions related to heavy physical workload: a cohort study of middle-aged and older workers in Sweden. International Archives of Occupational and Environmental Health. 2021;94(8):1851-61.	Fel utfall
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61	Korshøj M, Rasmussen CL, de Oliveira Sato T, Holtermann A, Hallman D. Heart rate during work and heart rate variability during the following night: A day-by-day investigation on the physical activity paradox among blue-collar workers. SCAND J WORK ENVIRON HEALTH. 2021;47(5):387-94.	Fel utfall
62	Sato TO, Hallman DM, Kristiansen J, Skotte JH, Holtermann A. Different autonomic responses to occupational and leisure time physical activities among blue-collar workers. International Archives of Occupational and Environmental Health. 2018;91(3):293-304.	Ej exponering
63	Holtermann A, Krause N, Van Der Beek AJ, Straker L. The physical activity paradox: Six reasons why occupational physical activity (OPA) does not confer the cardiovascular health benefits that leisure time physical activity does. Br J Sports Med. 2018;52(3):149-50.	Ej originalarbete
64	Clays E, De Bacquer D, Janssens H, De Clercq B, Casini A, Braeckman L, et al. The association between leisure time physical activity and coronary heart disease among men with different physical work demands: A prospective cohort study. European Journal of Epidemiology. 2013;28(3):241-7.	Population utanför Norden
65	Krause N, Brand RJ, Arah OA, Kauhanen J. Occupational physical activity and 20-year incidence of acute myocardial infarction: Results from the kuopio ischemic heart disease risk factor study. SCAND J WORK ENVIRON HEALTH. 2015;41(2):124-39.	
66	Hu G, Jousilahti P, Borodulin K, Barengo NC, Lakka TA, Nissinen A, et al. Occupational, commuting and leisure-time physical activity in relation to coronary heart disease among middle-aged Finnish men and women. Atherosclerosis. 2007;194(2):490-7.	
67	Gordon-Larsen P, Boone-Heinonen J, Sidney S, Sternfeld B, Jacobs Jr DR, Lewis CE. Active commuting and cardiovascular disease risk: The CARDIA study. Arch Intern Med. 2009;169(13):1216-23.	Population utanför Norden
68	Mäkinen T, Kestilä L, Borodulin K, Martelin T, Rahkonen O, Leino-Arjas P, et al. Occupational class differences in leisure-time physical inactivity - Contribution of past and current physical workload and other working conditions. SCAND J WORK ENVIRON HEALTH. 2010;36(1):62-70.	Ej utfall

	Publication	Orsak
69	Held C, Iqbal R, Lear SA, Rosengren A, Islam S, Mathew J, et al. Physical activity levels, ownership of goods promoting sedentary behaviour and risk of myocardial infarction: Results of the INTERHEART study. EUR HEART J. 2012;33(4):452-66.	Population utanför Norden
70	Fransson EIM, Alfredsson LS, de Faire UH, Knutsson A, Westerholm PJM. Leisure time, occupational and household physical activity, and risk factors for cardiovascular disease in working men and women: The WOLF study. Scand J Public Health. 2003;31(5):324-33.	Too few cases
71	Ostlin P. Negative health selection into physically light occupations. J EPIDEMIOL COMMUNITY HEALTH. 1988;42(2):152-6.	Ej exponering
72	Almås R, Ødegård J. Morbidity among Self-Employed Farmers in Norway. Scand J Public Health. 1985;13(4):169-72.	Ej Exponering
73	Hagman M, Wilhelmsen L, Wedel H, Pennert K. Risk factors for angina pectoris in a population study of Swedish men. J Chronic Dis. 1987;40(3):265-75.	Fel studiedesign
74	Tuomi K, Eskelinen L, Toikkanen J, Jarvinen E, Ilmarinen J, Klockars M. Work load and individual factors affecting work ability among aging municipal employees. SCAND J WORK ENVIRON HEALTH. 1991;17(SUPPL. 1):128-34.	Fel studiedesign
75	Ilmarinen J. Work and cardiovascular health: Viewpoint of occupational physiology. Ann Med. 1989;21(3): 209-14.	Fel studiedesign
76	Tuomi K. Characteristics of work and life predicting coronary heart disease. Finnish research project on aging workers. Soc Sci Med. 1994;38(11):1509-19.	För kort uppföljning
77	Møller L, Kristensen TS, Hollnagel H. Social Class and Cardiovascular Risk Factors in Danish Men. Scand J Public Health. 1991;19(2):116-26.	Ej riskestimat
78	Kagan AR. Atherosclerosis and myocardial disease in relation to physical activity of occupation. Bulletin of the World Health Organization. 1976;53(5-6):615-22.	Population utanför norden
79	Gyntelberg F, Lauridsen L, Schubell K. Physical fitness and risk of myocardial infarction in Copenhagen males aged 40-59. A five- and seven-year follow-up study. SCAND J WORK ENVIRON HEALTH. 1980;6(3):170-8.	För kort uppföljning

Appendix 3. Search strategy

TITLE-ABS-KEY ((lifting OR lifts OR heavy OR strenuous* OR physical* OR corporeal OR manual) AND (work OR workload OR workplace OR job OR labor OR occupation) AND (die OR death OR mortality OR decease OR lethal* OR fatal* OR "heart disease" OR "cardiovascular disease" OR "coronary artery disease" OR "heart health" OR "myocardial infarction" OR "heart attack" OR "acute zcoronary" OR "cardiac arrest" OR "ischemic attack" OR qaly OR "quality-adjusted life year*")) AND (TITLE-ABS-KEY (sweden OR swedish OR denmark OR danish OR norway OR norweg* OR finland OR finnish*) OR AFFILCOUNTRY (sweden OR denmark OR norway OR finland)) AND (LIMIT-TO (LANGUAGE , "English") OR LIMIT-TO (LANGUAGE , "Danish") OR LIMIT-TO (LANGUAGE , "Norwegian") OR LIMIT-TO (LANGUAGE , "Swedish"))

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