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Effectiveness of exercise-based interventions aimed at reducing injuries and musculoskeletal disorders in workers in forestry and other strenuous jobs: an overview of the literature

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Contents

Abstract

Introduction

Workers in strenuous job fields, such as forestry, are often exposed to hazardous conditions, awkward postures and repetitive movements and are therefore particularly prone to suffer from injuries and musculoskeletal disorders. According to the Swiss National Accident Insurance Fund (suva) the risk of work-related injuries, as well as the costs resulting for the insurance fund, are three to four times higher in forestry workers compared to the average of all insured employees. The consequences of these incidents are therefore not only personal harm, but also economic costs, which have to be borne by the individual, the employers with regards to production losses and society as a whole.

The aim of this literature overview was to investigate the evidence of the effectiveness of interventions including an exercise element aimed at reducing the risk of injuries and/or musculoskeletal disorders in workers in strenuous jobs, such as forestry workers and other groups with comparable occupational risks.

Methods

Due to the small number of studies on exercise interventions in forestry workers, the study population was expanded to cover other strenuous occupations, such as construction work, firefighting, farming or the police force. The databases Pubmed, Scopus, PEDro, and Cochrane Library were searched for literature on the prevention and management of injuries and musculoskeletal disorders, such as low back pain. The interventions had to include an exercise element and had to be initiated at the workplace. Articles in English, German and French were considered. Additional articles were retrieved by hand (snowballing) and literature was screened provided by the Swiss Federal Office for the Environment (FOEN) and other relevant contacts. 14 unique intervention programmes, evaluated in 15 studies and published in 21 articles met the inclusion criteria. Of these articles, data was extracted on study characteristics, population, design, intervention content and intervention effects on health and work-related outcomes, such as work ability or sick leave. Work-related outcomes were not specifically searched for, but were yet extracted as many of the identified studies also reported such outcomes.

Results

The interventions described in the identified studies varied widely. In 86% of the identified studies, organized exercise was a key element of the intervention. Two projects offered individualized counselling sessions with the aim to increase daily physical activity behaviour. Ten of the 14 projects investigated musculoskeletal disorder outcomes, four focused on injury outcomes and ten on work-related outcomes such as work ability, sick leave, functional limitations and work disability. The results were mixed for all outcome categories. For musculoskeletal disorders, half of the studies demonstrated significant intervention effects for all or for some of the assessed outcomes; the other half showed non-significant effects, however, mostly in the expected direction. Half of the studies on injuries outcomes found a significant positive effect and one found statistically non-significant effects in the expected direction. Another single study found an adverse effect in the intervention group, suffering from more injuries than the control group. For work-related outcomes that had been

extracted additionally from the identified articles, 8 out of 11 studies showed statistically significant effects in the desired direction for all or for some of the work-related outcome variables.

Discussion and conclusions

While we found mixed results from heterogeneous studies regarding occupations included, intervention approaches described and health outcomes measured, overall most studies showed improvements of health and work-related outcomes from interventions with an exercise-element. The high risk and costs related to occupational injuries in forestry workers and in other strenuous jobs justify further investment into well-conducted studies in these populations, as well as the funding of implementation projects that are well evaluated, documented and published.

1 Introduction

1.1 Background

Occupational health risks in forestry work

Forestry work includes the planting, cultivation, care, and harvesting of timber. This is strenuous and demanding work. Operating machinery and tools, such as chain saws or winches, require concentration, expertise and skill. Forestry work is outdoor work in sometimes rugged terrain and extreme weather conditions.

It is not surprising that forestry workers are prone to suffer from injuries. Often uneven terrain or objects are the cause of injuries: Loggers get injured when they slip, stumble or fall, when they are hit by branches, trees or rocks, or when they get caught, for example, between logs (Zische 2016). In fact, logging is recognized throughout the world as hazardous work. Data from the US National Health Interview Survey showed that over-all injury risk was 2.4 times higher in workers in the forestry/agriculture/ fishing and the construction sector, compared to the workforce in the service sector. Among 18-25 year olds in forestry/agriculture/fishing, the risk was even 4.8 times increased (Kachan, Fleming et al. 2012), and an Italian study found that the recovery period after an injury increases with age (Laschi, Marchi et al. 2016). These findings are consistent with the statistics of the Swiss National Accident Insurance Fund (suva): i.e. the risk of occupational injuries as well as the costs resulting for the insurance fund are about three to four times higher in forestry workers compared to the average of all insured employees (Swiss National Accident Insurance Fund suva 2016).

Loggers are not only at risk for occupational injuries, but also for musculoskeletal disorders. They work with heavy loads, do repetitive movements and execute activities with high-force, often in awkward postures. These risks have been known for a long time. A Norwegian study from 1998 found that low back pain was common among manual workers in forestry and the risk was twice as high as in administrative workers in the same field; the risk of neck/shoulder disorders was two- and three-fold increased in manual workers and machine operators, respectively (Hagen, Magnus et al. 1998). A specific cause for musculoskeletal problems, particularly of the upper limbs of forestry workers, is likely to be a high load due to (whole body and arm-hand) vibrations from operating chain-saws (Bovenzi, Zadini et al. 1991). Today, such load is less pronounced, but still significant, because there is newer technology with better shock absorption (personal communication Erwin Schmid, director of Staatsforst Canton of Zurich).

Safety and health protection

The consequences of accidents, injuries and musculoskeletal disorders are – apart from the harm to the individual – the economic costs that accumulate in different systems: i.e. health care costs from illness and injuries, which have to be covered by the individual and the society as a whole, as well as; loss of production covered by employers directly or through insurances.

In view of the current occupational health risks in forestry, improving work safety and health protection are important. In Switzerland, as in all other countries, establishing standards regarding equipment such as clothing and shoes, machinery and tools, procedures, work processes and regulations has been a focus of prevention at the workplace (see www.suva.ch/de-ch/praevention/branchenthemen/forst).

Prevention and health promotion at the workplace

Some 25 to 30 years ago, health promotion at the workplace focused often on improving health and fitness of workers in strenuous jobs and thus productivity. Today, health promotion programmes in the workplace setting focus primarily on supporting lifestyle changes for the prevention of non-communicable diseases (NCDs), such as cardiovascular disease or diabetes. Also in Switzerland, health promotion in the workplace setting is an element of the national strategy for NCD prevention (Bundesamt für Gesundheit and Schweizerische Konferenz der kantonalen Gesundheitsdirektorinnen und -direktoren 2016). Exercise-based interventions are a standard element of such programmes. The target populations are frequently workers in sedentary jobs and the aims of interventions are to increase daily physical activity, reduce sitting time or relieve musculoskeletal pain form screen-based work.

However, these intervention aims do not meet the needs of forestry work or other strenuous jobs. These workers do not need to be motivated for more daily physical activity or less sitting, but they must be prepared to meet the physical demands of their jobs: i.e. heavy lifting, operating heavy machinery in sometimes awkward positions and, walking and working in rough or uneven terrain. Required intervention elements are comparable to those observed in exercise-based sports injury prevention programmes in recreational or elite athletes or in army personnel. Such interventions have been shown to be effective (Martin-Diener, Brügger et al. 2010). Parallels have in fact been drawn between athletes and industry workers with the concept of the "industrial athlete" (Sevier, Wilson et al. 2000). It seems that this industrial athlete paradigm has had a revival since players on the market, mainly in the US, use the paradigm to promote intervention programmes in worker populations (see for example http://www.theindustrialathlete.com/)

In Germany, exercise-based interventions aimed at preparing forestry workers for their strenuous work have been initiated and tested in recent years (Zische 2016; Hanisch, Karcher et al. 2017; Rudolph, Kruft et al. 2017). One of them is included in the result section of this report (Rudolph, Kruft et al. 2017). Also in Switzerland, projects to improve fitness and coordination in forestry workers have been initiated in the cantons of Vaud, Valais and Zurich (Baudirektion Kanton Zürich 2010), and the Swiss Federal Office of the Environment currently conducts a project with apprentices in three pilot regions.

1.2 Aim of this literature review

The developments described above are encouraging. However, there is no overview of such exercise-based interventions in domains other than forestry workers, of their characteristics and their effectiveness to reduce work-related health risks. For the further development and implementation of such approaches for prevention and health promotion in the workplace setting, a broader overview of interventions in the field would be helpful. Therefore, the aim of this project was to conduct a review on the evidence of the effectiveness of exercise-based interventions aimed at reducing the risk of injuries or musculoskeletal disorders in workers in strenuous jobs, such as forestry workers and other groups with comparable occupational risks. Given the heterogeneity of inclusion and outcome variables and the different populations under study, it was not meaningful to conduct a systematic literature review. Therefore the review was restricted to a narrative overview, including peer-reviewed studies identified through data-bases, but also ‘grey’ reports identified through contacts and networks.

2 Methods

2.1 Main literature search in data bases

Preparation of data base search

To get an overview of the available body of peer-reviewed literature, an exploratory search was conducted first. It became apparent that there would be only a small number of studies covering exercise interventions in forestry workers. Therefore, it was decided that the study population would have to be expanded to cover also workers in other strenuous occupations, such as construction workers, firefighters, farmers, policemen and industrial jobs. The search strategy was then discussed with a collaborator at the medical library of the University of Zurich who specifically offers this service.

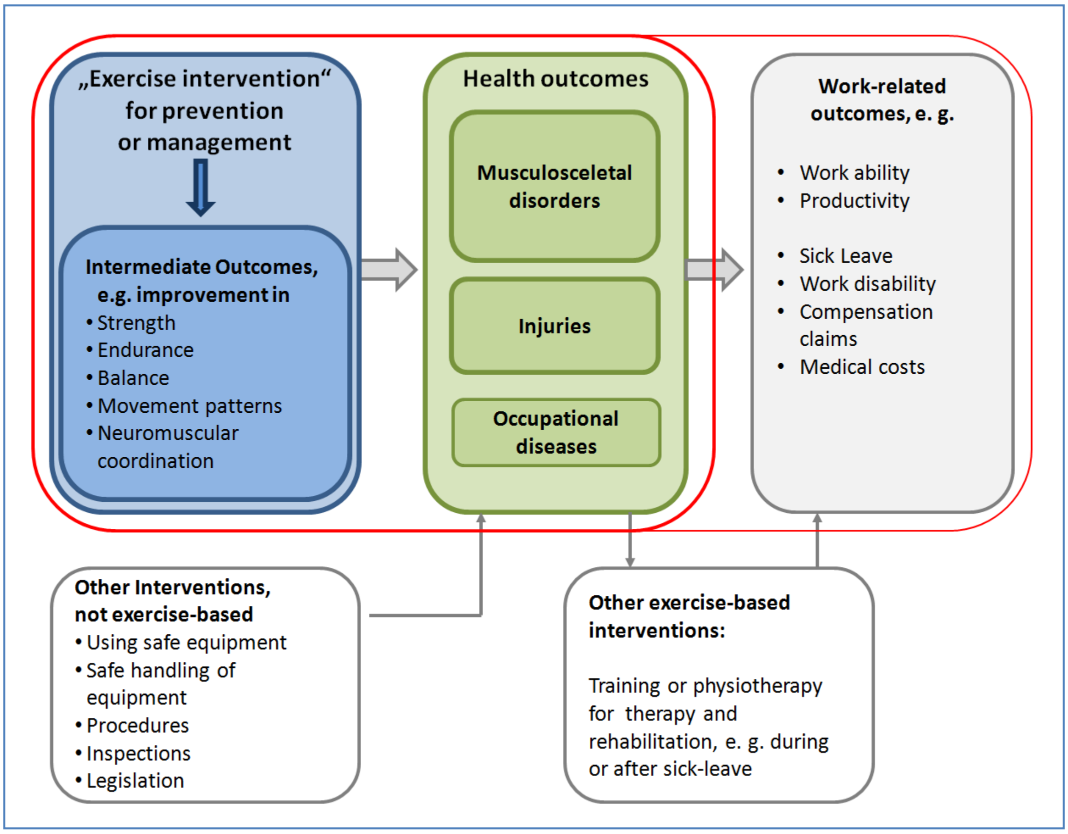

Figure 1. Intervention types and outcome categories in the context of the prevention of injuries and musculoskeletal disorders in strenuous jobs. The topics inside the red frame are included in this review.

In a meeting with a representative of the Federal Office of the Environment (Gerda Jimmy) the final search strategy was discussed. It was agreed that studies covering the topics described in table 1 should be retrieved (see also Figure 1). It was also decided to include the target population as described in Table 1. In addition, it was decided to complement the search with interventions in military personnel and in recreational athletes, but to not include the workforce in the health care sector, cleaners and musicians.

Table 1. Overall criteria for study inclusion, as agreed upon with FOEN

Aim of intervention	Prevention and management
Health outcomes	Injuries and musculoskeletal disorders such as low back pain
Intervention approach	Exercise-based interventions such as strength training, initiated at the workplace and implemented during or outside working hours
Target population	Workers in strenuous jobs: forestry workers, construction workers, firefighters, policemen, farmers
Language	English, German, French

Search of data bases

The following data bases were searched: PubMed, Scopus, PEDro and Cochrane Library. For PubMed, the following MeSH-term-based search was conducted:

> *(injuries OR accidents, occupational OR accident prevention OR accidental falls OR musculoskeletal disease OR occupational disease OR pain) AND (clinical study OR evaluation studies) AND (exercise OR exercise therapy OR sports OR stretching OR neuromuscular training OR resistance training OR physical activity) AND (workplace OR agriculture OR forestry OR construction industry OR athletes OR firefighters OR police OR farmers OR miners OR military personnel OR Logger* OR lumberjack* OR Carpent*).*

For the other libraries, combinations of the PubMed-terms were used. The search in Scopus was restricted to search in titles-abstracts-keywords because a search in all fields would have resulted in an output of more than 86'000 references. All references were retrieved on 01 November 2017.

Screening of references

The following screening steps were conducted, based on the overall criteria for the search described in Table 1.

Table 2. Screening of references retrieved from data bases

Number of references imported from data bases	2037
Titles screened (1st round), after removing duplicates	2020
Titles screened (2nd round)	358
Abstracts screened, or full-text (if needed)	74
Assessed for meeting specified inclusion criteria	36

Inclusion criteria for studies

In a next step, the overall criteria described in Table 1 were further differentiated and the following inclusion and exclusion criteria for original articles to be described in the main result section were defined. Two authors independently decided which of the remaining 36 articles should be included accordingly. Discordant decisions were discussed until consensus about inclusion was reached.

Table 3. Specified inclusion and exclusion criteria for studies to be included in literature overview

	Inclusion	Exclusion
Aim of intervention	Prevention or management	Therapy or rehabilitation (e.g. back to work programmes during or shortly after injury or sick leaves)
Outcomes	Musculoskeletal disorders or injuries	Only intermediate outcomes or NCD-related outcomes reported
Intervention approach	With at least one element of physical activity	Only ergonomics or only stretching Only intervention for other lifestyle behaviour or psychosocial intervention
Study design	Intervention studies with before-after-measurements or evaluation studies with retrospective quasi-experimental design	Observational studies (cross-sectional or longitudinal)
Occupations	Forestry workers, construction workers, firefighters, farmers, police, industrial jobs if they are strenuous	Industrial jobs that are not strenuous, such as technicians

2.2 Hand searches and searches via contacts and networks

To identify further articles to be included in this review, the following steps were undertaken:

- The reference lists of the final 36 articles from the data base search (Table 2) were hand-searched (i.e. snowballing)
- Already when this project was defined, the FOEN had provided the authors with articles on three interventions in forestry workers; one study is included in the result section
- Through personal contacts with the experts involved in this project, one additional study was identified
- The leader of the working group on worksite interventions of HEPA Europe, the European network for the promotion of health enhancing physical activity, was contacted. She was not aware of any other project that could be of interest for this literature overview.

After this final search steps, a total of 14 unique intervention projects or programmes, evaluated in 15 studies, and 21 published peer-reviewed articles (4 articles with information on the methodology and 17 articles providing outcome results) were maintained for the key section of this literature overview.

2.3 Data extraction

For each of the included 21 articles, data was extracted on basic study characteristics (year of publication, country), study population (job description, pre-existing musculoskeletal problems, mean age, % males, numbers of included participants in intervention and control groups), study design (study type, duration of follow-up), data analysis (loss to follow-up, intention-to-treat analysis, if applicable), intervention content in the intervention group (duration of intervention, intervention elements, duration and frequency of exercise sessions, elements of exercise sessions, intervention setting), type of intervention in the control group, results for health outcomes (intervention effects regarding the prevention of musculoskeletal disorders, intervention effects regarding the prevention of other injuries), intervention effects on work related outcomes.

2.4 Search and selection of references for complementary sub-chapters

For the complementary sub-chapters of the result section covering exercise interventions to prevent injuries or musculoskeletal disorders in army personnel and recreational athletes, references were selected opportunistically e. g. from the libraries of the authors of this report or from by-products of the main search described above. Reviews were drawn from the Cochrane library, from by-products of the main search or identified through reference lists of other papers.

3 Results

3.1 Overview of findings from review articles

Overall, only few published articles on the topic of this review were found. Particularly scarce were published intervention studies in forestry workers. We also searched review articles on evidence for exercised-based interventions for the prevention of injuries or musculoskeletal disorders in other strenuous jobs. However, no review covered one of the topics of interest in this literature overview as its main research focus.

3.2 Original articles included in the review

The results of the data extraction of the 21 articles (14 projects, 15 studies) that met the inclusion criteria are available in the annex. One programme (PHLAME) has been evaluated in two separate studies (Kuehl, Elliot et al. 2005; Kuehl, Elliot et al. 2013). In addition, a feasibility study on the same intervention has been published in a separate article (Elliot, Goldberg et al. 2004). However, in Tables 4 to 6 and in the table in the annex, the feasibility study has not been included.

3.2.1 Basic study characteristics

Only three projects could be identified that have studied the effects of exercise-based interventions in forestry workers. Two of them were conducted in professional forestry workers (Leino, Kivekäs et al. 1994; Rudolph, Kruft et al. 2017), and one investigated effects in tree planters, who are often not professionals, but seasonal workers or students (Roberts 2009). Six studies investigated effects of exercise interventions in construction workers (Ludewig and Borstad 2003; Holmström and Ahlborg 2005; Borstad, Buetow et al. 2009; Holtermann, Jorgensen et al. 2010; Gram, Holtermann et al. 2012; Viester, Verhagen et al. 2012; Viester, Verhagen et al. 2015; Malarvizhi, Divya et al. 2017; Viester, Verhagen et al. 2017), two projects (three studies) in firefighters (Kuehl, Elliot et al. 2005; Kuehl, Elliot et al. 2013; Poston, Haddock et al. 2013), one in farmers (Perkiö-Mäkelä 1999; Perkiö-Mäkelä 2000), one in police recruits (Orr, Ford et al. 2015), and one in slaughterhouse workers (Sundstrup, Jakobsen et al. 2013; Sundstrup, Jakobsen et al. 2014; Sundstrup, Jakobsen et al. 2014). The study characteristics are summarised in Table 4; further details can be found in the annex. Many of the studies included less than 100 participants and some of them seemed to have pilot character. Table 4 shows that only five of the fifteen studies had conducted a randomised controlled trial (RCT) and two studies a cluster-RCT.

Table 4. Summary description of study characteristics

	Study characteristics		**N**
14 projects	Occupation	Forestry workers	3
		Construction workers	6
		Firefighters	2
		Other jobs	3
	World region	Northern Europe	7
		North America	5
		Australasia	2
	Main focus	Musculoskeletal disorders	10
		Injuries	4
	Study population	General workforce	7
		Asymptomatic workers	2
		Workers with pre-existing musculoskeletal problems	5
15 studies	Number of participants	< 100	6
		100 to 500	6
		500-1000	1
		> 1000	2
	Study design	Randomised controlled trial (RCT)	5
		Cluster-randomised controlled trial (cRCT)	2
		Controlled trial with matched controls (CT)	1
		Quasi-experimental design	4
		Retrospective quasi-experimental design	3

3.2.2 Intervention characteristics

Intervention content varied within and across occupational groups. Most of the projects (86%) had exercise sessions as the key element of the interventions. Only two projects (Elliot, Goldberg et al. 2004; Viester, Verhagen et al. 2012) did not organise training sessions, but offered individualised counselling with the aim of increasing daily physical activity behaviour. Nine of the twelve projects implementing an exercise programme did not include any other intervention component, while the remaining three studies (Leino, Kivekäs et al. 1994; Perkiö-Mäkelä 1999; Perkiö-Mäkelä 2000; Poston, Haddock et al. 2013) chose a multi-component intervention targeting also other behaviours, e.g. healthy eating or the application of ergonomics. Characteristics of the included studies are summarised in Table 5.

Table 5. Summary description of intervention characteristics (14 projects)

Intervention characteristics		N
Type of physical activity intervention	Implemented programme	12
	Single-component (physical activity only)	*9*
	Multi-component (targeting other lifestyle factors)	*3*
	Counselling	2
Setting	At the workplace	5
	In specific facility	4
	At home	5
	Not specified	1
Integration into working hours	Yes	7
	No	4
	Not specified	3
Duration of the intervention	< 3 months	7
	3 – 6 months	4
	2 years and longer	2
	Not specified	1
Exercise frequency	< 3 trainings per week	2
	3 trainings per week	5
	> 3 trainings per week	2
	Not specified or not applicable	5
Type of exercise training	Strength	11
	Neuromuscular	1
	Stretching	5
	Mobilization	2
	Aerobic	6
Supervisor of exercise sessions	Professional instructor	6
	Peer supervisor	2
	No supervisor	4
	Not specified	2

Forestry workers

Among the projects in forestry workers, the most historic programme from Finland (Leino, Kivekäs et al. 1994) organized courses over seven full days, where exercise training was the main activity with the aim of decreasing the occurrence of low back symptoms in symptomatic lumberjacks. In addition to the work-outs, participants attended educational lessons (e.g. functional anatomy, nutrition) and they were instructed and encouraged to continue with a home-based exercise programme over the following year. The Canadian study "fit to plant" in tree planters (Roberts 2009) was a pilot intervention aimed at decreasing injury incidence in seasonally hired planters by training them intensively for six weeks (i.e. aerobic and resistance training and specific strength training of the wrist) before their actual work started; it is not clear whether this training was already part of their job. In the German study "fit im Forst" (Rudolph, Kruft et al. 2017), forestry workers attended weekly 90 min-training sessions over three years, consisting of strengthening exercises for the back and shoulders, neuromuscular training, and thoracic vertebra mobilization. It is not clear to what extent the training took place during working hours.

Construction workers

Considering the interventions in construction workers, three of the six projects (Ludewig and Borstad 2003; Borstad, Buetow et al. 2009; Malarvizhi, Divya et al. 2017) focused on strength exercises of the shoulder muscles, since shoulder pain is common among these workers. Borstad implemented a two-year exercise programme in construction apprentices at the start of their repetitive overhead work (Borstad, Buetow et al. 2009). The apprentices performed their exercise on their own at home, and exercise description was repeated once after one year. The compliance rate was 50%. The ten-week intervention by Ludewig (Ludewig and Borstad 2003) and the six-week intervention by Malrvizhi (Malarvizhi, Divya et al. 2017) were home-based as well. Exercise frequency was prescribed with three days per week in two studies (Ludewig and Borstad 2003; Borstad, Buetow et al. 2009), while such information was not available in the third project ((Malarvizhi, Divya et al. 2017). The FINALE programme (Holtermann, Jorgensen et al. 2010; Gram, Holtermann et al. 2012) set up a more flexible protocol consisting of twelve-week aerobic and strength training, tailored to the individual based on his health profile. Exercise was prescribed as three weekly sessions of 20 minutes each, during working hours, at the workplace or at a nearby facility. Holmström investigated the effects of daily 10 minutes of morning-warming up exercise, for three months at the building site, consisting of aerobic exercises and mobilization training (Holmström and Ahlborg 2005). This warming-up was led by a trained peer. The VIP (Vitality in practice)-project (Viester, Verhagen et al. 2012; Viester, Verhagen et al. 2015; Viester, Verhagen et al. 2017) focused on a personalized multi-component intervention, consisting of an individual motivation and action plan. The six-month intervention consisted of contacts with a personal health coach, who advised home-based strengthening and stabilization exercises for abdominal and dorsal muscles.

Firefighters

Poston's study (Poston, Haddock et al. 2013) and the PHLAME wellness programme (Kuehl, Elliot et al. 2005; Kuehl, Elliot et al. 2013) were two projects investigating comprehensive health promotion programmes in U.S. fire departments. The PHLAME multi-component intervention aimed at reducing injuries, sick leave, and medical costs and offered personal goal setting for the increase of daily physical activity and healthy eating behaviour. Poston's intervention fire departments had to actively facilitate physical activity behaviour at the workplace in order to be considered as intervention site; then effects on workers compensation claims and the risk of future serious illness were evaluated.

Farmers, police, slaughterhouse workers

Another multi-component programme (Perkiö-Mäkelä 1999; Perkiö-Mäkelä 2000) was implemented in female farmers with present musculoskeletal symptoms in Finland. The duration of the intervention was 2.5 months and follow-up assessments were conducted after one, three, and six years. Meetings were organized consisting of physical exercises, training in ergonomic work techniques, and lectures on healthy lifestyle; the frequency and duration of the physical exercises was not reported clearly or might have varied. Farmers were also encouraged to increase their leisure time physical activity. The remaining two projects (Sundstrup, Jakobsen et al. 2013; Sundstrup, Jakobsen et al. 2014; Sundstrup, Jakobsen et al. 2014; Orr, Ford et al. 2015) implemented an intervention programme in police recruits and slaughterhouse workers, respectively. Orr et al. replaced the usual training session of the police recruits by an ability-based training, so the total volume of physical activity was not increased in the intervention group, but adapted to personal capabilities. Sundstrup and team focused on the strengthening of shoulder and upper extremity muscles in employees suffering from chronic pain, through group-based training sessions on site, supervised by a training instructor.

3.2.3 Intervention effects

Outcomes and outcome measures varied largely across projects. As planned at the beginning of the study, we included musculoskeletal disorders and injury outcomes. Since many of the identified studies also reported on work-related outcomes including work ability, productivity, functional limitations, sick leave, compensation claims, or costs, we included these as well, even though we had not specifically searched the literature for these particular outcomes. A summary description of intervention effects is shown in Table 6.

Table 6. Summary description of intervention effects

Intervention effects		Number of projects
Effects on musculoskeletal disorders *(10 projects)*	Significant effects in expected direction for all reported outcomes	3
	Significant effects in expected direction for some reported outcomes	2
	None of the effects statistically significant	5
	Significant effects in opposite direction	---
Effects on injuries *(4 projects)*	Significant effects in expected direction for all reported outcomes	2
	Significant effects in expected direction for some reported outcomes	---
	None of the effects statistically significant	1
	Significant effects in inverse direction	1
Effects on work-related outcomes* *(11 projects)*	Significant effects in expected direction for all reported outcomes	5
	Significant effects in expected direction for some reported outcomes	3
	None of the effects statistically significant	3
	Significant effects in inverse direction	---

* work ability, productivity, functional limitations, work disability, sick leave, compensation claims, costs

Musculoskeletal disorders

Ten of the 14 projects investigated the intervention effects on musculoskeletal outcomes. Of these, six reported outcomes of back pain, eight focused on shoulder pain and six included other disorders in addition to back or shoulder problems.

The study in slaughterhouse workers revealed significant improvements in pain intensity for all reported body parts (shoulder, elbow/forearm, and hand/wrist), measured with a 0-10 visual analogue scale (Sundstrup, Jakobsen et al. 2013; Sundstrup, Jakobsen et al. 2014; Sundstrup, Jakobsen et al. 2014). Significant positive results on shoulder pain were also found in two other studies targeting construction workers (Ludewig and Borstad 2003), (Malarvizhi, Divya et al. 2017) which had measured shoulder pain and disability with self-report questionnaires. Some significant effects of an exercise intervention in reducing self-reported physical complaints and functional limitations in forestry workers were found by Rudolph (Rudolph, Kruft et al. 2017). Also, Perkiö-Mäkelä's study (Perkiö-Mäkelä 2000) revealed some positive significant results in the reduction of musculoskeletal disorders, namely pain, ache, and discomfort. The other five studies reporting musculoskeletal symptoms did not detect any significant changes from baseline to follow-up in the intervention compared to the control group (see annex). However, there was no reported worsening of musculoskeletal symptoms due to the interventions in any of the considered studies.

Injuries

Four projects focused on injury outcomes. In the PHLAME study in firefighters (Kuehl, Elliot et al. 2005), injury rates had significantly decreased in the intervention group. Also in the study in tree planters (Roberts 2009) the exercise intervention decreased injury risk, assessed as an injury composite, compared to the control group. Furthermore, this project was scaled up for larger implementation and according to an injury monitoring, recordable incidents per person-year seemed to decrease overall. Noticeable intervention effects for injury occurrence in the expected direction were observed in the study in police recruits, though not statistically significant (Orr, Ford et al. 2015). In the fourth study, adverse effects were observed: the intervention group of firefighters had an increased risk of injuries severe enough to be reported for workers compensation (Poston, Haddock et al. 2013).

Work-related outcomes

Most projects reported not only on health outcomes, but also on work-related outcomes; only three did not (Borstad, Buetow et al. 2009; Poston, Haddock et al. 2013; Malarvizhi, Divya et al. 2017).
Five studies reported on intervention effects on work ability, five on sick leave (overall or due to musculoskeletal disorders) and five on functional limitations or work disability. For all outcomes, findings were mixed with five studies showing significant improvements, some studies showing some significant and some showing non-significant effects mostly in the expected direction. None of the studies showed effects in the opposite direction. Two studies reported on intervention effects on productivity: the project in tree planters with significant (Roberts 2009) and a project with construction workers with non-significant effects (Gram, Holtermann et al. 2012). And finally, one study in firefighters demonstrated that up to four years after a prevention programme had been implemented, the intervention sites had a lower overall rate of compensation claims and lower mean medical costs than the control sites (Kuehl, Elliot et al. 2013).

3.3 Prevention of acute and overuse injuries through exercise interventions in army personnel

Physical activity demands are high during army training: recruits undergo several months of aerobic and muscular training such as marching, running or general conditioning exercise. A specific characteristic of such an army training is that young, healthy men and women of the general population with different baseline levels of physical activity or fitness have to perform at comparable levels. Thus, the need for individual increases in activity during army training in order to reach the minimum required level of fitness can differ substantially. Also, injury risk is high among military personnel, and particularly frequent are overuse injuries of the lower extremities, particulary of the ankle and knee (Almeida, Williams et al. 1999).

Several epidemiologic studies have demonstrated that injury risk during army training is lower among army personnel with higher fitness levels at the onset of training than in less fit individuals (Jones, Bovee et al. 1993; Jones, Cowan et al. 1993; Knapik, Sharp et al. 2001). Therefore, many countries have developed physical conditionning programmes for the prevention of injuries during army training or the attrition from duty. The following examples of army-related intervention studies give an overview of the field.

Singapore

An early intervention study including more than 9000 recruits was conducted in Singapore, which has a mainly conscript army (Lee, Kumar et al. 1997). A three months formal pre-course conditioning programme with more gradual increases of loads for recruits with low levels of fitness was conducted. The evaluation demonstrated that medical attrition rates mainly due to musculoskeletal injuries and sustained during training were substantially lower in the intervention group (RR = 0.26; CI = 0.21 to 0.33) than in a mixed comparison group with unfit and fit recruits who had not received the training.

USA

Knapik et al. conducted a series of studies in the US with a professional army. A first intervention study in some 2000 recruits evaluated the effect of a new physcial conditioning programme specifically designed to complement basic combat training (Knapik, Darakjy et al. 2005). The control group performed the standard daily one hour morning drill and training, including strength exercises and running. In the intervention group, progression was more gradual, there was more emphasis of precision and variety and a reduction in running mileage. After 9 weeks of training, injury risk was higher in the group with the tradional training programme than in the group with the specific programme (men: RR = 1.6, 95% CI = 1.2 to 2.0; women: RR = 1.5, 95% CI = 1.2 to 1.8). In another intervention study (Knapik, Darakjy et al. 2006), recruits were subjected to fitness tests at the beginning of basic combat training. One group of recruits not fit enough to pass the test had to train in a fitness programme until they passed and then they progressed to basic combat training. The training lasted up to three to four weeks and consisted of marching, running, and strength training and stretching. Another group of unfit recruits started with basic training right away. After nine weeks of basic training, injury rates in the unfit group without a training programme were highest in comparison to the initially fit control recruits (1.7 and 1.5 times higher in men and women, respectively). Injury risk in the unfit group with the conditioning programme was still elevated, but less pronounced (1.5 and 1.2 times higher in men and women, respectively).

Denmark

In Denmark (conscript army of volunteers), an exercise programme to reduce the incidence of overuse knee injuries and medial tibial stress syndrome was implemented (three times per week for 15 minutes) during the three-months basic training in an RTC including some 1000 soldiers (Brushoj, Larsen et al. 2008). No difference for injury occurrence was found between the intervention and control group, but the intervention group demonstrated greater improvement in running distances.

Finland

Finland has a conscript army with compulsory service. In a study, almost 1000 conscripts were randomised to an injury prevention intervention offering neuromuscular training to increase motor skills and body control, plus educational elements on injury prevention (Parkkari, Taanila et al. 2011). The 30- to 45-minute training sessions aimed at increasing trunk, knee and ankle stability, at improving control of the lumbar neutral zone, and at avoiding full lumbar flexion in all daily tasks of the conscripts. They were integrated into the first 8 weeks of basic training for three times per week. During the remaining 18 weeks of service, recruits had to continue with the training at least once per week by choosing a training session during their leisure time. After six months of training, the risk for acute ankle injury was significantly lower in the intervention group compared to the control group (HR = 0.34, 95% CI = 0.15 to 0.78). This risk decline was observed in conscripts with low as well as moderate to high baseline fitness levels. In the latter group of conscripts, the risk of upper-extremity injuries also decreased significantly (HR = 0.37, 95% CI = 0.14 to 0.99). In addition, the intervention group tended to have less time loss due to injuries (HR = 0.55, 95% CI = 0.29 to 1.04). Using the same intervention setting, a focus was also put on the prevention of low back pain (Suni, Taanila et al. 2013). After six months, the incidence of off-duty days due to low back pain was significantly lower in the intervention group compared with controls (HR = 0.42, 95%, Cl = 0.18 to0.94).

Australia

The findings from the Finnish study with neuromuscular training (Parkkari, Taanila et al. 2011) were not confirmed by a study in the Australian army (Goodall, Pope et al. 2013). In a cluster-RCT in almost 800 recruits, the intervention group performed specified balance and agility exercises, in addition to normal physical training, with the aim to prevent lower limb injury rates. However, injury rates in the intervention group tended to be higher than in the control condition (RR = 1.25, 95% CI = 0.97 to1.53). The authors conclude that such a programme might even be harmful when added to normal physical training and that caution needs to be used when adding further elements to an existing standard training.

Switzerland

Finally, comparable approaches to injury risk reduction have also been tested in Switzerland (conscript army with compulsory service). In a first project in 259 volunteer recruits, an outdoor circuit training (once per week for 60 minutes) was offered to the intervention group, in addition to the standard exercise or sports training of two sessions per week (Hofstetter, Mader et al. 2012). After seven weeks, the fitness scores had improved in both, the intervention and the control group (which received only the standard training), and the total fitness score was higher in the intervention than in the control group. However, there were no differences regarding injury occurrence between the two groups. In a second study, the effects of a progressive increase in marching distances over four weeks and a specific ten-week training programme on injury incidence and attrition were assessed in 650 recruits (Roos, Boesch et al. 2015). Two companies were subjected to one of the two conditions each, a third to both, and a fourth to none of the conditions. The specific training programme, supervised by trained professionals, included high-intensity interval endurance runs, functional strength circuit training, balance training and different team sports. The weekly volume of training was not reported clearly, however, the combination of the two interventions resulted in the greatest reduction of injury risk (-33%) during the 21 weeks of military service. Furthermore, the specific training reduced the military service attrition rates by 53%.

Overall, injury risk is high during army service, and there is consistent evidence that injuries are more frequent among army trainees with low fitness levels. A number of studies have shown that injury incidence can be reduced by specific targeted conditioning programmes, either before or during the basic combat training.

3.4 Intervention studies aimed at reducing injury risk in athletes

Although the active participation in sports activities leads to substantially more health benefits than it causes harm, increased participation might elevate risks for sports-related injuries. Exercise-based interventions are a well established approach to injury prevention in sports. This chapter highlights some good examples of programmes and implementation approaches.

The Norwegian **website** http://fittoplay.org/ for example gives an overview of frequent sports injuries. It offers instructions for targeted training exercises to prevent injuries at specific injury locations.

Injuries of the knee such as strains or ruptures of the anterior cruciate ligament (ACL) are frequent and serious. The German Knee Society has recently published its evidence-based 2017-**guidelines** for ACL and other knee injuries (Mehl, Diermeier et al. 2018). The board recommends specific balance, neuromuscular and strengthening exercises to compensate deficits and to stabilize the knee, along with running and flexibility training. The recommended key exercises are also elements of established training and warm-up programmes in team sports, particularly in football.

The well known **"11+" programme** is one example. A systematic review and meta-analysis of nine studies on the effectiveness of the specifically developed F-MARC (FIFA Medical and Research Centre) injury prevention programs in football teams found, that particularly their "11+" program was effective and could reduce injury rates by 20% to 50% in the long term. The "11+" consists of 15 exercises which serve as a standard warm-up before each training session and takes about 20 minutes. It includes strengthening exercises for the core and leg muscles, as well as coordination, balance and agility exercises, which aim at improving neuromuscular control. Another study found supporting evidence on the preventive effect of the "11+" programme in elite male basketball players during a 9-month intervention season (Longo, Loppini et al. 2012). Silvers-Granelli et al. (2015) reported that in collegiate male soccer players the highest number of injuries were ankle injuries. They investigated on the effectiveness of the "11+" in 61 teams and found that the programme reduced overall injuries in the intervention teams by 46.1% compared to the control teams. Also, total days of sports participation missed because of injury were 40% higher in the control than in the intervention group (Silvers-Granelli, Mandelbaum et al. 2015).

In the Netherlands, finally, a **home-based proprioceptive training programme** for the prevention of recurrent **ankle sprains** in athletes was extensively evaluated regarding its **effects on injury outcomes, on cost-effectiveness and regarding delivery methods.** In the eight-week 2BFit intervention, implemented after usual care rehabilitation, the intervention group showed a 35% lower risk of ankle sprain recurrences, and had also lost less training time than the control group (Hupperets, Verhagen et al. 2009). Proprioceptive training after usual care of ankle injury was also more cost-effective for the prevention of recurrent ankle sprains in the year following the intervention, compared to usual care alone. The authors estimated that about 35.9 million Euros in medical and lost productivity costs could be saved annually in the Netherlands by advocating this training programme, discounting for the intervention cost (Hupperets, Verhagen et al. 2010). The impact of such prevention programmes relies largely on patient adherence and on a well thought-through implementation. The Dutch compared the cost-effectiveness of the intervention programme described above using either an App or a printed booklet for delivery, respectively. The “Strengthen your ankle”-App and the booklet showed comparable cost-effectiveness ratios and recurrent injury occurrences at 12-month follow-up (Van Reijen, Vriend et al. 2018). There were also no differences between the two delivery methods regarding recurrent injury incidence rates in the long term, as well as regarding residual functional disability and pain (Van Reijen, Vriend et al. 2017), and both methods also lead to similar compliance rates of 73% to 77% in the short-term (eight weeks), respectively (Van Reijen, Vriend et al. 2016). Using the App for programme implementation at the population level is an obvious strategy, but remains a challenge: With extensive advertising the App reached 2.6% of the target population. Although user ratings for the App were high, compliance with the programme remained low. Therefore, more targeted efforts in eHealth are needed to reach wide and diverse populations for injury prevention (Vriend, Coehoorn et al. 2015).

4 Discussion

This literature overview covers the evidence on the effectiveness of exercise-based interventions in forestry workers and other strenuous occupations on musculoskeletal disorders and occupational injuries. Literature data bases were searched and a small number of additional studies were identified through expert contacts. We identified 14 projects evaluated in 15 studies and found mixed results for both outcome groups.

Intervention effects

Forestry work is strenuous with high injury risk and a prevalence of musculoskeletal problems. Other strenuous occupations face similar challenges regarding occupational health. Exercise-based interventions are an approach to tackle these health problems and have shown to be effective particularly in army personnel. Therefore the purpose of this work was to get an overview of the effectiveness of such interventions in civil occupations. The findings were mixed for all outcome categories. For musculoskeletal problems, half of the studies demonstrated significant positive intervention effects for all or some of the assessed outcomes; the other half showed non-significant effects, mostly in the expected direction. Half of the studies on occupational injuries found a significant positive effect, one found statistically non-significant effects in the expected direction. A single study showed an adverse effect in the intervention group suffering from more injuries than the control group. The authors speculated that the more active firefighters could have been injured while training and not whilst being on regular duty. For work-related outcomes 8 out of 11 studies that had been extracted additionally from the identified articles demonstrated statistically significant positive effects for all or some of the assessed outcome variables.

There might be several reasons for these mixed findings. The studies were heterogeneous including various occupations such as forestry workers, tree planters, construction workers, firefighters, female farmers, police recruits and slaughterhouse workers. There were different intervention approaches, and also the health outcomes studied varied, using different measures mainly for low back pain, shoulder pain or occupational injuries.

There was also a lot of heterogeneity regarding methods and quality of the studies with some well conducted research studies, small studies with pilot character and evaluations of programme implementation. Many studies had sample sizes that were probably too small to have sufficient statistical power to detect interventions effects. Given the worksite setting, it is not surprising that about half of the studies chose a prospective or retrospective quasi-experimental design. Therefore, potential selection bias cannot be excluded, which might have affected both studies demonstrating effects or no effects.

Most interventions focused on organized exercise sessions and there was also a large variety in this respect. Different training elements were used - mostly resistance training for specific muscle groups, but also neuromuscular training, stretching or mobilization exercises or even aerobic training. Some of the training programmes might not have been specific enough for the targeted health problem. In addition, the volume (i.e. the product of exercise duration, frequency and intensity) of the programme might not have been high enough to bring about a meaningful physiological effect.

We also compared subtypes of studies regarding their effectiveness, e.g. interventions with higher versus interventions with lower exercise volume; or interventions implemented at the workplace or at home; or randomised controlled studies versus quasi-experimental studies. No trends became apparent, which is not surprising, given the overall heterogeneity of the studies.

Regarding the findings for work-related outcomes such as work ability, functional limitations, sick leave, productivity or costs, it has to be mentioned again that the selection of the studies was opportunistic. As we did not specifically search for such studies, there might be more articles in the literature that were not identified. The results presented in this overview were extracted from the studies that had been selected because they reported on the health outcomes of primary interest. Nevertheless, it seemed that the interventions in the selected studies demonstrated comparable positive effects on work-related outcomes.

What can be learned from studies in army personnel and athletes?

Studies developing and investigating exercises-based interventions in strenuous jobs often use findings from army-based studies when argueing for their cause. However, it is unclear to what extent the findings from the army setting can be transferred to the civil worksite setting. Certainly, these studies deliver a “proof of concept” - they demonstrate that in principle, these approaches work under more or less controlled conditions: there is consistent evidence that less fit recruits suffer from injuries more frequently during standard army training than their fitter counterparts and that injury risk during basic combat training can be reduced if all or specifically the unfit recruits are subjected to targeted conditioning programmes, either before or during the regular service. The risk of injuries (mainly overuse, but also traumas) or musculoskeletal disorders, such as low back pain during strenuous work such as basic army training, can in fact be reduced with targeted exercise interventions. These specific interventions also demonstrate that in unfit individuals who start with their new strenuous job, the training load or drill has to be built up gradually, that variety is needed, and that initially even a reduction of the overall load is required. These are all fundamental principles of training science in sports.

However, there are aspects that are specific to the army setting that might hamper transferability of these approaches to civil settings or populations. Most army studies are conducted in recruits, young people around 20 years of age, and not in populations that cover the same age range as the civil work force. This population is selected in different ways than the populations in civil occupations; particularly in conscript armies with mandatory service the young men have no choice but to do this task for a limited number of weeks. The army setting is highly hierarchical, which is fundamentally different from a civil workplace. And finally, time and finance budgets are also different from the civil setting as training interventions by definition always take place during “work hours” and a substantial proportion of the work day can be dedicated to training.

There is consistent evidence that targeted training interventions are effective for the prevention of injuries in athletes. These intervention programmes consist mainly of neuromuscular training and specific resistance training, and can also include balance, coordination, flexibility or aerobic training elements. Usually, these injury prevention interventions are part of the organised group training sessions, but there are also models with home-based training. There is also evidence that such programmes are cost-effective, and there is already some experiences with approaches for broader implementation of feasible programmes, using credible Websites and Apps.

As for the training programmes in army personnel the question arises, to what extent intervention concepts in athletes can be transferred to the occupational setting. Athletes are younger than the general workforce. Specifically, they are used to exercise and to follow a training regimen; they are usually ambitious, and they set and follow their individual goals. Nevertheless, after some adaptations to the occupational setting, concepts corresponding to programmes such as “11+” could be feasible also for implementation at the workplace.

Strengths and limitations of this literature overview

This literature overview covered a broad variety of topics addressing different occupations, different interventions and outcomes. It is to our knowledge, the first literature overview on this important public health topic. While the literature search, the development of inclusion criteria for studies, data extraction and presentation of the results were planned and conducted as systematically as possible, it is not a formal systematic review.

In view of the many research questions that had to be included, the search strategy could not be inclusive, and given time and financial constraints it was not possible to follow the PRISMA guidelines for systematic reviews and meta-analyses (http://www.prisma-statement.org/). Thus, the interpretation of findings may have been less rigorous than stipulated by PRISMA. With the search strategy we had to apply, we cannot exclude that we may have missed relevant studies. However, the hand searches of reference lists, the screening of systematic reviews and contacts with experts resulted in a small, but valuable number of additional publications. In addition, upon screening the introduction sections of identified studies it became apparent that other authors had also identified a very small number of relevant studies, if any, in their respective research fields. Poston et al. for example (Poston, Haddock et al. 2013) found that for projects in firefighters the pilot study (Elliot, Goldberg et al. 2004) to the PHLAME project (Kuehl, Elliot et al. 2005; Kuehl, Elliot et al. 2013) had been the only (cluster)-randomized study in the field. Also the authors of a Swiss exercise training study investigating the effects of neuromuscular training in construction workers (not included in our literature overview because only intermediate but no health outcomes were reported) were not able to identify any other study in their field (Faude, Donath et al. 2015).

This literature overview is limited to intervention effects on musculoskeletal disorders and injuries; in addition, opportunistically, we also extracted work-related outcomes from these studies. This focus does not cover all the aims, intervention approaches and findings of some of the studies that were included. For example, some of the projects aimed at improving other outcomes such as risk factors for non-communicable diseases (Viester, Verhagen et al. 2012; Viester, Verhagen et al. 2017), wellbeing (Kuehl, Elliot et al. 2005; Kuehl, Elliot et al. 2013) and job satisfaction (Poston, Haddock et al. 2013). Thus, there might be additional (perhaps even intangible) benefits from the interventions included that have not been captured and acknowledged in this overview.

5 Conclusions

There are only very few studies documenting the effectiveness of exercised-based interventions for the prevention of musculoskeletal disorders and injuries in forestry workers.

In summary, there is limited evidence from a small number of very heterogenous studies, that exercise-based interventions can reduce the risk of work-related musculoskeletal disorders such as low back or shoulder pain, or occupational injuries.

Furthermore, there are mixed findings from these studies suggesting that such interventions can also have effects on work-related outcomes such as improved work ability and reduced sick leave. The number of studies reporting on productivity (2) and monetary (1) outcomes was very small; therefore, drawing conclusions would be premature.

It is plausible to use exercise-based approaches to tackle these health problems, because in other population groups such as army personnel or athletes there is consistent evidence that these interventions are effective. The interventions are generally very specific for the targeted health problem and the setting, and the training sessions have a certain volume (i.e. intensity*duration*frequency) of exercise. It is not yet clear to what extent implementation concepts particularly from the army setting can be transferred to civil workplaces.

Future directions

It is not new that workers in strenuous jobs often suffer from back pain or other musculoskeletal disorders or are at high risk of occupational injuries. The oldest identified study using an exercise-based intervention in forestry workers was conducted in Finland some 25 years ago. Still, there is a paucity of evaluated and documented projects that are published and available to a wider audience.

The current focus of interest in worksite health promotion interventions that include physical activity elements is clearly on sedentary jobs, attempting to increase daily physical activity levels of the workforce or to alleviate specific disorders from mostly screen-based office work. This tendency has even increased since the "sitting"-problem has appeared on the radar of public health. However, the workforce in strenuous jobs should not be neglected. As this overview demonstrates there are only few studies that address the specific health problems in these groups.

Therefore, more well-conducted studies in these populations are required. Furthermore, there is a need for more implementation projects that are well evaluated, documented and published. Finally, we should consider applying eHealth as a means to deliver feasible intervention strategies broadly, such as used in athletes.

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Effects of exercise-based interventions. Data extraction - part1

	Basic characteristics				Study population									Study design		Data analysis				
	Project (or author)	**Study, first author**	**year**	**Country**	**occupation**	**population / condition**	**mean age (IG)**	**males (IG)**	**N IG1**	**N CG1**	**N IG2**	**N CG2**	**N total**	**Study design**	**FU assessm. After end of intervention**	**data at follow up**			**analysis**	
																intervention group	control group	total	alpha level	intention to treat
1	**Leino**	Leino	1994	Finland	forestry workers	symptomatic	42	100%	87	61	n.a.	n.a.	148	QE	1 year	90%	67%		0.05	n.d.
2	**fit to plant**	Roberts	2009	Canada	tree planters	gen workforce	22	55%	18	20	n.a.	n.a.	38	CT	33 work days			84%	0.05	no
3	**Rudolph**	Rudolph	2016	Germany	forestry workers	gen workforce	43	98%	126	61	n.a.	n.a.	187	retro QE	end of int.	a)			0.05	n.a.
4	**Ludewig**	Ludewig	2003	USA	construction	symptomatic	49	100%	34	33	n.a.	((25))	67	RCT	end of int.	88%	97%		0.05	yes
5	**Holmström**	Holmström	2005	Sweden	construction	asymptomatic	40	100%	37	20	n.a.	n.a.	57	QE	end of int.	81%	85%		0.05	n.d.
6	**Borstad**	Borstad	2009	USA	construction	asymptomatic	27	>96%	117	123	n.a.	n.a.	240	QE	end of int.			87%	n.d.	n.d.
7	**FINALE**	Holtermann	2010	Denmark	construction	gen workforce	44	100%	35	32	n.a.	n.a.	67	RCT	end of int.				0.05	yes
		Gram	2012																	
8	**VIP - vitality in practice**	Viester	2012	Nether-lands	construction	gen workforce	46.3	100%	162	152	n.a.	n.a.	314	RCT	at 6 mt. (end of int.) and 12 mt.	79%	85%		0.05	yes
		Viester	2015																	
		Viester	2017																	
9	**Malarvizhi**	Malarvizhi	2017	India	construction	symptomatic	n.d.	100%	15	15	n.a.	n.a.	30	QE	end of int.	100%	100%		0.05	yes
10a	**PHLAME**	Kuehl	2005	USA	Firefighters	gen workforce	n.d.	n.d.	n.d	n.d	n.a.	n.a.	687	cRCT	up to 2 years	n.d.	n.d.		0.05	n.a.
10b		Kuehl	2013				42	93%	745	624	n.a.	n.a.	1369	retro QE	up to 4 years	n.d.	n.d.		0.05	n.a.
11	**Poston**	Poston	2013	USA	Firefighters	gen workforce	40	100%	522	480	n.a.	n.a.	1002	retro QE	end of int.				0.05	n.a.
12	**Perkiö-Mäkelä**	Perkiö-M.	2000	Finland	Farmers	symptomatic	38	0%	32	33	30	31	126	Cluster-RCT	end of int. And 1-, 3-, 6-year fu			2.5mt: 124, 1y: 110, 3y: 106, 6y:91	0.05	n.d.
		Perkiö-M.	1999																	
13	**IRMA06**	Sundstrup	2013	Denmark	Slaughter-house workers	symptomatic	48	77.30%	33	33	n.a.	n.a.	66	RCT	end of int	91%	94%		0.05	yes
		Sundstrup	2014																	
		Sundstrup	2014																	
14	**Orr**	Orr	2015	Australia	Police recruits	gen workforce	n.d.	63%	25	29	115	118	287	RCT	end of int.	100%	100%		0.05	yes

n.a.= not applicable; n.d.= no data reported

IG= intervention group; CG= control group; FU= follow-up

QE = quasi-experimental design; RCT= randomised controlled trial; CT= controlled trial; retro QE= retrospective quasi-experimental design

a) only those included who had attended 80% of the training sessions

Effects of exercise-based interventions. Data extraction - part3

	Basic characteristics: Project (or author)	Study, first author	year	Country	Study population: occupation	Effects for outcomes on MSD and injury outcomes: outcomes reported: back pain	shoulder pain	other MSD	injury	# of effects on MSD reported	# of effects on MSD in expected direction	% of effects on MSD in expected direction	# of effects on injuries reported	# of effects on injuries in expected direction	% of effects on injuries in expected direction	# of effects in inverse direction	Effects worksite-related outcomes: outcomes reported: work ability	productivity	funct. limitations	sick leave (due to MSD)	work disability	claims / costs	# of effects reported	# of effects in expected direction	% of effects expected direction	# of effects in inverse direction
1	**Leino**	Leino	1994	Finland	forestry workers	x		x		2	0	0%				0	x			x			3	1	33%	0
2	**fit to plant**	Roberts	2009	Canada	tree planters				x				1	1	100%	0		x					1	1	100%	0
3	**Rudolph**	Rudolph	2016	Germany	forestry workers	x	x	x		7	4	57%				0			x				7	4	57%	0
4	**Ludewig**	Ludewig	2003	USA	construction		x			2	2	100%				0					x		1	1	100%	0
5	**Holmström**	Holmström	2005	Sweden	construction	x				1	0	0%				0			x				1	0	0%	0
6	**Borstad**	Borstad	2009	USA	construction		x			1	0	0%				0										
7	**FINALE**	Holtermann	2010	Denmark	construction																					
		Gram	2012			x	x	x		8	0	0%				0	x	x		x			5	0	0%	0
8	**VIP - vitality in practice**	Viester	2012	Nether-lands	construction																					
		Viester	2015			x	x	x		4	0	0%				0	x		x	x			5	0	0%	0
		Viester	2017																							
9	**Malarvizhi**	Malarvizhi	2017	India	construction		x			1	1	100%				0										
10a	**PHLAME**	Kuehl	2005	USA	Firefighters				x				1	1	100%	0				x			1	1	100%	0
10b		Kuehl	2013																			x	2	2	100%	0
11	**Poston**	Poston	2013	USA	Firefighters				x	1						1										
12	**Perkiö-Mäkelä**	Perkiö-M.	2000	Finland	Farmers	x	x	x		9	4	44%				0	x			x			2	1	50%	0
		Perkiö-M.	1999														x						1	1	100%	0
13	**IRMA06**	Sundstrup	2013	Denmark	Slaughter-house workers																					
		Sundstrup	2014																		x		1	1	100%	0
		Sundstrup	2014				x	x		3	3	100%				0	x						1	1	100%	0
14	**Orr**	Orr	2015	Australia	Police recruits				x				2	0	0%	0										

MSD= musculoskeletal disorders

Effects of exercise-based interventions. Data extraction - part2

	Basic characteristics				Study population	Intervention IG																						Intervention CG
	Project (or author)	Study, first author	year	Country	occupation	intervention elements						duration	TR/ week	min/ TR	min/ week	exercise training elements					Intervention setting							
						exercise sessions	education	PA counselling	ind. adaptation	other lifestyles	ergonomics					strength	neuromuscular	stretching	mobilisation	aeorbic	at the worksite	in specific facility	home-based	prof. trainer	peer supervisor	during work hrs	outside work hrs	
1	**Leino**	Leino	1994	Finland	forestry workers	x	x			x		7 full days				"various"						x	x	x		n.d.		no intervention
2	**fit to plant**	Roberts	2009	Canada	tree planters	x						8 weeks	6			x				x	n.d.			n.d.		n.d.		no intervention
3	**Rudolph**	Rudolph	2016	Germany	forestry workers	x						3 years	1	90	90	x	x		x			x		x				no intervention
4	**Ludewig**	Ludewig	2003	USA	construction	x						10 weeks	3			x		x					x				x	no intervention
5	**Holmström**	Holmström	2005	Sweden	construction	x						3 months	5	10	50			x	x	x	x				x	x		no intervention
6	**Borstad**	Borstad	2009	USA	construction	x						2 years	3			x		x					x				x	no intervention
7	**FINALE**	Holtermann	2010	Denmark	construction	x			x			3 month	3	20	60	x				x	x	x		x		x		1-hr lecture on general health
		Gram	2012																									
8	**VIP - vitality in practice**	Viester	2012	Nether-lands	construction		x	x	x	x		6 months	3			x					x		x			x	x	no intervention
		Viester	2015																									
		Viester	2017																									
9	**Malarvizhi**	Malarvizhi	2017	India	construction	x						6 weeks	n.d.			x		x					x	n.d.		n.d.		ergonomic advice
10a	**PHLAME**	Kuehl	2005	USA	Firefighters		x	x		x		6 months	n.a.			n.a.					x				x	x		no intervention
10b		Kuehl	2013																									no intervention
11	**Poston**	Poston	2013	USA	Firefighters	x		x	x	x		n.d.	n.d.			n.d.					x			x	x	x		no intervention
12	**Perkiö-Mäkelä**	Perkiö-M.	2000	Finland	Farmers	x	IG2	x		IG2	x	2.5 months			72-120	x		x		x		x		x			x	no intervention
		Perkiö-M.	1999																									
13	**IRMA06**	Sundstrup	2013	Denmark	Slaughter-house workers	x						10 weeks	3	10	30	x					x			x		x		ergonomics
		Sundstrup	2014																									
		Sundstrup	2014																									
14	**Orr**	Orr	2015	Australia	Police recruits	x			x			10 weeks	1			x				x						x		standard training

n.a.= not applicable; n.d.= no data reported
IG= intervention group; CG= control group; FU= follow-up
MSD= musculoskeletal disorders
TR= number of training sessions