

Ph.D. Thesis

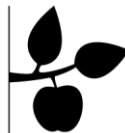
Exercise training among construction workers at the work site.

A randomized controlled intervention study

Valgerdur H. Bibi Gram

Institute of Sports Science and Clinical Biomechanics
Faculty of Health Sciences
University of Southern Denmark

2012



UNIVERSITY OF SOUTHERN DENMARK

Contents

Preface	4
Acknowledgements.....	4
List of papers	5
Summary (English)	5
Resume (Dansk)	7
List of abbreviations.....	9
1.0 Introduction	10
1.1 Work postures in the construction industry and prevalence of musculoskeletal disorders	10
1.2 Construction workers and prevalence of cardiovascular disorders.....	12
1.3 Measurements of physical activity	13
1.4 Physical activity and general public health purpose	15
1.5 Recommended physical activity and occupational physical activity	15
1.6 Work-site interventions	17
1.7 The FINALE program	18
2.0 Aim	22
2.1 Aims of the specific papers.....	22
3.0 Hypothesis	22
4.0 Methods	23
4.1 Study design	23
4.2 Study population	23
4.3 Procedures	24
4.3.1 Objective measurements	26
4.3.2. Self-report measurements	27
4.4 Intervention	29
4.4.1. Aerobic training and strength training	30
4.5 Statistics	30
5.0 Results	34
5.1 Baseline.....	34
5.1.1 Study population and data collection	34
5.1.2 Demographic and clinical measures	34
5.1.3 Questionnaire self-assessment	35
5.1.4 Physical activity measures	36
5.2 Intervention	40
5.2.1 Allocation to individually tailored exercise training	40

5.2.2 Adherence.....	40
5.2.3. Objective measures.....	40
5.2.4 Self-reported measures.....	43
5.3 Evaluation of methods	44
6.0 Discussion	46
6.1 Baseline measures	46
6.1.1 Exposure assessments (paper II)	46
6.1.2 The prevalence of work ability, musculoskeletal disorders, and sick leave (paper IV)	49
6.1.3 Physical capacity level (paper II).....	51
6.2 Individually tailored intervention	52
6.2.1 The training program.....	52
6.2.2 Primary outcome variables.....	53
6.2.3 Secondary outcome variables.....	54
6.3 General discussion	55
6.3.1 Framework for the intervention	55
6.3.2 Compliance to the intervention	56
6.3.3 Levels of leisure-time physical activity and perspectives of public health.....	56
6.4 Methodological considerations	57
6.4.1. Study population and time frame.....	57
6.4.2. Measurements methods.....	57
6.4.3 Text messages:	58
6.5 Strengths and weaknesses	59
7.0 Conclusion.....	60
8.0 Perspectives	60

Preface

This thesis was initiated and completed in collaboration between the Institute of Sport Science and Clinical Biomechanics, University of Southern Denmark and the National Research Centre for Working Environment, Copenhagen, Denmark. Financially, the project was supported by the Danish Working Environment Research Foundation.

The Regional Scientific Ethical Committee for Southern Denmark approved the study (No 20090058) and it was conducted in accordance with The Declaration of Helsinki. The study was registered in the International Standard Randomized Controlled Trial Number Register: NCT01007669.

Acknowledgements

First of all, there would not be a study had it not been for 67 construction workers who were willing to participate in the study. For 12 week, half of them performed vigorous exercising at 7 o'clock in the morning for 12 weeks.

The present thesis relies on contribution and support from a number of persons. In particular I want to thank;

Gisela Sjøgaard, Dr.Med.Sci, my principle supervisor, for excellent supervision and for sharing with me her huge knowledge and experience in the world of research. Mostly, I would like to thank Gisela for her loyalty and for having confidence in me throughout the process.

Karen Sjøgaard, PhD, my project supervisor, for providing valuable guidance and always being available for immediate support and advice. Thanks to Karen for being so cheerful and a warm person, - who also has taught me a lot about unwritten rules in the world of research.

Andreas Holtermann, PhD, for outstanding involvement throughout the study and for willingness to help me whenever needed and specially, for a persistent effort regarding the article writing and for always replying quickly with useful advice and guidance.

Kirsten Kjær, BSc in biomedical Laboratory Science, for professional assistance during the tests, and for spending many hours with me at different workplaces in Denmark. Thanks for being so adaptable and thanks for many pleasant hours in your company; on the road; in the red bus; everywhere.

Dorte Ekner, BSc in biomedical Laboratory Science and Klaus Hansen, Physiotherapist, for always being helpful whenever needed. Thanks for technical and practical assistance, and for making me feel welcome at NFA.

Søren Brage, PhD and Kate Westgate, BSc (Hons) in Physical Education & Sports Science, for giving me opportunity to work at MRC Epidemiology Unit, Cambridge. Thanks for lots of time spent on data processing and STATA. Your personality, your helpfulness and kindness, made my stay in Cambridge not only instructive but also a very enjoyable and unforgettable experience.

Thanks to all **exercise supervisors** affiliated with the study.

Thanks to my **colleagues at IOB** and **journal-club members** from NFA for good discussions and social events.

List of papers

Paper I: Worksite interventions for preventing physical deterioration among employees in job-groups with high physical work demands: Background, design and conceptual model of FINALE
Holtermann A, Jørgensen MB, Gram B, Jeanette R Christensen, Anne Faber, Kristian Overgaard, John Ektor-Andersen, Ole S Mortensen, Gisela Sjøgaard, Karen Sjøgaard. BMC Public Health.2010;10:120.

Paper II: Occupational and leisure-time physical activity and physical workload among construction workers. *Gram B, Westgate K, Holtermann A, Karstad K, Sjøgaard 1, Brage S, Sjøgaard G (manuscript-revised).*

Paper III: Effect of individualized worksite exercise training on aerobic capacity and muscle strength among construction workers – a randomized controlled intervention study. *Gram B, Holtermann A, Sogaard K, Sjøgaard G. Scan J Work Environ Health 2011.Sept 1;38(5):467-75.*

Paper IV Does an exercise intervention improving aerobic capacity among construction workers also improve musculoskeletal pain, work ability, perceived physical exertion, productivity and sick leave? A randomized controlled trial. *Gram B, Holtermann A, Bültmann U, Sjøgaard G Sjøgaard K, JOEM (August) in press(proof version) 2012.*

Summary (English)

The aim of this Ph.D. thesis study is to give an overview of the rationale behind physical training of workers with heavy workload, and in an intervention study to investigate the effect of individually tailored physical exercise training on aerobic capacity and muscle strength among employees with a physically heavy work. Furthermore, to investigate if such an intervention affects sick leave, work ability, musculoskeletal pain, and the general level of physical activity. As target group, employees in the construction industry are chosen, as they are exposed to physically heavy work such as frequent lifting, awkward positions, handling of heavy weights and unexpected physical loads.

Introduction

A high physical workload is associated with increased risk of musculoskeletal disorders, ischemic heart disease and all-cause mortality. Also, a heavy workload is associated with reduced work ability, increased risk of sick leave, and early retirement. This is in contrast to the health enhancing effect of leisure-time physical activity that includes exercise training of aerobic capacity and muscle strength. Additionally, employees with physically demanding work have a particular need for good physical capacity in order to tolerate a heavy workload and avoid deterioration of the body and early retirement. Therefore, there are several incentives to focus on health promoting activities among employees exposed to a high physical workload.

Method

The study was a randomized controlled trial with an exercise intervention and a health check before and after. Participants were individually randomized into an exercise or control group. In total 67 construction workers were included in the study and recruited from three workplaces and companies in Denmark. The health check included measures of VO_2max , isometric muscle strength, body mass, fat %, blood pressure, and blood lipid profile. Furthermore, physical activity was estimated by using a combined movement and heart rate sensor, observations on movement and work postures, and by participants' reply on questionnaires regarding work activities, leisure-time, transport- and sport related physical activities. The exercise program was individually tailored based on the health check and composed of aerobic and strength training. It was performed during work hours, lasted one hour per week (3×20 min per week) for 12 weeks and was supervised by skilled instructors.

Main findings

The study showed that construction workers had significantly higher occupational physical activity than leisure-time physical activity. The construction workers spent 81% of working time in an upright position, carrying their own weight and they were moving during 21% of working time (approx. 1.7 h). A large proportion of the employees reported handling loads of > 10 kg for approx. 25 % of the work time when pushing, pulling, lifting or carrying. Additionally, direct observation revealed strenuous work postures for 19% of the working time (approx. 1.4h) with the trunk bent, bent-double, twisted or bent and twisted. On average, the employees rated their perceived workload as 11 ± 0.4 on scale from 6-20, and as much as 45% of the employees reported increased respiratory rate ≥ 25 % of the work time. The study population had a relative VO_2max of 26.8 ± 6.6 ml/min/kg which was significantly lower compared to representative data on employees in Denmark (difference in z-score -1.13 ± 0.1 , $P < 0.001$). Their BMI (28.3 ± 4.7 kg/m²) was likewise

significantly higher compared to representative data on employees in Denmark (difference in z-score 1.10 ± 0.2 , $P < 0.001$). Their muscle strength was significantly higher in the abdomen (flexion) (difference in z-score 0.76 ± 0.2 , $P < 0.001$), in shoulder elevation (difference in z-score 0.56 , SE 0.1 , $P < 0.001$), and arm abduction (difference in z-score 0.29 , SE 0.1 , $P < 0.05$).

Training significantly increased relative VO_2max in the intervention group. There was an increase of 3.9 ± 2.7 ml/min/kg ($p < 0.001$) in the exercise group compared to 0.3 ± 4.5 ml/min/kg ($p = \text{NS}$) in the control group (difference between groups, $P < 0.001$). This is found in other studies to be a clinically relevant change in the long run regarding reduction in risk of cardiometabolic disorders. Regarding muscle strength, musculoskeletal disability, sick leave, and work ability, there were no statistically significant changes as a consequence of the intervention.

Conclusions

This study demonstrates that work site intervention among construction workers is effective regarding significant increase in VO_2max . Integrating health enhancing activities during work hours may be a strategy for a general health improvement in this occupational group with low aerobic capacity in combination with strenuous workloads.

Resume (Dansk)

Formålet med denne ph.d. afhandling er at give en oversigt over rationalet for fysisk træning af ansatte med fysisk belastende arbejde samt undersøge effekten af et individuelt tilrettelagt træningsprogram på aerob kapacitet og muskelstyrke af de ansatte. Samtidig, at undersøge om denne form for intervention påvirker sygefravær, arbejdsevne, bevægeapparats besvær samt mængden af fysisk aktivitet generelt. Målgruppen er ansatte i bygge- og anlægs branchen idet de er udsat for fysisk belastende arbejdsopgaver såsom mange tunge løft, uhensigtsmæssige arbejdsstillinger og uventede tunge byrder.

Introduktion

Fysisk hårdt arbejde på arbejdspladser er for arbejdstagere forbundet med øget risiko for bevægeapparats-besvær, hjerteinfarkt samt (tidlig)død af alle årsager. Arbejdsmæssig fysisk belastning har derfor ikke de samme positive sundhedsmæssige konsekvenser som høj fysisk aktivitet i fritiden. Samtidig har ansatte i jobs med høje fysiske krav brug for god fysisk kapacitet for at imødekomme belastningerne og forhindre nedslidning. Der er således mange gode grunde til at fokusere på sundhedsfremmende initiativer for ansatte i jobs med fysisk høje krav og belastning.

Metode

Studiet var et randomiseret, kontrolleret interventions studie over 12 uger. Alle deltagerne gennemgik ved start og afslutning af interventionen et sundhedstjek. Deltagerne blev randomiseret individuelt til enten træningsgruppe eller kontrolgruppe. I studiet blev inkluderet i alt 67 ansatte fra tre bygge- og anlægs virksomheder i Danmark. Sundhedstjekene bestod af målinger af $VO_2\text{max}$, isometrisk muskelstyrke, kropsvægt, fedtprocent, blodtryk og lipid profil. Derudover blev der målt mængden af fysisk aktivitet over ca. 1 uge ved hjælp af en påsat sensor, der måler hjertefrekvensen og fysiske accelerationer. Der blev gennemført observationer af arbejdsstillinger og – bevægelser på arbejdspladsen og samtlige deltagere udfyldte spørgeskemaer vedrørende arbejdsaktiviteter, fysisk aktivitet i forbindelse med fritid, transport og sport.

Resultater fra test af sundhedstjekket blev anvendt til at individualisere træningsprogrammerne.

Træningen, som var superviseret, foregik i arbejdstiden, 1 time om ugen (3x20 minutter hver gang) og varede i alt 12 uger.

Vigtigste fund

Bygge- og anlægsarbejdere i dette studie havde signifikant højere fysisk aktivitet på deres arbejde end i fritiden. De ansatte tilbragte 81 % af arbejdstiden i opretstående stilling, og samlet set var de i bevægelse 21 % af arbejdstiden (ca. 1.7t). En stor del af de ansatte angav, at de blev udsat for belastninger på > 10 kg i 25 % af arbejdstiden, når de skubbede, trak, løftede og bar. Desuden viste observationer belastende arbejdsstillinger i 19 % af arbejdstiden (ca. 1.4 t) med overkroppen foroverbøjet, meget foroverbøjet, vredet og samtidig vredet og bøjet. De ansatte vurderede deres arbejdsbelastning gennemsnitlig som værende 11 ± 0.4 på en skala fra 6-20, og 45 % af de ansatte vurderede, at ≥ 25 % af arbejdstiden var arbejdet så belastende, at de kom til at trække vejret hurtigere end normalt. Denne gruppe af bygge- anlægsarbejdere havde et kondital på 26.8 ± 6.6 ml/min/kg, hvilket var signifikant lavere end konditalet hos et repræsentativt udsnit af danske arbejdstagere: differencen i z-score -1.13 ± 0.1 , $P < 0.001$. BMI var 28.3 ± 4.7 kg/m² som var signifikant højere sammenlignet med et repræsentativt udsnit af danske arbejdstagere: differencen i z-score 1.1 ± 0.2 , $P < 0.001$. Tilsvarende var muskelstyrken signifikant højere i bugmuskulatur: differencen i z-score 0.8 ± 0.2 , $P < 0.001$, skuldermuskulatur: differencen i z-score 0.6 ± 0.1 , $p < 0.001$ og armmuskulatur: differencen i z-score 0.2 ± 0.1 $p < 0.05$. Med træningsinterventionen steg konditalet signifikant med en ændring på 3.9 ± 2.7 ml/min/kg i træningsgruppen og ikke-signifikant med 0.3 ± 4.5 ml/min/kg i kontrolgruppen (forskel mellem grupperne, $P < 0.001$).

Konklusion

Dette studie viser, at ansatte i bygge- og anlægs branchen i ringe grad dyrker fysisk aktivitet i fritiden, har lavt kondital og udsættes for høje fysiske belastninger i arbejdet. Dette studie viser, at det er muligt at forbedre de ansattes fysiske kondition tilstrækkeligt til at have sundhedsmæssige konsekvenser ved at integrere fysisk træning i arbejdstiden.

List of abbreviations

ACSM:	American College of Sports Medicine
EEACC+HR:	Energy expenditure from combined acceleration and heart rate measurements
BMI:	Body Mass Index
EE:	Energy expenditure
FINALE:	F rame for I nterventions for preserved work A bility; L ong term E ffect
HR:	Heart rate
h:	Hours
IPAQ:	International Physical Activity Questionnaire
ITT:	Intension to treat analyses
LBP:	Lower back pain
Loa:	Limits of agreement
min:	Minutes
MET:	Metabolic equivalent
MVC:	Maximal voluntary contraction
MVPA:	Moderate to vigorous physical activity intensity
PA:	Physical activity
PAEE:	Physical activity energy expenditure
PATH:	Posture, Activity, Tools and Handling
Pwear:	Time integral of wear probability based acceleration and heart rate
SD:	Standard deviation
SE:	Standard error of mean
s:	Seconds
VO ₂ max:	Maximum oxygen uptake

1.0 Introduction

It is well documented that working with a high physical workload has adverse health-related consequences. These workers are at a higher risk of musculoskeletal disorders (1), cardiovascular disease (2) and all-cause mortality (3). Additionally, studies have shown that a heavy workload is associated with reduced work ability (4), increased risk of sick leave (5), and early retirement (6;7).

There are several incentives to focus on the health related consequences of a physically heavy workload. In addition to the serious individual consequences, an unhealthy work force is also a socioeconomic burden and a serious public health problem. The economical part applies both to absenteeism, i.e. employees' time away from work/ sick leave and to presenteeism, i.e. decreases in productivity due to disabled workers who are not on sick leave but at work with decreased working capacity due to health problems (8). As an example of the size of the problem, the total sick leave in Denmark corresponds to 5 per cent of the workforce missing each year (9).

In the construction industry, workers are exposed to physically heavy workloads which include frequent lifting, awkward positions, static work postures, handling of heavy weights, and unexpected sudden impacts from physical loads (10). Such work demands require good musculoskeletal health and high physical capacity in order to attain a relative low workload. Thus, construction workers are at higher risk of occupational disability than workers in less physically demanding jobs, with musculoskeletal disorders and cardiovascular diseases considered to be the main causes (10;11). Work related musculoskeletal disorders include, in general, disorders in muscles, tendons, joints, peripheral nerves or vascular system associated with exposure to risk factors in the workplace. Local ischemia, degenerative processes, tendinitis, ligament and meniscal lesions are some of the physical factors leading to pain and discomfort induced by mechanical load (12).

1.1 Work postures in the construction industry and prevalence of musculoskeletal disorders

Construction workers have been found at high risk of musculoskeletal disorders and the prevalence of musculoskeletal disorder among construction workers are well documented (13-15). Quantification of the levels of biomechanical exposures among construction workers is needed but evaluation of the health risk related to exact loads is complex (16;17). "Construction workers" is a generic term that encompasses many different job tasks. Even though the group as a whole is exposed to physically heavy workload, the workload differs between the groups/trades. Among different trades, there are various load profiles, postures and manual handling. Hartmann et al (16) showed that scaffold workers handled weight over 10 kg for 13.7% of the regular daily work time, bricklayers using bricks requiring two hands for 7.1% and for carpenters for 6.7% of the work time. There is strong evidence that lower back disorders are associated

with lifting and forceful movement (18) and that handling of loads, frequently or with high force, is associated with occurrence of shoulder disorders (19).

Depending on work tasks, some construction workers are exposed to bent trunk position or awkward position of the back. Tak S et al (20)(Table1) used the observational method "PATH" and found that trunk flexion ranged from 35% to 55% of work time depending on the specific work tasks. Work related awkward postures are associated with lower back pain and working with hands above shoulder height increases neck/shoulder pain with a dose-response relationship (12;21).

Also, prolonged standing has been associated with occurrence of lower back pain (22;23) and contributes to discomfort and muscle fatigue particularly in the legs (22).

Kneeling and squatting positions are common work postures in some construction trades. An observational study of 120 highway construction workers (200-250 observation-hours) showed that the workers spent about 8% of the time in knee straining postures (24). Additionally, Hartmann et al (16) had documented that painters, plumbers, and carpenters worked in kneeling postures for 23.8%, 16.7% and 7.2% of their work time, respectively.

Kneeling and squatting are most common risk factors of listed knee disorders, with osteoarthritis (OA) as the most debilitating occupational knee disorder (25).

Studies using observational methods among construction workers are presented in Table 1

Besides the association between work related exposures and musculoskeletal disorders, the workers' individual capacity, influences the ability to handle the job and thereby the development of musculoskeletal complaints. Known individual factors are age, gender, smoking, personality, leisure-time physical activity, physical strength, and BMI (18). Evidence of the association between selected individual factors as leisure-time physical activity, physical capacity, physical strength and BMI and musculoskeletal disorder is ambiguous. The results differ, due to different methods and the way of controlling for the influence of the individual factors (18). However, in the spite of conflicting evidence, theoretically, factors such as leisure-time physical activity, physical capacity, physical strength and BMI and musculoskeletal are important in relation to musculoskeletal disorders.

Table 1**Exposure assessment studies using observational methods among construction workers**

Reference	N	Origin	Method	Outcome/resume relevant to this thesis
Tak S et al 2011 (20)	120	USA	PATH	On average, trunk flexion ranged from 35%-55% of the work time (by trade) Squatting and kneeling >10% of work time in certain operations Most of the load handled weighed <15 pounds but occasionally very heavy loads were handled
Hartman B et al 2005(16)	247	German	AEB	Weights of < 10kg was handled 13.9% of work time (shaffolders), 7.1% of the work time (bricklayers) and 6.7% of the work time (carpenters) 9.5% of work shift with hands in an overhead position (carpenters) >1/3 of the shift bricklayers worked in a bent position
van der Beek et al 2005 (26)	61 (7406 obs)	Dutch	Systematic observation	External loads <10 kg handled 1246 times of 3471 observations and 10-25 kg handled 305 times of 3471 observations. Trunk flexion <20 for 1/3 of the time 37% of the time were one or both arms elevated
Kivi P, Mattila M 1991(27)	58 (6457 obs)	Finish	OWAS	101 postures fell into OWAS category 4 (corrective measures needed immediately). The most common were 27% of all Cat 4post: Bent back, both arms above shoulders, the force was required to handle a mass from 10-20 kg.

Individual and environmental factors affecting musculoskeletal health are widely distributed in the general population and stratifying the effect of these factors is only seen in studies on large populations (28).

1.2 Construction workers and prevalence of cardiovascular disorders

High physical activity at work and physically demanding jobs do not seem to have the same favorable health effect as physical activity at leisure time. On the contrary, high physical activity at work is considered to a greater extent related to deterioration and actually has the opposite effect of the positive health effect related to leisure-time physical activity (29). Furthermore, studies have shown that high physical activity during work time is associated with increased risk of myocardial infarction and all-cause mortality (30-33).

Especially among men in jobs with high occupational physical activity, it is documented that low leisure-time activity and low physical fitness increase the risk of mortality from ischemic heart disease (34). This means, that important individual factor as deficient engagement in leisure-time physical activity has shown to be more predominant among employees in physically demanding jobs (35;36).

Many work-related and individual factors have been shown to influence on the risk of developing ischemic heart disease. However, Krause et al (2) showed that high energy expenditure at work was associated with accelerated progression of atherosclerosis even after control for factors as leisure-time physical activity, aerobic fitness, and socioeconomic status. Additionally, work postures contribute to cardiovascular strain, even though they do not lead to high levels of energy expenditure. Working in upright position and walking for many hours has impact on the cardiovascular strain due to venous pooling in the legs and resultant heart rate increases (2). In accordance, Dutch construction workers were shown to have 20% higher risk for cardiovascular disease compared to the general Dutch working population (37).

1.3 Measurements of physical activity

In the scientific literature, the wordings of both *physical activity* and *exercise* are both arbitrarily used. In this thesis focusing on physical activity intervention the term exercise is used as it is a more specific term indicating a form of physical activity that is planned, structured, repetitive, and where the goal is to improve health. Furthermore, in this thesis, it will be distinguished between occupational physical activity and leisure-time physical activity. Exercises will be used equal to health-enhancing physical activity.

The intensity of exercise plays an important role both for the achieved health effects and for the risk of injuries during the exercises. The intensity of aerobic exercise can be expressed both as absolute and as relative intensity. The absolute intensity refers to the energy required to perform the activity per unit time. For aerobic activity, absolute intensity is often expressed as rate of energy expenditure or speed of walking. For resistance exercises, absolute intensity is expressed as the amount of weight lifted or moved. Often, absolute intensity is also categorized into “light”, “moderate”, “hard”, and “very hard”. Relative intensity for aerobic exercise can be expressed as %VO₂max adjusted by the person’s bodyweight (ml/min/kg) or by rating the perceived physical exertion (38) (Table 2). In the course of time, the term “physical fitness” has been defined in a variety of ways. The most common definition is: “the ability to carry out daily tasks with vigour and alertness, without undue fatigue and with ample energy to enjoy leisure-time pursuits and meet unforeseen emergencies” (38). A measured VO₂ max values have been based on mean VO₂ max norms, classified into age related fitness categories. For example, according to Shvartz and Reibold (39) the fitness categories for men are: 1=excellent, 2=very good, 3=good, 4=average, 5= fair, 6=poor, 7=very poor (Figure 1).

Table 2

Classification of Physical Activity Intensity

Endurance Type Activity – relative intensity			Resistance Type Exercise – relative intensity
Intensity	Percent HRmax*	RPE **	Relative Intensity Percent 1 RM ***
Very light	<50	<10	<30
Light	50-63	10-11	30-49
Moderate	64-76	12-13	50-69
Hard	77-93	14-16	70-84
Very Hard	≥94	17-19	≥85
Maximal	100	20	100

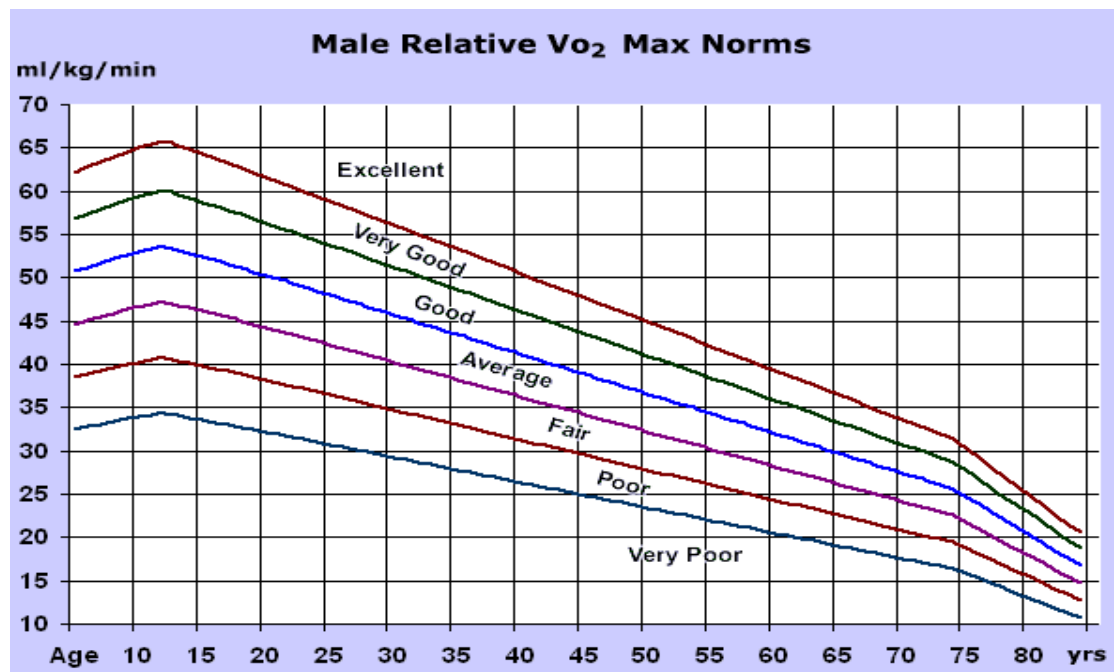
* %HRmax = $0.7305 (\%VO_{2max}) + 29.95$ (Blair 1989)(40).

**Borg Rating of Perceived Exertion 6-20 scale (Borg 1970) (41)

***RM = repetitions maximum, the greatest weight that can be moved once in good form Ref: (38;42)(modified).

Figure 1

VO₂max fitness norms for males



The Figure is from Shvartz and Reibold (39)

1.4 Physical activity and general public health purpose

Evidence of health enhancing physical activity effects on the cardiovascular and musculoskeletal systems is strong and there is also broad documentation of the effect of health enhancing physical activity on the metabolic, endocrine and immune systems. Thus, there is strong evidence that those who are physically active have lower rates of, coronary heart disease, high blood pressure, and all-cause mortality compared to those who are less physically active (physical activity guidelines advisory committee)(38).

Both aerobic capacity training and muscle strength training have an effect on risk factors for cardiovascular diseases i.e. blood pressure and lipid profile, even though there is no consensus about the dose response (38). The scientific evidence for the inverse relationship between aerobic fitness (43;44) and risk of all-cause mortality is strong. For men, the risk increases significantly when the relative VO_2max is below 30-32 ml/kg/min (45-47) or below 28 ml/kg/min according to a meta-analysis (48)(Figure 2).

Even though muscular fitness has been found to be inversely related to all-cause mortality (49;50) scientific evidence for a threshold limit value similar to relative VO_2max has not been established.

Besides the effect on mortality, being physically active per se is beneficial. Exercise decreases the risk of several diseases and increases the general state of health. However, PA may also include some risks.

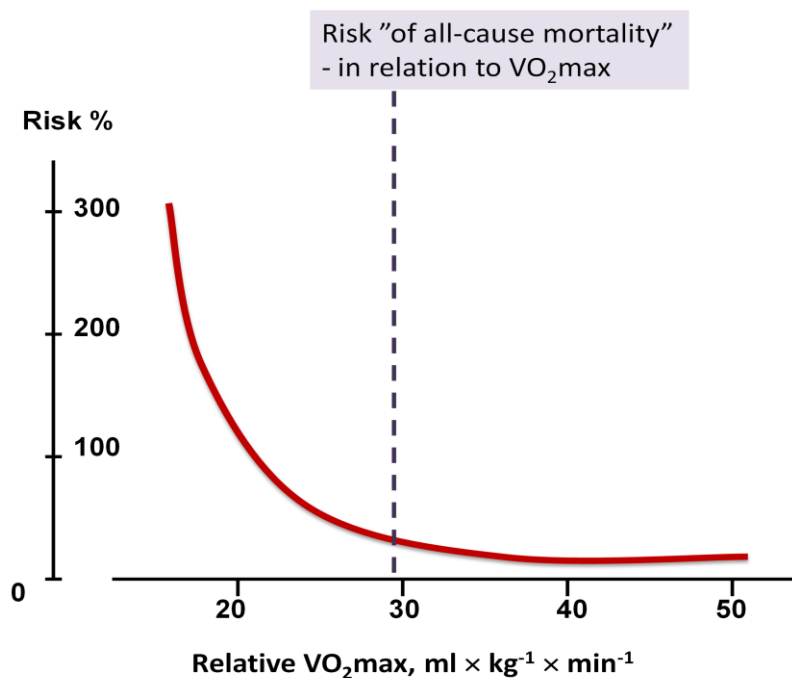
Musculoskeletal injuries increase when the intensity increases both in jobs with high occupational PA (51) and leisure-time PA (50). However, dose-response relationship in different activities/jobs is unknown (50).

1.5 Recommended physical activity and occupational physical activity

The international and national recommendation for health promoting physical activity does not distinguish between physical activity during work time and physical activity during leisure time. The official Danish recommendations on physical activity to promote and maintain health are that all healthy adults aged 18 to 65 years should engage in moderate-intensity cardio respiratory exercise training for more than $30 \text{ min} \cdot \text{d}^{-1}$ on $\geq 5 \text{ d} \cdot \text{week}^{-1}$ for a total of $\geq 150 \text{ min} \cdot \text{week}^{-1}$, vigorous-intensity cardio respiratory exercises training for $\geq 20 \text{ min} \cdot \text{d}^{-1}$ on $\geq 3 \text{ d} \cdot \text{week}^{-1}$ ($\geq 75 \text{ min} \cdot \text{week}^{-1}$) or use a combination of moderate- and vigorous intensity exercise to achieve a total energy expenditure of $\geq 500\text{-}1000 \text{ MET} \cdot \text{min} \cdot \text{wk}^{-1}$ (www.sst.dk/august 2012). These recommendations are in alignment with international guidelines that in addition also recommend resistance exercise 2-3 $\text{d} \cdot \text{wk}^{-1}$ for each of the major muscle groups (52). The recommendations for physical activity, time and intensity can be met by accumulating for example 3 bouts lasting 10 minutes or more into more than 30 minutes in total.

Figure 2

Risk of all-cause mortality in relation to VO₂max



The Figure is modified from Blair et al 1996 (44)

With respect to recommendations, perhaps not only the type (aerobic and muscle strength) of physical activity is crucial, but also the context is of interest. The requirements for occupational physical activity and leisure- time physical activity are different.

The physiological knowledge about physical activity is a prerequisite for health-enhancing changes, but it is often a challenge to have this knowledge embedded individually. Based on the fact that many adults spend many hours at the workplace, it has been suggested that worksites are promising settings for exercise promotion (53). Additionally, a physical intervention in work site settings makes it possible to focus on a specific target group exposed to specific work exposures. In this way, an exercise program in work-place setting can have bipartite dimension; a sustained work ability dimension and a public health dimension. By integrating health enhancing physical activity program as part of the working hours among employees with a physically heavy workload, the general health status can be improved. This approach reach a group at risk of not performing health enhancing physical activity and even when the overall focus is on the job groups and their exposure profile.

In 2009, the American Heart Association (54) recommended a comprehensive program in order to improve employees' cardiovascular and general health. These programs should, among other initiatives, include regular physical activity to encourage healthy behavior and occupational health.

1.6 Work-site interventions

In the last decade, several work-site exercise intervention studies have been published as randomized controlled trial (Appendix I). Ten out of 17 studies are on office workers (55-64) and only four studies include participants with a physically heavy workload (65-68) among those two from the FINALE project. Even though the interventions all took place at the workplace, the compliance differed between 18 -90% among the studies.

Only few intervention studies among construction workers have been published and the effectiveness of exercise intervention in work-site settings among these workers is not well documented. Physical activity interventions among construction workers are challenging to accomplish. The group presents specific complications for a study as the employees frequently change work sites and are often hired for temporary employment. Table 3 shows 7 intervention studies including exercise or life-style interventions among construction workers. Four of the studies were designed as a randomized controlled trial (69-72). Only one study measured $VO_2\text{max}$ with no significant changes after the intervention (71). Two studies documented positive results on pain (72;73) and one study showed increase in leisure-time physical activity (71). None of studies documented positive results on work ability. The studies in Table 3 have different designs and outcome measures, and therefore are not easy to compare. Six out of seven studies reported compliance but the measures are different and not always transparent. Compliance is sometimes reported as attendance rate or to which extend the participants completed the program. Among the studies in Table 3 on construction workers, de Boer et al (74) demonstrated relatively high compliance i.e. 28 out of 30 of the participants completed the program. This may be due to the non-randomized design of at the study and a possible selection bias. Compliance or adherence to the exercises, i.e. how well they performed the exercises at the prescribed intensity was not reported. Groeneveld et al (69) found that individual-based lifestyle intervention for workers in the construction industry had effect in terms of weight loss and improved HDL cholesterol. The study focused on physical activity intervention as a part of 'face-to-face' and telephone contacts, but did not measure the amount and pattern of PA directly. Kaukiainen et al (71) demonstrated an effect on leisure-time physical activity in the intervention group compared to controls in a physical activity intervention study among a subgroup of unemployed construction workers.

All in all, there is a need for well-designed studies focusing on the effect of health-enhancing exercises at the work, tailored to employees with strenuous work.

1.7 The FINALE program

The conceptual framework for the present PhD project, as a part of the FINALE-program, was to establish knowledge about the effect of physical workload, lifestyle factors, physical capacity, pain-related cognitive, and behavioral skills on work ability (paper I) (75). The focus of FINALE was on job groups with high physical work demands, and includes 3 RCT studies to tailor interventions to the specific physical demands of the employees in three different job groups. The job groups in the FINALE RCT-studies were besides construction workers, health care workers and cleaners. All studies include the FINALE main common outcomes: musculoskeletal disorders, work ability and sick leave. However, each study has an independent set-up and the primary outcome and secondary outcome are specifically tailored for each respective intervention (75).

The FINALE- study on cleaners (76) had limited effect on changes in musculoskeletal pain, work ability or sick leave after the intervention. Unfortunately, the study suffers from insufficient compliance with mean adherence rate as 37% and 48% respectively in the two intervention groups (see Appendix I). The FINALE - study on health care workers, on the contrary, demonstrates good compliance as only 7 participants dropped out during the program (see Appendix I). In spite of that the study did not show any positive results on musculoskeletal pain (65). Results on work ability and sick leave among health care workers are not yet published. Both studies are presented in Appendix I and are additionally mentioned in the discussion section.

None of the FINALE RCT-studies implies economical cost-effective evaluations; however, it is expected that results and experiences from the studies can provide meaningful scientifically-based information for public health policy, health promotion strategies and further research for employees in jobs with high physical work demands.

The present PhD study focuses on construction workers and contributes to the evaluation of an intervention balancing the relation between individual capacities and physical work demands to prevent physical deterioration. The principal purpose of the intervention on construction workers was to improve the physical capacity and general health of the individual worker and thereby enhance his physical precondition to manage his work. As a consequence, it may change the level of musculoskeletal pain, work ability, productivity, perceived physical exertion, and sick leave.

The exercise training intervention was tailored for each individual worker based on baseline measures of physical capacity and health outcome. Generic criteria were established to deduce individual training programs from the baseline measures and allowing for generalization of the findings on a group level.

Table 3

Interventions studies (lifestyle and/or exercise) among construction workers.

The results shown are changes in the intervention group (s) compared to the control group after the intervention.

Reference	Design	Intervention	Variables	Results	Comment
Groeneveld IF et al(2011) (70) The Netherlands	RCT Individual randomization 2 groups: Intervention group (I) Control group (C) <u>Subjects (n=595):</u> Construction workers with ↑ risk of CVD.	3 'face to face' contacts + 4 telephone contacts: focus on CVD risk profile, health status, PA, diet, and smoking (6 months).	Leisure-time PA Food intake (snack, fruit, vegetables) Smoking.	After 6 months: ↓ ↑ Leisure-time PA ↑ Fruit intake ↓ Snack intake ↑ Quit smoking	Compliance to the intervention approx. 2/3 of participants had five or more (approx. 71%) counseling sessions.
Groeneveld IF et al (2010) (69) The Netherlands	RCT Indiv. randomization 2 groups: Intervention group (I) Control group (C) <u>Subjects (n=517):</u> Male workers in the construction industry with ↑ risk of CVD.	3 'face to face' contacts + 4 telephone contacts: focus on CVD risk profile, health status, PA, diet, and smoking (6 months).	Body weight BMI Diastolic BP Systolic BP HDL cholesterol HbA1c	After 6 months: ↓ Body weight ↓ BMI ↓ Diastolic BP ↓ ↑ Systolic BP ↓ ↑ HDL ↓ ↑ HbA1c	The results in this study are on secondary effect variables. Approx. > 2/3 (72%) had five or more (~71%) counseling sessions.
Borstad JD et al (2009) (73) USA	A prospective cohort intervention study. No randomization 2 groups: Exercise group (Ex) Control group (C) <u>Subjects (n=240):</u> Construction apprentices.	Home-exercise program (8 week): i) 2 stretch exercises ii) progressive resistance exercises 3 days/week for 2 muscle groups.	Developing of first-episode shoulder pain.	↑ RR for new-onset shoulder pain in C ↓ RR for new-onset shoulder pain in Ex.	Daily compliance with the exercise programme at year 1 was mean 3.4 (SD 1.1) days/week The subjects were not working construction workers.

de Boer AGEM (2007) (73) The Netherlands	<p>Prospective intervention study with follow-up. No randomization</p> <p>2 groups: Intervention group (I) Control group (C)</p> <p><u>Subjects (n=291):</u> workers employed in the construction industry.</p>	<p>Individual counseling education program, and coaching at the workplace (6 months) No exercises.</p>	<p>Workability (WA) Working situation (work yes/no, disability pension yes/no).</p>	<p>↓ ↑ in any variables. Only borderline (0.09) change of some WA variables.</p>	<p>Dichotomisation into successful completion of the programme (yes/no): 29 subjects (42%) with successful completion of the programme Difference between the groups at baseline as Int. had lower WA At baseline: moderate WA scores in both groups.</p>
Holmström E, Ahlborg B (2005)(114) Sweden	<p>Intervention study No randomization.</p> <p>2 groups: Experimental group (Ex) Control group (C)</p> <p><u>Subjects (n=47):</u> Construction workers.</p>	<p>Daily morning exercise program (3 months) Different light exercises + stretching</p>	<p>Pain (scale 0-36) Dysfunction Leisure-time PA Workload Range of motion Stretch ability Muscle strength</p>	<p>↓ ↑ Pain ↓ ↑ Dysfunction ↓ ↑ Leisure-time PA ↓ ↑ Workload ↑ Flexion in upper body ↑ Stretch ability in hamstrings ↑ Back muscle isometric endurance</p>	<p>Baseline pain was 3 in Ex and 0 in Control Examiners not blinded Difference in back muscle end. was found due to ↓ endurance in the Control 28 out of 30 in Ex completed the program 3xweek.</p>
Ludewig PM, Borstad JD (2003)(72) USA	<p>RCT 3 groups: Intervention group with symptoms Control group with symptoms Control group without symptoms.</p> <p><u>Subjects (n= 92):</u> Construction workers with shoulder symptoms.</p>	<p>Home-exercise program (8 week): i) 2 stretch exercises ii) progressive resistance exercises 3 days/ week for 2 muscle groups.</p>	<p>Self-report on: Pain (SRQ) Disability in occupational setting (SPADI)</p>	<p>↓ Shoulder symptoms ↑ Functional status</p>	<p>External validity limited to a narrow group of construction workers with restricted shoulder movement, history of shoulder symptoms and positive shoulder impingement tests.</p> <p>Randomization was done before baseline measurements.</p>

Kaukiainen A et al (2002)(71) Finland	RCT 2 groups: PA group Control group <u>Subjects (n=76):</u> Unemployed construction workers.	Supervised training 2xweek (14 weeks): i) dynamic exercise, mobility exercise, strength exercise, and stretching ii) Guidance on leisure-time PA.	Muscular capacity Isometric muscle strength PA leisure-time Balance Aerobic capacity Muscular symptom Workability (1-10)	↑ Muscular fitness of back ↑ Muscular fitness of upper extremities ↑ Leisure-time PA ↑ Balance ↓ ↑ Aerobic capacity ↓ ↑ Muscular symptoms ↓ ↑ Workability	Compliance: High drop-out rate in the PA group On average the men participated 14 times in the intervention (out of 28 possible) The study was a part of larger study originally randomized in 3 groups: here only analyzing 2 groups.
--------------------------------------------------------	----------------------------------------------------------------------------------------------------------------------	----------------------------------------------------------------------------------------------------------------------------------------------------------------	--------------------------------------------------------------------------------------------------------------------------------------------	-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------	-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

RCT: Randomized Control Trial, PA: Physical activity, CVD: Cardiovascular disease, BP: Blood Pressure, VO2max: maximum oxygen uptake

↑: significant increase

↓: significant decrease

↓ ↑: no significant change.

2.0 Aim

The overall aim of this thesis was to investigate the effect of an individual exercise program on aerobic capacity and muscle strength among employees with a physically heavy workload. Furthermore, to investigate if such intervention affects sick leave, work ability, musculoskeletal disability, and general physical activity.

2.1 Aims of the specific papers

The aim of paper I was to outline the framework of the program about *Worksite interventions for preventing physical deterioration among employees in job-groups with high physical work demands* (the FINALE -program) and, to describe the background and the content of the FINALE studies.

The aim of paper II was to investigate the physical strain at work, the level and pattern of physical activity at work and leisure-time among construction workers.

The aim of paper III was to assess the physical capacity of construction workers and evaluate the effect of individually tailored exercise programs on their physical fitness and muscular capacity.

The aim of paper IV was to investigate the effect of the intervention on musculoskeletal pain, work ability, and sick leave 3 month following the exercise training program.

3.0 Hypothesis

The hypotheses of this study are:

1. Employees in the construction industry are exposed to high physically heavy workload. They have high prevalence of musculoskeletal disorders, low work ability and high occurrence of sick leave.
2. The physical capacity in terms of aerobic capacity and muscle strength is low among construction workers compared to a representative Danish working population.
3. Physical exercise intervention tailored to work exposure and individual health profiles has positive effects on physical capacity and health risk factors.
4. Physical exercise intervention improves workers' musculoskeletal disorders, work ability, and sick leave.

4.0 Methods

4.1 Study design

This study was a single-blinded randomized controlled intervention study (RCT) carried out in a work place setting. The participants were individually randomized into exercise group or control group. The randomization was performed blinded and balanced regarding age (≥ 40 years) and workplace. Before the randomization, all the participants completed a health check, which was repeated after the intervention.

The intervention period was 12 weeks and consisted of an individually tailored exercise program based on data from the first health check.

Written informed consent was obtained from all participants before enrollment in the study.

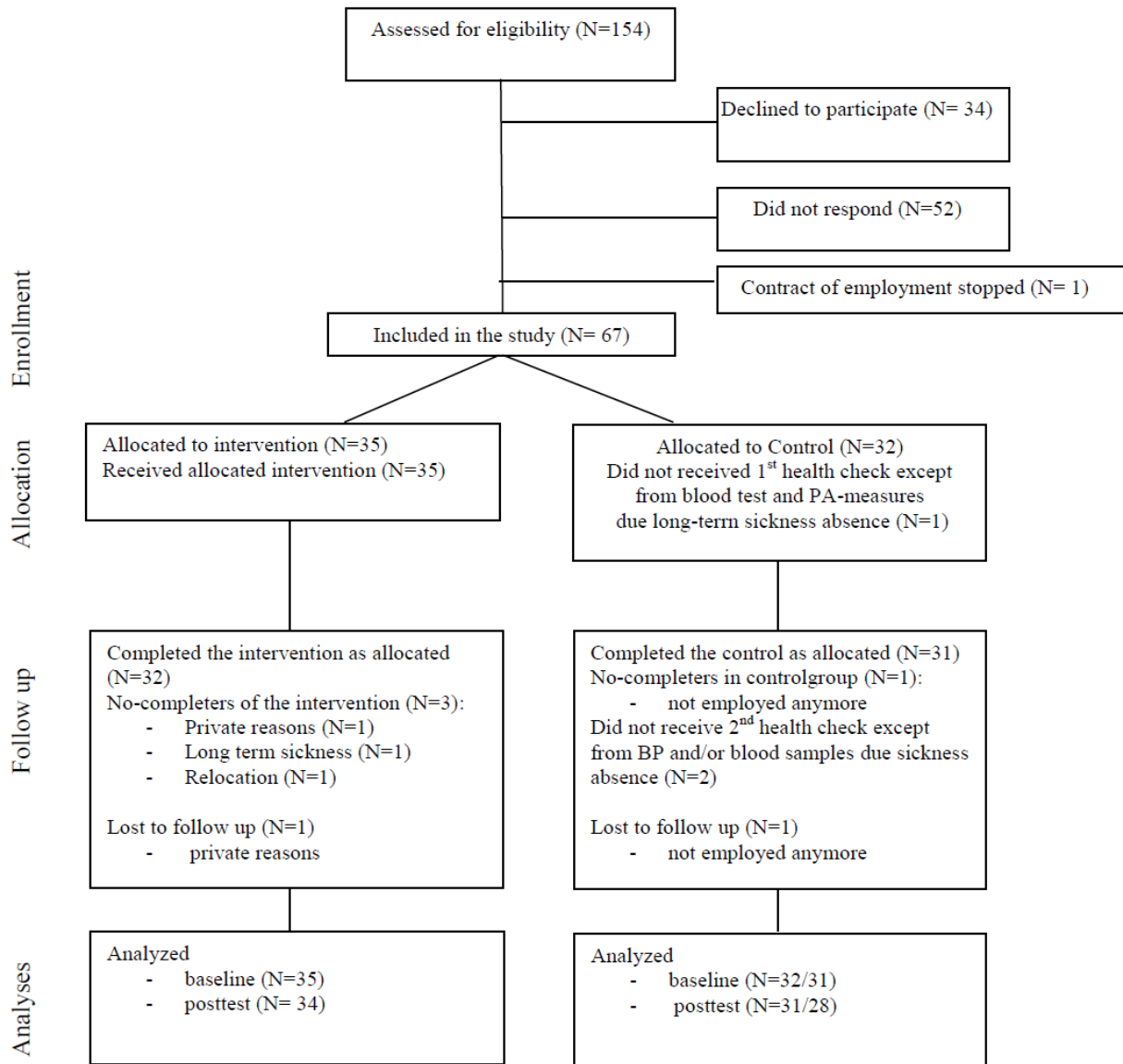
4.2 Study population

The participants were employees working in the construction industry. Introductory meetings were conducted in 11 companies and during the period May 1, 2009 – August 1, 2010, participants were recruited from three workplaces and companies representative for the industry in Denmark. The contact to the workplaces was initiated through direct contact, announcement in trade publications, and networking. In close cooperation with a key member of the staff in the companies and insight into the company's personnel lists, contact with managers and employees was implemented. The study's inclusion criteria were that participants should have physically demanding tasks with high peak loads at work. The exclusion criteria were work hours below 20 h/week. Initially, all employees meeting the inclusion- and exclusion criteria were invited to participate in a screening survey. The objective of the screening survey was to explore the employees' interest to participate in the study, to screen the subjects in accordance to the inclusion- and exclusion criteria, and to gain insight into possible decliners. The screening survey contained questions about body height, bodyweight, disability and musculoskeletal pain in neck-shoulder, back, hip, and knee. The total number of eligible participants who were offered to participate in a screening survey was 154. Of these, 52 did not complete the screening survey and 34 declined to participate in the study. In total, 67 participants were included in the study and randomized to either exercise (n=35) or control group (n=32). See Flow chart, Figure 3.

Analysis on difference between decliners (n=34) and those who accepted to participate in the study (n=67) did not show any significant differences between these two groups according to age, bodyweight, disability, and pain. Only approx. 10% of the decliners gave a reason why they did not wish to participate. Reasons as "lack of interest" and "I am physically ok" were most predominant.

Figure 3

Flow chart of the trial



4.3 Procedures

Health check

The study included two health checks. The purpose of the health check was two-fold. First, to constitute outcome measurements and second, data from the first health check was used to tailor the exercises in the interventions. The first health check was completed before the randomization and the second health check after the 12 weeks intervention period. Only participants included in the study completed the

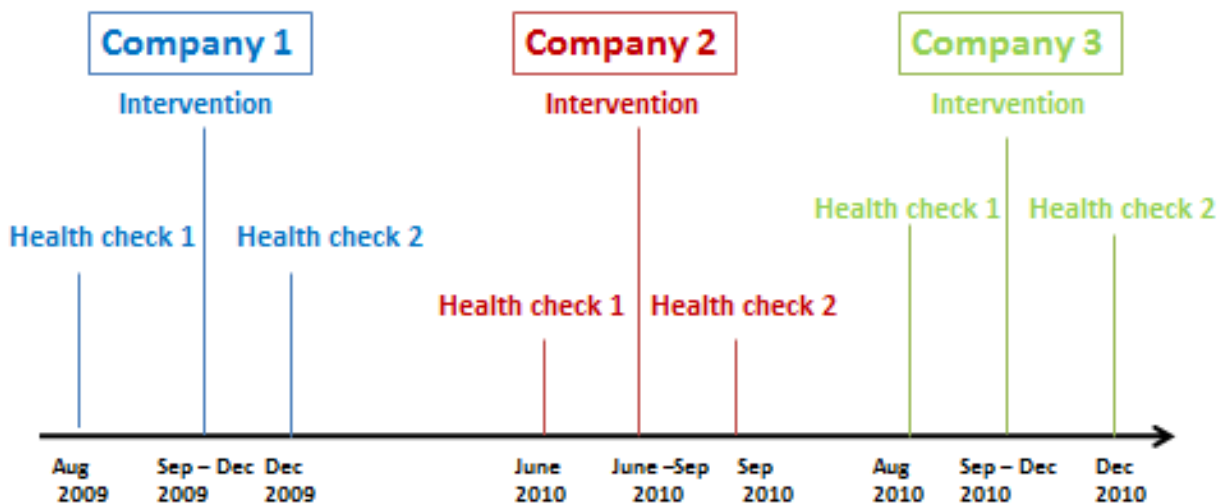
health checks. The time-schedule for the completion of the health checks at the respective workplaces is shown in Figure 4.

This study's primary outcome variable was physical capacity expressed as aerobic capacity and muscle strength. In addition to measures of VO₂max and isometric muscle strength, body mass and fat%, blood pressure, and blood lipid profile were included in the health check. Furthermore, as part of the health checks and for the purpose of measuring physical activity expenditure and physical activity intensity, the participants were equipped with a combined heart rate and movement sensor (Actiheart) which they wore for 7 days. In connection to these objective physical activity measures, the participants filled out a questionnaire sheet about work tasks on the 7th day of the time period they were wearing the movement sensor. Additionally, as a part of the health check, the participants filled out the FINALE-Questionnaire (75) including the International physical activity questionnaire (IPAQ) (77). The questionnaire included e.g. questions about pain in neck-shoulder, back and hip-knee region, work ability, productivity, perceived exertion at work, and sick leave.

Finally, a randomly selected subset of the study group was observed during working hours in the same period of time they were wearing the movement sensor. All participants were individually notified of results from the health check shortly after the health checks were completed.

Figure 4

Time-schedule for the completion of the health checks on respective workplaces



4.3.1 Objective measurements

Maximal oxygen uptake (VO_2max):

Maximal oxygen uptake was estimated from the relation between sub-maximal workload and stable heart rate obtained in Åstrand one-point sub-max test on a bicycle and subsequently using the Åstrand nomogram (78). VO_2max was corrected for age also according to Åstrand (79). The test procedure started with a load of 100 watts on a 1.0 kg, 80 rpm Monark bicycle (Monark 874E, Monark Exercise AB, Sweden). During the first 2 min, the load was adjusted based on the measured heart rate. If the heart rate was below 120 beats per minute (BPM) during the first 2 min, 0.5 kg was added; further weight was added at 3 and 4 min if needed to attain a stable heart rate between 120–170 BPM. When heart rate was recorded as stable for 1 minute, the test was terminated. The duration of each test was approximately 7–10 min. The post intervention test was performed following the same protocol regarding pedal rate and weights added to the bicycle (i.e., with the same external workload and duration at each incremental load as in the pre-randomization test). Heart rate was thus the only parameter that could differ between the pre-randomization and post-intervention tests.

Maximal voluntary contraction:

Isometric muscle strength was measured with a Bofors MODEL dynamometer (Bofors Elektronik, Karlskoga Sweden) in five tests: (i) shoulder strength (elevation), (ii) arm abduction (iii) abdominal strength, (iii) back strength, and (iv) kneeextension (right and left). Three maximal voluntary contractions (MVC) with 30s of recovery between attempts were conducted and the highest value was recorded. Maximal force and the corresponding moment arm were registered (80). Additionally, submaximal (30%) isometric steadiness contractions for 30s of shoulder elevation were performed. The participants were seated and provided with visual feedback. Furthermore, handgrip strength was measured with a handheld dynamometer (model 281111, Smedley, Tokyo, Japan).

Blood pressure:

Supine blood pressure (BP) was measured after a 5-minute rest using a sphygmomanometer (Omron M7, OMRON Corporation, Kyoto, Japan). Three measurements were taken and the mean of the two lowest measures was applied.

Blood lipid profile:

Fasting blood samples were analyzed within 4 hours after the collection by using standard methods (enzymatic colorimetric method).

Objectively monitored physical activity:

Physical activity expenditure (J/kg/min) and physical activity intensity was estimated using a combined HR and accelerometry (ACC) sensor (Actiheart, CamNtech, Papworth, UK). For the 7 days following the baseline health check, participants were asked to wear the sensor. The unit is 7 mm thick, has a diameter of 33 mm and contains a movement sensor, a rechargeable battery, a memory chip and other electronics (81). The sensor was attached to the chest, clicked onto two ECG electrodes. The device was set up to continuously measure HR and acceleration along the body's longitudinal axis with an epoch of 1 minute. Participants were instructed to change the electrodes when needed.

HR data were pre-processed using Gaussian Process Regression (82) and an estimation of activity energy expenditure in terms of J/kg /min and MET·min·wk⁻¹ was obtained using branched equation modelling (83) for combining the ACC with the individually calibrated (84)HR component using HR response parameters from the fitness test described above. This approach has been shown to yield valid estimates of activity energy expenditure during both laboratory (83;85;86) and free-living conditions (87). Prolonged periods of no movement and non-physiological heart rate patterns, were inferred as non-wear, which were taken into account when summarising the physical activity time-series. Analysis of objective activity data uses person-hours as basis in a multi-level model; however, only participants with a minimum of 48 hours of wear data were included in the statistical analysis.

Non-sleep data were analysed as weekdays (Mon-Fri, time-period 07-23) and weekends (Sat-Sun, time-period 07-23). Additionally, data were analysed for working hours (Mon-Fri, time-period 07-15) and leisure time (Mon-Fri, time-period 15-23 + Sat-Sun, time-period 07-23).

Observational measurements:

The observational tool PATH (88) was used to observe the participants' postures and movement, but in this study it was modified as not all PATH's codes were used. Arm, trunk and leg postures were observed as well as the amount of walking. Registrations were done for each minute and the participants were observed within a period of 5 to 43 consecutive min. The number of periods observed differed between the participants and the number of observations within each period varied from 40-120 observations for each participant.

4.3.2. Self-report measurements

International Physical Activity Questionnaire (IPAQ):

The International Physical Activity Questionnaire was developed as a self-report instrument for cross-national assessment of PA and it has been validated in 12 countries (77). The content validity has been found high in IPAQ as it assesses frequency, intensity, and duration of PA. The long form of IPAQ, as used in the current study evaluates four domains of PA separately (occupational, transport, household and

leisure)(77). According to the Guidelines for Data Processing and Analysis of the IPAQ, physical activity for each participant was converted into $\text{MET} \cdot \text{min} \cdot \text{wk}^{-1}$ ($\text{MET level} \times \text{min of activity/day} \times \text{days per week}$). Outcome measures from the IPAQ were total physical activity expressed as $\text{MET} \cdot \text{min} \cdot \text{wk}^{-1}$ within the categories; work, transport, domestic and gardening, and leisure-time physical activity. The IPAQ scoring protocol and recommendation for data truncation has been followed (www.ipaq.ki.se).

FINALE-questionnaire:

Pain intensity

Self-reported musculoskeletal symptoms were measured by text messages as well as questions in the extensive questionnaire commonly used in all FINALE interventions (75). For each body region the 7 days prevalence of musculoskeletal symptoms was assessed by the question: "On a scale ranging from 0-10 please specify the degree of pain in the last 7 days" (0 = no pain and 10 = pain as bad as it can be). In the weekly text messages, 3 questions about pain were asked and scored on a scale ranging from 0-9 (to allow single-digit answers). One for each body region (neck-shoulder, lower back, and hip-knee): On a scale ranging from 0-9 how much pain did you experience in the [body region] during the last week? (0 = no pain, 9 = worst pain imaginable).

Work ability

Self-reported work ability was assessed using the FINALE-questionnaire (2-WAI items) (75) and by text messages. The questions regarding work ability were 1) "How would you rate your current work ability on a scale ranging from 0-10?" (0=completely unable to work, 10=work ability at its best) and 2) "If you think about your health, do you think that you will still be able to perform your job in 2 years' time?" ('inconceivable', 'not sure', 'surely').

In the text messages, the question was: "On a scale ranging from 0-9 how would you rate your work ability during the last week?" (0 = completely unable to work, 9 = work ability at its best).

A rating of 7 was chosen as cut-off point for low work ability.

Perceived exertion

Perceived exertion as an expression of workload was measured using Borg scale (range, 6-20) (41). The question in the FINALE-questionnaire was: "How physically hard do you perceive your current job?"

Productivity

To measure changes in productivity due to disabled worker, the question used was: "How do you assess your productivity in your work the last month?" (range, 0-10, 0=the worst anyone could perform, 10= the absolute best as an employee of my job has to offer) (75).

Sick leave

Self-reported sick leave was obtained by the question: “How many days of sick leave have you had in the previous 3 months?” (75).

Occupational exposure questionnaire:

A total of 10 questions about workload and perceived exertion from the FINALE questionnaire (75) were asked during the same week as participants were objectively monitored. The questions were: 1) “Did your work last week involve manual material handling?” and if so, 2) “How many kg did you handle”? In the following three questions, [handling] was substituted by pushing/pulling, lifting, and carrying, respectively. The reply categories for these questions were a) Almost all the time, b) 75% of the time, c) 50% of the time, d) 25% of the time, e) seldom or never, and the load categories were, a) 5 kg or less, b) 6-10 kg, c) 11-15 kg, d) 16-20 kg, e) 21-25 kg, f) more than 25 kg. There was one question on perceived physical exertion: “On a scale ranging from 6-20, how would you perceive your level of exertion last week?” (41). Furthermore, the participants were asked to which extent their job induced rapid breathing. The reply categories were the same as to above-mentioned question 1.

4.4 Intervention

The exercise intervention was performed during working hours, on or near the workplace, and the training was implemented in collaboration with the employer. The 12-week program was structured as three weekly sessions, each lasting 20 min and was supervised by skilled instructors in two of the three weekly sessions.

The exercise program was designed to target the two primary variables in this study, maximal oxygen uptake (VO_2max) and muscle strength. The training program was individually tailored and based on estimated VO_2max (79) and test of maximal muscle strength in 3 body regions: Neck-shoulder (2 tests) Abdominal-back (2 tests) and Hip-knee (1 test) (89). To meet the goal of making individual-based programs, we used a systematic form of distribution. The individual test results from the first health check were compared to reference values from the Danish Working Population (89). If the test value was below 80% of reference value, the corresponding training element was included in the individual training instruction. Regarding strength training, the three body regions were considered separately and training included only those regions that met the 80 % criteria for at least one of the tests. Participants with all their test values being above 80 % of reference value trained the capacity that was lowest on the job-group level. All training sessions included 10 min. dynamic exercises for warm-up and aerobic capacity, (increasing from approx.

50-70% estimated maximal workload) followed by 10 min with the individually tailored exercises. Participants received their own individual exercise protocol in a training log that had to be completed at each training session (Appendix IV). Exercises for aerobic capacity included bicycling and rowing, exercises for strength training were selected from 11 different exercises (3 for Neck/Shoulder: “Lateral raise”, “Shrugs”, and “Rows”. 5 for Abdominal/Back: “Back extensions”, “Bird dog”, “Plank”, “Crunch”, and “Oblique crunch”, 3 for Hip/Knee: “Static lunges”, “Step-up”, and “Hip abduction”) that could be graded by dumbbells/ resistance bands or body postures (Appendix III).

4.4.1. Aerobic training and strength training

The intensity of the muscle strength training was approximately 60% of one repetition maximum (RM) and the intensity of the aerobic capacity training was at least 70% of VO_{2max} . Two times during the 12-week training period, the participants were tested regarding the intensity of both aerobic capacity and muscle strength training. They were supervised at every session and, if necessary, intensity was adjusted for both muscle strength (number of repetitions and adjusted state of the exercise, see Appendix V), and on aerobic capacity training (based on the Borg rated perceived exertion (RPE 6–20) scale (41). Target RPE was 17).

The control group was not offered exercise training but a one hour lecture on general health promotion.

4.5 Statistics

The statistical analyses were based on an intention-to treat approach (paper III and IV). Missing values in either baseline or post measurements were substituted with data carried forward or backward. When measurements had missing values in both baseline and post measurement, these were replaced by means of all existing values within the particular variable.

Sample size calculation was based on a minimal relevant difference in physical capacity in terms of aerobic capacity and muscle strength of 10% and with a type 1 error of 5% and a power of 80% and resulted in a requirement of 46 participants in each group.

Main variables

Differences between groups in changes of VO_{2max} , muscle strength anthropometry variables (paper III) and pain intensity, work ability, workload, productivity and sick leave (paper IV) were tested using Analyses of covariance (ANCOVA). The part of the questions concerning work ability; now and in the future, were tested using Chi2 test. All analyses were performed on group level, comparing intervention and control group.

Post-hoc analyses

Muscle strength: Post hoc-analyses on muscle strength were performed for those participants only who were training muscle strength exercises. When analyzing the whole group of employees performing strength training exercises (n=20), subjects from the control group were matched to the exercise groups by using the same criteria of inclusion for each specific strength training group, i.e. the controls were divided into the strength training groups they would have been allocated to if they had been in the training group (for allocation, see Figure 6B) (n=21). Significant changes were analysed using one-way analysis of variances (ANOVA). Furthermore, as post-hoc analysis, paired- t-tests were used to analyse significant pre-post differences within the respective strength training groups.

Pain: With specific focus on pain, pain cases were defined as participants reporting 3 or above in lower back pain (n=16 in intervention group) (n=15 in control group). Differences between the groups on lower back pain, neck-shoulder pain and pain in the hip were tested using ANCOVA.

Finally, as post-hoc analysis; with an aim to examine the association between selected variables, correlations analyses were used. Variables were chosen with focus on metabolic load vs. aerobic capacity, metabolic load measured objectively vs. self-report, aerobic capacity vs. work ability, aerobic capacity vs. perceived exertion, and pain vs. mechanical workload.

Text messages

Text messages (paper IV) had reply options on a scale from 0 to 9 in order to have only one digit reply options. Therefore, the text message-based information was scaled by 10/9 before further analysis to improve the basis for comparison. The questions via text messages about pain were phrased as “neck-shoulder” and “hip-knee”, which is why the answers from the questionnaire concerning these questions were pooled when analysing the agreement. The pooled variables were constructed by using the highest value answered concerning questions about neck or shoulder. The same procedure was used concerning hip or knee.

Text message-based variables were analysed with mixed linear model and ANCOVA. To evaluate the differences in pain intensity between the intervention group and the control group, ANCOVA was used pre (week 1 and 2) and post (week 11 and 12) intervention.

Agreement between methods

In order to assess the agreement between the two measurement methods (questionnaire and text messages) Bland Altman plots were used. The method calculates limits of agreement i.e. the difference between the two measurements per subject is plotted against the mean of the two measurements. The plot is a scatter plot and includes three reference lines; one as the mean of the differences (represents the bias of the measurement) and two lines showing 95% confidence

limits; which represent the upper and lower limits of inaccuracy between the two measurements. The vertical dispersion of the scatter of the points reflects how closely the measures concur and when the plots lie along the horizontal axis, the measures are in perfect concordance. Significance between the methods was tested using unpaired two sample t-tests.

Physical activity measures

Differences between questions from IPAQ (paper II) were estimated using Wilcoxon signed-rank test. Objective activity data (person-hours) were analysed using ANOVA repeated measures, with random effect on the individual level. Physical activity expenditure from objective activity data (person-hours) were analysed using ANOVA repeated measures, with random effects on the individual level. Measures of physical activity intensity, from objective data and self-report data (IPAQ) are shown as medians with interquartile range (IQR).

Z-scores

A representative group of employees in Denmark has been tested by the same procedure and the same methods as in the present study (89). To allow comparison between this study random sample and the representative groups calculations of z-scores for relative VO₂max, muscle strength (abdominal, back, dominant shoulder, dominant arm, and dominant hand), and BMI were performed by the following equation:

$$Z = (\text{Measured value} - \text{Average value in the reference population}) / (\text{SD of reference population})$$

Calculating z-scores for VO₂max, muscle strength and BMI, the means were stratified by age: < 30 years, 30-40 years, and > 44 years. Calculating z-scores for blood pressure, a sample of men in Denmark (Copenhagen Heart study) was used (90) and the means were stratified by age: 20-29, 30-39, 40-49, 50-59, 60-69. To calculate z-scores for lipid profile, we used reference data from four population-based samples in Sweden (91) (a cohort from 2002 was used) and the means were stratified by age: 25-34, 35-44, 45-54, and 55-64.

Differences between these groups were calculated by unpaired two sample t-tests.

Data are shown as means \pm SD (\pm SE in tables number 4 and 5), and group mean differences as means \pm SE are presented with 95% confidence intervals (95% CI). Self-report PA data (IPAQ) are calculated as median. Z-scores are shown as means \pm SE. Results were considered statistically significant if the 2-tailed P value was < 0.05. The statistical computer program used was STATA SE10 (StataCorp LP, College Station,

Texas) was used for all analyses except the Gaussian Process Regression, which used a custom-written JAVA program with a MySQL database (paper II).

5.0 Results

The main results from this PhD study are presented in the following section. For more details, see the respective papers this thesis is based upon.

5.1 Baseline

5.1.1 Study population and data collection

Sixty-seven male construction workers participated in the study. Only one participant worked for less than 37 h/wk. Two participants (one from the intervention group, one from the control group) did not accomplish all tests in the health check due to sick leave but did answer the questionnaire and replied to text messages. Two participants did not fill out the baseline questionnaire but completed the follow-up measurement and replied to the text messages. Concerning text messages, the response rate was 85%, i.e., 10 participants (six from the intervention group and four from the control group) or 15% did not reply to any text messages. Sixty participants wore a movement sensor at baseline. Due to difficulties in fixing time for appointments, five participants did not get any measurements from the movement sensor at baseline, one device failed to get any information during the wearing time and one participant withdrew from the study. Information on combined HR and ACC with individual calibration of HR was available in 48 participants. Five did not complete a bike test, so for those we used as calibration, the average HR response of all remaining participants' bike tests but anchored at individual sleeping HR. In total, we analysed 7577 observations on combined HR and ACC, collected from 53 participants. Calculating the total domain sub-scores from IPAQ, 7 participants had missing data in leisure-time physical activity, 9 participants in domestic and gardening, 12 in transportation and 14 in work domain. Out of these, four participants were missing in all domains.

Postures and movement observations were done on 16 participants from two different workplaces.

Three participants in the intervention group withdrew from the intervention program but two of them completed post-test.

All in all, only two participants (one from the intervention group, one from the control group) were lost at follow-up. Figure 3 shows the flow chart of the study.

5.1.2 Demographic and clinical measures

At baseline, there were no statistically significant differences between the groups in any of the variables (Table 4).

Participants in this study had significantly higher BMI than a representative group of employees in Denmark (89) with a mean difference in z-score 1.10 (± 0.2 , $P < 0.001$). Furthermore, they had significantly

higher muscle strength in the abdomen (flexion) (difference in z-score $0.76, \pm 0.2, P<0.001$), shoulder elevation (difference in z-score $0.56, \pm 0.1, P<0.001$) and arm abduction (difference in z-score $0.29, \pm 0.1, P<0.05$). In addition, this study population had significantly lower relative $VO_2\max$ (difference in z-score $-1.13, \pm 0.1, P<0.001$) than a representative group of employees in Denmark (89).

The participants had significantly lower total cholesterol (difference in z-score $-0.26 \pm 0.1, P<0.05$) compared to the Swedish reference group while according to BP, high- and low-density lipoproteins (HDL and LDL), and triglycerides there were no significant differences between the participants compared to the Danish and Swedish references (90;91).

Table 4

Baseline Demographic and Clinical Characteristics of study population

Characteristics	Exercise group N=35	Control group N=32	Total N=67 (range)
Age, y	44 \pm 11.1	43 \pm 10.0	43.7 \pm 10.5 (21.9-63.4)
Weight, kg	91.2 \pm 15.8	89.2 \pm 19.8	90.2 \pm 17.7 (63.2-141.4)
BMI kg/m ²	28.8 \pm 4.1	27.9 \pm 5.2	28.3 \pm 4.7 (18.9-44.6)
Fat, %	26.2 \pm 5.6	24.8 \pm 6.1	25.5 \pm 5.8 (9.8-34.7)
$VO_2\max$, l/min	2.4 \pm 0.5	2.3 \pm 0.5	2.3 \pm 0.5 (1.1-3.6)
Relative $VO_2\max$, ml/min/kg	27.1 \pm 6.9	26.5 \pm 6.4	26.8 \pm 6.6 (13.6-43.0)
Isometric Muscle strength, nm:			
- Shoulder Dominant	139.5 \pm 40.3	140. \pm 34.6	140.1 \pm 37.0 (65.6-265.1)
- Arms Dominant	77.2 \pm 19.1	75.1 \pm 30.8	76.2 \pm 25.2 (33.4-201.1)
- Abdominal	220.3 \pm 52.6	219.4 \pm 56.2	219.9 \pm 54.4 (128.4-380.3)
- Back	224.3 \pm 69.5	214.8 \pm 56.2	219.8 \pm 63.2 (93.4-435.3)
- Leg Right	188.1 \pm 53.6	190.5 \pm 66.1	189.2 \pm 59.4 (82.5-360.9)
- Leg Left	176.4 \pm 49.3	186.1 \pm 61.9	181.0 \pm 55.5 (91.6-359.9)
- Handgrip Dominant	53.3 \pm 8.9	54.0 \pm 9.2	53.6 \pm 9.0 (26.0-72.0)
Systolic blood Pressure, mm Hg	135 \pm 14	132 \pm 17	133.6 \pm 15.4 (107-171)
Diastolic blood Pressure, mm Hg	86 \pm 10	85 \pm 11	85.2 \pm 10.5 (65-115)
Total cholesterol, mmol/l	5.1 \pm 0.9	5.2 \pm 1.1	5.2 \pm 1.0 (3.0-7.3)
HDL cholesterol, mmol/l	1.3 \pm 0.3	1.4 \pm 0.3	1.3 \pm 0.3 (0.8-2.4)
LDL cholesterol, mmol/l	3.2 \pm 0.7	3.3 \pm 1.0	3.3 \pm 0.9 (1.5-5.4)
Triglyceride, mmol/l	1.4 \pm 0.9	1.4 \pm 0.6	1.4 \pm 0.7 (0.6-4.1)

Values are mean \pm SD and number (%). P values for the 1-way analysis of variances (ANOVA). HDL: high-density cholesterol, LDL: low-density cholesterol.

5.1.3 Questionnaire self-assessment

In the questionnaire, the participants reported a mean work ability of 7.9 ± 2.0 (scale, range 0-10).

However, 27 % of the participants reported seven points or less on the work ability scale which corresponds to poor to moderate work ability (92). Among the workers who were not on long term sick leave, the mean days of sick leave during three months was 1.4 ± 2.9 . Baseline characteristics and outcomes are presented in Table 5.

Correlations analysis on LBP and the amount of kg lifted did not show any linear relation (Appendix II). Analyses on pain cases (n=31) showed mean pain intensity during the last seven days: 5.2±0.3 in LBP, 2.3±0.4 in right shoulder, 1.6±0.5 in left shoulder, and 3.0±0.5 in knees. The pain-cases had a mean of 7.5±0.4 in work ability and a mean of 14.5±0.4 in perceived physical exertion.

Table 5

Baseline questionnaire based measures of the study population

Characteristics	Exercise group N=35	Control group N=32	Total N=67 (range)
Work ability (scale 0-10)	7.8±2.0	8.1±1.9	7.9±2.0 (1-10)
Able to do the job in 2 years (inconceivable, not sure, surely) (%)	3/14/83	3/9/88	3/12/85
Perceived exertion at work (scale 6-20)	13.4±2.9	14.0±2.4	13.7±2.7(6-20)
Self-rated productivity (scale 0-10)	8.2±1.5	8.6±1.8	8.4±1.7 (2-10)
Sick leave(days)			
Last 3 months (n=64)	0.8±1.4	2.0±3.9	1.4±2.9 (0-15)
PAIN intensity last 7 days (scale 0-10)			
- Neck	1.3±2.1	1.4±1.7	1.3±1.9 (0-7)
- Shoulder right	1.4±2.3	1.1±1.7	1.3±2.0 (0-8)
- Shoulder left	1.0±2.3	0.8±1.5	0.9±2.0 (0-10)
- Shoulder dominant	1.7±2.7	1.1±1.7	1.4±2.3 (0-10)
- Upper back	1.3±1.9	1.2±2.1	1.2±2.0 (0-8)
- Low back	2.7±2.9	2.6±2.6	2.6±2.7 (0-10)
- Hip	1.0±2.4	0.8±2.0	0.9±2.2 (0-10)
- Knee	1.9±2.7	1.6±2.4	1.8±2.6 (0-10)

Values are mean ± SD and %

5.1.4 Physical activity measures

Objectively monitored physical activity

Physical activity expressed as physical activity energy expenditure (PAEE) (J/kg/min) and measured for a period of one week is shown in Table 6, broken down by different time periods; the whole period (31.2±1.7), weekdays only (33.5±1.8), weekend only (24.7±1.6), work hours only (56.6±3.2), and leisure-time only (35.7±2.2). The amount of conducted physical activity on weekdays was significantly higher than the amount of physical activity conducted during weekends (P<0.001). Additionally, there was a significant difference between working hours and leisure time in the amount of conducted physical activity, with more physical activity in working hours, p<0.001 (Table 6). During work hours (from 7-15 h) and using Mondays as reference for comparison (59.4±3.6 J/kg/min), no difference in physical activity was found between the days except for Fridays (mean Δ±SE) (Δ=-12.2±2.1 J/kg/min), p<0.001. Furthermore,

during leisure time, there was significantly lower physical activity on Tuesdays, Wednesdays, and Sundays compared to Mondays (Figure 5).

With the purpose to estimate fraction of time spent on different MET-categories, the activity intensity distribution during work and leisure-time were divided into intensity categories with “small range”. In all, there were 18 categories with “small ranges” and the intensity interval were: 0-1.25 MET, >1.25-1.5 MET, >1.5- 1.75 MET, >1.75-2.0 MET, >2.0-2.25 MET, > 2.5-2.75 MET, >2.75-3.0 MET, >3.0-3.5 MET, >3.5-4.0 MET, >4.0-4.5 MET, >4.5-5.0 MET, >5.0-6.0 MET, >6.0-7.0 MET, >7.0-8.0 MET, >8.0-9.0 MET, >9.0-10.0 MET, >10.0-11.0 MET, and >11MET. At least, fifty per cent of measured observations in the work hours showed that half of the time, the physical activity was performed at the lowest intensity level (1.125 MET). Analysis of intensity of physical activity in “broad categories” defined as: sedentary (< 1.5 MET), light (1.5 – 3 MET), and moderate-to-vigorous (> 3 MET) showed that the participants spent most of the work time in light intensity physical activity (median= 88.3%, IQR:2-97 %, $p<0.001$), compared to sedentary (2%, 0-13 %) and moderate-to-vigorous (2%, 0-10 %), amounting to an average intensity at work of around 1.8 MET (in total). Similarly, during leisure-time, the largest fraction of time was spent in light physical activity (72%, 47-90%), which was significantly different from time spent <1.5 MET (20%, 3-50 %, $p<0.001$) and > 3MET (0%, 0-2 %, $p<0.001$), amounting to an average intensity at leisure-time of around 1.5 MET (in total).

Table 6

Physical activity energy expenditure estimated with combined movement and heart rate sensor in Danish construction workers

The Table shows mean values for PA measures measured with combined movement and heart rate sensor (J/kg/min).

Weekdays: Mon - Fri

Weekends: Sat and Sun

Working hours: 7-15 on weekdays

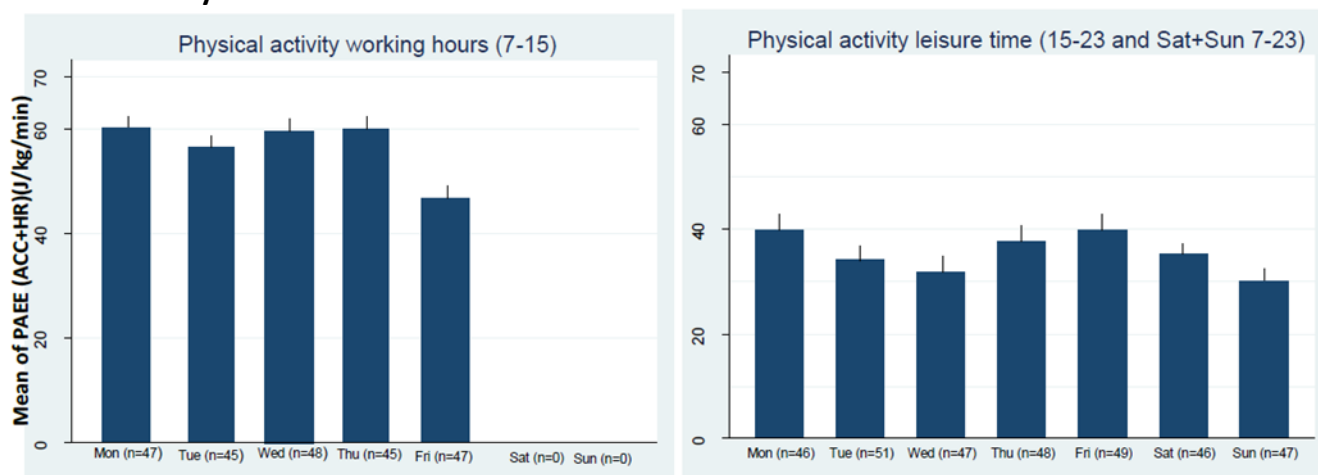
Leisure time: 15-23 on weekdays and 7-23 on Saturdays and Sundays

Variable	Mean±SE	CI (95%)	P value
Whole period (person-h =7577, n=53)	31.3±1.7	28.0-34.6	0.000*
Weekdays (person-h= 5484, n=53)	33.5±1.8	29.9-37.0	
Weekend (person-h = 2093, n=49)	24.7±1.6	21.4-27.9	
Non-sleep hours (5135 person-h, n=53)			0.000*
Working hours (person-h= 1745, n=53)	56.6±3.2	50.3-62.9	
Leisure time (person-h=3390, n=53)	35.7±2.2	31.5-40.1	

Values are means and SE. Differences are estimated as the difference between means with 95% confidence intervals (95% CI) based on ANOVA repeated measures random effects model. *: significant difference.

Figure 5

Physical activity during working hours (7-15) and leisure time (15-23 + Sat and Sun 7-23) on different days of the week.



Mean of PA measured with combined ACC and HR (J/kg/min). Monday used as a reference.

During work hours: significantly lower PA on Fridays compare to Mondays

During leisure-time: significantly lower PA on Tuesdays, Wednesdays, and Sundays compare to Mondays.

Self-reported physical activity (IPAQ)

The self-reported physical activity (IPAQ) was measured stratified in domains: work-related physical activity, transport-related physical activity, domestic and gardening activities, and leisure time physical activity (median MET·min·wk⁻¹) (paper II). The largest amount of physical activity was reported as physical activity at work (5036 MET·min·wk⁻¹) and when pooling 'transport', 'domestic and gardening' and 'leisure-time' physical activity (=leisure: 2842 MET·min·wk⁻¹) it showed significant higher physical activity at work compared with physical activity during leisure time: P<0.01 (Table 7). When assuming a 40 h work per week (5x8 hrs.), the IPAQ data correspond to a mean of approx. 2 MET.

Table 7

Self-Reported Physical Activity (PA) from IPAQ, 50th Median (25th and 75th Percentiles) of MET·min·wk⁻¹.

Variable	Median (interquartile range) PA (MET·min·wk ⁻¹)	Work vs leisure P value
PA at Work (n=53)	5036 (2571;7093)	p<0.01
PA Transport (n=55)	849 (24;1980)	
PA Domestic/gardening (n=58)	838 (86;1980)	
PA at Leisure (n=60)	424 (0;1543)	

IPAQ=International Physical Activity Questionnaire, MET=metabolic equivalent. Difference between PA at work vs. leisure, transport, and domestic, respectively, is estimated using Wilcoxon signed-rank test.

*: significant difference.

Direct observations of occupational posture and movement

Observations on postures and movements at work in terms of occupational workload showed that 59% of the working hours, the employees were standing (approx. 4.7 h) and 21% of the time (approx. 1.7 h) they were moving. This resulted in the employees working in an upright position bearing their own weight 81% of the time they worked. As a percentage of the working time, working postures were observed with the trunk bent (19%), bent-double trunk (12%), twisted (1%), and bent and twisted (3%). In addition, the participants worked 9% of the working hours with one or two arms above shoulder height and 6 % of the working hours kneeling.

Self-reported occupational workload:

The workload questionnaire showed that participants on average rated their perceived workload to 11.1 ± 0.4 . Among 45 % of the participants, the respiratory rate was increased for $\geq 25\%$ of the working time. For each of the three manual material handling tasks of 1) pushing/pulling, 2) carrying, and 3) lifting during the last week more than 90% of the participants reported these activities, and they were performed for $\geq 25\%$ of working time by 50%, 57%, and 52% of the participants. Results regarding specific loads during manual material handling are shown in Table 8. Working with a bent-double or bent or twisted back during the last week was reported by 75% (bent-double) and 89 % (bent or twisted) of the employees, and this was true for $\geq 25\%$ of working time for 38% (bent-double) and 53% (bent or twisted). Seventy two per cent of the worker reported work with the arm above shoulder and 20% of the participants did so for $\geq 25\%$ of the work time. Additionally, kneeling postures during the last week was reported by 82% of the participants, and this was true for $\geq 25\%$ of the working time for 45% of the participants.

Table 8
Percentage of the participants reporting specific workloads in kg, handled within pushing/pulling, carrying, and lifting

Self-report Workload questionnaire			
Load handled	Percentage of participants reporting the work tasks:		
	Pushing/pulling	Carrying	Lifting
≥ 10 kg	55%	52%	41%
≥ 20 kg	25%	19%	15%
≥ 25 kg	18%	9%	6%

5.2 Intervention

5.2.1 Allocation to individually tailored exercise training

The allocations to the individually tailored training are shown in Figure 6A. Six participants strength trained only one body region, 13 participants strength trained two body regions, and one participant trained all three body regions.

5.2.2 Adherence

The overall average attendance rate for the intervention group was 68%. Of the participants, 59% had an attendance rate of >70% and 75% of the participants had an attendance rate of ≥50%.

The reason for an attendance rate of <70% was either (i) absence due to illness (N=2) or vacation (N=2), (ii) pain in the musculoskeletal system (N=2), or (iii) lack of motivation (N=8). Eight participants (24%) had an attendance rate of ≤50% due to lack of motivation.

5.2.3. Objective measures

The absolute changes from pre- to post-intervention are shown in Table 9. The exercise group had a significantly higher increase in VO_2max compared to the control group: $\Delta = 0.40 \text{ L/min}$, $P = 0.001$, while body weight did not change from pre- to post-intervention in either group. Therefore, the $\text{VO}_2\text{max}/\text{min/kg}$ increased significantly more in the exercise group (from 27.1 ± 6.9 to $31.0 \pm 7.3 \text{ ml/min/kg}$) compared with the control group (from 26.5 ± 6.4 to $26.7 \pm 7.2 \text{ ml/min/kg}$), $P < 0.05$. The average watts used in the bicycle tests for both pre- and post-intervention tests were 130.3 ± 24.4 , in the intervention group and 126.3 ± 25.1 , in the control group. In different age groups (20–39, 40–49, 50–63 years), at baseline there was an uneven distribution of relative VO_2max in the categories ‘very poor’, ‘poor’, ‘fair’, ‘average’, and ‘good’ (39). The oldest had the relatively highest VO_2max , (i.e. in the older age group), (>50 years) 4 out of 18 participants (22%) at baseline had VO_2max corresponding to the “average” or “good” categories, while in the youngest group (<40 year) no one reached the “average” category, only 4 of 21 (19%) were placed in the “fair” category and the rest were placed in the “poor” and “very poor” category. In the age group 40–49 years, only 1 participant could be placed in the “average” category, 7 of 26 participants (27%) had at baseline relative VO_2max corresponding to the “poor” category and 16 participants (62%) were in the “very poor” category. In the exercise group, the youngest men (<30 years old, N=4) increased their relative VO_2max the most (from 32, SD 8.4, to 38, SD 5.2), $P < 0.05$.

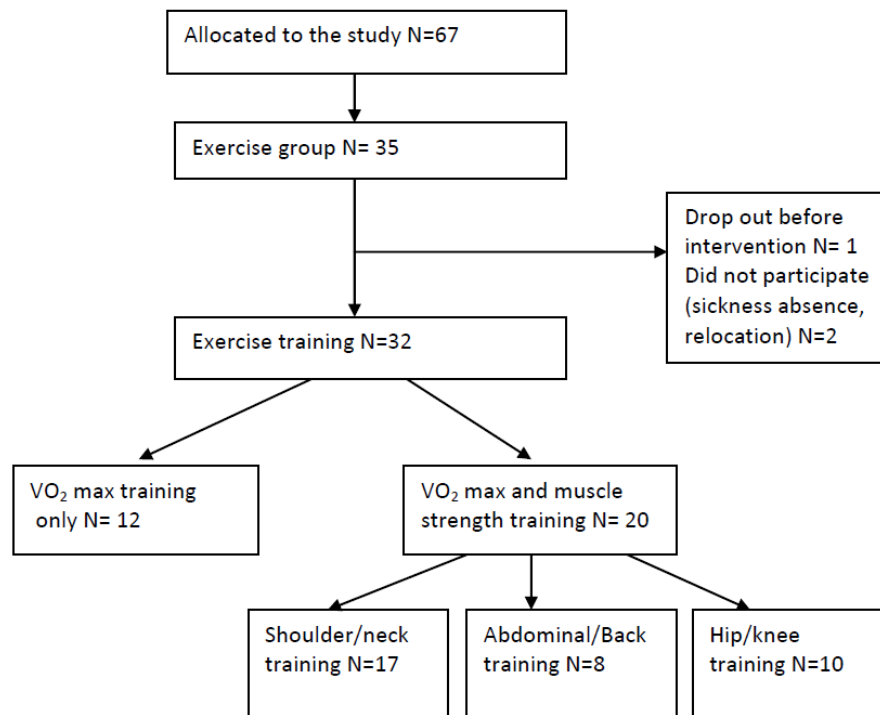
There were no significant changes in maximal isometric muscle strength. However, there were significantly fewer fluctuations when testing isometric steadiness contractions of shoulder elevation, in coefficient of variance being in the exercise group: $\Delta = -0.05$ compared to the control group: $\Delta = 0.17$, $P = 0.001$.

Regarding BMI, fat percentage, BP, total cholesterol, HDL cholesterol, LDL cholesterol, and triglyceride levels, no significant changes occurred (Table 9).

Post-hoc analyses of the participants training muscle strength (all body regions together, n=20) compared to matched control group (n=21) did not show any significant changes in muscle strength after the intervention. Neither did paired analyses on the single strength training groups.

Figure 6

A) Allocation in individual strength training groups



B) Allocation among Controls into possible individual training groups

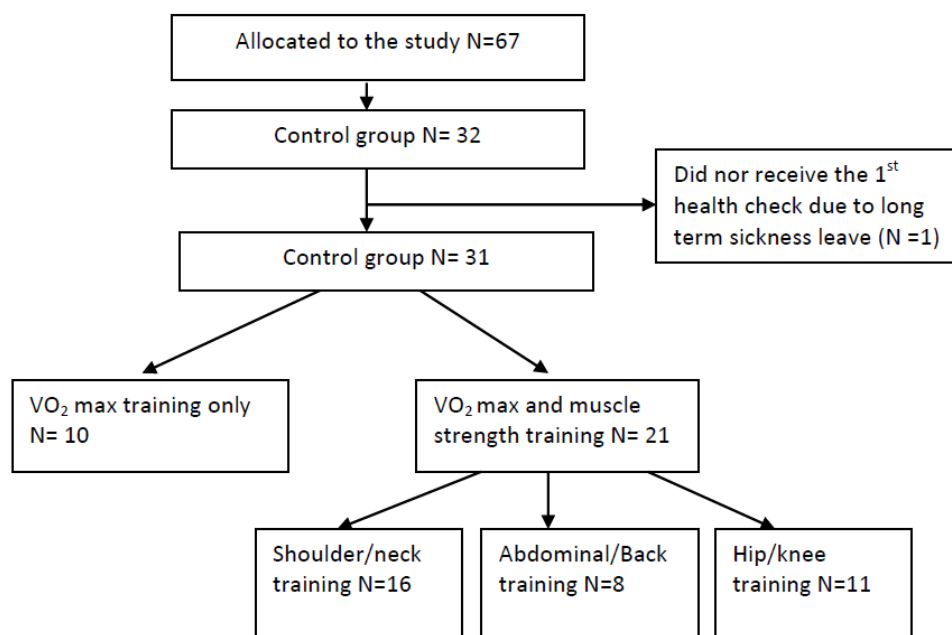


Table 9**Summary results for each study group after 12 weeks intervention**

Characteristics	Exercise Post- Pre(SD) N=35	Control Post- Pre(SD) N=32	Difference: Ex vs. Control (SE) N=67	95% CI	P
Weight, kg	-0.6±2.1	-0.8±2.9	0.3±0.6	(-1.0, 1.5)	0.68
BMI, kg/m ²	-0.3±0.7	-0.4±1.1	0.1±0.2	(-0.3, 0.6)	0.55
Fat, %	9.3±15.2	5.9±11.7	2.9±3.3	(-3.6, 9.4)	0.37
VO ₂ max, l/min	0.3±0.4	-0.0±0.4	0.4±0.1	(0.2, 0.5)	0.000*
Relative VO ₂ max, ml/min/kg	3.9±4.4	0.3±4.5	3.7±1.1	(1.5, 5.9)	0.001*
Isometric Muscle strength, Nm					
- Shoulder Dominant	3.9±2.7	7.1±34.9	-3.5±7.6	(-18.6, 11.6)	0.65
- Arm Dominant	0.7±14.8	-1.0±16.1	2.1±3.6	(-5.1, 9.4)	0.56
- Abdominal	-7.1±29.0	-7.7±30.2	0.7±7.0	(-13.3, 14.7)	0.92
- Back	-17.7±49.1	-16.2±32.7	1.7±8.3	(-14.9, 18.4)	0.84
- Leg Right	-2.0±54.0	-5.7±37.8	2.7±9.7	(-16.6, 22.1)	0.77
- Leg Left	-4.1±20.2	-7.4±28.6	0.7±4.7	(-8.6, 10.1)	0.88
- Handgrip Dominant	-0.4±5.5	-0.5±5.5	-0.1±1.2	(-2.6, 2.3)	0.90
Systolic blood pressure, mm Hg	-1.8±13.4	-2.0±11.3	0.8±2.9	(-4.9, 6.6)	0.77
Diastolic blood pressure, mm Hg	-1.9±10.4	-2.9±11.2	1.6±2.4	(-3.2, 6.4)	0.51
Total Cholesterol, mmol/L	-0.2±0.7	0.1±0.6	0.2±0.7	(-0.1, 0.4)	0.56
HDL cholesterol, mmol/L	0.0±0.1	0.0±0.2	0.0±0.0	(-0.1, 0.1)	0.78
LDL cholesterol, mmol/L	0.0±0.4	0.0±0.5	0.0±0.1	(-0.2, 0.3)	0.77
Triglyceride, mmol/L	0.0±0.7	0.0±0.6	-0.0±0.1	(-0.3, 0.3)	0.80

Changes in Post-Pre values are absolute and not adjusted. Differences are estimated as the difference between means with 95% confidence intervals, based on the 1-factor analysis of covariance (ANCOVA) with the level at baseline applied as a covariate.

HDL: high-density cholesterol, LDL: low-density cholesterol. *: significant change.

5.2.4 Self-reported measures

Musculoskeletal disorders

There were no significant changes in pain intensity in shoulders, upper and lower back, hip and knee neither based on the questionnaire data nor on text message replies.

Work ability

No significant changes were found in work ability in the ITT analyses (Δ 0.4±0.3, $p < 0.21$).

Subsequent post-hoc analyses on effect within the group did not reveal any significant changes or differences. The question as to whether the participants feel they would be able to do the job in two years was estimated as frequencies and did not change significantly from baseline to follow-up.

Perceived physical exertion at work

There were no significant changes in perceived exertion neither in the ITT analyses nor in the post hoc analyses.

Self-rated productivity

No significant change in self-rated productivity was observed.

Sick leave

Sick leave measured three month after the training intervention during the past 3 months did not show any significant change using self-reported measures.

Correlation between VO₂max, on the one hand and work ability, and perceived physical exertion on the other hand did not show any linear relationship (Appendix II).

5.3 Evaluation of methods

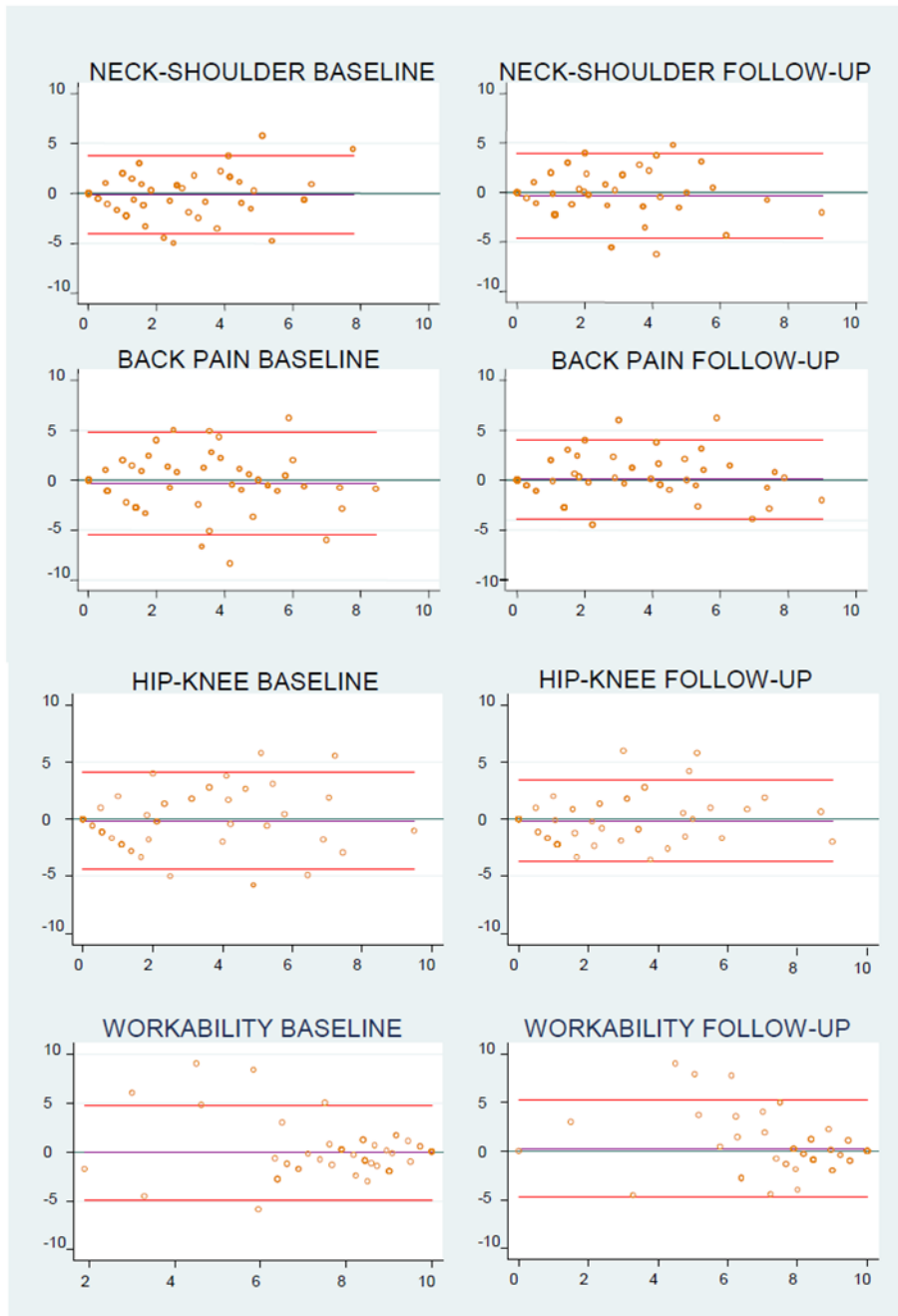
In the questionnaire, the participants reported a mean work ability of 7.9 ± 2.0 (scale, range 0-10) whereas the reply with text messages was 8.1 ± 2.3 (adjusted to scale, range 0-10). The mean intensity of lower back pain (LBP) using questionnaire was 2.5 ± 2.6 and in text messages 2.8 ± 2.7 . The mean intensity of neck-shoulder pain using questionnaire was 2.1 ± 2.4 and in text messages 2.2 ± 2.1 . The mean intensity of hip-knee pain using questionnaire was 0.9 ± 2.2 and in text messages 2.1 ± 2.5 . Bland Altman analyses showed at baseline a mean difference (95% limits of agreement (loa)) of LBP of -0.33 (-5.5 to 4.8) and a Spearman's rho = 0.5 which indicates reasonable agreement on group level between the two methods as there was no significant difference between the variables at baseline ($P < 0.30$) or after the intervention ($P < 0.74$). In neck-shoulder pain at baseline, the mean difference (95% loa) was -0.09 (-4.0 to 3.8) and Spearman's rho 0.5. There was reasonable agreement both at baseline ($P < 0.72$) and at follow-up ($P < 0.21$). The mean difference at baseline in hip-knee pain was -0.1 (-4.4 to 4.1), Spearman's rho=0.7. No significant difference between these variables neither at baseline ($p < 0.53$) nor at follow-up ($p < 0.53$) and for work ability: mean -0.1 (-4.9 to 4.7), Spearman's rho = 0.3. Concerning work ability, at baseline there was agreement between the two methods while at follow-up showed significant differences; reporting higher work ability in the questionnaire ($p < 0.001$). Results for Bland Altman analyses on pain variables and work ability on a group level after the intervention are shown in Figure 7.

Figure 7

Level of agreement on pain variables and work ability between questionnaire and text message

— : observed average agreement
— : 95 %limits of agreement
Y=0 is line of perfect average agreement

Difference between questionnaire outcome and TEXT outcome



Mean of questionnaire outcome and TEXT outcome

6.0 Discussion

The main findings in the present PhD study are: 1) Employees in the construction industry are exposed to physically heavy workload in terms of strenuous working postures and external loads but not in terms of high metabolic load. 2) Their physical capacity is low regarding aerobic capacity but not regarding muscle strength. 3) The employees have significantly lower leisure-time physical activity compared to their physical activity at work. 4) Individually tailored exercise intervention improves aerobic capacity which is one of the primary outcomes in the study.

In spite of this, no improvement of general health status, musculoskeletal disorders, work ability or sick leave is seen after the exercise intervention.

In the following section, the results will be discussed in relation to the hypotheses of this study.

Overall, the paragraphs in the discussion section are organised into baseline measures, the individually tailored intervention, general discussion, methodological considerations, and strength and weaknesses.

6.1 Baseline measures

6.1.1 Exposure assessments (*paper II*)

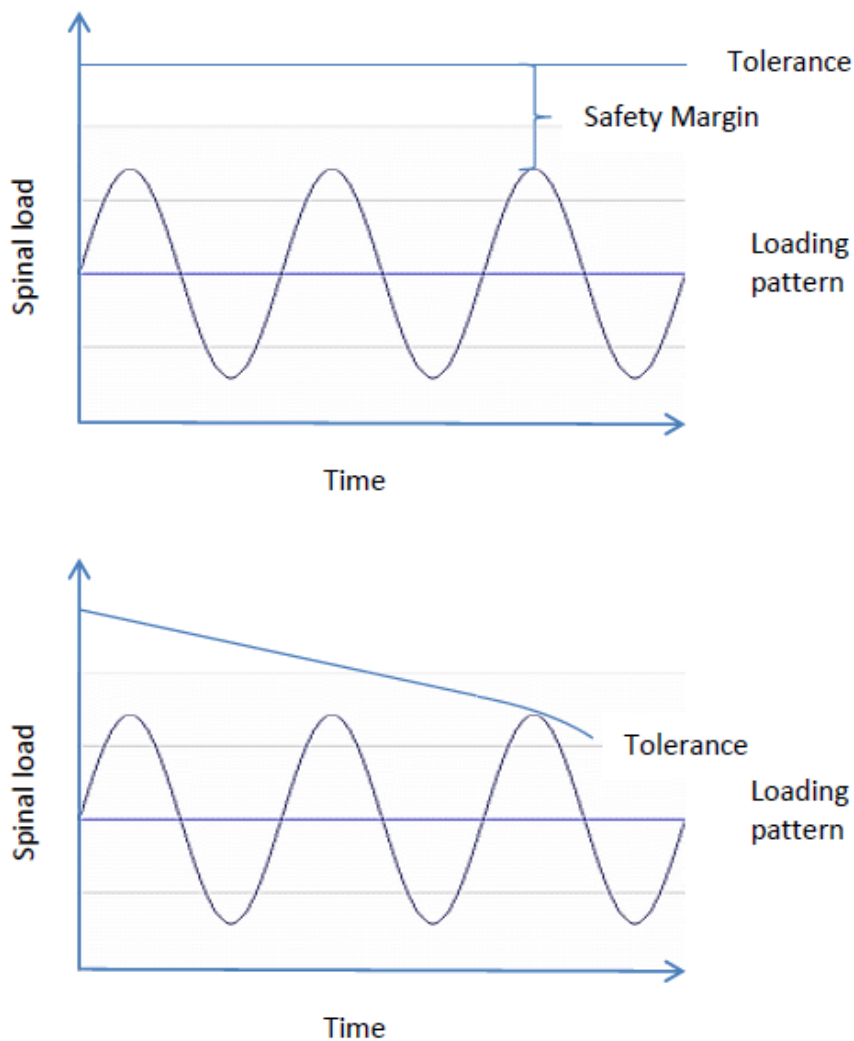
From a biomechanical point of view, it is a fundamental concept that the load on the body's musculoskeletal structures should not exceed the load tolerance of the structure. Generally, construction workers may be exposed for two types of trauma: acute trauma and so-called cumulative trauma. The acute trauma is associated with e.g. a single lift of an extremely heavy object where the peak load exceeds the load tolerance of one or more of the tissues loaded. The cumulative trauma refers to deterioration of the structures over time and thereby lowering the tolerance (Figure 8) (93). Based on the definition of work related muscular disorders shown in the introduction, 1st section, the cumulative trauma pattern is primarily of interest in this thesis. Measuring the biomechanical load can be done by quantitative assessment of the mechanical load; however, such measurement is not included in this thesis. On the other hand, other methods, such as observational techniques, can be used to characterize the work exposure by observations on work postures and work activity. Several studies have been published concerning physical work exposure and health related consequences among construction workers, (10;94;95) but the present study is one of the few that have used an observational method to quantify exposure. While the abovementioned studies (94;95) found relationship between work related musculoskeletal disorders and exposures as high workload, awkward postures and heavy lifting, the present study could not, despite of observed high mechanical load, confirm musculoskeletal disorders.

To get an estimate of the mechanical and the metabolic load of the participants in this study, a systematic observational method, IPAQ questionnaire, and a movement sensor to record PA accelerations, and HR were used.

A variety of different observational tools exists (96), which complicates direct comparison between studies (Table 2). In this study, the observational method PATH was used. This method has been found effective to identify operations and tasks within the construction industry (88). It is considered that PATH is easy to use at worksites and it has been thoroughly developed (96). But, like other observational tools, PATH requires some training of the observer (96).

Figure 8

Traditional concept and realistic scenario of biomechanical risk



The Figure is from Fundamentals and assessment tools for occupation ergonomics (94)

Hartmann and Fleischer (16) did observations on a large study group; 247 construction workers. The study clarifies the possibility of ranking different construction tasks with respect to load and links the causes of

the physical overload among construction workers to the musculoskeletal system. In the present study, observations were done on only sixteen participants and therefore, they have not been divided into different job tasks. In total, the observation time was 17 hours and 17 min and the observations took place in two different workplaces in Denmark representing different work tasks and work profiles. In spite of that, it must be acknowledged that our observations do not encompass every variation and complexity of construction workers' daily work, but is a complimentary contribution to assessment of work exposures among the study group in relation to the health factors examined in this study. Our observations, as well as Hartman and Fleischer's observations, showed that construction workers were exposed to strenuous working postures and high external mechanical workloads.

The construction workers had a mean physical activity energy expenditure of 31.9 ± 1.7 J/kg/min, corresponding to 45.9 kJ/kg/day measured with combined movement and HR sensor. Compared to a study from the InterAct Consortium (97) who used the same objective method as in the present study the participants in the present study had an average physical activity energy expenditure. The InterAct Consortium measured physical activity expenditure in 591 healthy middle aged men from different European countries and reported mean physical activity energy expenditure: 44 kJ/kg/day. However, the 591 middle aged participants were not employees working with heavy workloads, and the majority had sedentary jobs (97).

Among the construction workers, the accumulated occupational PA was high compared to leisure time PA. The physical activity level at work measured by combined movement and HR sensor showed intensity level corresponding to light activity, however, these measures alone do not give the overall picture of the cardiovascular work exposure among the group.

Care must be taken to interpret the measurements from the combined movement and HR sensor as an evidence of the sole cardiovascular work exposure. Static postures such as during drilling work tasks etc. may be experienced as strain whereas the objective measurement would not register any loads, as no acceleration occurs. Handling of heavy loads even without major acceleration of body segments may increase HR. However, the registration of very short (few seconds) explosive and rapid handling of heavy loads presumably requires sensors with epoch length less than 1 minute and still it might be difficult to document that an increase in HR for only few seconds is related to strenuous postures and handling of heavy loads. Therefore, the objective measurements of physical activity may underestimate the total work exposure on the cardiovascular system among construction workers.

In large population samples evidence has been presented of an improved cardiorespiratory fitness/relative VO_2max in relation to physical activity level (98-100) Therefore, it was expected to find linear correlations between relative VO_2max and physical activity during work and at leisure time. However, the analyses did

not show any linear relationships (Appendix II). One explanation for this could be the large range between minimum and maximum values of relative VO_2max among the participants.

Summary regarding workload findings in relation to the study's hypothesis

As a group, the participants were exposed to strenuous work in terms of mechanical and perceived workload. This confirms part of hypothesis I. However, a full comprehensive exposure assessment also includes measures of metabolic load. The present study showed using two independent methods that the metabolic load was only light-moderate, which is a novel finding. The results on the mechanical load is in line with the scientific literature, which has documented that construction workers are exposed to physically heavy workload and are at increased risk of musculoskeletal injuries (Table 2). On the other hand, there is on a group level little evidence about high metabolic load among construction worker even though the study showed indications on a perceived high aerobic workload. Among 45 % of the participants, the respiratory rate was increased $\geq 25\%$ of the working time. The construction workers spent 81% of work time in an upright position, carrying their own weight. A study has shown that work postures e.g. working in an upright position are assessed to contribute to cardiovascular strain, even though they do not lead to high levels of energy expenditure (2).

6.1.2 The prevalence of work ability, musculoskeletal disorders, and sick leave (paper IV)

Work ability:

At baseline, 27% of the participants reported work ability corresponding to 7 or below. A study on the Danish working population (101) showed, that only approximately 10% of the general population rated 7 or below on the work ability scale. In light of this, a relatively large percentage of the construction workers reported "low" work ability. Thirty six of the participants reported 8 (moderate or good) on the single item work ability scale, 12% reported 9 and 25% reported 10 (good or excellent). Compared with a study on Dutch construction workers, (102) fewer construction workers in the present Danish study scored good or excellent. Still, a relatively high percentage of participants in this study reported work ability above 7, which resulted in a mean of 7.9 ± 2.0 on the work ability scale for the entire group. The aforementioned Dutch study on construction workers showed a mean work ability of 40.9 ± 5.1 using the Work ability index (scale ranging from 1 – 49) which corresponds to good work ability (corresponding to a single-item score of 8 or 9) (102).

The FINALE study on cleaners (76) showed average work ability at baseline of 7.5, which is slightly lower than the average work ability among the construction workers in this study.

Correlations between relative VO_2max and work ability did not show any linear relationship (Appendix II). A large range between minimum and maximum values of relative VO_2max may explain the lack of a linear

relationship. On the other hand, different factors influence work ability and therefore, it may be difficult to show linear relation between only one of several possible factors. Additionally, if a study group due to different work tasks is very inhomogeneous, it probably is a greater challenge to show linear relation.

Musculoskeletal disorders:

A review on injuries in the construction industry showed that construction workers had a high incidence of musculoskeletal disorders and that there were strong correlations between particular trades and musculoskeletal disorders in specific parts of the body (17). This Ph.D. study did not confirm high prevalence of musculoskeletal disorders among the study group. The FINALE study on health care workers showed a mean intensity in lower back pain in the last seven days of approx. 2.8 ± 2.7 on a scale ranging from 0-10 which is in agreement with the results in the present study (mean LBP 2.6 ± 2.7). Interestingly, musculoskeletal pain was in general only modest on a group level and in line with studies including participants with jobs usually considered less physically strenuous. Andersen et al (55) showed for example pain intensity in lower back corresponding to 3.2 ± 2.3 on a scale ranging from 0-9 in office workers and Jay K et al (103) showing LBP corresponding to approx. 2.8 ± 2.5 on a scale ranging from 0-10. In the present study, the different body regions showed a wide range in individual pain scores. Analyses on pain cases only (defined in proportion to $LBP \geq 3$) showed slightly higher mean-values of pain not only in the lower back but also in other body regions and in perceived physical exertion as well. However, there was only statistically significant difference in pain in knees and perceived physical exertion between pain cases and no-pain cases ($LBP < 3$).

Only one of the participants worked less than 37 hours per week, so the study group represented workers working relatively many hours per week. This may indicate that those with musculoskeletal disorders are not able to remain for longer periods of time in the workforce.

Sick leave:

A positive relationship has been documented between aerobic capacity and work ability (95;104) and a low aerobic capacity and musculoskeletal disability was found significantly related to sick leave (105;106). In the present study, only six participants at baseline had sick leave for 10 days or more in the last three months. Of these, two participants had sick leave at baseline for more than 60 days, one had 21 days, and three had sick leave below 16 days during the previous three months. Forty two participants (63%) had no sick leave at all during the last 3 months and 19 participants (28%) had between 1-5 days sick leave.

The mean-value of days on sick leave including all participants ($n=67$) was 3.7 ± 1.5 . Leaving participants with more than 60 days sick leave out of the calculation, the mean was 1.7 ± 0.5 . According to Statistics Denmark (www.statistikbanken), employees in the construction industry in Denmark had on average approx. 7 days

of sick leave per year (2010) per full time worker. Our result of a low sickness absence (a mean of 1.7 ± 0.5 in the previous 3 month) is in accordance with this statistics.

It has been documented that awkward work positions and working with heavy loads increase the risk of long-term sick leave (5;107;108). In the present study, documenting high mechanical and perceived workload, approx. 90% of the participants had sick leave below five days previous 3 months at baseline (mean of 1.4 days) which is not considered a high prevalence of sick leave. Three participants (approx. 4%) had sick leave above 2 weeks (long term sick leave), two of them due to low back pain. The measurement of sick leave in the present study was self-reported and the participants were asked about days of sick leave in the previous 3 months. Even though, the specificity and sensitivity of self-reported sick leave are showed acceptable for sick leave lengths below one week (109), measuring sick leave for only 3 month is a relatively short period of time when evaluating sick leave. Most of the participants (84%) filled out the questionnaire at the end of August and the summer period including summer holiday may affect the prevalence of sick leave resulting in lower prevalence of sick leave.

Among pain cases, the mean number of sick leave days was 3.4 ± 2.1 , including one participant with 65 days sick leave. It was not possible to show any correlations within the entire study group between sick leave and pain (data not shown).

Summary regarding prevalence of work ability, musculoskeletal disorders, and sick leave findings in relation to the study's hypothesis:

Mean values did not confirm hypothesis I regarding a high prevalence of low work ability, musculoskeletal disorders as well as sick leave among construction workers. The results are not in line with the literature, which reports a high prevalence of musculoskeletal disorders among construction workers. However, the literature is not consistent in reporting low work ability within the group. The limited number of participants, a short evaluation period (3 month), and a healthy work force participating in the study could be explanations.

6.1.3 Physical capacity level (paper II)

The physical capacity on a group level in terms of $VO_2\text{max}$ at baseline was low and according to the epidemiological literature, this means an increased risk of all-cause mortality (Figure 2). The low aerobic capacity may increase the perceived workload and increase the experience of overall fatigue.

In contrast, the physical capacity in terms of muscle strength was measured as significantly higher in abdomen, shoulder and arms than in a representative group of employees in Denmark (89). Among construction workers, the main health focus has been on the high prevalence of musculoskeletal disorders. These musculoskeletal disorders may be a consequence of low muscle strength, and/or too high workload

in relation to the physical resources. In this context, our results are credible, as muscle strength was found high and the prevalence of musculoskeletal disorders was low.

An earlier study among construction workers found similarly high trunk muscle strength and did not find any association between muscle strength and low back pain status (110). In the present study, calculations only on pain-cases did not show significantly lower muscle strength in abdomen, shoulder and arms than in non-cases. This study did not measure muscular endurance in the large muscle groups. Retrospectively, this could be interesting as many construction work tasks may require muscular endurance.

Summary regarding physical capacity level according to the study's hypothesis:

The hypothesis concerning low aerobic capacity among construction workers (hypothesis II) was confirmed by estimating $VO_2\text{max}$ (bicycle-test). Another part of hypotheses II, concerning low physical capacity in terms of muscle strength was rejected. This was unexpected and the explanations are speculative. In the present study, only one of the participants worked less than 37 hour per week. Thus, the study group represents workers working many hours per week. Probably, in order to manage so many work hours per week in the construction industry, it is essential to have good muscle strength. This means that, due to such a healthy worker effect, those with either musculoskeletal disorders or low muscle strength do not stay long in the workforce and this may also explain the low prevalence of muscle pain.

6.2 Individually tailored intervention

6.2.1 The training program

Our purpose was to use an individual approach in relation to the exercise intervention so that 1) the exercise was tailored to individual capacities and disorders and 2) so that the physiological capacity would balance the occupational exposure. The exercise program lasted 1 hour per week and the intensity of the program was based on scientific evidence regarding efficient dose response in exercise training (111). The relative intensity of the aerobic capacity was at least 70% of $VO_2\text{max}$. Thus, the participants should exercise at an intensity level corresponding to vigorous activity (52). The exercise program resulted in a significant increase in $VO_2\text{max}$.

Constructing an individual program, which enables scientific documentation, requires the use of a systematic framework. Construction workers have various work exposures (16) and these exposures affect different body regions. Therefore, our strength-training program was divided into 3 body regions. Results from a representative study on Danish workforce (89), using the same measurements as in the present study, were used to make cut off points for allocation into the strength training groups. It may be discussed what percentage of the reference value should determine the allocation. In this study, less than 80% of the reference value was chosen as a relatively low cut-off point to be certain of reduced muscle strength and a real need for training. Participants with all their test values >80% of reference value trained the capacity

that was lowest on the job-group level. This resulted in the fact that all the participants trained aerobic capacity and for some of them, this type of training was the only type of training. The group which only exercised aerobic capacity had a mean relative VO_2max of 25.9 ± 2.3 , which is comparable to the entire study group, with a mean relative VO_2max of 26.8 ± 6.6 .

6.2.2 Primary outcome variables

It is well-known that aerobic capacity increases with aerobic exercise training. The present study demonstrates for the first time an increase in aerobic capacity among construction workers exercising at the work site for only one hour per week. Additionally, according to epidemiologic literature the 10% increase is large enough to be clinically relevant for risk of all-cause mortality (43;45-47). For construction workers only few RCT-studies focusing on physical activity have been published (Table 3). Kaukiainen et al (71) did not demonstrate a significant increase in VO_2max even though each exercise session was longer than in the present study. The study had only 28 exercise sessions and the participants' baseline values on VO_2max were somewhat higher (VO_2max ml/kg/min: approx. 46) than in the present study. A low VO_2max at baseline increases the likelihood for improvement than a high VO_2max at baseline (71;99). Two of the studies shown in Appendix I, were conducted on the workplace and successfully improved VO_2max (57;112). In both studies, VO_2max at baseline was relatively low (< 35). Only 4 (57;61;65;112) out of 17 studies in Appendix I had VO_2max as outcome variable in their studies. One of them was the FINALE study among health care workers (65), which demonstrated a significant increase in relative VO_2max ; however, the increase was due to a decrease in body weight, as absolute VO_2max did not change.

The intensity of the muscle strength training was approximately 60% of one repetition maximum (RM). According to American College of Sports Science (ACSM)(111) novice individuals are recommended to use loads corresponding to 60–70% of 1RM for 8–12 repetitions in strength training. Actually, data from meta-analyses have shown that 60% of 1 RM produces the largest effect sizes for strength increases in novice individuals (111). The choice of a target force at approximately 60 % in the exercise program was based on careful consideration of pain experience and to avoid possible overload. For the purpose of optimizing the training intensity, the intensity of both the aerobic training and muscle strength training was assessed two times during the 12 weeks training period by indirect methods.

Other RCT- studies that have conducted a work-site intervention program, succeeded to improve muscle strength(56;57;61;62;65;113). Two of them included strength training exercises with intensity of 70% or below (56;57;61).

Still, the lack of a significant increase in muscle strength can be due to the relatively low intensity of 60 % and the high number of repetitions that could have increased muscular endurance instead of strength. Besides, this may also explain the increase in isometric steadiness/ fewer fluctuations, and possibly

contribute to the increase in $VO_2\text{max}$. Such concurrent training (combining endurance and strength training) has proved, at the molecular level, to be mutually complementary (114).

Two intervention studies among construction workers in Table 3 (71;115) demonstrate an increase in muscle strength among construction workers. None of these detail the intensity of the training and one of the studies was not randomized (115).

6.2.3 Secondary outcome variables

The secondary variables musculoskeletal pain, work ability, perceived physical exertion, productivity, and sick leave were self-reported in a questionnaire (paper IV). The assumption was that improvements in physical capacity also would affect these variables. Studies have been published showing positive correlation between $VO_2\text{max}$ and work ability (104;116) and it is stated that a fit worker has a better work ability. Furthermore, several studies have documented the positive effects of exercise training on musculoskeletal disorders (58;61;68;103). Theoretically, it would be conceivable that a significant improvement in aerobic capacity among construction workers with high physical work demands would lead to corresponding improvements in musculoskeletal pain, work ability, perceived physical exertion, productivity, and sick leave.

An important factor for achieving an improvement in work ability is the baseline level, as a low level has a higher potential for improvement while a high level may result in a ceiling effect. Similarly, the variability and generally modest pain level may be a reason for the lack of improvement in musculoskeletal pain. Work ability is a broad term and is influenced by multiple factors (116). A systematic review on work-related and individual factors on work ability showed that many important factors are associated with work ability i.e. obesity, high mental work demands, lack of autonomy, poor physical work environment, and high physical workload (4). With regards to the content of the intervention in this thesis, the emphasis was on improving physical capacity and a change only in aerobic capacity may have limited effect on work ability, sick leave or productivity. The limited effect in the present study may indicate that physical exercise should be part of more multifaceted interventions in order to increase the effect as also suggested in other studies (4). Additionally, a bigger sample size would presumably be needed to demonstrate differences in these variables. The sample size calculation in this thesis was based on minimal difference in physical capacity after the intervention. Even though associations between work ability and several factors have been proven (4), this is primarily based on cross sectional studies. Knowledge is scarce regarding changes in work ability as a consequence of an intervention and evidence regarding the minimal significant difference (MIREDIFF) in work ability is not available. One study has shown in a prospective epidemiological design a 15% increase in sick leave with just 1 point decrease in work ability (101). However, it turns out that a change of just one point on the work ability scale is a rather dramatic change in work ability and the general lack of evidence gives rise to difficulties, when estimating changes for a conclusive result in an

intervention study. Regarding the non-significant changes in work ability among the construction workers, a post-hoc calculation based on the changes in work ability ($\Delta=0.4\pm0.3$) showed that a change of ± 0.85 in work ability was required to show a significant difference.

Finally, even though a single-item work ability question has been suggested as being a good alternative to using the full Work ability Index, some information may be lost. Also, the tool may not be sensitive enough for the group of relatively healthy, working men and it might be more appropriate for certain patient categories or individuals on sick leave (92;117;118). Finally, the follow-up period was only the 12 weeks of training and longer follow-up period may be requested before changes in the secondary variables can be demonstrated.

Summary regarding individual tailored intervention according to the study's hypothesis:

The study demonstrates good effectiveness for integrating exercises among construction workers at the workplace with relatively good compliance.

The hypothesis concerning the study's primary outcome (Hypothesis III) was partly confirmed as the intervention had a positive effect on aerobic capacity. Furthermore, there were significantly fewer fluctuations in isometric steadiness contractions of shoulder elevation in the exercise group, which could indicate increased endurance/less fatigue in the muscles after the intervention period.

However, parts of hypothesis III and hypothesis IV were not confirmed, as there were no improvements in muscle strength, musculoskeletal disorders, work ability, or sick leave after the training intervention.

6.3 General discussion

6.3.1 Framework for the intervention

A physical intervention at the worksite settings makes it possible to focus on a specific target group exposed to specific work exposures. However, even within a certain work group there is a risk of selection bias, as those who are already physically active and interested in an increase in physical activity may be the same individuals who choose to participate. A counseling offer linked to a survey is not necessarily enough to reach the target group (119). The approach to contact and make a contract with the workplaces plays a vital part when offering counseling or an intervention at the workplaces. There are some indications that fitness testing, brief conversations with potential participants and individually based approaches in the initial phase are applicable methods in order to achieve a broader participation (119).

In this study, provision of workout room, health checks and ongoing contact to the mid-level manager proved to be positive incentives and are, presumably, contributing explanations of the good attendance rate.

6.3.2 Compliance to the intervention

Conducting an exercise intervention with high compliance, even with exercise sessions within work hours, is challenging, particularly, among groups with a poor tradition for practicing leisure-time physical activity. Compared to other intervention studies at work places, an average attendance rate of 68% is interpreted as satisfying (Table 3 and Appendix I). Especially, considering that 59% of the participants had an attendance rate of >70%.

Apart from the reasons mentioned earlier (section 5.2.2) for an attendance rate <70% related to the intervention, there are many reasons for being absent from work (and thus also being absent from the intervention). These can include short term sickness, meetings, days off, vacation etc. Actually, at one workplace, the intervention took place in July and August (Figure 4), which in Denmark are common months for summer holiday.

6.3.3 Levels of leisure-time physical activity and perspectives of public health

For decades, it has been known that poor fitness is an important precursor of mortality (43;54) and the health related consequences of a sedentary lifestyle are well established (40;120). Likewise, high BMI, elevated blood pressure and an abnormal serum lipid profile are well known risk factors for cardiovascular diseases (121). Recommendations on physical activity have in particular focused on the intensity of aerobic physical activity – assessed by e.g. heart rate or oxygen uptake – in light of the dose-response relation between such physiological responses and health. Especially, the combination of being a man with high work demands and having low leisure-time physical activity has been shown to impose a high risk of cardiovascular disease (34). Among the construction workers, there was a significant difference in the amount of metabolic rate during working hours compared to leisure time, with lower metabolic rate at leisure time. This was found both measured by objectively measured PA and by self-reporting. Since the MET-values were estimated as $\text{MET} \cdot \text{min} \cdot \text{week}^{-1}$, it was not possible to assess more detailed information about for example intensity per unit of time. Therefore, it is difficult to state if the participants actually meet the intensity in the health recommendations regarding physical activity. Objective measurements showed that the largest fraction of time during leisure time was spent on light physical activity and IPAQ data showed medians for transport, domestic and leisure time PA only corresponded to ‘somewhat active’ or ‘sedentary’ (www.ipaq.ki.se). The low metabolic load at leisure-time and the measured low aerobic capacity among the construction workers in the present study should be an incentive to promote health also at the workplace. Lack of physical leisure-time activity can be a health threat for workers working with heavy workload and ergonomic initiatives should not only focus on avoiding physical strain but also on improving physical capacity and health (122).

6.4 Methodological considerations

6.4.1. Study population and time frame

Trade unions, municipalities and construction companies in Denmark were contacted but only 3 workplaces accepted participation. The economic crisis since 2008 presumably played a role and prevented some companies from participating in the study. Among the participating workplaces, the work tasks differed somewhat as the employees at the one workplace worked most of the time indoors (building houses/kits are made as finished modules). Thus, the companies in this study provide a broad representation of industry and were from geographically different locations.

The overall time frame for this study was 3 years. According to the protocol, a one-year follow-up of the FINALE-questionnaire was planned. As it was a period marked by economic crisis in the trade, working conditions and tasks for both employees and workplaces changed along the way. Therefore, in consideration of the overall study's time frame, the possibility of one year follow-up, and possible changes in the industry were instrumental when deciding to end the recruitment of participants after 1.5 years.

6.4.2. Measurements methods

There are no reliability or validity tests of the measurements included in this PhD study as all the objective measurements are tested reliable and valid (78;80). Additionally, these measurements were chosen because they were assessed to be suitable to field testing and appropriate to use as pre- and post-test. Moreover, they are widely used which enables comparison to other studies.

The Åstrand bicycle test is a sub-maximal test based on an assumed linear relationship between HR and oxygen consumption where HR response to sub-maximal workload on the bicycle ergometer is used to estimate VO_2max . By using the nomogram and age-correction factor, correlations of $r=0.92$ (123) and $r=0.80$ (124) have been found. The test is particularly suitable to assess changes in VO_2max over time in each individual.

It is a possibility that the intervention group has benefited from the test being on a cycle ergometer that they also used for training. However cycling is expected to be common to both the intervention group and the control group as cycling is a common transport form in Denmark. Furthermore, the aerobic exercises were supplemented with training on rowing machine.

Retrospectively, a test of muscle endurance would have been a good complement to the isometric muscle test.

Questionnaires and self-reported measurements are inexpensive and relatively easy to administrate but have some limitations primarily due to recall bias. Furthermore, it cannot be excluded that the workers

were not quite comfortable with answering attitudinal questions about their workplace, despite the fact that they had previously been assured full confidentiality. The FINALE-questionnaire (75) is a structured self-administered questionnaire with validated measures, however it includes 140 questions which could be discouraging to some target groups. As shown in this study (paper IV), regarding some questions, text-messages could be an equally credible method to administrate for the construction workers.

The calculations of the objectively measured physical activity data was based on preconditions for defining work hours as being from 7 o'clock to 15 o'clock. Most of the workers started the working day at 7 o'clock in the morning. The participants worked approx. 40 hours week which on average means a working day from 7 to 15.

Some of the participants worked for long hours on Thursdays and had "short" day on Fridays. The exact time schedule for each worker does not exist in the data, but the significantly lower objectively measured PA found during work hours on Fridays is probably explained by some workers got off early on Fridays.

The combined HR and movement sensor, estimating energy expenditure has been found technically reliable and valid (81) though, it overestimates energy expenditure slightly during the non-ambulatory activities (125). However, not much is known, about the applicability of a combined HR and movement sensor, when measuring free-living physical activity in workplace settings for seven days at a time. In the present study, several problems arose in connection to replacing electrodes, in spite of exhaustive instructions. Sweating, in particular, was problematic for this workgroup, as it caused frequent shift of electrodes and for some caused itching. Further long-term free-living analyses are needed since it is not clear if a combined monitor sensor can reflect the workload during work hours.

6.4.3 Text messages:

The Bland Altman plots showed reasonable agreement and paired t-tests did not show any significant difference between the methods except from the post-test of work ability.

The Bland Altman plot visualizes the difference between the two methods by plotting the differences (vertical axis) against the mean of the two methods (horizontal axis). Another approach to compare methods is to use Pearson's correlation coefficient in order to assess concordance between quantitative measures. However, one of the problems when using Pearson's correlation coefficient is that the strong correlation does not necessarily mean that there is an agreement between the measures.

Both text messages and questionnaire are methods that measure the variable indirectly and, therefore, both have measurement errors. Thus, some lack of agreement between two measurements will always exist. Even though the plots show some outliers outside the upper and lower limits of inaccuracy between the two measurements, it does not indicate a systematic pattern. However, the work ability plots might be an area to explore further. The work ability plots seems to have some imbalance as it looks like the

variation of at least one method depends strongly on the magnitude of measurements. One method for further investigations is to log-transform the work ability data.

Certain tests methods may be better suited to some test persons than others. However, comparing the two methods in this study was done using the entire study group. Overall, the same results were achieved when explorative calculations using Bland Altman plots were used to assess the agreement between the two measurements methods only among the construction workers that were considered to have a need for strength training.

The average discrepancy between the methods is not big, however; the 95% confidence limits are large in all of the plots. That is, the variation is broad within both methods and in a clinical interpretation the methods are either equally credible or equally unreliable.

6.5 Strengths and weaknesses

The rigorous RCT design and the individual, blinded randomization are the strengths of the study. The attendance rate to the intervention was relatively high (paper III) and the study has only a few dropouts. One of the limitations of this study is the low acceptance to participate in exercise training within the job group. We invited eligible participants well above the required number according to our power calculation. However, there was a high decline rate (approx. 1/3) among those who replied to our invitation (approx. 2/3) resulting in group sizes below those estimated in the power calculation.

All sample size calculations rely on assumptions. In this study, we did in spite of only 67 participants effectively show a significant change in one of the primary outcome after the intervention. Therefore, in this respect the study is not underpowered. On the other hand, it is challenging to design a study with various outcome variables if demands in study size are highly different. The present study included variables which probably required much larger sample size. For many studies with different variables, it may be challenging to demonstrate significant results on all variables. Despite this, there are good reasons to publish well-designed studies even with non-significant results, as these may contribute to the combined knowledge and be used in reviews and meta-analyses.

Another weakness is the division of the intervention group into small strength training groups and it cannot be ruled out that this maneuver induced type 2 errors in relation to muscle strength. The allocation to groups who should train different body regions was done based on the health check and after randomization. Making individual training programs within one intervention group reduces the power and the possibility to demonstrate statistically significant differences in muscle strength.

7.0 Conclusion

This PhD study demonstrates that a 12 week work site exercise intervention of one hour per week (3x20min) did increase aerobic capacity among construction workers with a clinically relevant magnitude with regard to the risk of cardio-metabolic disorders.

Working in the construction industry is associated with strenuous working postures and exposure to heavy workload. However, this is a concern primarily for the mechanical strain on the musculoskeletal system, as the metabolic load at work is only moderate. The employees are significantly more physically active at work than in leisure time, however, the leisure-time physical activity does not reach the health recommendations about physical activity regarding intensity and this may call for concern.

Compared to representative data on employees in Denmark, the construction workers have significantly lower aerobic capacity, higher BMI and higher muscle strength in shoulder, arm, and abdomen.

Lack of leisure- time physical activity and low aerobic capacity, increase the relative load at work and can in a long-term perspective contribute to increased risk of deterioration in health.

8.0 Perspectives

Clinical

Integrating health-enhancing physical activity at workplaces with physically demanding jobs may be a good investment for companies as well as society. Organized exercise training programs that are individually tailored and with sufficiently high intensity do not need to last for more than a total of one hour per week, to have a health effect. This study shows a good effectiveness for integrating short exercise sessions into organizational routines among construction workers. However, more focus is needed on an exercise program targeting the musculoskeletal system, individualized for employees with low isometric muscle strength in specific body regions. It is a great challenge to motivate workers to increase their physical activity, especially among individuals who do not have a tradition for being physically active in the sense of health-enhancing physical activity. Many actions are necessary from different actors and the workplace is a particularly convenient arena, since the majority of the adult population meets and joins in various social activities there.

Research

This study comprises the results after 12 weeks of intervention and therefore cannot reveal any long-term effect. Future research should focus on long-term effect and tools to maintain interest in ongoing projects among employees and among the leadership in the workplaces.

It is important to perform well-designed studies that make it possible to measure effects of the intervention, also compared to no intervention. In particular, the focus should be on work-related outcome variables, for which changes and effects have not yet been proven experimentally.

Individualization of training has two important elements. 1) Based on the individual's musculoskeletal disorders, the training can be regarded as treatment. The individual's physical exposure at work, unfavorable working posture and habits can be changed using an individual approach that solve current problems and at the same time promotes health. 2) When the training is targeting relevant problems for the individual, it presumably increases motivation for exercise. The individual training approach also allows for an increased focus on the individual's motivation which is crucial for adherence, especially at long term perspective.

Planning of well-designed studies with an individual approach requires, among other things, consideration concerning small subgroups of the participants. The present study could be used as an example of the percentage distribution, which can be relied on when conducting power calculations for future studies among construction workers.

It is a challenge to design and accomplish well-designed research studies at the workplaces. The need for control groups, in the sense of classical RCT-design, can be a hindrance for participation for some companies. This thesis highlights the challenges concerning recruitment of participants. Furthermore, implementation of the project's positive results ought to be a focus area in a future research, as this can be pivotal for a company's involvement. A design with continuation of the strength of the RCT but adjusted to research in worksite setting, and including approach of implementation could be a relevant area for future development.

Appendix I

RCT- studies including exercise training at the work-site published 2002-2012 (exl. Construction workers).

The results shown are changes in the intervention group (s) compared to the control group after the intervention.

Reference	Job group	Intervention period	Randomization	Variable	Evaluation	Results	Comments
Andersen CH et al (2012)(55) Denmark	Office workers	20 weeks 1hr /week ¹ : 1 x 60 min ² : 3 x 20 min ³ : 9 x 7min	¹ : Strength ex (WS) (n=116) ² : Strength ex (3WS) (n=126) ³ : Strength ex (9WS) (n=106) ⁴ : Reference (REF) (n=101)	Pain M.strength	Questionnaire	↓ Neck pain ↓ Shoulder pain	Compliance: 39% participated 40–60 min/week, 18% participated 20–40 min/week. High drop-out rate in 9WS
Nassif H et al (2011) (67) France	Employees with LBP in automotive industry	2 months 1hr 3xweek.	Experimental gr: (n=37) Control (n=38)	Pain Flexibility M. Endurance	Questionnaire Sorensen test Shirado tests Clinical tests	↓ Pain ↑ Flexibility ↑ Back functions	Compliance not described in detail. Only showing missing's to tests.
Zebis M et al (2011) (68) Denmark	Industrial workers	20 weeks 1hr/week	Training (n=282) Control (n=255)	Pain (neck + shoulder)	Questionnaire	↓ neck pain ↓ ↑ Shoulder pain	Borderline ↓ in shoulder pain (p=0.07). 85% exercised 1xweek.
Christensen J et al (2011) (65) Denmark	Health care workers	3 months 1 hr/week	Target population: Intervention(n=54) Reference (n=44)	Bodyweight BP M. strength VO2max Pain	Questionnaire Electronic BP Device Isometric M. test Bicycle test	↓ Bodyweight ↓ Diastolic BP ↑ M. strength in Back ext. ↓ ↑ VO2max ↓ ↑ Pain	A FINALE-study Compliance: Only 7 subjects out of 97 dropped out during the intervention.

Jørgensen MB et al (2011)A (66) Denmark	Cleaners	¹⁾ 12 weeks 1hr/week ²⁾ 12 weeks 2-3 hr every second week	Strength coordination group: PCT (n=95) ¹⁾ Cognitive gr CBT (n=99) ²⁾ Reference (n=100)	M. Strength Kinesiophobia	Isometric M. test Balance force platform Questionnaire	↑ Trunk flex in PCT ↑ Rambling in PCT vs. CBT ↓ Kinesiophobia in CBT vs. PCT and REF.	A FINALE-study Compliance: PCT: 37% CBT: 49%
Jørgensen MB et al (2011)B (76) Denmark	Cleaners	¹⁾ 12 week 1hr/week ²⁾ 12 week 2-3 hr /second week	¹⁾ : Strength coordination gr: PCT (n=95) ²⁾ : Cognitive gr CBT (n=99) Reference (n=100)	Pain Work ability Sickness absence	Questionnaire	↓ ↑ Pain ↓ ↑ Work ability ↓ ↑ Sickness absence	The same study as Jørgensen MB et al (2011)A (2 publications)
Skoglund L et al (2011) (63) Sweden	Office workers	6 weeks Daily	Cross-over design (n=37) Qigong group Control	Neck disability Physical health Mental health Pain Health related quality of life Perceived stress	Questionnaire	↓ Neck disability ↓ ↑ Physical health ↓ ↑ Mental health ↓ ↑ pain ↓ ↑ health related quality of life ↓ ↑ stress	42 out of 300 invited persons were recruited On average 80% compliance to the program. Possible carry-over effect.
Pedersen MT (2009) (61) Denmark	Office workers	1 year ¹ 1hr/week ² guidance 1-4 times /month	¹ : Strength ex (SRT) (n=180) ² : Various PA (APE) (n=187) ³ : Reference (n=182)	PA General health Pain Productivity M. strength VO2max BP Anthropometry	Questionnaire Isometric M. test. Sub-max bicycle test blood pressure monitor body composition monitor	↓ ↑ PA ↓ ↑ Gen. health ↓ ↑ Productivity ↓ Pain ↓ Bodyfat ↓ Systolic BP ↑ M. strength shoulder ↓ ↑ VO2max	Low compliance rate and high dropout, e.g. only 2/3 of the study participants completed the questionnaires at follow-up. Compliance to the intervention?

Andersen LL et al (2008) A (56) Denmark	Office workers	1 year 1hr/week	Specific resistance ex (SRT) (n=180) All-round ex (APE) (n=187) Reference (n=182)	M. Strength Pain	Isometric M test Questionnaire	↓ Neck pain (pain cases) ↑ Preventive effect in shoulder ↑ M. strength (shoulder elevation)	Compliance to the intervention First 6 m: SRT:54% APT:31% Last 6 m: SRT: 35% APT: 28%
Andersen LL et al (2008) B (57) Denmark	Workers with monotonous tasks (e.g., computer-intensive work).	10 weeks 1hr/week	Strength training (SST) (n=18) Leg bicycling (GFT) (n=16) Reference (n=14)	Pain VO2max M. strength	Visual analog scale Åstrand bicycle test Isometric M. strength	↑ Pain in SST ↑ VO2max only in GFT ↑ M. strength only in SST	Compliance to the training: SST: ~ 80% GFT: ~ 90% High drop out of the Ref group (~40%)
Blangsted AK (2008)(58) Denmark	Office workers	1 year 1hr/week	Specific resistance ex (SRT) (n=180) All-round ex (APE) (n=187) Reference (n=182)	M.skeletal sympt Perceived work ability (WA)	Questionnaire	↓ Duration of neck symptoms in SST and APE vs. Ref ↓ ↑ WA	Same study population as in Andersen LL (2008)A The dropout for the full year: SRT : 26.6% APE 14.4% REF: 18.7%
Kietrys DM (2007) (60) USA	Computer operators	4 weeks 2xdaily	Resistance ex (n=24) Stretching ex (n=24) Control (n=24)	Pain Neck disability	Visual analog scale Questionnaire Pain drawing	↓ ↑ Pain ↓ Neck disability	Compliance: Both groups performed ex on average 1.5 times /day The participants received payment after the intervention

Atlantis E et al (2006) (112) USA	Employees in casinos	24 weeks 2.5 hr week	Treatment (n=36) Control (n=37)	Waist circumference VO2max Diary	Measured with to the nearest 0.1cm Treadmill Protocol Questionnaire	↓ Waist circumference ↑ VO2max	42 out of 44 completed follow-up test Compliance to the exercise program?
Sjögren T et al (2005) (62) Finland	Office workers	15 weeks	Cross-over design (53) Exercise Controls	Pain M.strength PA	Borg CR10 Sub-maximal 5RM test PA Diary	↓ Pain (neck and head) ↑ M.strength UE extension ↓ ↑ PA	Compliance to training: ~ 70% Carry over effect? Length of training sessions?
Maul I et al (2005)(113) Switzerland	Hospital employees	3 months 1hr 2xweek	2 groups: Exercise (n=74) Comparison (n=74)	LBP Well-being	Questionnaire	↑ M. endurance ↑ M. strength 1 year follow-up: ↓ LBP ↓ Well-being	74 out of 97 completed the program (~ 76%)
Jau-Yih T et al (2004)(59) Taiwan	Employees from departments in an airline company	2 weeks 2) 1xdaily 3) 2xdaily	1: Self-ex group (n=56) 2: Team-ex group 1 (n=69) 3: Team-ex group 2 (n=14) 4: Reference (n=39)	Pain Cervical mobility	Questionnaire Pressure algometry Inclinometer device	↓ Neck and shoulder symptoms	Drop-out from ex (~ 15%)
Viljanen M et al (2003) (64) Finland	Office workers	12 weeks 1.5hr/week	Dynamic muscle training (n=135) Relaxation training (n=128) Control group (n = 130)	Pain Work ability Cervical range of motion, M. strength Sick leave owing to neck pain	Questionnaire Clinical tests	↓ ↑ Pain ↓ ↑ Work ability ↓ ↑ Cervical flex and extension ↑ Cervical rot and lateral flex. ↓ ↑ M. strength ↓ ↑ Sick leave	Compliance to the training: Dynamic gr: 39% Relaxation gr: 42%

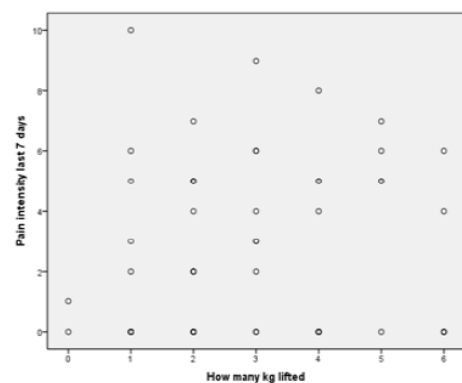
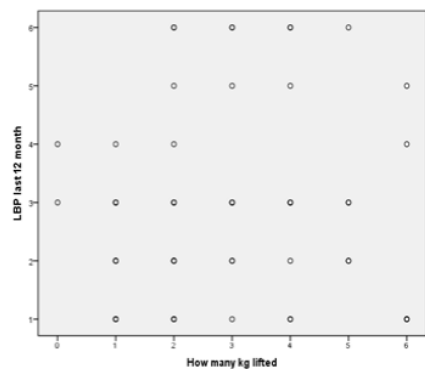
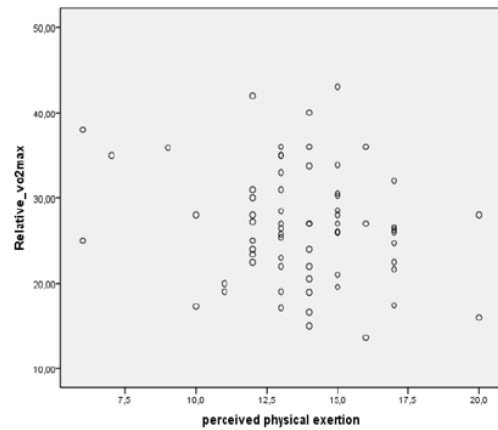
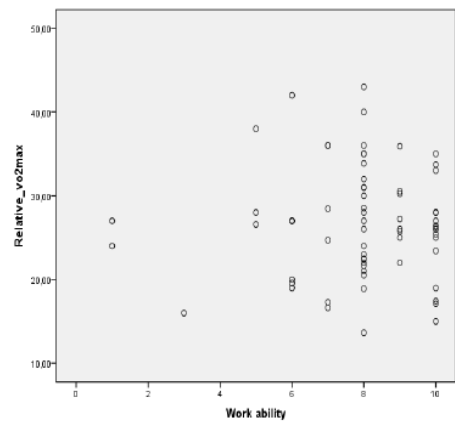
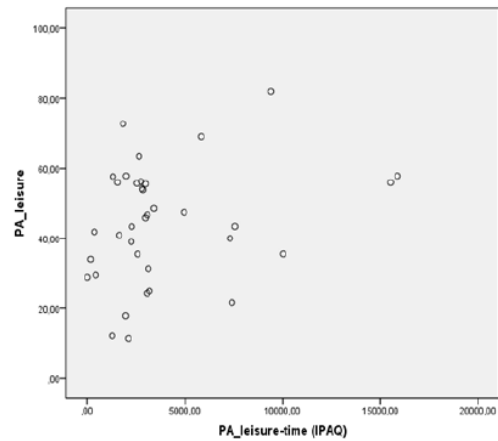
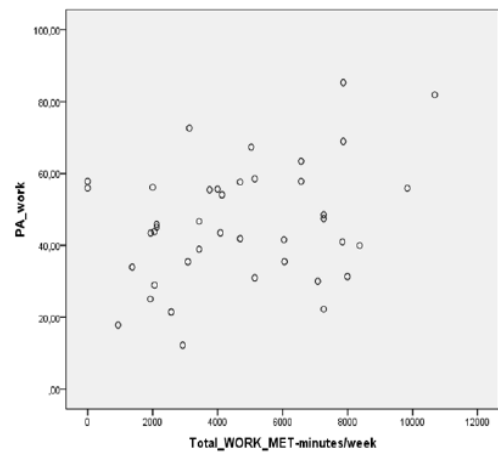
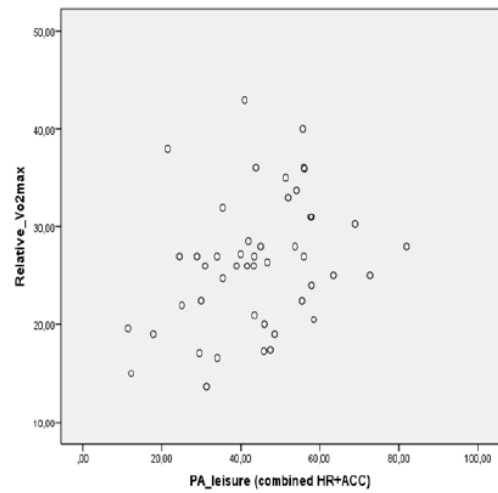
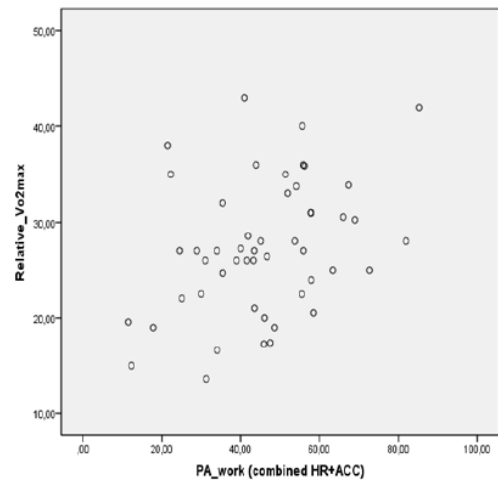
RCT: Randomized Control Trial, PA: Physical activity, LBP: Low Back pain, BP: Blood Pressure, VO2max: maximum oxygen uptake, UE: Upper extremity

↑: significant increase

↓: significant decrease

↓ ↑: no significant change.

Appendix II



Appendix III

The muscle strength training program

Regarding strength training there were three body regions: Neck-shoulder, Abdominal-back, and Hip-knee. They were considered separately and training included only those regions that met the 80 % criteria for at least one of the tests. Each participant received their own individual exercise protocol in a training diary. Exercises for strength training were selected from 11 different exercises (3 for Neck/Shoulder/upper arm: "Lateral raise", "Shrugs", and "Rows". 5 for Abdominal/Back: "Back extensions", "Bird dog", "Plank", "Crunch", and "Oblique crunch", 3 for Hip/Knee: "Static lunges", "Step-up", and "Hip abduction") that could be graded by dumbbells/ resistance bands or body postures .

Neck /Shoulder/upper arms

Lateral raise



Shrugs



Rows



Back

Back extensions



Bird dog



Plank



Abdominal

Crunch



Oblique crunch



Hip-knee

Static lunges



Step-up












Hip abduction



Bibi Gram, PhD Fellow.
Institute of Sports Science and Clinical Biomechanics

Appendix IV

Exercise protocol/training diary – an example

Neck/shoulder			Lateral raise			Rows			Shrugs		
											
Date	Pas	Instructor present? (mark X)	Number of repetitions	kilo	Pain (mark X)	Number of repetition	kilo	Pain (mark X)	Number of repetitions	kilo	Pain (mark X)
	1		20			20			20		
			20			20			20		
Abd/back			Crunch			Back extension			Plank		
											
Date	Pas	Instructor present? (mark X)	Number of Repetitions	Stage (1-3)	Pain (mark X)	Number of repetitions	Stage (1-3)	Pain (mark X)	Time (sec)	Stage (1-3)	Pain (mark X)
	2		20			20			20		
			20			20			20		
Hip/knee			Step-up			Static lunges			Hip aduction		
											
Date	Pas	Instructor present? (mark X)	Number of Repetitions	Stage (1-3) /kilo	Pain (mark X)	Number of repetitions	Stage (1-3)	Pain (mark X)	Number of repetitions	Stage (1-3)	Pain (mark X)
	3		20			20			20		
			20			20			20		

Reference List

- (1) 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 Rheum* 2007 April;56(4):1355-64.
- (2) Krause N, Brand RJ, Kaplan GA, Kauhanen J, Malla S, Tuomainen TP et al. Occupational physical activity, energy expenditure and 11-year progression of carotid atherosclerosis. *Scand J Work Environ Health* 2007 December;33(6):405-24.
- (3) Holtermann A, Mortensen OS, Burr H, Sogaard K, Gyntelberg F, Suadicani P. The interplay between physical activity at work and during leisure time--risk of ischemic heart disease and all-cause mortality in middle-aged Caucasian men. *Scand J Work Environ Health* 2009 December;35(6):466-74.
- (4) van den Berg TI, Elders LA, de Zwart BC, Burdorf A. The effects of work-related and individual factors on the Work Ability Index: a systematic review. *Occup Environ Med* 2009 April;66(4):211-20.
- (5) Lund T, Labriola M, Christensen KB, Bultmann U, Villadsen E. Physical work environment risk factors for long term sickness absence: prospective findings among a cohort of 5357 employees in Denmark. *BMJ* 2006 February 25;332(7539):449-52.
- (6) Karpansalo M, Manninen P, Lakka TA, Kauhanen J, Rauramaa R, Salonen JT. Physical workload and risk of early retirement: prospective population-based study among middle-aged men. *J Occup Environ Med* 2002 October;44(10):930-9.
- (7) Krause N, Lynch J, Kaplan GA, Cohen RD, Goldberg DE, Salonen JT. Predictors of disability retirement. *Scand J Work Environ Health* 1997 December;23(6):403-13.
- (8) Cancelliere C, Cassidy JD, Ammendolia C, Cote P. Are workplace health promotion programs effective at improving presenteeism in workers? A systematic review and best evidence synthesis of the literature. *BMC Public Health* 2011;11:395.
- (9) Analyse af sygefraværet (analyse of sickness absence). Copenhagen, Denmark. Beskæftigelsesministeriet (The Danish Ministry of Employment); 2008.
- (10) Arndt V, Rothenbacher D, Daniel U, Zschenderlein B, Schuberth S, Brenner H. Construction work and risk of occupational disability: a ten year follow up of 14 474 male workers. *Occup Environ Med* 2005 August 1;62(8):559-66.
- (11) Guberman E, Usel M. Permanent work incapacity, mortality and survival without work incapacity among occupations and social classes: a cohort study of ageing men in Geneva. *Int J Epidemiol* 1998 December;27(6):1026-32.
- (12) Holmstrom E, Moritz U, Engholm G. Musculoskeletal disorders in construction workers. *Occup Med* 1995 April;10(2):295-312.
- (13) Hildebrandt VH. Back pain in the working population: prevalence rates in Dutch trades and professions. *Ergonomics* 1995 June;38(6):1283-98.

- (14) Holmstrom EB, Lindell J, Moritz U. Low back and neck/shoulder pain in construction workers: occupational workload and psychosocial risk factors. Part 1: Relationship to low back pain. *Spine (Phila Pa 1976)* 1992 June;17(6):663-71.
- (15) Sturmer T, Luessenhoop S, Neth A, Soyka M, Karmaus W, Toussaint R et al. Construction work and low back disorder. Preliminary findings of the Hamburg Construction Worker Study. *Spine (Phila Pa 1976)* 1997 November 1;22(21):2558-63.
- (16) Hartmann B, Fleischer AG. Physical load exposure at construction sites. *Scand J Work Environ Health* 2005;31 Suppl 2:88-95.
- (17) Schneider SP. Musculoskeletal injuries in construction: a review of the literature. *Appl Occup Environ Hyg* 2001 November;16(11):1056-64.
- (18) Bruce P. Bernard, Vern Putz-Anderson, Susan E. Burt, and Libby L. Cole et al. Musculoskeletal disorders and workplace factors. A critical review of Epidemiologic evidence for work-related musculoskeletal disorders of the neck, upper extremity, and low back. US Department of Health and Human Services: National Institute for Occupational Safety and Health; 1997.
- (19) van Rijn RM, Huisstede BM, Koes BW, Burdorf A. Associations between work-related factors and specific disorders of the shoulder--a systematic review of the literature. *Scand J Work Environ Health* 2010 May;36(3):189-201.
- (20) Tak S, Buchholz B, Punnett L, Moir S, Paquet V, Fulmer S et al. Physical ergonomic hazards in highway tunnel construction: Overview from the Construction Occupational Health Program. *Applied Ergonomics* 2011 July;42(5):665-71.
- (21) Engholm G, Holmstrom E. Dose-response associations between musculoskeletal disorders and physical and psychosocial factors among construction workers. *Scand J Work Environ Health* 2005;31 Suppl 2:57-67.
- (22) Halim I, Omar AR. Development of prolonged standing strain index to quantify risk levels of standing jobs. *Int J Occup Saf Ergon* 2012;18(1):85-96.
- (23) Macfarlane GJ, Thomas E, Papageorgiou AC, Croft PR, Jayson MI, Silman AJ. Employment and physical work activities as predictors of future low back pain. *Spine (Phila Pa 1976)* 1997 May 15;22(10):1143-9.
- (24) Tak S, Paquet V, Woskie S, Buchholz B, Punnett L. Variability in risk factors for knee injury in construction. *J Occup Environ Hyg* 2009 February;6(2):113-20.
- (25) Reid CR, Bush PM, Cummings NH, McMullin DL, Durrani SK. A review of occupational knee disorders. *J Occup Rehabil* 2010 December;20(4):489-501.
- (26) van der Beek AJ, Erik MS, Windhorst J, Burdorf A. An evaluation of methods assessing the physical demands of manual lifting in scaffolding. *Appl Ergon* 2005 March;36(2):213-22.
- (27) Kivi P, Mattila M. Analysis and improvement of work postures in the building industry: application of the computerised OWAS method. *Appl Ergon* 1991 February;22(1):43-8.
- (28) Cole DC, Rivlis I. Individual Factors and Musculoskeletal Disorders. In: Marras WS, Karwowski W, editors. *Fundamentals and assessment tools for occupational ergonomics*. Boca Ration FL: CRC Press Taylor & Francis Group; 2006.

- (29) Holtermann A, Hansen JV, Burr H, Sogaard K, Sjogaard G. The health paradox of occupational and leisure-time physical activity. *Br J Sports Med* 2012 March;46(4):291-5.
- (30) Eaton CB, Medalie JH, Flocke SA, Zyzanski SJ, Yaari S, Goldbourt U. Self-reported physical activity predicts long-term coronary heart disease and all-cause mortalities. Twenty-one-year follow-up of the Israeli Ischemic Heart Disease Study. *Arch Fam Med* 1995 April;4(4):323-9.
- (31) Holtermann A, Mortensen OS, Burr H, Sogaard K, Gyntelberg F, Suadicani P. Physical demands at work, physical fitness, and 30-year ischaemic heart disease and all-cause mortality in the Copenhagen Male Study. *Scand J Work Environ Health* 2010 September;36(5):357-65.
- (32) Kristal-Boneh E, Harari G, Melamed S, Froom P. Association of physical activity at work with mortality in Israeli industrial employees: the CORDIS study. *J Occup Environ Med* 2000 February;42(2):127-35.
- (33) Stender M, Hense HW, Doring A, Keil U. Physical activity at work and cardiovascular disease risk: results from the MONICA Augsburg study. *Int J Epidemiol* 1993 August;22(4):644-50.
- (34) Holtermann A, Mortensen OS, Sogaard K, Gyntelberg F, Suadicani P. Risk factors for ischaemic heart disease mortality among men with different occupational physical demands. A 30-year prospective cohort study. *BMJ Open* 2012;2(1):e000279.
- (35) Makinen T, Kestila L, Borodulin K, Martelin T, Rahkonen O, Leino-Arjas P et al. Occupational class differences in leisure-time physical inactivity--contribution of past and current physical workload and other working conditions. *Scand J Work Environ Health* 2010 January;36(1):62-70.
- (36) Schneider S, Becker S. Prevalence of physical activity among the working population and correlation with work-related factors: results from the first German National Health Survey. *J Occup Health* 2005 September;47(5):414-23.
- (37) Groeneveld IF, Proper KI, van der Beek AJ, van DC, van MW. Design of a RCT evaluating the (cost-) effectiveness of a lifestyle intervention for male construction workers at risk for cardiovascular disease: the health under construction study. *BMC Public Health* 2008;8:1.
- (38) Physical activity guidelines advisory committee. Physical activity guidelines advisory committee report, 2008. Washington DC: US Department of Health and Human Services; 2008.
- (39) Shvartz E, Reibold RC. Aerobic fitness norms for males and females aged 6 to 75 years: a review. *Aviat Space Environ Med* 1990 January;61(1):3-11.
- (40) Blair SN, Kohl HW, III, Paffenbarger RS, Jr., Clark DG, Cooper KH, Gibbons LW. Physical fitness and all-cause mortality. A prospective study of healthy men and women. *JAMA* 1989 November 3;262(17):2395-401.
- (41) Borg G. Perceived exertion as an indicator of somatic stress. *Scand J Rehabil Med* 1970;2(2):92-8.
- (42) Howley ET. Type of activity: resistance, aerobic and leisure versus occupational physical activity. *Med Sci Sports Exerc* 2001 June;33(6 Suppl):S364-S369.
- (43) Blair SN, Kampert JB, Kohl HW, III, Barlow CE, Macera CA, Paffenbarger RS, Jr. et al. Influences of cardiorespiratory fitness and other precursors on cardiovascular disease and all-cause mortality in men and women. *JAMA* 1996 July 17;276(3):205-10.

- (44) Blair SN, Cheng Y, Holder JS. Is physical activity or physical fitness more important in defining health benefits? *Med Sci Sports Exerc* 2001 June;33(6 Suppl):S379-S399.
- (45) Kurl S, Sivenius J, Makikallio TH, Rauramaa R, Laukkanen JA. Exercise workload, cardiovascular risk factor evaluation and the risk of stroke in middle-aged men. *J Intern Med* 2009 February;265(2):229-37.
- (46) Laukkanen JA, Rauramaa R, Salonen JT, Kurl S. The predictive value of cardiorespiratory fitness combined with coronary risk evaluation and the risk of cardiovascular and all-cause death. *J Intern Med* 2007 August;262(2):263-72.
- (47) Laukkanen JA, Rauramaa R, Kurl S. Exercise workload, coronary risk evaluation and the risk of cardiovascular and all-cause death in middle-aged men. *Eur J Cardiovasc Prev Rehabil* 2008 June;15(3):285-92.
- (48) KODAMA S, Saito K, Tanaka S, Maki M, Yachi Y, Asumi M et al. Cardiorespiratory fitness as a quantitative predictor of all-cause mortality and cardiovascular events in healthy men and women: a meta-analysis. *JAMA* 2009 May 20;301(19):2024-35.
- (49) FitzGerald SJ., Barlow CE, Kampert JB, Morrow J, Jackson AW, Blair SN. Muscular Fitness and All-Cause Mortality: Prospective Observations. *Journal of Physical Activity & Health* 2004 January;1(1):7-18.
- (50) Haskell WL, Lee IM, Pate RR, Powell KE, Blair SN, Franklin BA et al. Physical activity and public health: updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. *Med Sci Sports Exerc* 2007 August;39(8):1423-34.
- (51) Kumar S. Theories of musculoskeletal injury causation. *Ergonomics* 2001 January 15;44(1):17-47.
- (52) Garber CE, Blissmer B, Deschenes MR, Franklin BA, Lamonte MJ, Lee IM et al. American College of Sports Medicine position stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise. *Med Sci Sports Exerc* 2011 July;43(7):1334-59.
- (53) Physical activity and health:a report of the Surgeon General. Atlanta. US Department of Health and Human Services, Center for Disease Control and Prevention; 1996.
- (54) Carnethon M, Whitsel LP, Franklin BA, Kris-Etherton P, Milani R, Pratt CA et al. Worksite wellness programs for cardiovascular disease prevention: a policy statement from the American Heart Association. *Circulation* 2009 October 27;120(17):1725-41.
- (55) Andersen CH, Andersen LL, Gram B, Pedersen MT, Mortensen OS, Zebis MK et al. Influence of frequency and duration of strength training for effective management of neck and shoulder pain: a randomised controlled trial. *Br J Sports Med* 2012 June 29.
- (56) Andersen LL, Jorgensen MB, Blangsted AK, Pedersen MT, Hansen EA, Sjogaard G. A randomized controlled intervention trial to relieve and prevent neck/shoulder pain. *Med Sci Sports Exerc* 2008 June;40(6):983-90.
- (57) Andersen LL, Kjaer M, Sogaard K, Hansen L, Kryger AI, Sjogaard G. Effect of two contrasting types of physical exercise on chronic neck muscle pain. *Arthritis Rheum* 2008 January 15;59(1):84-91.

- (58) Blangsted AK, Sogaard K, Hansen EA, Hannerz H, Sjogaard G. One-year randomized controlled trial with different physical-activity programs to reduce musculoskeletal symptoms in the neck and shoulders among office workers. *Scand J Work Environ Health* 2008 February;34(1):55-65.
- (59) Jau-Yih T, Hsin-Yi L, Jin-Huei H, Chao-Ying C, Chiou-Jong C. Physical exercise and health education for neck and shoulder complaints among sedentary workers. *Journal of Rehabilitation Medicine* (Taylor & Francis Ltd) 2004 November;36(6):253-7.
- (60) Kietrys DM, Galper JS, Verno V. Effects of at-work exercises on computer operators. *Work* 2007;28(1):67-75.
- (61) Pedersen MT, Blangsted AK, Andersen LL, Jorgensen MB, Hansen EA, Sjogaard G. The effect of worksite physical activity intervention on physical capacity, health, and productivity: a 1-year randomized controlled trial. *J Occup Environ Med* 2009 July;51(7):759-70.
- (62) Sjogren T, Nissinen KJ, Jarvenpaa SK, Ojanen MT, Vanharanta H, Malkia EA. Effects of a workplace physical exercise intervention on the intensity of headache and neck and shoulder symptoms and upper extremity muscular strength of office workers: a cluster randomized controlled cross-over trial. *Pain* 2005 July;116(1-2):119-28.
- (63) Skoglund L, Josephson M, Wahlstedt K, Lampa E, Norback D. Qigong training and effects on stress, neck-shoulder pain and life quality in a computerised office environment. *Complement Ther Clin Pract* 2011 February;17(1):54-7.
- (64) Viljanen M, Malmivaara A, Uitti J, Rinne M, Palmroos P, Laippala P. Effectiveness of dynamic muscle training, relaxation training, or ordinary activity for chronic neck pain: randomised controlled trial. *BMJ* 2003 August 30;327(7413):475.
- (65) Christensen JR, Faber A, Ekner D, Overgaard K, Holtermann A, Sogaard K. Diet, physical exercise and cognitive behavioral training as a combined workplace based intervention to reduce body weight and increase physical capacity in health care workers - a randomized controlled trial. *BMC Public Health* 2011;11:671.
- (66) Jorgensen MB, Ektor-Andersen J, Sjogaard G, Holtermann A, Sogaard K. A randomised controlled trial among cleaners--effects on strength, balance and kinesiophobia. *BMC Public Health* 2011;11:776.
- (67) Nassif H, Brosset N, Guillaume M, Delore-Milles E, Tafflet M, Buchholz F et al. Evaluation of a randomized controlled trial in the management of chronic lower back pain in a French automotive industry: an observational study. *Arch Phys Med Rehabil* 2011 December;92(12):1927-36.
- (68) Zebis MK, Andersen LL, Pedersen MT, Mortensen P, Andersen CH, Pedersen MM et al. Implementation of neck/shoulder exercises for pain relief among industrial workers: a randomized controlled trial. *BMC Musculoskelet Disord* 2011;12:205.
- (69) Groeneveld IF, Proper KI, van der Beek AJ, van MW. Sustained body weight reduction by an individual-based lifestyle intervention for workers in the construction industry at risk for cardiovascular disease: results of a randomized controlled trial. *Prev Med* 2010 September;51(3-4):240-6.
- (70) Groeneveld IF, Proper KI, van der Beek AJ, Hildebrandt VH, van MW. Short and long term effects of a lifestyle intervention for construction workers at risk for cardiovascular disease: a randomized controlled trial. *BMC Public Health* 2011;11:836.

- (71) Kaukiainen A, Nygård C, Virtanen P, Saloniemi A. Physical Activity Intervention among Unemployed Male Construction Workers. *Advances in Physiotherapy* 2002 March;4(1):3-15.
- (72) Ludewig PM, Borstad JD. Effects of a home exercise programme on shoulder pain and functional status in construction workers. *Occup Environ Med* 2003 November;60(11):841-9.
- (73) Borstad JD, Buetow B, Deppe E, Kyllonen J, Liekhus M, Cieminski CJ et al. A longitudinal analysis of the effects of a preventive exercise programme on the factors that predict shoulder pain in construction apprentices. *Ergonomics* 2009 February;52(2):232-44.
- (74) de Boer AG, Burdorf A, van DC, Frings-Dresen MH. The effect of individual counselling and education on work ability and disability pension: a prospective intervention study in the construction industry. *Occup Environ Med* 2007 December;64(12):792-7.
- (75) Holtermann A, Jorgensen MB, Gram B, Christensen JR, Faber A, Overgaard K 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.
- (76) Jorgensen MB, Faber A, Hansen JV, Holtermann A, Sogaard K. Effects on musculoskeletal pain, work ability and sickness absence in a 1-year randomised controlled trial among cleaners. *BMC Public Health* 2011;11:840.
- (77) Craig CL, Marshall AL, Sjöström M, et al. International Physical Activity Questionnaire: 12-Country Reliability and Validity. *Medicine and Science in Sports and Exercise* 2003 August;35:1381-95.
- (78) ÅSTRAND PO, RYHMING I. A nomogram for calculation of aerobic capacity (physical fitness) from pulse rate during sub-maximal work. *J Appl Physiol* 1954 September;7(2):218-21.
- (79) Åstrand I. Aerobic work capacity in men and women with special reference to age. *Acta Physiol Scand Suppl* 1960;49(169):1-92.
- (80) Essendrop M, Schibye B, Hansen K. Reliability of isometric muscle strength tests for the trunk, hands and shoulders. *International Journal of Industrial Ergonomics* 2001 December;28(6):379-87.
- (81) Brage S, Brage N, Franks PW, Ekelund U, Wareham NJ. Reliability and validity of the combined heart rate and movement sensor Actiheart. *Eur J Clin Nutr* 2005 April;59(4):561-70.
- (82) Stegle O, Fallert SV, MacKay DJ, Brage S. Gaussian process robust regression for noisy heart rate data. *IEEE Trans Biomed Eng* 2008 September;55(9):2143-51.
- (83) Brage S, Brage N, Franks PW, Ekelund U, Wong MY, Andersen LB et al. Branched equation modeling of simultaneous accelerometry and heart rate monitoring improves estimate of directly measured physical activity energy expenditure. *J Appl Physiol* 2004 January;96(1):343-51.
- (84) Brage S, Ekelund U, Brage N, Hennings MA, Froberg K, Franks PW et al. Hierarchy of individual calibration levels for heart rate and accelerometry to measure physical activity. *J Appl Physiol* 2007 August;103(2):682-92.
- (85) Strath SJ, Brage S, Ekelund U. Integration of physiological and accelerometer data to improve physical activity assessment. *Med Sci Sports Exerc* 2005 November;37(11 Suppl):S563-S571.

- (86) Thompson D, Batterham AM, Bock S, Robson C, Stokes K. Assessment of low-to-moderate intensity physical activity thermogenesis in young adults using synchronized heart rate and accelerometry with branched-equation modeling. *J Nutr* 2006 April;136(4):1037-42.
- (87) Assah FK, Ekelund U, Brage S, Wright A, Mbanya JC, Wareham NJ. Accuracy and validity of a combined heart rate and motion sensor for the measurement of free-living physical activity energy expenditure in adults in Cameroon. *Int J Epidemiol* 2011 February;40(1):112-20.
- (88) Buchholz B, Paquet V, Punnett L, Lee D, Moir S. PATH: a work sampling-based approach to ergonomic job analysis for construction and other non-repetitive work. *Appl Ergon* 1996 June;27(3):177-87.
- (89) Faber A, Hansen K, Christensen H. Muscle strength and aerobic capacity in a representative sample of employees with and without repetitive monotonous work. *International Archives of Occupational and Environmental Health* 2006 January 1;79(1):33-41.
- (90) Andersen UO, Henriksen JH, Jensen G. Sources of measurement variation in blood pressure in large-scale epidemiological surveys with follow-up. *Blood Press* 2002;11(6):357-65.
- (91) Berg CM, Lissner L, Aires N, Lappas G, Toren K, Wilhelmsen L et al. Trends in blood lipid levels, blood pressure, alcohol and smoking habits from 1985 to 2002: results from INTERGENE and GOT-MONICA. *Eur J Cardiovasc Prev Rehabil* 2005 April;12(2):115-25.
- (92) Ahlstrom L, Grimby-Ekman A, Hagberg M, Dellve L. The work ability index and single-item question: associations with sick leave, symptoms, and health--a prospective study of women on long-term sick leave. *Scand J Work Environ Health* 2010 September;36(5):404-12.
- (93) Marras WS. Biomechanical Basis for Ergonomics. In: Marras WS, Karwowski W, editors. *Fundamentals and assessment tools for occupational ergonomics*. Boca Ration: CRC Press Taylor & Francis; 2006.
- (94) Alavinia SM, van den Berg TI, van DC, Elders LA, Burdorf A. Impact of work-related factors, lifestyle, and work ability on sickness absence among Dutch construction workers. *Scand J Work Environ Health* 2009 October;35(5):325-33.
- (95) da Costa BR, Vieira ER. Risk factors for work-related musculoskeletal disorders: A systematic review of recent longitudinal studies. *Am J Ind Med* 2010 March;53(3):285-323.
- (96) Takala EP, Pehkonen I, Forsman M, Hansson GA, Mathiassen SE, Neumann WP et al. Systematic evaluation of observational methods assessing biomechanical exposures at work. *Scand J Work Environ Health* 2010 January;36(1):3-24.
- (97) The InterAct Consortium. Validity of a short questionnaire to assess physical activity in 10 European countries. *European Journal of Epidemiology* 2011;1-11.
- (98) Stofan JR, DiPietro L, Davis D, Kohl HW, III, Blair SN. Physical activity patterns associated with cardiorespiratory fitness and reduced mortality: the Aerobics Center Longitudinal Study. *Am J Public Health* 1998 December;88(12):1807-13.
- (99) Swain DP, Franklin BA. VO(2) reserve and the minimal intensity for improving cardiorespiratory fitness. *Med Sci Sports Exerc* 2002 January;34(1):152-7.

- (100) Wenger HA, Bell GJ. The interactions of intensity, frequency and duration of exercise training in altering cardiorespiratory fitness. *Sports Med* 1986 September;3(5):346-56.
- (101) Sell L, Bultmann U, Rugulies R, Villadsen E, Faber A, Sogaard K. Predicting long-term sickness absence and early retirement pension from self-reported work ability. *Int Arch Occup Environ Health* 2009 October;82(9):1133-8.
- (102) Alavinia SM, van DC, Burdorf A. Influence of work-related factors and individual characteristics on work ability among Dutch construction workers. *Scand J Work Environ Health* 2007 October;33(5):351-7.
- (103) Jay K, Frisch D, Hansen K, Zebis MK, Andersen CH, Mortensen OS et al. Kettlebell training for musculoskeletal and cardiovascular health: a randomized controlled trial. *Scand J Work Environ Health* 2011 May;37(3):196-203.
- (104) Strijk JE, Proper KI, van Stralen MM, Wijngaard P, van MW, van der Beek AJ. The role of work ability in the relationship between aerobic capacity and sick leave: a mediation analysis. *Occup Environ Med* 2011 October;68(10):753-8.
- (105) Roelen CAM, Koopmans PC, Groothoff JW. Subjective health complaints in relation to sickness absence. *Work* 2010 September;37(1):15-21.
- (106) Holtermann A, Hansen JV, Burr H, Sogaard K. Prognostic factors for long-term sickness absence among employees with neck-shoulder and low-back pain. *Scand J Work Environ Health* 2010 January;36(1):34-41.
- (107) Trinkoff AM, Storr CL, Lipscomb JA. Physically demanding work and inadequate sleep, pain medication use, and absenteeism in registered nurses. *J Occup Environ Med* 2001 April;43(4):355-63.
- (108) Boedeker WDrn. Associations Between Workload and Diseases Rarely Occurring in Sickness Absence Data. [Article]. *Journal of Occupational & Environmental Medicine* 2001 December;43(12):1081-8.
- (109) Stapelfeldt CM, Jensen C, Andersen NT, Fleten N, Nielsen CV. Validation of sick leave measures: self-reported sick leave and sickness benefit data from a Danish national register compared to multiple workplace-registered sick leave spells in a Danish municipality. *BMC Public Health* 2012 August 15;12(1):661.
- (110) Holmstrom E, Moritz U, Andersson M. Trunk muscle strength and back muscle endurance in construction workers with and without low back disorders. *Scand J Rehabil Med* 1992;24(1):3-10.
- (111) Progression Models in Resistance Training for Healthy Adults. [Miscellaneous Article]. *Medicine & Science in Sports & Exercise* 2009 March;41(3):687-708.
- (112) Atlantis E, Chow CM, Kirby A, Fiatarone Singh MA. Worksite intervention effects on physical health: a randomized controlled trial. *Health Promot Int* 2006 September;21(3):191-200.
- (113) Maul I, Laubli T, Oliveri M, Krueger H. Long-term effects of supervised physical training in secondary prevention of low back pain. *Eur Spine J* 2005 August;14(6):599-611.

- (114) Wang L, Mascher H, Psilander N, Blomstrand E, Sahlin K. Resistance exercise enhances the molecular signaling of mitochondrial biogenesis induced by endurance exercise in human skeletal muscle. *J Appl Physiol* 2011 November;111(5):1335-44.
- (115) Holmstrom E, Ahlborg B. Morning warming-up exercise--effects on musculoskeletal fitness in construction workers. *Appl Ergon* 2005 July;36(4):513-9.
- (116) Tuomi K, Ilmarinen J, Seitsamo J, Huuhtanen P, Martikainen R, Nygard CH et al. Summary of the Finnish research project (1981-1992) to promote the health and work ability of aging workers. *Scand J Work Environ Health* 1997;23 Suppl 1:66-71.
- (117) Hoving JL, Bartelds GM, Sluiter JK, Sadiraj K, Groot I, Lems WF et al. Perceived work ability, quality of life, and fatigue in patients with rheumatoid arthritis after a 6-month course of TNF inhibitors: prospective intervention study and partial economic evaluation. *Scand J Rheumatol* 2009;38(4):246-50.
- (118) Taskila T, Martikainen R, Hietanen P, Lindbohm ML. Comparative study of work ability between cancer survivors and their referents. *Eur J Cancer* 2007 March;43(5):914-20.
- (119) Aittasalo M, Miilunpalo S. Offering physical activity counselling in occupational health care -- does it reach the target group? *Occup Med (Lond)* 2006 January;56(1):55-8.
- (120) Sesso HD, Paffenbarger RS, Jr., Lee IM. Physical activity and coronary heart disease in men: The Harvard Alumni Health Study. *Circulation* 2000 August 29;102(9):975-80.
- (121) Graham I, Atar D, Borch-Johnsen K, Boysen G, Burell G, Cifkova R et al. European guidelines on cardiovascular disease prevention in clinical practice: full text. Fourth Joint Task Force of the European Society of Cardiology and other societies on cardiovascular disease prevention in clinical practice (constituted by representatives of nine societies and by invited experts). *Eur J Cardiovasc Prev Rehabil* 2007 September;14 Suppl 2:S1-113.
- (122) Straker L, Mathiassen SE. Increased physical work loads in modern work--a necessity for better health and performance? *Ergonomics* 2009 October;52(10):1215-25.
- (123) Teraslinna P, Ismail AH, MacLeod DF. Nomogram by Astrand and Ryhming as a predictor of maximum oxygen intake. *J Appl Physiol* 1966 March;21(2):513-5.
- (124) Glassford RG, Baycroft GH, Sedgwick AW, Macnab RB. Comparison of maximal oxygen uptake values determined by predicted and actual methods. *J Appl Physiol* 1965 May;20(3):509-13.
- (125) Spierer D, Hagins M, Rundle A, Pappas E. A comparison of energy expenditure estimates from the Actiheart and Actical physical activity monitors during low intensity activities, walking, and jogging. *European Journal of Applied Physiology* 2011 April 1;111(4):659-67.