FACULTY OF HEALTH SCIENCES
UNIVERSITY OF COPENHAGEN

NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

# Physical Capacity

## The interplay between job type, physical capacities and future health, sickness absence, and job status among Danish employees.

Ph.D. thesis

Anne Faber Hansen

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Det Sundhedsvidenskabelige Fakultet
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Academic advisors:
Professor, PhD Karen Søgaard, Institute of Sports Science and Clinical Biomechanics, University of Southern Denmark, Odense
Senior Researcher, PhD Andreas Holtermann, Danish National Research Centre for the Working Environment, Copenhagen.

Evaluation Committee:
Professor, Dr. Med.Sci., PhD, Kirsten Avlund, Department of Public Health, Section og Social Medicine, University of Copenhagen (Chairperson).
Professor Gisela Sjøgaard, Institute of Sport Science and Clinical Biomechanics, Research Unit for Physical Activity and Health in Worklife, University of Southern Denmark.
Professor Clas-Håkan Nygaard, School of Health Sciences, University of Tampere, Finland.

# Preface

This PhD project was initiated at the Danish National Research Centre for the Working Environment (the former National Institute of Occupational Health). The thesis was submitted to the faculty of Health Sciences, University of Copenhagen, in June 2011.
The studies were conducted in accordance with the declaration of Helsinki.
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# Contents

# Summary in English

**Background:** Traditionally, physical work environment is assessed and interpreted in relation to external exposures. However, since workers have different individual resources, varying with gender, age, body size, and fitness level, the relative size of a burden varies. A load that is heavy for workers with e.g. low muscle strength may be effortless for strong workers. Therefore the long-term effects of physically demanding work may differ between individuals. Whether the physical exposures have training, maintaining or deteriorative effects in the long-term may depend on the individual relationship between physical workload and physical capacity.

**Aim:** Overall, this thesis has two purposes, 1) to examine if physical capacities vary with job groups, and 2) to examine the significance of physical capacity for future signs of physical deterioration, measured as muscle strength, musculoskeletal pain, sickness absence, job turnover and drop-out among Danish employees.

**Methods**: The first purpose was studied by objective measurements of 1) hand grip strength, aerobic capacity, motor control and flexibility among 19 construction workers with 12-hour workdays and 14-day work periods; 2) hand grip strength, trunk and shoulder muscle strength, and aerobic capacity among 47 waste collectors and a comparison group of 46 employees without physically heavy work 3) hand grip strength, trunk and shoulder muscle strength, and aerobic capacity among 421 employees of mixed occupations divided into employees with primarily monotonous or varied work tasks. The second purpose was studied 1) among construction workers by repeated measurements of hand grip strength and aerobic fitness in the beginning and in the end of the 14-day work period; 2) in the cohort of 421 Danish employees of mixed occupations, the predictive value of low muscle strength of hand, trunk and shoulder muscles for future musculoskeletal disorders was followed up in national registers after 5 years and the predictive value for long-term sickness absence was followed up after 10 years. Finally, low self-rated muscle strength and flexibility as well as prevalence, duration and severity of low back pain the last 12 months as possible predictors for job turnover or job drop-out among 5,696 recently educated eldercare workers were followed up in national registers after 2 years.

**Results:** No conclusive associations between physical work exposures and muscle strength of employees of different job groups were found. On the one hand, capacities in the cohort of 421 Danish employees showed no significant associations with the job exposures being primarily monotonous or varied. On the other hand, shoulder muscle strength of elderly waste collectors with high seniority was similar to the shoulder muscle strength of young waste collectors with low seniority. Generally, the most obvious differences in physical capacities were between men and women.

The level of physical capacity measured by objective and self-rated muscle strength and flexibility was not found associated with any future signs of physical deterioration. Nineteen construction workers working long hours did not decrease their physical performance after 14 days of construction work. Low muscle strength among 421 employees of mixed occupations did neither predict musculoskeletal disorders after 5 years, nor long-term sickness absence after 10 years. Low self-rated muscle strength or flexibility did not predict job turnover or job drop-out after 2 years. However, duration and severity of low back pain the last 12 months were predictors for changed job status 2 years later.

**Discussion:** Compared to the effect of gender and age, work exposure seems to be of minor importance for the physical capacity both evaluated in a cross-sectional and prospective design. No clear picture emerged regarding associations between physical capacities and work exposures of different job groups. On the one hand, the cohort of 421 Danish employees of mixed occupations showed no physical capacity differences associated with job type. On the other hand, the high shoulder muscle strength found among elderly waste collectors with high seniority indicates a possible maintaining or training effect from the exposures in waste collection on particularly the shoulder muscles. However, healthy worker effect among the elderly waste collectors and early selection among the young waste collectors may explain the results. In the prospective studies, the level of physical capacity measured as objective and self-rated muscle strength and as self-rated flexibility was not found associated with any future signs of physical deterioration in terms of decreased physical performance, prevalence of musculoskeletal disorders or long-term sickness absence, job turnover or job drop-out. Duration and severity of low back pain the last year were predictors for later change of job status. Thus, low back pain was the only individual factor with predictive value for later outcome parameters.

**Conclusion:** Overall, the cross-sectional studies I and II show that while the general measurements of the mixed worker populations show no associations, the job specific tests of capacity within homogenous samples of workers show some association between the physical exposures at work and the muscle strength of employees of different job groups. Furthermore, low physical capacity both in terms of objectively measured and self-reported, was not associated with any future signs of physical deterioration in terms of decreased capacity or test performance, musculoskeletal disorders, long-term sickness absence, job turnover or job drop-out. However, disability due to and duration of LBP were predictors for change of job status.

## Dansk resume (Summary in Danish)

**Baggrund:** Fysisk arbejdsmiljø vurderes traditionelt som eksterne eksponeringer. Men da lønmodtageres ressourcer er individuelle og varierer med køn, alder, kropsstatur og træningstilstand, varierer den relative belastning fra person til person. Langtidseffekterne af fysisk krævende arbejde kan derfor også være forskellige. Om langtidseffekten af en fysisk eksponering er opbyggende, vedligeholdende eller nedslidende kan derfor afhænge af forholdet mellem de fysiske arbejdskrav og den individuelle fysiske kapacitet.

**Formål:** Denne afhandling har to formål:
1) at belyse om den fysiske kapacitet varierer med eksponeringer i arbejdet og
2) at belyse om fysisk kapacitet prædikterer fremtidige tegn på fysisk nedslidning, såsom nedsat fysisk præstationsevne, muskelskeletbesvær, sygefravær og jobskifte eller -ophør blandt danske lønmodtagere.

**Metode:** Første formål belyses med objektive målinger af 1) muskelstyrke i hånd, bug, ryg og skuldre, målinger af iltoptagelse og beregninger af kondition, målinger af motorisk kontrol og bevægelighed på 19 bygningsarbejdere med 12 timers arbejdsdage og 14 dages arbejdsperioder; 2) på 47 skraldemænd og en sammenligningsgruppe på 46 lønmodtagere uden fysisk tungt arbejde samt på 3) en repræsentativ kohorte af 421 lønmodtagere fra erhverv med og uden ensidigt gentaget arbejde blev ligeledes målt muskelstyrke i hånd, bug, ryg og skuldre, samt iltoptagelse, og konditionen blev beregnet.

Andet formål blev belyst med 1) gentagne målinger på de 19 bygningsarbejdere af håndgrebsstyrke og kondition i begyndelsen og slutningen af en 14-dages arbejdsperiode. 2) På de 421 blandede lønmodtagere blev den prædiktive værdi af lav muskelstyrke i hånd, bug, ryg og skuldre for muskelskeletbesvær 5 år senere, og for langtidssygefravær 10 år senere, analyseret i et registerstudie. Endelig blev 3) den prædiktive værdi af selvrapporteret muskelstyrke, bevægelighed samt forekomst, varighed og alvor af lænderygbesvær for frafald fra arbejdsmarkedet eller jobskifte fra ældreplejen efter 2 år, analyseret i et registerstudie blandt 5.696 nyuddannede SOSU-hjælpere og -assistenter.

**Resultater:** Studierne var inkonklusive mht. en mulig association mellem fysisk arbejdseksponering og fysisk kapacitet blandt lønmodtagere fra forskellige jobgrupper. På den ene side viste kohorten af 421 danske lønmodtagere ingen signifikante forskelle i relation til om arbejdet primært var ensidigt gentaget eller varieret. På den anden side peger den høje skuldermuskelstyrke blandt unge og ældre skraldemænd med hhv. lav og høj anciennitet på en mulig vedligeholdelses- eller træningseffekt af skraldearbejdet, specielt for skuldermusklerne (hypotese 1). Generelt var de største forskelle i fysisk kapacitet, forskellen mellem mænd og kvinder.

Niveauet af fysisk kapacitet målt som objektivt målt muskelstyrke og som selvrapporteret muskelstyrke og bevægelighed var ikke associeret med fremtidige tegn på fysisk nedslidning. Den fysiske præstationsevne blev ikke formindsket blandt 19 bygningsarbejdere efter 14 dage med lange arbejdsdage. Lav muskelstyrke blandt 421 lønmodtagere fra erhverv med og uden ensidigt gentaget arbejde prædikterede hverken muskelskeletbesvær efter 5 år eller langtidssygefravær efter 10 år. Lav selvvurderet muskelstyrke og bevægelighed prædikterede ikke ændret jobstatus efter to år. Funktionsnedsættelse pga. lænderygbesvær, og varighed af et lænderygbesvær indenfor de seneste 12 måneder prædikterede ændringer i jobstatus 2 år senere (hypotese 2).

**Diskussion:** Sammenlignet med effekten af køn og alder, synes arbejdseksponeringen at have en beskeden betydning for den fysiske kapacitet, både set i tværsnits- og prospektive undersøgelser. Resultaterne gav ikke noget klart billede af associationer mellem fysisk kapacitet og jobgrupper med forskellig fysisk eksponering. På den ene side viste kohorten på 421 danske lønmodtagere med og uden ensidigt gentaget arbejde ingen forskelle i fysisk kapacitet. På den anden side pegede den høje skuldermuskelstyrke blandt ældre skraldemænd med høj anciennitet på en mulig vedligeholdelses- eller træningseffekt af de fysiske eksponeringer i skraldearbejde. Det kan dog ikke udelukkes, at "healthy worker" effekten blandt de ældre, og en evt. tidlig selektion enten ind i eller ud af job blandt de yngre skraldefolk forklarer disse resultater. Niveauet af fysisk kapacitet målt som objektivt målt og selvvurderet muskelstyrke og selvvurderet bevægelighed prædikterede ingen senere tegn på fysisk nedslidning, hverken målt som nedsat fysisk præstationsevne, forekomst af muskelskeletbesvær, langtidssygefravær, frafald fra arbejdsmarkedet eller jobskifte. Længden og alvoren af et lænderygbesvær det seneste år var den eneste individuelle faktor, der prædikterede senere ændringer i jobstatus. Således var lænderygbesvær den eneste individuelle faktor med prædiktiv virkning på senere udfaldsparametre.

**Konklusion:** Overordnet viste tværsnitsstudierne, at mens generelle målinger på blandede grupper af lønmodtagere ikke viste nogen association, viste de job-specifikke tests af lønmodtagere med homogene eksponeringer i et vist omfang sammenfald mellem de fysiske eksponeringer i arbejdet og den fysiske kapacitet. Endvidere kunne hverken selvvurderet eller objektivt målt fysisk kapacitet prædiktere nogen fremtidige tegn på fysisk nedslidning, hverken i form af nedsat kapacitet eller testpræstation, muskelskeletbesvær, langtidssygefravær, jobskifte eller frafald fra arbejdsmarkedet. Varighed og intensitet af lænderygbesvær var således den eneste individuelle faktor med prædiktiv virkning på senere udfaldsparametre.

## List of papers:

This thesis is based on five papers. They will be referred to in the text by their roman numerals.

**Study I**
Schibye B, **Hansen AF**, Søgaard K, Christensen H. Aerobic power and muscle strength among young and elderly workers with and without physically demanding work tasks. Appl Ergon 2001; 32: 425-431.

**Study II**
**Faber A**, Hansen K, Christensen H: Muscle strength and aerobic capacity in a representative sample of employees with and without repetitive monotonous work.
Int Arch Occup Environ Health 2006;79: 33-41.

**Study III**
**Faber, A**., Strøyer, J., Hjortskov, N., and Schibye, B. Physical performance among construction workers with 12 hour workdays and extended workweeks.
Int. Arch. of Occ. and Environ. Health (2010) 83; 1-8.

**Study IV**
**Faber A**, Giver H, Strøyer J, Hannerz H. Are low back pain and low physical capacity risk indicators for dropout among recently qualified eldercare workers? A follow-up study.
Scand. J Publ. Health (2010) 38: 810-816.

**Study V**
**Faber A,** Sell, L., Hansen, J.V., Lund, T., Holtermann, A., Søgaard, K.: Does Muscle strength Predict Future Musculoskeletal Symptoms and Sick Leave?
E-pub. ahead of print, in Occup Med Oct. 19, 2011.

## List of abbreviations:

| | |
|---|---|
| CI | Confidence Interval |
| DWECS | Danish Work Environment Cohort Study |
| LBP | Low Back Pain |
| LTSA | Long-Term Sickness Absence |
| MRW | Monotonous Repetitive Work |
| MSD | Musculoskeletal trouble, pain or discomfort |
| OR | Odds Ratio |
| SHA | Social and Health care Assistant |
| SHH | Social and Health care Helper |
| $VO_{2max}$ | Maximal Oxygen uptake per minute |

# 1. Introduction

## 1.1 Theoretical framework

People need movement and physical strain in the right doses to maintain good health. Too light or too heavy physical loads may result in negative health effects. Too light loads decrease the physical stimulus of cartilage, ligaments, muscles and circulation, which is needed to preserve the tissues intact, whereas too heavy loads may deteriorate the tissues [1, 110].

In working-life, exposures are absolute. By tradition, the work environment is evaluated by external exposures, e.g. the weight of a burden, the number of lifts and the lifting situation [9]. According to Danish law, it is legal to lift 50 kg as one single lift under optimal circumstances (body position, handles, lifting height, and density of the burden). However, workers have individual resources, varying with gender, age, body size, and fitness level. Therefore, it is obvious that a 50 kg burden may feel heavier, even impossible to lift for a small, overweight 55-year-old female healthcare helper, compared to a slim, tall, and fit 25-year-old male construction worker. It has been well documented that workers with high physical work demands have elevated risk for impaired workability [3, 94, 119], musculoskeletal disorders [5], cardiovascular disease [74], ischemic heart disease and all-cause mortality [59], long-term sickness absence [80] and early retirement from the labour market [109].

The model in Figure 1 illustrates the association between the relative size of physical exposures and long-term effects on biological tissue. To avoid inappropriate loads, the exposure should be optimized (in figure 1 called: ”moderate active exercise”). “Moderate active exercise” is a broad definition of optimal load with adequate intensity, variability and restitution time between the work passes to create optimal conditions for tissue preservation and growth [1, 110]. Earlier studies on humans and animals tend to confirm the model. In real life, “little or no motion” can result in decreased aerobic fitness [102], decreased bone density [122], and decreased muscle and ligament strength [47, 83]. The long-term effects of “little or no motion” may be a lowered failure tolerance and thereby a higher risk for injury or trauma. Trauma can be defined as a continuum of injuries from minor tissue irritation to severe tissue damage [85]. Moreover, overuse and high peak loads (the right third of figure 1) may create trauma [85]. On the contrary, physical exercise in optimal doses (“moderate active exercise”) is shown to increase muscle strength and aerobic capacity [17, 101].

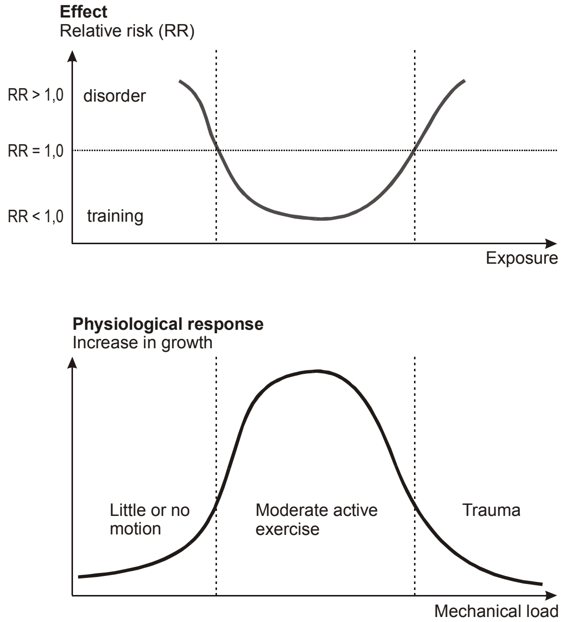


**Figure 1. Lower: Theoretical model of the association between mechanical load (e.g. compressions, traction or torsion forces on tissue response ("increase in growth"). Upper: Theoretical model of the association between exposure and long-term effects on biological tissue (Relative Risk for either training or disorder) [110].**

*Physical capacity* is influenced by a combination of the individual factors: gender, age, inheritance and physical fitness. In this thesis, physical capacity is measured as muscle strength, muscle endurance, aerobic fitness, balance and flexibility. Physical capacity is decisive for the *workability,* which reflects the relation between the capacity and demands of the worker. For example, the higher the peak performance, the less is the relative load of an absolute burden, and the higher is the safety margin (the distance between the applied load and the failure tolerance) [60-62, 91]. The importance of good workability is highlighted by the relation between low workability and several health-related measures like stress and burnout [53], chronic diseases [78], long-term sickness absence [87, 96, 109], early retirement from the labour market [2, 4, 5, 78, 79, 94], and all cause mortality [108].

During the 1990s, Danish politicians became increasingly aware that not only physically heavy work, but also monotonous repetitive work (MRW) could be a risk factor for *physical deterioration*, and they therefore prioritized reduction of MRW [51]. Physical deterioration is not a well-defined condition but covers different manifestations such as a gradual decrease of physical performance, gradually increasing musculoskeletal trouble, pain or discomfort (MSD), prevalence of sickness absence [60-62], job turnover, and possible early retirement [2, 78, 109]. Physical deterioration is particularly frequent in jobs with high and/or repetitive, monotonous physical loads, such as in the fishing, textile and electronic industries and the cleaning industry [2, 4, 5, 56, 67, 79, 94]. Physical deterioration is costly for the employee with respect to pain, sick-leave and fear of losing his/her workability and quality of life. It is also costly for society with respect to loss of productivity, expenses for long-term sickness absence and disability pensions.

Figure 2 models the relation between work exposure and the risk for future physical deterioration. It is assumed that the physical capacity (as one of several individual factors) modifies this relation: low physical capacity increases the risk for future deterioration, high capacity decreases the risk. A time-line of the manifestation of physical deterioration, initiated by a gradual decrease of physical performance (discussed in studies I, II and III), possibly followed by later MSD, sickness absence and early retirement (discussed in studies IV and V) was assumed.

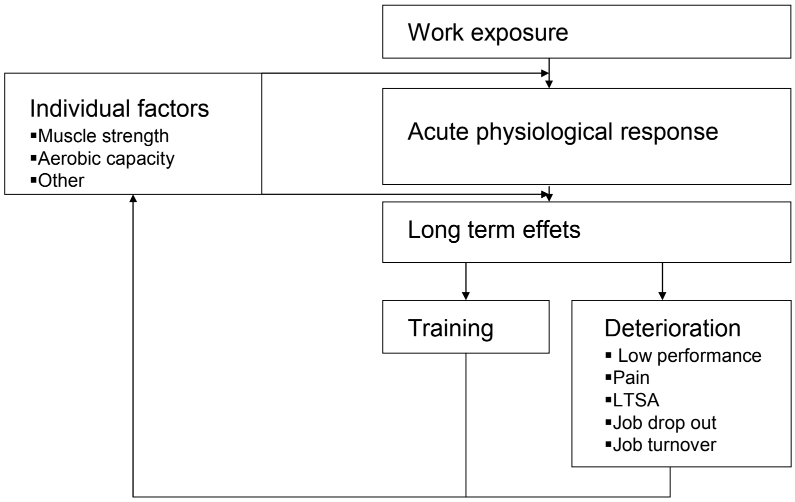


**Figure 2. Exposure-response model. The model indicates that individual factors, such as gender, age and physical capacity (and psycho-social factors as well) are significant for the acute physiological response as well as for the long-term effects on the musculoskeletal system (training or deterioration) of exposures from work [110].**

For decades, work environment interventions and research have mainly focused on minimizing physical work loads. However, these efforts have provided little or no effect on MSD, sick-leave or early retirement [120, 121]. Gaining more knowledge about the significance of physical capacity may potentially help optimizing the relation between work-load and work capacity, and thereby help creating better tools to minimize the risk for physical deterioration in the long term.
Whether the long-term effects of physical exposures are training, maintaining or deteriorative effects may depend on the relationship between physical workload and physical capacity [63, 88, 91], as well as the absolute size, accumulated dose and peak forces of the exposure, (exceeding or being below the failure limit of the tissue in question [21, 22, 66, 85]), the repetitivity of the job [85, 97], and the restitution time between the work days [72].
Earlier studies on the relationship between physical capacity and physical work exposures point towards a lower muscle strength among elderly employees with physically heavy work [68, 88-89, 90-91, 99, 104, 117]. However, studies on job specific exposures and capacities point towards a training effect of some jobs, resembling the effects of physical training, while other jobs apparently have a wearing effect on certain body parts [42, 105]. This may be explained by an inappropriate and unbalanced loading of the musculoskeletal system as a whole or of specific body parts [42, 105-107]. The main focus of this thesis is on jobs with physically heavy exposures.
Thus, the background literature presents a non-conclusive picture of the significance of physical capacity for physical performance and for future signs of physical deterioration.

## 1.2 Aim

This thesis has two purposes. To elaborate if the physical capacities vary with job exposures, and to study the significance of physical capacity for future signs of physical deterioration among Danish employees.

This thesis poses the following research questions:

1. Are differences in physical work loads reflected in the workers' physical capacity?
2. Are employees with low physical capacities at excessive risk for impaired physical performance, MSD, sickness absence, job turnover or job drop-out?

Research question 1 is explored in three cross-sectional studies (Studies I, II and III). Studies I and III look into physical performance among employees with physically heavy, varied work (waste collectors and construction workers), and study II looks into a representative group of Danish employees [23] with varied and monotonous work.

Research question 2 is explored in three prospective studies (Studies III, IV and V). Study III investigates changes of physical performance during long working hours and extended workweeks among construction workers in a very short time perspective (14 days). Study IV explores 90 % of all Danish healthcare helpers and assistants, who graduated in 2004, in a two-year perspective, and study V explores the subgroup from Study II in a 5 and 10-year perspective. Study IV and V are register studies, in which physical capacity at the time of measurement is used as a predictor for later MSD, sickness absence, job turnover and drop-out.

## 1.3 Hypotheses

More specifically, the hypotheses of this thesis are:

1. There is a positive association between job exposures and physical capacities
2. Low physical capacities predict future physical deterioration

2. a. Low physical capacities predict decline in physical performance, future musculoskeletal disorders and sickness absence as well as in future job turnover and job drop-outs

# 2. Materials and methods

## 2.1 Study populations and designs

Four cohorts were used in five studies: Waste collectors in Study I, a subsample from the Danish Working Environment Cohort Study (DWECS) in studies II and V, construction workers in study III, and recently educated SHHs and SHAs in Study IV. Table 1 gives an overview of baseline measurements, and the time-span of follow-up measurements.

**Table 1. Baseline and follow-up measures in the 4 cohorts.**

| | Hand grip strength | Shoulder and trunk muscle strength | Aerobic capacity | Alternative measures of physical capacity | Outcome measures |
|---|---|---|---|---|---|
| **Study I**<br>47 Waste collectors<br>54 Controls | Baseline | Baseline | Baseline | | Hand grip strength<br>Shoulder and trunk muscle strength<br>Aerobic Capacity |
| **Study II**<br>421 Mixed employees | Baseline | Baseline | Baseline | | Hand grip strength<br>Shoulder and trunk muscle strength<br>Aerobic Capacity |
| **Study III**<br>19 Construction workers | Baseline<br>After 1 day<br>After 14 days | | Baseline<br>After 1 day<br>After 14 days | Baseline<br>After 1 day<br>After 14 days | Hand grip strength<br>Aerobic Capacity<br>Alternative measures of physical capacity |
| **Study IV**<br>5,696<br>Health care workers | | | | Baseline | Job status<br>National registers after 2 years |
| **Study V**<br>421 Mixed employees | Baseline | Baseline | Baseline | | Musculoskeletal disorders<br>Long-term Sickness Absence<br>National Registers after 5 and 10 years, respectively |

### Study I

The waste collectors from study I are a sub-population of 47 participants recruited from a national cross-sectional survey on work conditions and health among waste collectors, employed in Denmark in 1994 (N=2,303) [64, 65]. The survey was initiated to give priority to future action plans and regulatory needs. Waste collection was characterised as physically heavy, with much lifting, pushing, pulling, standing, walking, and stair-climbing. At that time, nearly 80% of the collection units were sacks and containers without wheels (buckets). The participants in study I were recruited from 3 companies in suburban Copenhagen, which fulfilled the criteria for employing young employees (less than 30 years) with short seniority (less than 2 years) as well as elderly employees (more than 45 years) and long seniority (more than 20 years). Age, gender and seniority matched control groups without physically heavy work were extracted from the DWECS based on the subsample of 421 mixed employees on whom identical physiological measurements had been performed (see below) [24, 36]. The selection criteria for the exposure of the control groups were the answer either \`seldom´ or \`never´ to the question: "Is your work so physically demanding that your breathing rate is affected?" Data on the participants are shown in table 2.

**Studies II & V**

The Danish National Working Environment Cohort (DWECS) is an ongoing National survey on approx. 10,000 randomly selected Danish citizens. It was initiated in 1990, where a random sample of 10,703 members of the Danish population between 18 and 64 years of age were interviewed. Since then, approx. 10,000 Danish employees have filled out an extensive questionnaire every fifth year [20, 23]. DWECS provides information about physical work exposures (time of workday with standing, walking, lifting etc.) as well as musculoskeletal disorders of several body regions (e.g. low back, neck/shoulder, knee) by a modified version of the Nordic Questionnaire [75].

In the 1995 survey, 4,194 participants (75%) agreed to be physically examined for further measurements. For this purpose, a random sample of 839 was made. The sample was equally divided into males and females, employees having varied or monotonous repetitive work, and divided in three age groups, of which the young and the elderly groups are reported here. In this way we wanted to assure that the "average Danish employee" in regard to gender and age could be estimated. The work of each participant was categorized as being repetitive or varied based on the answers to the following questions:

1) "Does your work require that you repeat the same work tasks many times per hour?"

The question could be answered: "Almost all working hours"; "Approx. ³/4 of working hours"; "Approx. ½ of working hours"; "Approx. ¼ of working hours"; "Seldom/very little"; "Never".

2) "Is your work varied?"

This question could be answered: "Very much"; "To some extent"; "Not much"; "No, or only very little".

The work of each participant was categorized as being repetitive if the answer was "Almost all working hours" or "Approx. 3/4 of working hours" to the first question and "Not much" or "No, or only very little" to the second [40].

The employees classified as having monotonous repetitive work included service jobs and manual jobs: butchers, clerks, assembly line workers, skilled and unskilled workers in the electronic and metal industries, workers in the fishing industry, and workers in the leather and textile industries. Employees with varied work included academics, employees in the human and healthcare sector, managers, manual jobs, and teachers.

Due to missing address or unable to contact (n=98), refused participation (n=169), not showing up, cancelling appointment (n=105) or exclusion in case of self-reported or measured elevated resting blood pressure, angina pectoris, previous disc prolapse, use of heart or lung medicine or musculoskeletal pain in the specific body region on the test day (n=46), 421 subjects (213 men and 208 women) participated in the measurements.

For the analyses in study V, the sample was divided into groups according to gender, and the respective 25th percentiles of muscle strength were calculated. Workers with less strength than the 25th percentile (the lowest quartile) were defined as having low muscle strength. Separate analyses were performed on muscle strength in 1995 and the two outcomes: self-reported MSD in 2000 and LTSA in a 10-year follow-up period. The Cox proportional hazard model [26] was used for modelling the probability of LTSA in the period 1996-2007, and logistic regression was used to model MSD in 2000. Data on the participants are shown in table 2.

**Study III**
The construction workers from study III were recruited from a sub-population from a larger questionnaire (N=509) on work environment and health among construction workers on large transportation infrastructure projects [84]. The work environment in the construction industry and particularly in large construction projects such as construction of bridges or metros is physically demanding comprising heavy lifting and carrying, pushing and pulling, sudden loadings and vibrations as well as awkward work postures, e.g. static full forward flexion of the trunk during reinforcement work [27, 52]. During the past 25 years, many construction workers have been employed on large scale construction projects in Denmark (Great Belt Bridge, Øresund Bridge and the Copenhagen Metro).
The participants were recruited from two metro construction sites in Copenhagen with work schedules of 12-hour workdays, two weeks at work and two weeks off duty. The two sites were in the last phase of construction, meaning that most working hours were spent on reinforcement work and shuttering. We informed all workers (n=51) about the project, 28 accepted to participate and 25 fulfilled the inclusion criteria. Their mean seniority as construction workers living in building site camps was 7.3 years (range 2-15 years). Due to medical reasons before and during the tests, 6 persons were excluded. In all, 19 male construction workers performed the physiological tests four times in total during the two work weeks, in the morning before work and in the evening after work on the second and on the next-to-last workday. There were no measurements on the first and the last workdays to reduce possible bias from change of sleeping habits and social behaviour in connection with shift between a work period and a duty free period. The 19 participants did not differ from the rest of the survey by age, height, weight or body mass index (BMI). Data on the participants are shown in table 2.

**Study IV**
The healthcare workers from study IV were recruited among all SHHs and SHAs in Denmark, who graduated in 2004 (N= 6,347) [37]. In Denmark, healthcare workers are divided into SHHs with 14 months of education and SHAs with additionally 20 months of education. SHHs are trained exclusively to work in the eldercare sector while SHAs are trained to work primarily in the eldercare sector but also, on a limited scale, in healthcare in general. All 28 Danish colleges training SHAs and SHHs were invited to participate in the study: 27 colleges (6,347 trainees) agreed to participate. The baseline questionnaire on individual factors, social situation, educational level, physical/mental health and resources, and lifestyle, was handed out to all 6,347 students during 2004, just before they finished their training. A total of 5,696 (90 %) responded.
After graduation, the SHHs and SHAs will most probably experience the tough exposures of the healthcare sector. Generally, healthcare workers are exposed to many sorts of strenuous mechanical loads, often varying with the acute condition of the patients they nurse. Awkward, rotated, and flexed work postures take place during patient handling and patient care, and in the eldercare, cleaning may be carried out in difficult accessible spaces. Moreover, patient handling situations frequently involve sudden exposures, which further increase the load of the worker's low back [7, 34]. However, the physical exposures for the population in study IV were not described in 2004, as they were still training. Physical exposures one year after graduation are described elsewhere [37]. Two questions on physical capacity and two questions on low back pain from the baseline questionnaire were used as possible predictors for future job status. A register study was made two years after graduation (Study IV).

**Table 2. Data on the participants in studies I–V.**

| Study | Participants | Age mean (range) | BMI Mean (range) |
|---|---|---|---|
| Study I | 47 M waste collectors<br><br>54 M control group without physically heavy work | Y: 25 (19-32)<br>E: 54 (47-64)<br><br>Y: 25 (19-30)<br>E: 56 (49-63) | 24 (19.5-30.4)<br>30.1 (19.2-38.5)<br><br>23.9 (18.3-38.0)<br>26.6 (20.7-34.4) |
| Study II & V | 421 employees of mixed occupations | 40 (18 – 64) | F: 24.1 (17.2-40.5)<br>M: 25.6 (17.4-36.5) |
| Study III | 19 M construction workers | 39 (27-50) | 26 (20-33) |
| Study IV | 5,696 F healthcare workers | 33 (16-64) | 24.4 (13.7-67.4) |

Y=young, E=elderly, F=female, M=male

Five different registers were used to obtain information about the participants' attachment to the labour market, educational status, association to trade, and information about emigration and deaths two years after graduation. The study sample was subsequently divided into 5 outcome groups describing the participants' attachment to the labour market in 2006: 1) eldercare sector (homecare or nursing homes for the elderly) (63 %); 2) other health and welfare sectors such as work in kindergartens or hospitals (13 %); 3) all other sectors (7 %); 4) participants under education (12%); and 5) participants outside the labour market (not registered with an industrial code but with a socio-economic status such as unemployed, receiving cash benefit, rehabilitation allowance or early retirement pension, or other forms of social transfer payments) (5 %). For description in more detail, see Giver et al., 2010 [45]. Data on the participants are shown in table 2.

## 2.2 Performance-based physical capacity

Physical capacity was objectively measured in studies I, II and III. All participants matching the target group of each of the cohorts were informed about the project. After the participants agreed to participate by signing a written informed content, they were interviewed prior to the first measurements about their general health status and musculoskeletal symptoms for the last seven days and had their blood-pressure measured.

All measurements were approved by the local Ethics Committee. Participants were excluded in case of excessive blood pressure, angina pectoris, pregnancy, fever, previous disc prolapse, use of heart or lung medicine [8], or considerable pain in the body regions to be tested.

### 2.2.1 Maximal muscle strength

In studies I and II, maximal isometric muscle strength (MVC) was measured for back extension and flexion, shoulder elevation, shoulder abduction and handgrip. In study III, only the hand grip strength was measured. The standardized measurements are proven valid and reliable [11, 12, 35, 51]. For each muscle group, the measurement was performed at least three times with 30 seconds restitution. If the third registration was more than 5% higher than the higher of the previous two registrations, a fourth test was performed. A maximum of 5 tests were performed.

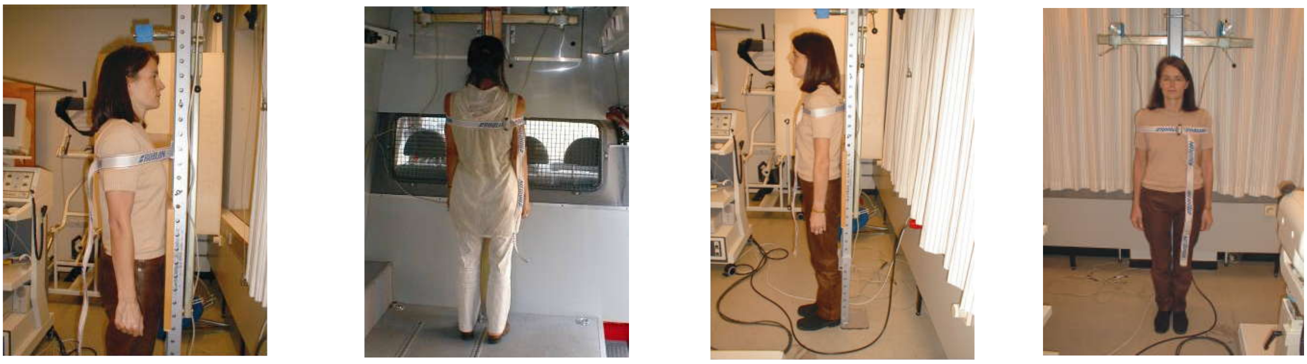

**Figure 3. Set-up for measurement of maximal trunk extension (left) and trunk flexion (right).**

The participant was instructed to build up the force over 5 seconds, then to keep the tension for about 2 seconds and finally to lower the force to zero. The highest value obtained during a one second period was used. Verbal encouragement was given when found optimal.

**Maximal trunk flexion / extension**

The participant was standing in an upright position with a strap around the shoulders at the level of the insertion of the deltoid muscle (Figure 3). The strap was horizontally connected to a strain gauge dynamometer. For MVC of the back extensor muscles, the participant was facing the dynamometer with the pelvis against a plate placed with the upper edge aligned with the iliac crest of the participant. In this position, a maximal isometric back extension was performed [12]. Correspondingly, for MVC of the abdominal muscles, the participant was placed with the back towards the dynamometer and the pelvis against the plate. In this position, a maximal isometric back flexion was performed. The vertical distance between the L4/L5 level and the middle of the strap was measured for torque calculation.

**Figure 4. Set-up for measurement of maximal shoulder abduction (left) and shoulder elevation (right).**

**Shoulder elevation / abduction**

The participant was placed in a specially designed chair adjustable in height so that the participant's feet had no contact with the floor. For MVC of the shoulder elevation muscles, the participant's arms were hanging vertically without support (Figure 4). Two Bofors dynamometers were placed bilaterally 1 cm medial to the lateral edge of the acromions [67, 112]. In this position, the participant performed a bilateral maximal shoulder elevation and the highest value registered for each side was used. The distances from the dynamometers to the sternoclavicular joints were measured for calculation of the torques.

For MVC of the shoulder abduction muscles, the elbows were flexed 90 degrees with the upper arms in vertical position. Two Bofors dynamometers were placed bilaterally 1 cm proximal from the elbow joints. In this position, the participant performed bilateral maximal shoulder abduction and the highest value registered for each side was used [15]. The distances from the two dynamometers to the acromions were measured and a subtraction of 5 cm was used to estimate the lever arm for shoulder abduction torque calculation [93].

**Figure 5. Set-up for measurement of maximal hand-grip strength.**

**Hand grip strength**

The maximal handgrip strength of the dominant side was measured in a sitting position with the elbow flexed 90 degrees and the upper arm in vertical position (Figure 5). A Jamar dynamometer was used, preset for the suitable hand size [15, 35, 39].

**2.2.2 Other objective measurements**

In studies I, II and III, a bicycle ergometer test was performed, and furthermore, a muscle endurance test, two tests of motor control, and a balance test were performed in study III.

**2.2.2.1 Maximal oxygen uptake**

In studies I and II, the aerobic power was estimated indirectly by use of a submaximal test on a bicycle ergometer (Monarc 864, Sweden). The maximal oxygen consumption rate ($VO_{2max}$) was estimated from work intensity and the heart rate (Sport tester, Polar Electro, Finland) measured in the sixth minute according to the nomogram of Åstrand and Rhyming [14] and corrected for age according to Åstrand [13]. The workload was set between 50-75% relative workload (validated from the heart rate increase above resting level) where the validity of the test is found to be highest [13]. The participants were told to stop if they felt uncomfortable. In addition to the absolute $VO_{2max}$, the aerobic power was calculated as the absolute $VO_{2max}$ divided by the participant's weight.

In study III (Figure 6), the bicycle test included three sub-maximal loads. The first two workloads (a 6-minute load of 84 watts followed by a 3-minute load of 119 watts) were identical for all participants. Work intensity and HR measured in the 6th minute were used for calculation of maximal oxygen consumption rate according to the nomogram of Åstrand and Rhyming [14] and was identical to the tests in studies I and II. The last 3-minute load was individually adjusted, depending on the HR responses during the first 9 minutes of the test. The purpose was to optimise the linear correlation between the increase in the workload and the increase in the HR.

To evaluate the relative workload during the workdays, heart rate was registered continuously throughout the two test days.

**Figure 6. Construction worker performing bicycle ergometer test in an office on the construction site.**

## 2.3 Alternative measures of physical capacities

### 2.3.1 Alternative performance-based physical capacities

In study III, motor control, flexibility and fatigue were evaluated by four tests. Motor control was tested by a balance test in sitting position on a wobble board placed on a table [86, 114]. Furthermore, the ability to react to a sudden loading of the back was measured in a set-up in which a standardized horizontal force was suddenly applied to the upper part of the participant's trunk in a forward direction [111]. Flexibility of the spine was measured by maximal forward and lateral bending mobility of the spine (finger-to-floor test) measuring the finger to floor distance in maximally forward and laterally flexed position standing with straight legs [44, 98, 114, 116].
The tests chosen to be functional according to the exposures of construction workers are described in detail in study III and will only be briefly mentioned here.

### 2.3.2 Self-assessed physical capacity

Physical capacity was self-assessed in study IV. Physical capacity was self-rated on five Visual Analogue Scales (VAS) of 100 mm with illustrations and verbal anchors for the extremes on muscle strength, muscle endurance, flexibility, aerobic fitness, and balance (figure 7).
The participants were asked:" How would you score the following components of physical fitness in relation to people of your own age and gender?" The participants made a vertical mark on each horizontal line to assess each of the physical fitness components. The method has been proven valid by Strøyer, who tested self-rated muscle strength from 935 women and men towards objective measurements of trunk flexion and extension strength and found a good correlation (ICC=0.80). The correlation of flexibility was fair (ICC=0.68) [114].

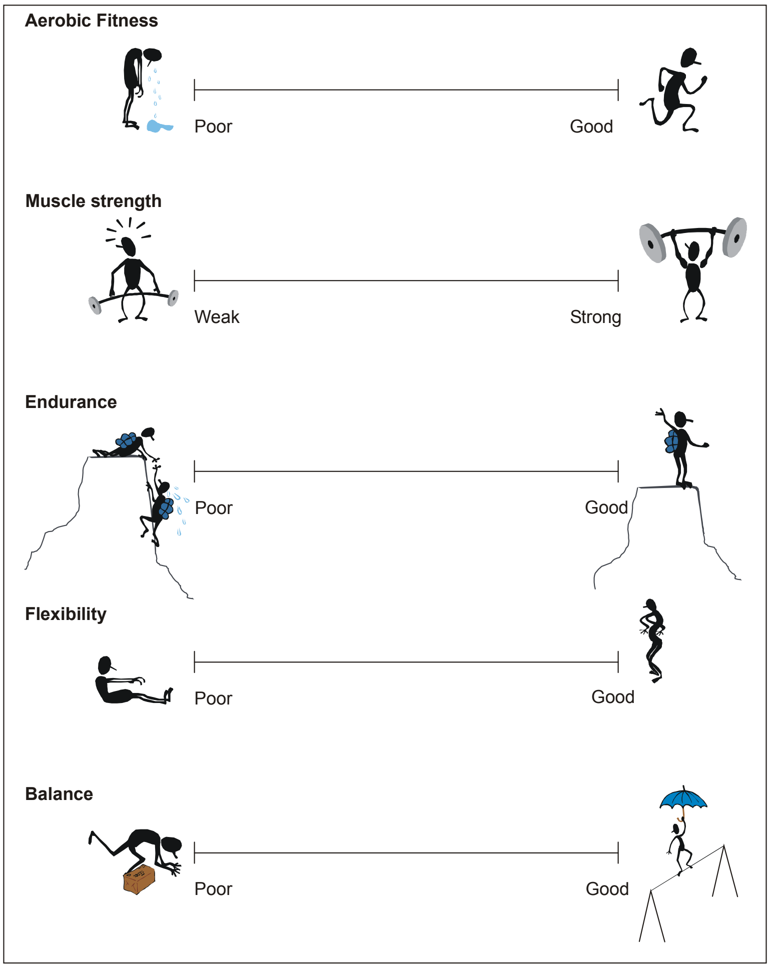


**Figure 7. The self-assessment Visual Analogue Scale used in the questionnaire of study IV.**

### 2.3.1 Muscle strength and flexibility

Self-assessed muscle strength and flexibility were chosen out of the five physical capacity parameters based on the following criteria: Both parameters are highly relevant for matching high mechanical exposures during patient-handling and care, they showed acceptable validity, and they showed low inter-item correlation [115]. The self-rated physical capacity was classified as: Low: 0-24.99 mm, medium: 25-74.99 mm, high 75-100 mm. High level of strength and high level of flexibility were chosen as reference levels.

## 2.4. Self-reported musculoskeletal trouble, pain or discomfort

### 2.4.1 Self-rated low back pain

In study IV, Low Back Pain (LBP) was self-rated by the following questions from the Nordic Questionnaires [75] and the DWECS [20, 23]: to measure the duration of low back pain a): "What is the total length of time that you have had low back trouble (pain or discomfort) during the last 12 months" (0 days, 1-7 days, 8-30 days, more than 30 days but not every day, every day); to measure disability due to low back pain: b) "Have you at any time during the last 12 months been prevented from doing your normal work (at home or away from home) because of the trouble (pain or discomfort) ?" (Yes/no); and c) "On a scale of 0 to 9 with 0 being no discomfort at all and 9 being the worst possible pain, state your average degree of discomfort in your low back in the last 3 months". The questions have been proven valid and reliable [31, 75]. Two items (questions a and

b) with low inter-item correlation which describe LBP as broadly as possible by as few variables as possible were chosen for the statistical analysis. Question c was left out after a correlation analysis showing a large overlap between the answers to questions c) and a) (r=0.88). Questions a) and b) were selected for their low inter-item correlation (r=0.44). Thus, two items were chosen to describe elements of frequency, intensity, duration and disability due to LBP during the last 12 months. Zero days of LBP and no disability due to LBP were assessed to be reference levels.

**2.4.2. Other items of self-reported musculoskeletal trouble, pain or discomfort**
In study V, other items of self-reported musculoskeletal trouble, pain or discomfort were self-rated by the following questions from the DWECS 1995: "Have you had symptoms (pain or discomfort) in your low back / neck / shoulder / wrist/hand within the last 12 months?" (yes/no). Data on the MSD in 1995 were followed up in 2000 by the question: "Please indicate the average degree of symptoms (pain or discomfort) in your low back, neck/shoulder and wrist/hand symptoms within the last three months on a scale from 0 to 9. Zero indicates no symptoms at all and 9 indicates the worst possible pain", earlier proven valid and reliable [31, 75]. Pain levelled 3 or more was defined as musculoskeletal disorders.

## 2.5 Outcome measures

Outcome measures are shown in table 1. Altogether they describe the time perspective of the 5 studies from physical performance in different job groups in cross-sectional study designs (studies I, II and III), changes in physical performance associated with physically heavy work in a very short follow-up study (study III), changes in musculoskeletal pain, long-term sickness absence and change of job status as possible long-term effects of physical deterioration (studies IV and V).

## 2.6 Statistical methods

Student's T-test was used to compare group means (studies I and II).
Mann-Whitney's test was used to compare data, which were not normal distributed (study II).
Pearson's correlation coefficient was used to describe correlations between physical capacities (study II).
Chi square colloquial was used to compare the distributions of categorized variables (study II).
One and two way MANOVAs were used to compare outcome variables between groups (study I).
Linear regressions were used to examine for connections between physical capacities and other background data (study II).
A general linear model (3-way ANOVA) was used to test effect of workday and effect of work period as fixed factors and participants as random factors (study III).
Logistic, Multivariate and Cox regressions were used to analyse associations between muscle strength / flexibility / muscle skeletal pain with later outcomes: pain, long-term sickness absence or later job status (studies IV and V).
In all cases, the chosen statistical significance level was P=0.05, except for the analysis of the two questions in study IV concerning duration and severity of LBP. Since the two questions concerning LBP deal with two overlapping concepts, we used a Bonferroni-correction. Hence, each of these two items was tested at p=0.025 level.

# 3. Results

This section presents the results. First the hand strength, which is measured as a baseline measurement in studies I, II and III, then trunk and shoulder muscle strength, which is measured in studies I and II, and finally the aerobic capacity, which is measured in studies I, II and III. Secondly, repeated measurements of identical tests from study III are presented as short-term follow-up measurements. Finally, 2, 5 and 10-year register follow-up measurements from studies III, IV and V are presented.

## 3.1. Baseline strength measurements

### 3.1.1. Hand grip strength

The hand grip strength is measured with the same method in studies I, II and III.
In study I, 44 waste collectors were compared with 46 employees without physically heavy work.
In study II, 213 males and 208 females were divided according to work exposures (having repetitive, monotonous work versus varied work) and age: young: 18-29 years, medium: 30-44 years and elderly: 45-64 years. Results from the young and the elderly groups are reported here. In study III, the 19 construction workers were not divided into age groups. Their mean age of 39 (27-50) years was somewhat overlapping the age groups in studies I and II.
Figure 8 presents the hand grip strengths of waste collectors; their gender, age and seniority matched comparison groups; mixed male and female employees with varied and repetitive work; and construction workers. The hand grip strengths within the same age or gender groups are similar regardless of job type, with young men ranging between 549 and 574 N being approx. 10% stronger than elderly men. Elderly men ranged between 492 and 517 N being around 30% stronger than women (lowest: 330 among elderlies with varied work; highest: young with varied work). The mean strength of the construction workers are similar to the young men of studies I and II, ranging from 334 to 668 N.

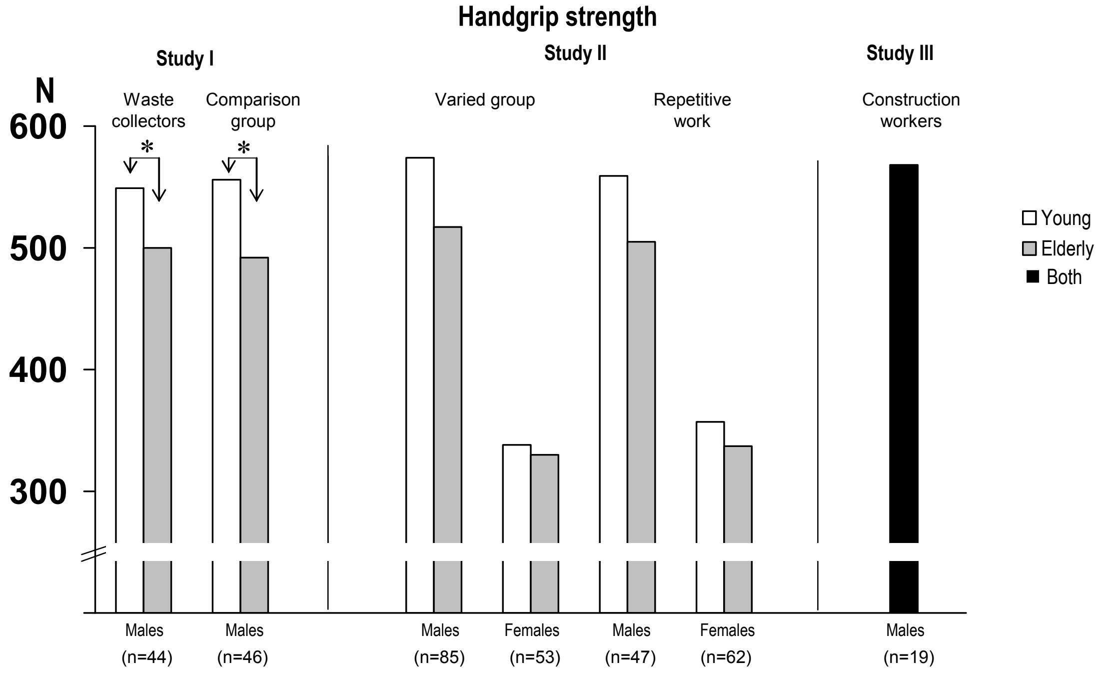


**Figure 8. Handgrip strength (mean values) measured in studies I, II and III. * refers to significant differences.**

### 3.1.2 Trunk muscle strength

The trunk muscle strength is measured with the same method in studies I and II.
Figures 9 and 10 present the trunk muscle strengths of waste collectors; their gender, age and seniority matched comparison groups; and mixed male and female employees with varied and repetitive work.
The overall picture of back flexion strength (Figure 9) shows a slightly higher strength among younger men compared to elderly men. The back extension strength has no clear age relation (Figure 10). The largest difference is between men and women, i.e. men being almost twice as strong as women.
In study I, the back extension strength was significantly higher among young waste collectors than among young employees in the comparison group.
In study II, comparisons of the results between employees of the same age and gender showed no significant differences between employees with varied work and employees with repetitive monotonous work. There was a non-significant tendency towards higher back extension strength among males with varied work compared with males with repetitive monotonous work, which was not present in the female group.

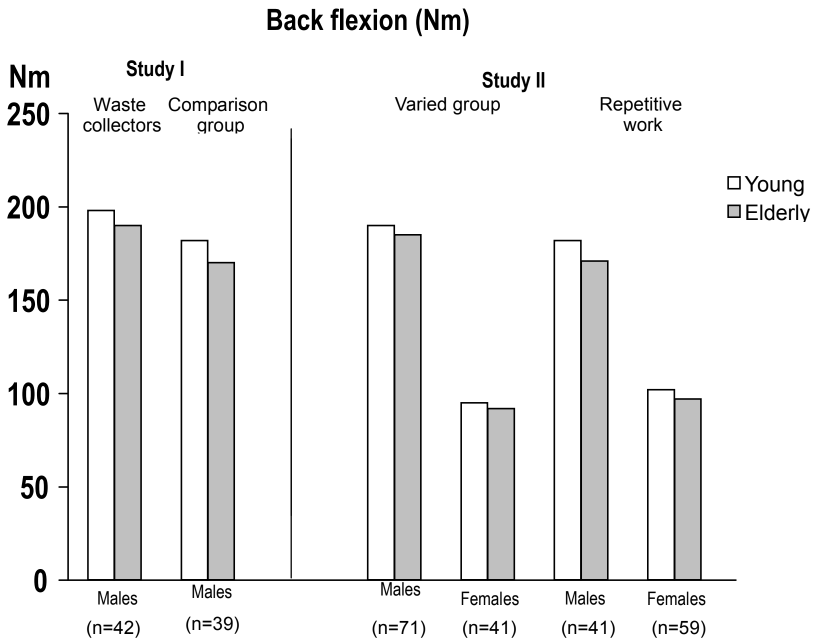


**Figure 9. Back flexion strength (abdominal muscles) (mean values) measured in studies I, II and III. * refers to significant differences.**

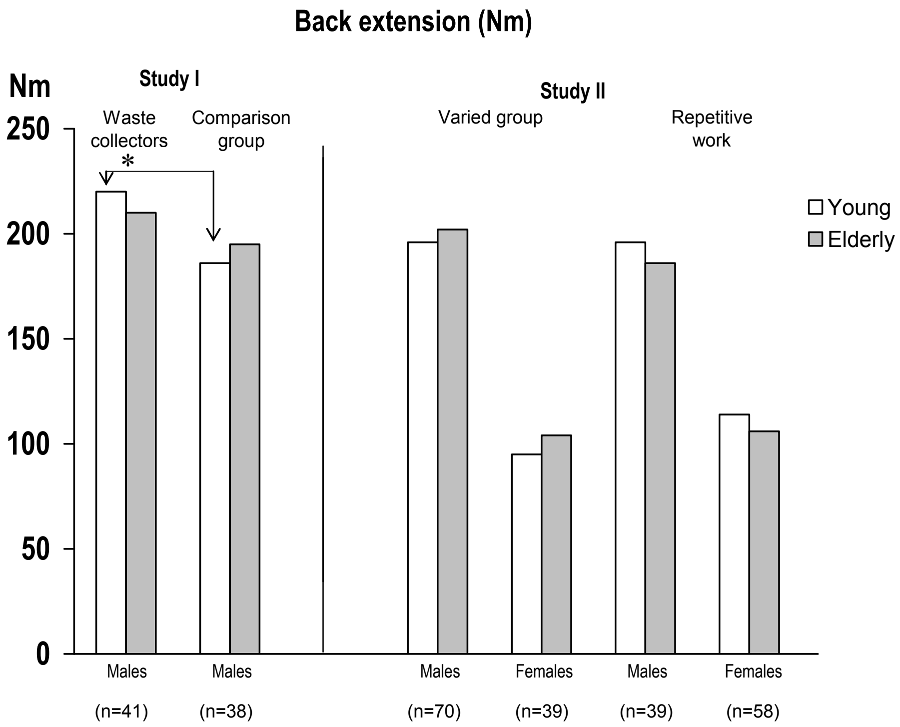


**Figure 10. Back extension strength (back muscles) (mean values) measured in studies I, II and III. * refers to significant differences.**

### 3.1.3 Shoulder muscle strength

The shoulder muscle strength was measured with the same method in studies I, II and III. Figures 11 and 12 show shoulder muscle strength of waste collectors; their gender, age and seniority matched comparison groups; and mixed male and female employees with varied and repetitive work.

The overall picture of both shoulder elevation and abduction shows higher strength among younger men than among elderly men. The largest difference is between men and women, men being almost twice as strong as women.

In study I, there are no tendencies to an age-related decrease of shoulder elevation and shoulder abduction among the waste collectors. In the comparison group, the strengths of the elderly men are lower than among the young men. The shoulder muscle strengths of the elderly waste collectors are higher than the strengths of the elderly comparison group.

In study II, comparisons of the results between employees of the same age and gender showed no significant differences between employees with varied work and employees with repetitive monotonous work. There was a non-significant tendency towards higher shoulder elevation strength among males with varied work compared with males with repetitive monotonous work, which was not present in the female group.

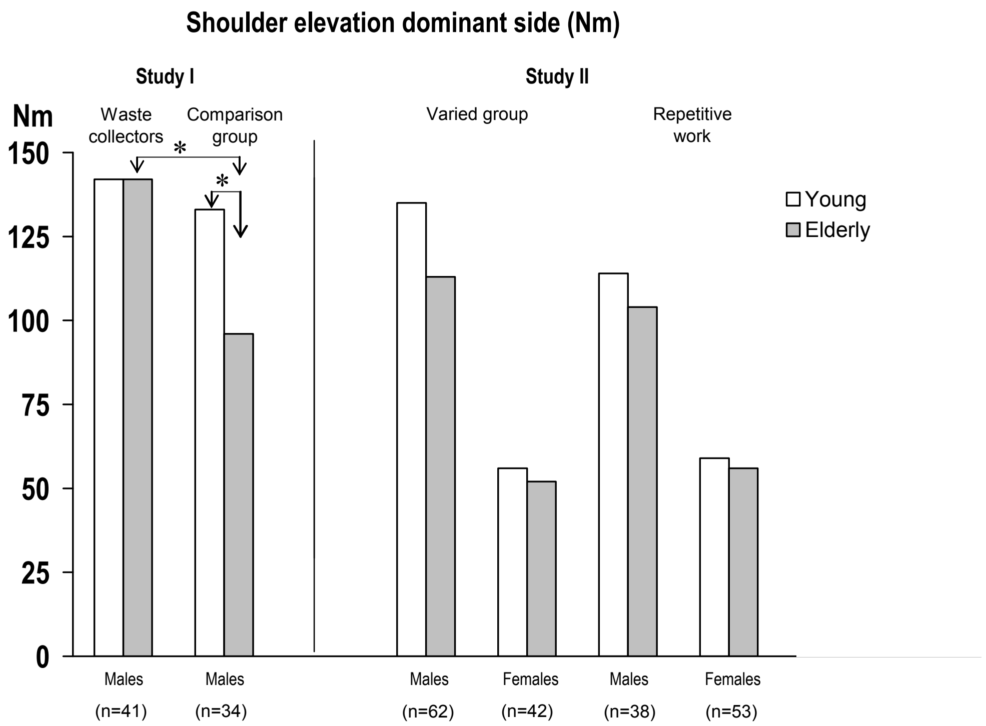


**Figure 11. Shoulder elevation strength (mean values) measured in studies I and II. * refers to significant differences.**

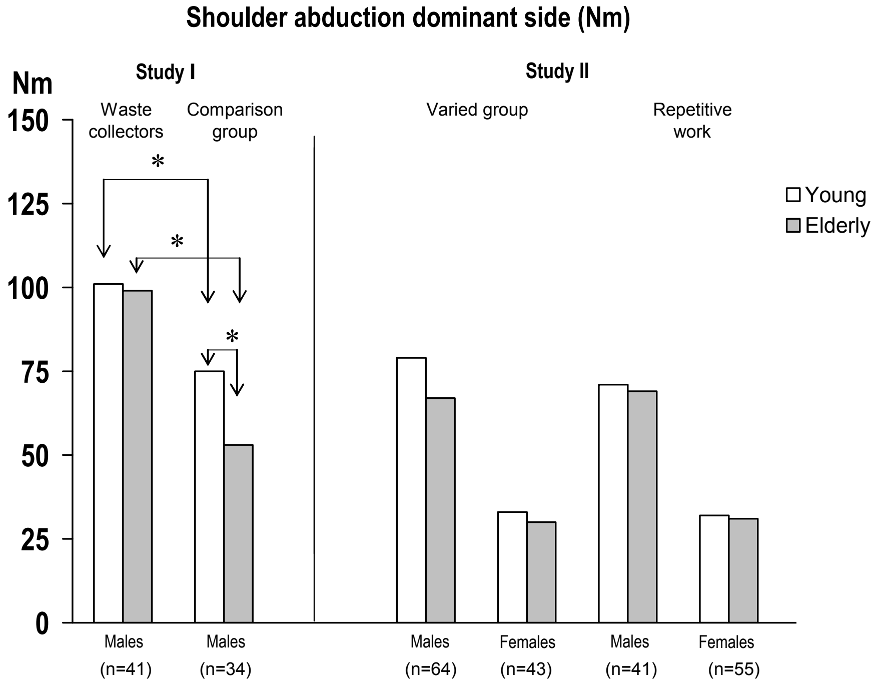


**Figure 12. Shoulder abduction strength (mean values) measured in studies I and II. * refers to significant differences.**

### 3.1.3 Waste collectors versus their comparison group

In study I, detailed analyses of differences by job or by age were made. A Manova test was performed on all the muscle strength parameters as a whole. It showed that work, but not age, had a significant effect on muscle strength. To sum up the analyses on the different muscle groups: For both the waste collectors and the comparison group, significantly lower values (approx. 10%) of handgrip strength were found for the elderly group compared with the young group. With respect to the waste collectors, this is the only measured muscle strength that is lower in the elderly group compared with the young group. In contrast to this, significantly lower values (approx. 30%) were found for shoulder abduction and elevation for the elderly comparison group compared with the young comparison group.

When comparing waste collectors with the comparison group, a general tendency to larger muscle strength is found for both the young and the elderly waste collectors, showing significant differences for back muscles in the young groups, shoulder elevation in the elderly groups, and shoulder abduction for both age groups.

## 3.2 Aerobic capacity

The aerobic capacity is measured with the same method in studies I, II and III.

Figures 13 and 14 present the absolute aerobic capacity ($VO_2max$ $lO_2/min$) and the aerobic power ($VO_2max$ $mlO_2/kg*min$) among waste collectors; their gender, age and seniority matched comparison groups; mixed male and female employees with varied and repetitive work; and construction workers.

The overall picture of both the absolute aerobic capacity and the aerobic power is a higher aerobic capacity among young employees of both genders than among elderly employees. The difference

between men and women concerning absolute aerobic capacity is ruled out in the aerobic power calculation, where the female data are 90-99 % of the male data.
In studies I and II, comparisons of the results between employees of the same age and gender showed no significant differences between employees of different job groups.

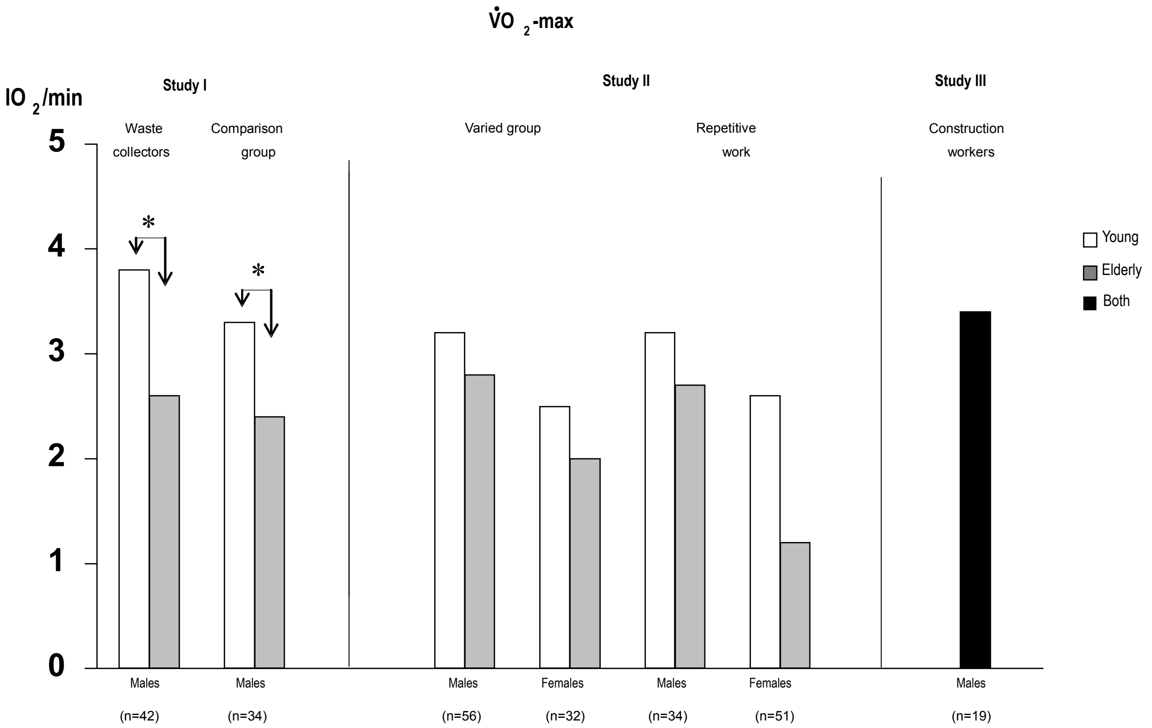


**Figure 13. Aerobic capacity ($VO_2max$ $lO_2/min$) estimated from a submaximal Åstrand test [14] performed in studies I and II. * refers to significant differences.**

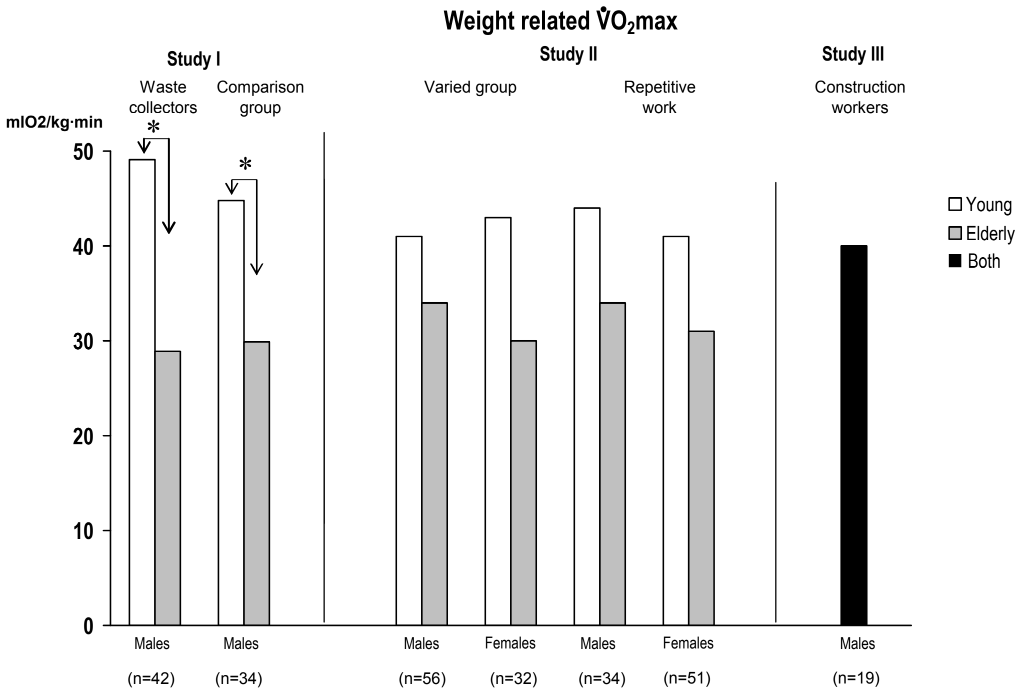


**Figure 14. Aerobic power ($VO_2max$ $mlO_2/kg*min$) calculated from the submaximal Åstrand test [14] performed in studies I, II and III. * refers to significant differences.**

### 3.3 Objective measurements with short-term follow-up

In study III, identical tests were performed on 19 male construction workers in the morning before work and in the evening after work on the second and the next-to-last workdays. The purpose was to measure performance changes after long workdays and long work periods. Figures 15 and 16 show a selection of the results.

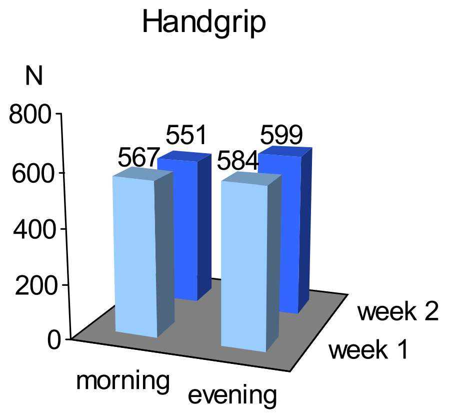


**Figure 15. Hand grip strength (N) in the mornings and the evenings of the second and next-to-last workdays. Data from study III.**

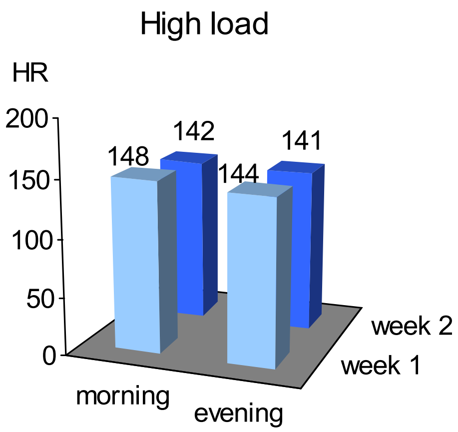


**Figure 16. Steady state heart rates from the highest of 3 loads of the bicycle ergometer test. Data from study III.**

There was a significant effect of workday (p=0.022) for the heart rate at the highest of 3 loads (shown in figure 16), showing a reduced heart rate in the evenings compared with the mornings. The effect of a work period was significant for all three work loads. The heart rates were lower at the end of the work period (day 11) compared to the beginning (day 2)(p=0.028 (low work load), p=0.004 (medium work load), p=0.004 (high work load)).

The overall picture of results from study III is that the performance did not decrease after a workday or after a two-week work period. On the contrary, several parameters (hand grip strength, heart rate response to a fixed workload, as well as the motor control, flexibility and fatigue tests) showed a trend towards improved performance throughout the four test sessions.

There were no statistical differences between the relative workload throughout the second workday (mean heart rate = 90, mean workload = 25 % (range 14-56 %)) and the next-to-last workday (mean heart rate = 89, mean workload = 23 % (range 14-37 %)).

## 3.4 Muscle strength and future musculoskeletal trouble, pain or discomfort

Table 3 presents the risk of MSD in 2000 from having low muscle strength (lowest quartile) in different body regions in 1995 (Study V). The estimated Odds ratio for MSD in the neck/shoulder region for those having low muscle strength in shoulder abduction was 1.39. However, neither this nor the effect on MSD of low muscle strength in any of the other muscle regions was statistically significant.

**Table 3. Frequencies of MSD among workers with low and high muscle strength, and Odds ratios and confidence intervals of MSD in 2000 from having low muscle strength in 1995. Data from study V.**

| | Frequency of MSD % | | Risk for MSD | | |
|---|---|---|---|---|---|
| | Low strength | High strength | n* | Odds ratio | 95% CI |
| Trunk extension | 9.09 | 12.56 | 300 | 0.78 | 0.32 – 1.92 |
| Trunk flexion | 11.25 | 12.05 | 304 | 1.09 | 0.47 – 2.57 |
| Shoulder elevation | 14.08 | 18.42 | 299 | 0.84 | 0.36 – 1.94 |
| Shoulder abduction | 21.69 | 16.44 | 308 | 1.39 | 0.66 – 2.91 |
| Handgrip | 6.67 | 7.45 | 360 | 0.89 | 0.35 – 2.30 |

* n varies due to task-specific exclusion criteria

## 3.5 Muscle strength and future long-term sickness absence

Table 4 presents the risk of LTSA in the period from 1996 to 2007 from having low muscle strength (lowest quartile) in different body regions in 1995 (Study V). The estimated Hazard ratio for LTSA for those having low muscle strength in shoulder elevation was 1.38. Neither this nor the effect on LTSA of low muscle strength of any of the other muscle regions was statistically significant.

**Table 4. Frequencies of long-term sickness absence among workers with low and high muscle strength, and Hazard ratios and confidence intervals of LTSA in the period 1996 to 2007 from having low muscle strength in 1995. Data from study V.**

| | Frequency of LTSA % | | Risk for LTSA | | |
|---|---|---|---|---|---|
| | Low strength | High strength | n* | Hazard ratio | 95% CI |
| Trunk extension | 32.58 | 36.60 | 343 | 0.86 | 0.55 – 1.34 |
| Trunk flexion | 34.41 | 36.09 | 347 | 1.07 | 0.69 – 1.66 |
| Shoulder elevation | 39.08 | 34.38 | 335 | 1.38 | 0.90 – 2.11 |
| Shoulder abduct | 26.67 | 39.25 | 345 | 0.75 | 0.47 – 1.21 |
| Handgrip | 29.06 | 39.39 | 402 | 0.70 | 0.47 – 1.05 |

* n varies due to task-specific exclusion criteria

## 3.6 Self-rated physical capacity and future job status

Data from study IV on self-rated muscle strength from 4,848 participants and data on self-rated flexibility from 4,844 participants were analysed by multinomial logistic regression. Neither low muscle strength (p=0.16) nor low flexibility (p=0.57) predicted drop-out from the eldercare sector into any of the 5 outcome groups two years after qualification as SHH or SHA.

## 3.7 Self-rated musculoskeletal disorder and future job status

A majority of the cohort in study IV, 63.3 % (n=3,098), was employed in the eldercare sector in 2006, two years after qualification as SHHs and SHAs. 13.3 % (n=652) had left to other health and welfare sectors, 12 % (n=588) were under further education, 6.7 % (n=327) had left for other sectors and 4.7 % (n=230) were outside the labour market. Furthermore, the one-year prevalence of self-reported LBP in 2004 was 56.9 %, divided into 25.4 % with 1-7 days of pain, 20.3 % with 8-30 days of pain, and 11.2 % with more than 30 days of pain. In total, 15.6 % reported discomfort or disability due to low back pain the last 3 months in 2004.
Data on self-rated pain, discomfort or disability due to LBP from 4,975 participants and data on self-rated duration of LBP from 4,895 participants entered the analyses.

### 3.7.1 Disability due to low back pain and drop-out

Disability due to LBP the last 12 months (measured at baseline) is an overall significant predictor for drop-out from the eldercare sector two years after qualification (p=0.0036). Disability due to LBP the last 12 months (measured at baseline) did not predict drop-out into education. However, it increased the odds for drop-out into other health and welfare sectors by around 30 % (OR 1.31), and the odds for drop-out into all other sectors or out of the labour market by around 50 % (OR 1.47-1.53) two years after qualification.
Calculation of excess fractions showed that 4 % of the drop-out into other health and welfare

sectors, 6 % of the drop-out from the labour market and 7 % of the drop-out into all other sectors (unrelated to health and welfare) could be attributed to disability caused by LBP.

**Table 5. The relationship between disability due to low back trouble in 2004 and job drop-out or job turnover from the eldercare sector among recently qualified eldercare trainees in Denmark. Data from study V.**

| | Eldercare sector 2006 versus | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Other health and welfare sectors | | All other sectors | | Under education | | Outside labour market | |
| | OR | CI | OR | CI | OR | CI | OR | CI |
| **Disability due to low back trouble** | | | | | | | | |
| **No** | 1.00 | | 1.00 | | 1.00 | | 1.00 | |
| **Yes** | 1.31* | 1.04-1.65 | 1.53* | 1.15-2.04 | 1.04 | 0.82-1.33 | 1.47* | 1.05-2.07 |

* p≤ 0.025; OR=Odds Ratio; CI=Confidence Interval

### 3.7.2 Duration of low back pain and job drop-out

Table 6 shows the effects of the duration of LBP (0, 1-7, 8-30, 31-90 days) the last 12 months (measured at baseline) and the odds for job drop-out or job turnover from the eldercare sector, two years after qualification. 4,895 participants entered this analysis. Duration of LBP was a highly significant predictor (p= 0.0045) for drop-out from the eldercare sector, particularly drop-out into all other sectors and out of the labour market. They suggest a trend towards a dose-response-relationship: The longer the duration of LBP, the higher odds for drop-out. 31-90 days with LBP increased the odds for drop-out by 57-67 % (OR 1.57 to 1.67). However, predictive effect on drop-out into education or into other health and welfare sectors was not shown.

**Table 6. The relationship between duration of low back trouble in 2004 and job drop-out or job turnover from the eldercare sector among recently qualified eldercare trainees in Denmark. Data from study V.**

| | Eldercare sector 2006 versus | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Other health and welfare sectors | | All other sectors | | Under education | | Outside labour market | |
| | OR | CI | OR | CI | OR | CI | OR | CI |
| **Total amount of days with low back trouble the last year** | | | | | | | | |
| **0** | 1.00 | | 1.00 | | 1.00 | | 1.00 | |
| **1-7** | 1.12 | 0.90-1.39 | 0.65* | 0.48-0.90 | 0.89 | 0.71-1.13 | 1.06 | 0.75-1.49 |
| **8-30** | 1.09 | 0.87-1.38 | 1.12 | 0.83-1.51 | 0.99 | 0.78-1.27 | 1.15 | 0.79-1.66 |
| **31-90** | 0.98 | 0.72-1.33 | 1.57* | 1.12-2.21 | 1.20 | 0.90-1.61 | 1.67* | 1.11-2.52 |

* p≤ 0.025; OR=Odds Ratio; CI=Confidence Interval

Calculation of excess fractions showed that 10 % of the drop-out from the labour market was due to the duration of LBP, whereas no gross excess drop-out into all other sectors (unrelated to health and welfare) could be attributed to duration of LBP.

# 4. Discussion

### 4.1 Main results

Compared to the effect of gender and age, work exposure seems to be of minor importance for the physical capacity. However, no clear picture emerges regarding the associations between physical capacities and work exposures of employees of different job groups. On the one hand, a representative cohort of Danish employees of mixed occupations showed no association between job type and physical capacities. On the other hand, the high shoulder muscle strength found among waste collectors with high seniority indicates a possible maintaining or training effect from the exposures in waste collection on particularly the shoulder muscles. However, a healthy worker effect among the elderly waste collectors and an early selection among the young waste collectors may explain these results (hypothesis 1). In the prospective studies, the level of physical capacity measured as objective and self-rated muscle strength and as self-rated flexibility was not associated with any future signs of physical deterioration in terms of future decreased performance, musculoskeletal disorders, long-term sickness absence, job turnover or job drop-out. Duration and severity of low back pain were predictors for later change of job status (hypothesis 2).

### 4.2 Muscle strength

All muscle strength results from studies I, II and III are obtained with identical measurement methods. Generally, the most obvious differences in muscle strength are found between men and women, and between young and elderly workers. These general findings are also confirmed by other studies [10, 28, 88, 90].

Hand grip strength

Hand grip strength was similar for the young waste collectors and their comparison group in study I, the male employees of mixed occupations in study II and the construction workers in study III with a mean of around 550 N in all jobs. Thus, these results showed no job specific differences in physical capacity. This is in line with the findings of Era et al. [33], who found that hand grip strength in a random sample of 750 Finnish men of different ages and occupations, declined with age irrespective of occupational status, physical activity at leisure-time, or self-rated health.

Trunk muscle strength

There was a tendency, although non-significant, to higher back extension strength among males with varied work compared with males with repetitive monotonous work (study II). Similarly, differences between waste collectors of both age groups compared with their comparison groups (study I) (figure10) show a possible association between job exposures and trunk muscle strength. However, only the difference between young waste collectors and their comparison group is significant and this may as well be a result of selection of the stronger workers into waste collection.

Shoulder muscle strength

There was a non-significant tendency of higher shoulder elevation strength among males with varied work compared with males with repetitive monotonous work in study II. Furthermore, both young and elderly waste collectors showed a general tendency to larger shoulder muscle strength compared with the comparison group in study I (figures 11 and 12). These differences were significant for shoulder elevation in the elderly groups, and for shoulder abduction in both age groups. The larger shoulder muscle strength among elderly waste collectors with high seniority indicates a positive effect of job exposures of specific muscle groups on the corresponding muscle strengths. This was supported by a Manova test performed on all muscle strength parameters in study I, concluding that work, not age, had a significant effect on muscle strength. However, a healthy worker effect among the elderly waste collectors cannot be excluded.

**Job groups with different physical job exposures and muscle strength**

Study II, with its cross-sectional epidemiological study design (421 employees of mixed occupations), showed no association between job type and muscle strength. The study had particular focus on monotonous work and decreased physical capacity compared to workers with more variable work. However, the division in monotonous repetitive work and more varied work may not present a large enough contrast regarding physical exposure at work.

On the other hand, study I, which is a cross-sectional study design in a group with more homogeneous exposures (waste collectors) and with detailed physiological measurements, showed stronger shoulder muscle strength among elderly waste collectors than among elderly workers of mixed occupations. These results are in line with results of another cross-sectional study with a parallel design. Schibye and Christensen, 1997, measured handgrip strength of 48 meat cutters, 38 waste collectors, and a control group of 198 males with low and high job seniority [105]. Those results showed that the hand grip strength was higher among the waste collectors than among the other job groups (indicating a training or maintaining effect). But the results also showed that the elderly meat cutters with high seniority showed markedly lower hand grip strength compared with the elderly control group, whereas there was no difference between the young groups with low seniority. The authors concluded that the repetitive, monotonous forceful work of meat cutters enhanced the natural age-related strength decline in the forearm muscles (indicating deterioration).

Another cross-sectional study performed physical tests on 40 young and elderly power line technicians specifically designed to assess the participants' capacities to meet the physical requirements of their occupation [42]. In a standard test of maximal handgrip strength, significantly lower handgrip strength was found among the elderly compared to the young technicians, probably due to a natural age-related strength decline. But interestingly, no significant difference was found between the age groups when performing a more job specific handgrip strength test, which points towards the importance of test specificity. Likewise, the hand grip strength tests [105], and the shoulder strength tests of study I may be considered a job specific test for capacity; the handgrip for the meat cutters who grip around the knife and the measurements of shoulder muscle strength for the waste collectors with high daily shoulder exposures of lifting, pushing and pulling of sacks and buckets.

However, selective recruitment into the job or selection out early or later in working life (healthy worker effect) are well-known points of discussion in cross-sectional studies. In the case of the waste collectors, the higher physical capacity among the young waste collectors may be an indication of early selection either into the job or early selection out of the job in the beginning of the working life. For the elderly, it cannot be excluded that the job may have a maintaining or training effect. However, another possible explanation may be that among the elderly waste collectors, those with either musculoskeletal problems or too low capacity compared to the job demands have left the job already. Since both studies I and II are cross-sectional studies, no confirmatory conclusion can be drawn. The answer may be found in longitudinal study-designs where the same individuals are followed for several years or in a study, where the physical capacities are measured in waste collectors still working as well as waste collectors who have left the job.

## 4.3 Aerobic capacity

As for the muscle strength measurements, the aerobic capacity in studies I, II and III were obtained with identical measurement methods. Generally, the most obvious differences are observed between young and elderly employees (studies I and II), which is in line with earlier studies [13, 28, 30, 61]. When the aerobic capacity was reported as aerobic power (figure 14), there was hardly any gender difference observed (study II). This is in contrast to other studies [13, 100]. This finding may be explained by a combination of two factors. First, the Body Mass Index among the men is approx. 10 % higher than among the women in study II, but as percentage of body fat was not reported, it is not clear whether this can explain the result. Second, the Åstrand test has shown a possible methodological weakness, possibly underestimating young men and overestimating young women [73].

**Physical job exposures and aerobic capacity**

In studies I and II, comparisons of the results between employees of same age and gender showed no significant differences in capacities between job groups with different physical exposure.
In study I, the young waste collectors had a non-significant tendency to higher aerobic capacity than the comparison group, which may be caused by the aforementioned possible selection into the job.
However, this tendency is not present among the elderly workers. Assuming that the elderly workers initially had the same aerobic power as found in the younger groups, no training or deteriorating effect was found for the waste collectors compared with those not having physically heavy work. This is in line with the findings of Ruzic et al. 2003 [99], who concluded that a higher physical workload in the workplace did not provide adequate intensity, volume and duration to induce positive changes in the aerobic capacity among 274 male workers with a higher workload and 220 male workers with a lower workload measured by the *"Work Index"*. These results are supported by a 30-year follow-up study on 5,000 Danish male employees (The Copenhagen Male Study) [57, 58]. A possible explanation may be that the mean relative workload during waste collection is below the "training threshold". Earlier findings suggest that a relative workload should be above at least 50% of the individual's maximal aerobic power to produce a sufficient stimulus to evoke training adaptations on the oxygen-transporting system [29]. As the relative workload in an 8-hour workday should not exceed 33% [19] and the recommendations of the Danish working environment authorities are in line with this, even jobs with physically heavy exposures may therefore not have any training effect at all.
The results on aerobic capacities of study III are similar to the data of studies I and II. Furthermore, heart rate registrations during two whole workdays confirm that the construction work performed in study III is also below the "training threshold", with a relative workload of 23-25 % on the two measured workdays.

## 4.4 Physical capacity and future physical performance

In study III, we performed a number of different capacity measurements to provide job specific testing of the possible effect of the wide range of exposures construction workers typically meet (heavy lifting and carrying, pushing and pulling, sudden loadings, and work in awkward postures). In this discussion, the focus is on muscle strength and aerobic capacity although also measurements of motor control, flexibility and fatigue were made in this short-term prospective study design as well. All the results of study III point in the same direction, showing a stable or even slightly improved test performance in the evenings after a 12-hour workday as well as after a two-week work period. Habituation to the four identical tests are not supposed to be the cause since the hand grip and bicycling are normal daily life skills and therefore not technically difficult for a Danish population.

These results indicate sufficient restitution from day to day. Furthermore, the improvement in capacity from morning to evening may be explained by a low test performance in the very early morning tests [38, 71].

The somewhat unexpected improvement of physical capacity in a short perspective, lends some support from other studies. Garde et al. 2007 [43] examined the concentrations of cortisol, testosterone and glycated haemoglobin among 40 construction workers with and without extended workdays, and their data also indicated sufficient restitution among construction workers with extended workdays and work weeks. Similarly, a study of 64 construction workers on the Oresund Belt Link working 84 hours a week concluded that self-chosen work weeks of 84 hours did not result in more fatigue in the short-term in terms of cognitive performance, sleepiness or increase in reaction time than 40-hour work weeks [92]. Thus, there seems to be no negative short-term effects of physically demanding work, long work days and work periods in this job group.

However, these short-term results reveal a discrepancy between changes of physical capacity in the short-term and the negative long-term effects of the job found in epidemiological studies. Construction workers with extended workdays and workweeks generally have a higher prevalence of long-term negative health effects when evaluated by prevalence of low back pain [23, 32], higher hospitalization rates and increased risk for disability retirement compared with construction workers with normal work schedules and compared with other employees in general [50, 118].

The discrepancy between short and long-term effects is not fully understood and may be caused by several factors. First, the workload among the construction workers in study III may have been lower than normally, as the work was in the last phase of construction, meaning that most of the working hours were spent on reinforcement work and shuttering. Second, the participants may be a selected population. None of them had musculoskeletal pain and only 19 out of 51 invited workers passed all 4 test sessions. They had a high job-seniority as construction workers living in building site camps, which indicates that they may have chosen a job with demands that matches their physical or other capacities. Those who did not match the job exposures well may have chosen not to participate in the study or may have dropped out of the job earlier.

### 4.5 Physical capacity and future MSD and LTSA

Low muscle strength as a predictor for future MSD and for future LTSA is investigated in study V. Overall, study V showed that workers with low muscle strength in different body regions did not have significantly increased risk for either future MSD in the same body region in a 5-year prospective study design nor for future LTSA in a 10-year prospective study design. None of the Odds Ratios for later MSD or the Risk Ratios for later LTSA was significant, and the conclusion of the study was that low muscle strength was not a strong predictor for either future MSD or LTSA. As the tendency for an increased risk for MSD in the neck/shoulder region from having low muscle strength in shoulder abduction and the tendency for an increased risk for LTSA from having low muscle strength in shoulder elevation was nearly 40%, it cannot be excluded that muscle strength in these body regions has some effects. These tendencies did not reach statistical significance, but this may be due to lack of statistical power. The statistical power of the analyses was not very strong, as the power analysis showed a 38–58 % chance of detecting a true odds ratio of 1.4 at a significance level of 5 %. Even though study V showed no association between low shoulder muscle strength and later MSD, such associations has been indicated in cross-sectional studies both within physically heavy and sedentary jobs. A multicenter study on computer workers found a significantly lower shoulder elevation strength among those with shoulder muscle pain compared to those without pain [6, 18]. A study on 30 sewingmachine operators with highly repetitive work similarly found a significantly lower shoulder flexion strength among those with shoulder pain than among those without pain [67], and a study on 141 cleaners with more than 8 years seniority found higher muscle strength of the trunk, neck and particularly the shoulder region among cleaners without pain compared to those with pain [55].

Very few studies have reported on the longitudinal relationship between physical capacity and the risk of neck or shoulder pain. A systematic review on physical capacity and musculoskeletal pain found inconclusive evidence for a relation between neck/shoulder muscle strength and risk of neck/shoulder pain, mainly due to a limited number of available studies [49]. However, a 3-year prospective cohort study on 1789 Dutch employees of mixed occupations found associations between low performance in 1) a static endurance test of the neck muscles and, 2) an isokinetic neck/shoulder lifting strength test at baseline and increased risk of neck/shoulder pain in a 3-year follow-up period [48]. The measurements of muscle strength, muscle endurance and flexibility of neck, shoulders and back were combined with a self-administered questionnaire every year during the follow-up period.

Few studies have reported on the relationship between physical capacity and the risk of LTSA. The present study is to our knowledge the only longitudinal study on the relation between muscle strength and sickness absence performed on a general working population. A cross-sectional study on 7,179 male employees from the Finnish military found a higher prevalence of sickness absence among those with high BMI and poor muscle capacity. However, the strength measurements in the study involved lifting of the centre of gravity in 4 out of 6 tests, thereby making body weight a possible modifier of the test results [76]. There is a large number of both physical and psychosocial work exposure factors, which are well-known predictors for LTSA [16, 77, 80-82]. It may call for a much larger investigation to have the statistical power to confirm the conclusion in this study regarding the low predictive value of low muscle strength for later LTSA.

### 4.6 Self-rated physical capacity, musculoskeletal pain and future job status

Low physical capacity and future job turnover or drop-out is reported in study IV. Overall, study IV showed no effect of low self-rated muscle strength or flexibility on job status two years after qualification as SHH or SHA. This result is consistent with the results of study V even though there are several methodological differences between the two studies (size of cohort, measurement methods, and outcome measures).

As the data for study IV were provided by a questionnaire, all data were self-reported. The muscle strength (and flexibility) data were reported as relative to others of the same age and gender. Therefore, the method is not directly comparable to objective measurements. However, the method has been shown to be reliable, but with a rather low correlation to objectively measured physical capacity [114, 115].

The reasons for job turnover or drop-out from the eldercare sector are multi-factorial. Both individual and work environmental factors may predict drop-out or job turnover from the eldercare sector, and study IV also showed that in contrast to self-reported capacity, LBP during the last year of education (study IV) could predict drop-out or job turnover. Likewise, in a recent study within the same cohort, medium or low psychological well-being [45], exposure to bullying during the training period [54], and poor self-rated health [46] were all significant predictors for drop-out or job turnover two years after qualification.

## 4.7 Methodological considerations

**Sample size**

The 5 studies included in this thesis represent sample sizes from 19 (study III) to 5,696 (study IV) participants. In studies I, II and III detailed physiological measurements were possible due to the rather low number of participants. However, in such detailed measurements, selection bias such as test exclusion criteria and the representativity of the included participants compared with non-participants may be limitations [25]. To protect participants from health risks due to maximal exertion in the test situation, only participants not having pain on the test day and with acceptable health status according to the exclusion criteria were allowed to participate in the objective measurements. It may induce a "healthy worker effect" in the test situation if only the soundest, and possibly the strongest and most fit participants for the job in question volunteer and are included for strenuous physical tests. In study II, a representative sample of Danish employees of mixed occupations was chosen, but was reduced to half the sample size (from 839 to 421) due to the inclusion and exclusion process as well as drop-out. Tests of the representativity of the selected groups against the total cohort population for relevant parameters (as was done in studies II and III) may reduce the risk for such an effect. On the other hand, the recently educated eldercare workers of study IV had a very high response rate as 90 % of all, who graduated in 2004, participated. Therefore, this study had a high representativity and a low selection bias.

**Measurement methods**

Reliable self reported capacity obtained by questionnaires could be a way to obtain capacity measures for large representative cohorts or larger samples of specific job types. However, the self-rating method in general has limitations due to possible measurement error [25]. Tests of validity and reliability of the VAS-scale method used in study IV showed fair to good reliability concerning muscle strength and flexibility, and the method was therefore found to be acceptable for use as an estimate of muscle strength and flexibility in large epidemiological studies. However, Strøyer tested the validity and reliability towards back flexion and extension strength, not towards hand grip or shoulder muscle strength [115]. Furthermore, the self-reports of physical capacities used in study IV were made in relation to others of the same age and gender, and were therefore not directly comparable to the objective measurements.

The objective measurement methods are valid and reliable [35]. However, there are reasons to believe that the choice of test parameters is of significance for the test results as indicated by studies I and II, by Schibye and Christensen 1997 [105] and by Gall and Parkhouse 2004 [42]. Thus, development of more job specific functional tests may be necessary to reveal possible job specific capacity adaptations.

**The outcome parameters**

Physical performance

The identical test and re-test measures of physical test performance in study III provides a direct measure of performance changes in the short follow-up period where the effects of possible confounders such as e.g. marital status, overweight, alcohol consumption, smoking and physical activity in leisure time, or work-environmental factors are relatively stable. On the other hand, the difference in morning and evening measures revealed that there may be an influence of time of measuring and that seasonal variations also cannot be ruled out. Learning effects may be a problem in standardized tests, but are not considered a major problem for relatively simple tests where repeated tests are allowed if the increase in performance is more than 5% [35].

Long-term sickness absence and musculoskeletal trouble, pain or discomfort
In study III, the applied register in sickness absence (DREAM) did not report whether the sickness absence period was caused by MSD or other factors. This weakens the chance of finding a connection between muscle capacity and LTSA. However, other studies recognize MSD as a major risk factor for LTSA [95, 113]. Moreover, MSD was self-reported in 1995 and 2000, and the probability for recall bias may influence a possible association between muscle capacity and MSD as well. Finally, as the prevalence and severity of MSD in the general population is rather high and varies both in time and between persons, several factors may overshadow possible associations.
In study IV, we have no knowledge about changes in muscular strength, lifestyle or other factors that may affect the risk for MSD or LTSA during the long follow-up period.

Job turnover
In study IV, change of job status was interpreted as being employed in a job in sectors outside the eldercare, being under education or outside the labour market, which may be a crude definition. First, we have no registrations of whether the recently educated SHHs and SHAs ever started working in the eldercare. Second, job turnover may be a strategy for coping with unsatisfying working conditions in jobs with plenty of alternatives. In the healthcare sector, with good opportunities to change job or receive further education, job turnover may not barely be due to physical deterioration, but may as well be due to a positive choice into an improved job situation [41, 70].

## 4.8 Strengths and limitations

The strengths of studies I to V are that both detailed measurements on small cohorts and questionnaires on large cohorts are represented and the same measures of capacity are used in the different settings. Particularly study V has a strong study design with a prospective design, combining questionnaire and physical examination at baseline, with a register-based follow-up. The research questions of this thesis are explored in several time-perspectives from cross-sectional, through a short-term14-day follow-up to 2, 5, and 10 years follow-ups.
However, this broad handling of the aims also has limitations both concerning sample sizes, measurement methods, and the relevance of the outcomes as described above.
A major limitation across all the studies in the present thesis focusing on the capacity is that job titles by large are used as a proxy for job exposure based on general descriptions of the physical workload within different sectors. None of the studies have direct measurements of physical exposures on the individual level, which should be recommended for future research.
In studies II and V where objective measurements of physical capacities were followed up after 5 and 10 years, we did not have the possibility to specifically analyze specifically the association between employees with physically heavy work and later MSD or LTSA. The cohort in study II was divided into jobs with repetitive work tasks and jobs with more variation and therefore does not provide a strong contrast in jobs with and without physically heavy tasks, which would be ideal for the aims of this thesis.
All in all, the study design of study V is strong, but it would have strengthened the study considerably, if the cohort had been twice the size. Other improvements would have been larger

contrasts and objective measures of physical exposures as well as more job specific, functional capacity tests.

# 5. Conclusions

A summary of the results from studies I to V is:

Study I

- 47 waste collectors had a higher physical capacity than employees without physically heavy work.
- The waste collectors with high seniority had higher shoulder muscle strength than a comparable group of male workers without physically heavy work.

Study II

- There was no association between physical capacities in a cohort of 421 employees of mixed job types with varied work versus monotonous repetitive work.

Study III

- Aerobic fitness and hand grip strength among 19 construction workers did not differ from Danish male workers in general.
- No short-term deterioration was found among construction workers, as physical test performance was similar after two weeks of 12-hour work days.

Study IV

- Low self-reported physical capacity among 5,696 recently educated female healthcare workers did not have any associations with future signs of physical deterioration measured by job status two years after graduation.
- Duration of and disability due to low back pain among 5,696 recently educated female healthcare workers predicted future signs of physical deterioration measured by job status two years after graduation.

Study V

- Low muscle strength among employees of mixed occupations did not have any associations with MSD 5 years later.
- Low muscle strength among employees of mixed occupations did not have any associations with LTSA 10 years later.

Compared to the effect of gender and age, work exposure seems to be of minor importance for the physical capacity both evaluated in a cross-sectional and prospective design.
Overall, the cross-sectional studies I and II show that while the general measurements on the mixed worker populations show no associations, the job specific tests of capacity within homogenous samples of workers show some association between the physical exposures at work and the muscle strength of employees of different job groups. However, such a potential association cannot be isolated from the possible healthy worker or worker selection effects in studies I and II.
Furthermore, low physical capacity both in terms of objectively measured and self-reported, could not be shown to be associated with any future signs of physical deterioration in terms of decreased capacity or test performance, musculoskeletal disorders, long-term sickness absence, job turnover or job drop-out. However, disability due to and duration of LBP were predictors for change of job status.

# 6. Perspectives

The current demographic change in the Western countries towards a growing population of elderly employees is a major challenge for the political and economical systems. To keep workers productive on the labor market with maintained workability as long as possible is a highly prioritized issue for the Danish government. In particular, for workers with physically heavy work, maintaining physical capacity may be crucial for an optimal relationship between workload and working capacity.

The findings in the present thesis indicate that the training effect on physical capacity from physically heavy work, if present at all, is small and job specific, and therefore no overall positive health effect can be expected.

Several studies point towards the positive health effects of physical activity in the leisure time [58, 103] even though it is not clear whether the effect is due to an increased capacity or a beneficial effect of leisure time physical activity in itself. However, leisure time physical activity to maintain physical capacity may be equally important for job groups with physically heavy work as for job groups with low physical activity. Among the latter, job specific strength training interventions (the concept of "intelligent physical exercise training") have shown promising results on pain prevention and relief and several studies point towards an association between low muscle strength and pain [6,18,48,55-56,67,69].

Since the occupational physical activity has no general effect on physical capacity, there is an urgent need for testing the effect of workplace interventions that are offering physical training tailored to improve physical capacity of workers within physically heavy jobs.

# 7. References

1 *Basisbog i arbejdsfysiologi, bind I+II*. København: Arbejdsmiljøinstituttet 1995:(1-160)-(1-166).

2 Alavinia SM, de Boer AGEM, van Duivenbooden JC, *et al.* Determinants of work ability and its predictive value for disability. *Occup Med (Lond)* 2009;**59** (1):32-7.

3 Alavinia SM, van den Berg TIJ, van Duivenbooden C, *et al.* Impact of work-related factors, lifestyle, and work ability on sickness absence among Dutch construction workers. *Scandinavian Journal of Work & Environmental Health* 2009;**35**:325-33.

4 Alavinia SM, van Duivenbooden C, Burdorf A. Influence of work-related factors and individual characteristics on work ability among Dutch construction workers. *Scandinavian Journal of Work Environment & Health* 2007;**33** (5):351-7.

5 Andersen JH, Haahr JP, Frost P. Risk factors for more severe regional musculoskeletal symptoms - A two-year prospective study of a general working population. *Arthritis and Rheumatism* 2007;**56** (4):1355-64.

6 Andersen LL, Andersen JL, Suetta C, *et al.* Effect of contrasting physical exercise interventions on rapid force capacity of chronically painful muscles. *J Appl Physiol* 2009;**107** (5):1413-9.

7 Andersen TB, Schibye B, Skotte J. Sudden movements of the spinal column during health-care work. *Int J Ind Ergon* 2001;**28** (1):47-53.

8 Appleyard M, eds. The Copenhagen City heart study. Østerbroundersøgelsen. A book of tables with data from the first examination (1976-78) and a five year follow-up (1981-83). *Scandinavian Journal of Social Medicine* 1989 (Supplementum 41):1-160.

9 Arbejdstilsynet. AT-vejledning D.3.1 om Løft, træk og skub. *At-meddelelse* 2002:1-16.

10 Asmussen E, Heebøll-Nielsen K. Isometric muscle strength of adult men and women. *Comm Nat Ass Infant Paral* 1961:3-44.

11 Asmussen E, Heebøll-Nielsen K. Isometric muscle strength in relation to age in men and women. *Ergonomics* 1962;**5(1)**:167-9.

12 Asmussen E, Heebøll-Nielsen K, Molbech S. Methods for evaluation of muscle strength. *Comm Nat Ass Infant Paral* 1959:3-13.

13 Åstrand I. Aerobic work capacity in men and women with special reference to age. *Acta Physiol Scand Suppl* 1960 (169):1-92.

14 Åstrand P-O, Ryhming I. A nomogram for calculation of aerobic capacity (physical fitness) from pulse rate during submaximal work. *J Appl Physiol* 1954;**7**:218-21.

15 Bäckman E, Johansson V, Häger B, *et al.* Isometric muscle strength and muscular endurance in normal persons aged between 17 and 70 years. *Scand J Rehabil Med* 1995;**27**:109-17.

16 Bang CK, Lund T, Labriola M, *et al.* The fraction of long-term sickness absence attributable to work environmental factors: prospective results from the Danish Work Environment Cohort Study. *Occup Environ Med* 2007;**64** (7):487-9.

17 Berger R. Effect of varied weight training programs on strength. *Research Quarterly* 1962;**33(2)**:168-81.

18 Blangsted AK, Søgaard K, Hansen EA, *et al.* A one-year randomized controlled trial with different physical-activity programs to reduce musculoskeletal symptoms in neck and shoulders among office workers. *Scand J Work Environ Health* 2008;**34** (1):55-65.

19 Bonjer FH. Energy expenditure. In: Parmeggiani L, ed. *Encyclopedia of Occupational Health and Safety*. Geneva: International Labour Organisation 1971:458-60.

20 Borg V, Burr H. *Danske lønmodtageres arbejdsmiljø og helbred 1990-95, Borg,V.; Burr,H.(eds)*. København: Arbejdsmiljøinstituttet 1997:1-368.

21 Brinkmann P, Biggemann M, Hilweg D. Fatigue fracture for human lumbar vertebrae. *Clin Biomech* 1988;**(suppl )**.
22 Brinkmann P, Porter RW. A laboratory model of lumbar disc protrusion. *Spine* 1994;**19** (2):228-35.
23 Burr H, Bjorner JB, Kristensen TS, *et al.* Trends in the Danish work environment in 1990-2000 and their associations with labor-force changes. *Scandinavian Journal of Work Environment & Health* 2003;**29** (4):270-9.
24 Christensen H, Finsen L, Hansen K, *et al.* Muscle strength in relation to type of work and musculoskeletal symptoms. International Ergonomics Association. XIVth Triennial Congress and Human Factors and Ergonomics Society 44th Annual Meeting. Ergonomics for the New Millennium; July 29- August 4, 2000; San Diego, California USA. Santa Monica: HFES [CD-rom] 2000:5-775-5-777.
25 Coggon D, Rose MJ, Barker DJP. *Epidemiology for the uninitiated.* BMJ Publishing Group 2003 2008:1-73.
26 Cox DR. Regression models and life-tables. *Statist Soc* 1972;**B** (24):187-220.
27 Damlund M, Gøth S, Hasle P, *et al.* Low back strain in Danish semi-skilled construction work. *Applied Ergonomics* 1986;**17**:31-9.
28 Danneskiold-Samsoe B, Bartels EM, Bülow PM, *et al.* Isokinetic and isometric muscle strength in a healthy population with special reference to age and gender. *Acta Physiol* 2009;**197** (Suppl. 673):1-68.
29 Davies CTM, Knibbs AV. The training stimulus. The effects of intensity, duration and frequency of effort on maximum aerobic power output. *Int Z angew Physiol Arbeitsphysiol* 1971;**29**:299-305.
30 De zwart BCH, Frings-Dresen MHW, van Dijk FJH. Physical workload and the ageing worker: a review of the literature. *Int Arch Occup Environ Health* 1995;**68**:1-12.
31 Endahl L. Statistical and epidemiological aspects of analysing self-rated repetitive strain injuries in follow-up studies. København: Arbejdsmiljøinstituttet 2000.
32 Engholm G, Holmström E. Dose-response associations between musculoskeletal disorders and physical and psychosocial factors among construction workers. *Scand J Work Environ Health* 2005;**31** (2 (suppl)):57-67.
33 Era P, Lyyra AL, Viitasalo JT, *et al.* Determinants of isometric muscle strength in men of different ages. *Eur J Appl Physiol* 1992;**64**:84-91.
34 Essendrop M, Hye-Knudsen CT, Skotte J, *et al.* Fast development of high intra-abdominal pressure when a trained participant is exposed to heavy sudden trunk loads. *Spine* 2003;**29** (1):94-9.
35 Essendrop M, Schibye B, Hansen K. Reliability of isometric muscle strength tests for the trunk, hands and shoulders. *Int J Ind Erg* 2001;**28**:379-87.
36 Faber A, Hansen K, Christensen H. Muscle strength and aerobic capacity in a representative sample of employees with and without repetitive monotonous work. *Int Arch Occup Environ Health* 2006;**79** (1):33-41.
37 Faber A, Nabe-Nielsen K, Giver H, *et al.* SOSU'er årgang 2004 - det første år. Arbejdsmarkedstilknytning, arbejdsmiljø, ressourcer og helbred (The Danish Health Care Worker Cohort - Class of 2004 - The first year of employment. Attachment to labour market, working environment, resources and health). Copenhagen: National Research Centre for the Working Environment 2007:1-83.
38 Faber A, Strøyer J, Hjortskov N, *et al.* Changes in physical performance among construction workers during extended workweeks with 12-hour workdays. *Int Arch Occup Environ Health* 2010;**83** (1):1-8.

39 Fairfax AH, Balnave R, Adams RD. Variability of grip strength during isometric contraction. *Ergonomics* 1995;**38** (9):1819-30.
40 Feveile H, Jensen C, Burr H. Risk factors for neck-shoulder and wrist-hand symptoms in a 5-year follow-up study of 3,990 employees in Denmark. *Int Arch Occup Environ Health* 2002;**75** (4):243-51.
41 Fochsen G, Josephson M, Hagberg M, *et al.* Predictors of leaving nursing care: a longitudinal study among Swedish nursing personnel. *Occup Environ Med* 2006;**63** (3):198-201.
42 Gall.B, Parkhouse W. Changes in physical capacity as a function of age in heavy manual work. *Ergonomics* 2004;**47** (6):671-87.
43 Garde AH, Faber A, Persson R, *et al.* Concentrations of cortisol, testosterone and glycosylated haemoglobin (HbA1C) among construction workers with 12-h workdays and extended workweeks. *Int Arch Occup Environ Health* 2007;**80** (5):404-11.
44 Gauvin MG, Riddle DL, Rothstein JM. Reliability of clinical measurements of forward bending using the modified fingertip-to-floor method. *Phys Ther* 1990;**70** (7):443-7.
45 Giver H, Faber A, Hannerz H, *et al.* Psychological well-being as a predictor of dropout among recently qualified Danish eldercare workers. *Scand J Public Health* 2010;**38** (3):239-45.
46 Giver H, Faber A, Strøyer J, *et al.* Do life-style factors and general health predict dropout among recently qualified eldercare workers? A two-year follow-up study. *Scand J Public Health* 2011.
47 Goldberg AL, Etlinger JD, Goldspind DF, *et al.* Mechanism of work-induced hypertrophy of skeletal muscle. *Medicine and Science in Sports* 1975;**7(3)**:185-98.
48 Hamberg-van Reenen HH, Ariens GAM, Blatter BM, *et al.* Is an imbalance between physical capacity and exposure to work-related physical factors associated with low-back, neck or shoulder pain? *Scandinavian Journal of Work Environment & Health* 2006;**32** (3):190-7.
49 Hamberg-van Reenen HH, Ariens GAM, Blatter BM, *et al.* A systematic review of the relation between physical capacity and future low back and neck/shoulder pain. *Pain* 2007;**130** (1-2):93-107.
50 Hannerz H, Spangenberg S, Tüchsen F, *et al.* Disability retirement among former employees at the construction of the Great Belt Link. *Public Health* 2005;**119** (4):301-4.
51 Hansen K, Hansen AF, Feveile H, *et al. Muskelstyrke og kondition hos danske arbejdstagere*. København: Arbejdsmiljøinstituttet 2002:5-85.
52 Hartmann B, Fleischer AG. Physical load exposure at construction sites. *Scand J Work Environ Health* 2005;**31** (2 (suppl)):88-95.
53 Hasselhorn HM, Tackenberg P, Müller B. Working conditions and intent to leave the profession among nursing staff in Europe. University of Wuppertal 2007.
54 Hogh A, Giver H, Hannerz H, *et al.* Bullying or violence during training and the risk of dropout from the elder-care sector two years later. *Submitted to Scandinavian Journal of Caring Science,* may 2011.
55 Holtermann A, Blangsted AK, Christensen H, *et al.* What characterizes cleaners sustaining good musculoskeletal health after years with physically heavy work? *Int Arch Occup Environ Health* 2009;**2009** (82):1015-22.
56 Holtermann A, Jorgensen MB, Gram B, *et al.* Worksite interventions for preventing physical deterioration among employees in job-groups with high physical work demands: Background, design and conceptual model of FINALE. *BMC Public Health* 2010;**10** (120):http://dx.doi.org/10.1186/1471-2458-10-120.
57 Holtermann A, Mortensen OS, Burr H, *et al.* The interplay between physical activity at work and during leisure time - risk of ischemic heart and all-cause mortality in middle-aged Caucasian men. *Scandinavian Journal of Work Environment and Health* 2009;**35** (6):466-74.

58 Holtermann A, Mortensen OS, Burr H, *et al.* Physical demands at work, physical fitness, and 30-year ischaemic heart disease and all-cause mortality in the Copenhagen Male Study. *Scandinavian Journal of Work Environment and Health* 2010;**36** (5):357-65.
59 Holtermann A, Mortensen OS, Burr H, *et al.* Physical work demands, hypertension status, and risk of ischemic heart disease and all-cause mortality in the Copenhagen Male Study. *Scandinavian Journal of Work Environment and Health* 2010;**36** (6):466-72.
60 Ilmarinen J. Job design for the aged with regard to decline in their maximal aerobic capacity: Part I - Guidelines for the practitioner. *Int J Ind Erg* 1992;**10**:53-63.
61 Ilmarinen J. Job design for the aged with regard to decline in their maximal aerobic capacity: Part II - The scientific basis for the guide. *Int J Ind Erg* 1992;**10**:65-77.
62 Ilmarinen J. Work ability - a comprehensive concept for occupational health research and prevention. *Scandinavian Journal of Work Environment & Health* 2009;**35** (1):1-5.
63 Ilmarinen J, Tuomi K, Klockars M. Changes in the work ability of active employees over an 11-year period. *Scand J Work Environ Health* 1997;**23 Suppl 1**:49-57.
64 Ivens UI. Epidemiologisk undersøgelse af helbredseffekter ved indsamling og genanvendelse af husholdningsprodukter. København: Arbejdsmiljøinstituttet 1998:1-195.
65 Ivens UI, Hansen J, Skov T, *et al. Sikkerhed og sundhed ved affald og genanvendelse. Rapport nr. 5. Spørgeskemaundersøgelsen blandt skraldemænd - "Baselineundersøgelsen"*. København, Danmark: Arbejdsmiljøinstituttet 1996:1-160.
66 Jäger M, Luttmann A. Assessment of low-back load during manual materials handling. In: Seppälä P, Luopajärvi T, Nygård C-H, *et al.*, eds. *From experience to innovation. Proceedings of the 13th triennial congress of the international ergonomics association Tampere, Finland 1997. Musculoskeletal disorders. Rehabilitation*. Tampere, Finland: The International Ergonomics Association 1997:171-3.
67 Jensen BR, Schibye B, Søgaard K, *et al.* Shoulder muscle load and muscle fatigue among industrial sewing- machine operators. *Eur J Appl Physiol* 1993;**67**:467-75.
68 Jensen LD, Schibye B, Hansen AF, *et al. Personhåndtering - Arbejdsmiljø og helbred*. København: Arbejdsmiljøfondet 1998:1-132.
69 Jørgensen MB, Faber A, Hansen J, *et al.* Effects on musculoskeletal pain, work ability and sickness absence from a 1-year randomised controlled trial among cleaners. *Int Arch Occup Environ Health* 2011.
70 Josephson M, Lindberg P, Voss M, *et al.* The same factors influence job turnover and long spells of sick leave--a 3-year follow-up of Swedish nurses. *Eur J Public Health* 2008:ckn009.
71 Kecklund G, Åkerstedt T, Lowden A. Morning work: Effects of early rising on sleep and alertness. *Sleep* 1997;**20** (3):215-23.
72 Kecklund G, Ekstedt M, Åkerstedt T, *et al.* The effects of double-shifts (15.5 hours) on sleep, fatigue and health. *J Hum Ergol* 2001;**30**:53-8.
73 Kilbom Å, Wigaeus-Hjelm E, Käll C, *et al.* Validering av submaximalt cykelergometertest. *Stockholmsundersökningen 1* 1991.
74 Krause N, Brand RJ, Kaplan GA, *et al.* Occupational physical activity, energy expenditure and 11-year progression of carotid atherosclerosis. *Scandinavian Journal of Work and Environmental Health* 2007;**33** (6):405-24.
75 Kuorinka I, Jonsson B, Kilbom Å, *et al.* Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms. *Appl Ergo* 1987;**18** (3):233-7.
76 Kyröläinen H, Häkkinen K, Kautinainen H, *et al.* Physical fitness, BMI and sickness absence in male military personnel. *Occup Med* 2008;**58** (5):251-6.
77 Labriola M, Christensen KB, Lund T, *et al.* Multilevel analysis of workplace and individual risk factors for long-term sickness absence. *J Occup Eniviron Med* 2006;**48** (9):923-9.

78 Liira J, Matikainen E, Leino-Arjas P, *et al.* Work-ability of middle-aged Finnish construction workers - a follow-up study in 1991-1995. *Int J Ind Erg* 2000;**25**:477-81.
79 Lund T, Labriola M, Christensen KB, *et al.* Physical work environment risk factors for long term sickness absence: prospective findings among a cohort of 5357 employees in Denmark. *British Medical Journal* 2006;**332** (7539):449-51.
80 Lund T, Labriola M, Christensen KB, *et al.* Physical work environment risk factors for long term sickness absence: prospective findings among a cohort of 5357 employees in Denmark. *BMJ* 2006;**332** (7539):449-52.
81 Lund T, Labriola M, Christensen KB, *et al.* Psychosocial work environment exposures as risk factors for long-term sickness absence among Danish employees: results from DWECS/DREAM. *J Occup Environ Med* 2005;**47** (11):1141-7.
82 Lund T, Labriola M, Villadsen E. Who is at risk for long-term sickness absence? A prospective cohort study of Danish employees. *Work* 2007;**28** (3):225-30.
83 MacDougal JD, Elder GCB, Sale DG, *et al.* Effects of strength training amd immobilization on human muscle fibres. *Eur J Appl Physiol* 1980;**43**:25-34.
84 Mathiesen K, Fløe T, Brendstrup T, *et al.* Arbejdsmiljø, helbred og camps. Arbejdstilsynet 2003:7-143.
85 McGill SM. The biomechanics of low back injury: implications on current practice in industry and the clinic. *J Biomech* 1997;**30** (5):465-75.
86 McGill SM, Grenier S, Kavcic N., *et al.* Coordination of muscle activity to assure stability of the lumbar spine. *J Electromyogr Kinesiol* 2003;**13**:353-9.
87 Nygaard C-H, Arola H, Siukola A, *et al.* Percieved work ability and certified sickness absence among workers in a food industry. *International Congress Series 2005* 2005 (1280):296-300.
88 Nygaard C-H, Loupajärvi T, Cedercreutz G, *et al.* Musculoskeletal capacity of employees aged 44 to 58 years in physical, mental and mixed types of work. *Eur J Appl Physiol* 1987;**56**:555-61.
89 Nygård C-H, Kilbom Å, Hjelm EW, *et al.* Life-time occupational exposure to heavy work and individual physical capacity. *Int J Ind Erg* 1994;**14**:365-72.
90 Nygård C-H, Luopajärvi T, Ilmarinen J. Musculoskeletal capacity of middle-aged women and men in physical, mental and mixed occupations. *Eur J Appl Physiol* 1988;**57**:181-8.
91 Nygård C-H, Luopajärvi T, Suurnäkki T, *et al.* Muscle strength and muscle endurance of middle-aged Women and men associated to type, duration and intensity of muscular load at work. *Int Arch Occup Environ Health* 1988;**60**:291-7.
92 Persson R., Ørbæk P., Ursin H, *et al.* Effects of the implementation of an 84-hour workweek on neurobehavioral test performance and cortisol responsiveness during testing. *Scand J Work Environ Health* 2003;**29** (4):261-9.
93 Plagenhoef S. *Patterns of human motion*. New Jersey: Prentice-Hall, Inc. 1971:1-224.
94 Pohjonen T. Perceived work ability of home care workers in relation to individual and work-related factors in different age groups. *Occup Med (Lond)* 2001;**51** (3):209-17.
95 Punnett L, Wegman DH. Work-related musculoskeletal disorders: the epidemiologic evidence and the debate. *Journal of Electromyography and Kinesiology* 2004;**14** (1):13-23.
96 Reiso H, Nygard JF, Brage S, *et al.* Work ability and duration of certified sickness absence. *Scand J Public Health* 2001;**29** (3):218-25.
97 Riihimäki H. Low-back pain, its origin and risk indicators. *Scand J Work Environ Health* 1991;**17**:81-90.
98 Rinne MB, Pasanen ME, Miilunpalo SI, *et al.* Test-retest reproducibility and inter-rater reliability of a motor skill test battery for adults. *Int J Sports Med* 2001;**22** (3):192-200.
99 Ruzic L, Heimer S, Misigoj-Durakovic M, *et al.* Increased occupational physical activity does not improve physical fitness. *Occup Environ Med* 2003;**2003** (60):983-5.

100 Saltin B. Menneskets fysiske arbejdsevne. Udvikling, vedligeholdelse og funktionel betydning. *Månedsskrift for Praktisk Lægegerning* 1989;**Temanummer**:805-24.
101 Saltin B. Physiological adaptation to physical conditioning. *Acta Med Scand* 1994;**Suppl. 711**:11-24.
102 Saltin B, Blomqvist G, Mitchell JH, *et al.* Response to excercise after bed rest and after excercise. Alongitudinal study of adaptive changes in oxygen transport and body composition. *Am Heart Assoc Monograph* 1968;**23**:VII1-VII77.
103 Saltin B, Rowell LB. Functional adaptations to physical activity and inactivity. *Fed Proc* 1980;**39(5)**:1506-13.
104 Savinainen M, Nygård C-H, Ilmarinen J. A 16-year follow-up study of physical capacity in relation to percieved workload among ageing employees. *Ergonomics* 2004;**47** (10):1087-102.
105 Schibye B, Christensen H. The work load during waste collection and meat cutting among workers in different age groups. *Arbete och Hälsa* 1997;**29**:272-8.
106 Schibye B, Hansen AF. Arbejdsfysiologiske kapacitetsmålinger på skraldemænd i relation til alder/anciennitet. København: Arbejsmiljøinstituttet 1999:1-38.
107 Schibye B, Hansen AF, Søgaard K, *et al.* Aerobic power and muscle strength among young and elderly workers with and without demanding work tasks. *Applied Ergonomics* 2001;**32**:425-31.
108 Seitsamo J, Martikainen R. Work ability and all cause mortality: A 25-year longitudinal study among Finnish municipal workers. In: Kumashiro M, ed. *Promotion of work ability towards productive ageing*. London: Taylor & Francis Group 2009:101-4.
109 Sell L, Bültmann U, Rugulies R, *et al.* Predicting long-term sickness absence and early retirement pension from self-reported work ability. *Int Arch Occup Environ Health* 2009;**82** (9):1133-8.
110 Sjøgaard G, Jensen BR. Muscle pathology with overuse. In: Ranney D, ed. *Chronic musculoskeletal injuries in the workplace*. Philadelphia, USA: W.B. Saunders Company 1997:17-40.
111 Skotte JH, Fallentin N, Pedersen MT, *et al.* Adaptation to sudden unexpected loading of the low back - the effects of repeated trials. *J Biomech* 2004;**37**:1483-9.
112 Søgaard K, Fallentin N, Nielsen J. Work load during floor cleaning. The effect of cleaning methods and work technique. *Eur J Appl Physiol* 1996;**73**:73-81.
113 Steenstra IA, Verbeek JH, Heymans MW, *et al.* Prognostic factors for duration of sick leave in patients sick listed with acute low back pain: a systematic review of the literature. *Occupational and Environmental Medicine* 2005;**62** (12):851-60.
114 Strøyer J. Physical fitness and low back pain. Copenhagen: National Research Centre for the Working Environment 2007:3-99.
115 Strøyer J, Essendrop M, Jensen LD, *et al.* Validity and reliability of self-assessed physical fitness using visual analogue scales. *Percept Mot Skills* 2007;**104**:519-33.
116 Suni JH, Oja P, Laukkanen RT, *et al.* Health-related fitness test battery for adults: aspects of reliability. *Arch Phys Med Rehabil* 1996;**77** (4):399-405.
117 Torgén M, Punnett L, Alfredsson L, *et al.* Physical capacity in relation to present and past physical load at work: A study of 484 men and women aged 41 to 58 years. *Am J Ind Med* 1999;**36**:388-400.
118 Tüchsen F, Hannerz H, Spangenberg S. Mortality and morbidity among bridge and tunnel construction workers who worked long hours and long days constructing the Great Belt Fixed Link. *Scand J Work Environ Health* 2005;**31** (Suppl 2):22-6.
119 van den Berg T, Elders L, de Zwart B, *et al.* The effects of work-related and individual factors on the work ability index: A systematic review. *Occupational and Environmental Medicine* 2008:oem.

120 Westgaard RH, Winkel J. Guidelines for occupational musculoskeletal load as a basis for intervention: a critical review. *Applied Ergonomics* 1996;**27** (2):79-88.

121 Westgaard RH, Winkel J. Review article. Ergonomic intervention research for improved musculoskeletal health: A critical review. *Int J Ind Erg* 1997;**20**:463-500.

122 Wolman RL. Osteoporosis and exercise. *BMJ* 1994;**309** (6):400-3.