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The Role of Physical Exercise in the Prevention of Musculoskeletal Disorders in Manual Workers: A Systematic Review and Meta-Analysis

Valentina Bullo[1,2], Francesco Favro[1], Davide Pavan[2], Alessandro Bortoletto[1], Stefano Gobbo[1,2,*], Giuseppe De Palma[3,4], Stefano Mattioli[5], Emma Sala[4], Lucia Cugusi[6], Andrea Di Blasio[7], David Cruz Diaz[8], Danilo Sales Bocalini[9], Marco Bergamin[1,2]

[1] Department of Medicine, University of Padova, Padova, Italy
[2] GymHub S.r.l., Spin-off of the University of Padova, Padova, Italy
[3] Occupational Health Unit – DSMC, University of Brescia, Brescia, Italy
[4] Occupational Health, Hygiene, Toxicology and Prevention Unit, University Hospital ASST Spedali Civili di Brescia, Brescia, Italy
[5] Department of Environmental and Prevention Sciences, University of Ferrara, Ferrara, Italy
[6] Department of Biomedical Sciences, University of Sassari, Sassari, Italy
[7] Department of Medicine and Sciences of Aging, G. d'Annunzio University of Chieti-Pescara, Chieti, Italy
[8] Department of Health Sciences, Faculty of Health Sciences, University of Jaén, Jean, Spain
[9] Laboratorio de Fisiologia e Bioquimica Experimental, Centro de Educacao Fisica e Deportos, Universida-Federal do Espirito Santo (UFES), Goiabeiras, Espírito Santo, Brazil

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Summary

Work-related Musculoskeletal Disorders (WMSDs) are the most common occupational health problem in the European Union. Physical exercise interventions have been investigated to prevent WMSDs in many sectors. Therefore, we aimed to assess the effect of physical exercise on manual workers for the primary and secondary prevention of WMSDs. We conducted a systematic search of the literature, and papers were included if the participants were adult employees exclusively engaged in manual labor tasks, non-acute physical exercise intervention, pain, disability, physical functioning, or health-related quality of life outcome, with pre-post intervention measurements. We retrieved 10,419 unique records and included 23 studies. A random effect meta-analysis was conducted on the studies with a control group design, using a three-level model to estimate the pooled effect for pain outcomes (g=0.4339, 95% CI: 0.1267–0.7412, p<0.01), and a two-level model for disability outcomes (g=0.6279, 95% CI: 0.3983–0.8575, p<0.0001). Subset analysis revealed a moderate-to-large effect on the VAS outcome (g=0.5866, 95% CI: 0.3102–0.8630, p<0.0001). Meta-regression on pain outcomes revealed a significant effect for sex, age, study quality, and body segments tested. The analyses on all outcomes except VAS showed substantial heterogeneity ($^{I2}{}_{pain}$=93%, of which 72% at the study level, $^{I2}{}_{disability}$=78%, and $^{I2}{}_{vas}$=56%, of which 44% at the study level). Physical exercise programs seem to have a positive effect on pain and disability stemming from WRMSDs in manual workers.

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*Corresponding Author: Stefano Gobbo; E-mail: stefano.gobbo@unipd.it; Phone number: +39 049 6895870)

1. Introduction

Work-related Musculoskeletal Disorders (WRMSDs) affect muscles, tendons, ligaments, nerves, and other soft tissues in the body. Musculoskeletal Disorders (MSDs) are the most common work-related health problem in the European Union, and workers in all sectors and occupations can be affected [1]. Indeed, looking at the EU Labour Force Survey (LFS) [2] ad hoc modules from 2007 and 2020, reported rates of self-reported MSDs across 27 EU countries increased from 54.2% to 60.1% in persons from 15 to 64 years of age, within this time frame [3]. Additionally, in the 2023 European Agency for Safety and Health at Work report, the prevalence of MSDs is not decreasing, as could be expected due to the sectoral shifts of the workforce from industry and agriculture to services [4]. Indeed, the authors of the EU-OSHA study 'Work-related musculoskeletal disorders: why are they still so prevalent?' consider several reasons for this: the ergonomic burden shifted to other tasks like handling patients instead of handling heavy loads, more inactivity with other musculoskeletal consequences, more time pressure, an ageing workforce, and inadequate work organization and contractual arrangements [3].

Moreover, WMSDs result from various factors, with the work environment and performance playing a significant but varying role in causing the disorder. Occupational factors such as repetitive tasks, awkward postures, forceful exertions, prolonged sitting or standing, and other secondary risk factors can cause or worsen MSDs.

Examples of these disorders include carpal tunnel syndrome, tendonitis, back pain, and discomfort in the neck and shoulders; these conditions can cause pain, restrict mobility, and impair functionality, affecting an individual's ability to perform job tasks effectively. To manage and reduce the risk of WMSDs, it is crucial to implement ergonomic interventions, provide proper training, and foster a healthy work environment. Furthermore, peer-reviewed literature about the effectiveness of workplace interventions in preventing upper extremity musculoskeletal disorders and symptoms concluded that many intervention types did not meet the criteria for high or moderate levels of evidence [5]. While it may be inferred that the interventions were ineffective, it is important to note that the current scientific evidence is insufficient to support their recommendation. For example, job stress management training, EMG biofeedback training and workstation adjustment alone interventions had a moderate level of evidence of no effect for upper extremity MSDs outcomes [5].

Another systematic review debated participatory ergonomic intervention facilitators and barriers that could be decisive for a good improvement plan [6].

In addition, ergonomic risk assessment is estimated by several methodologies based on the type of task, environment, or legislation. For example, for manual handling, there are NIOSH (National Institute for Occupational Safety & Health) lifting equations [7], Snook & Ciriello procedure [8], Key indicator method (KIM-MHO) [9], and others. This wide heterogeneity of evaluations and a limited or non-existent consideration given to the sex factor in popular ergonomic assessment methods [10] could be one or generate unhelpful resolutions for both genders.

Another type of intervention used to prevent WMSDs is physical exercise (PE), which seems to reduce low back pain with only 10–15 minutes of adapted exercise performed 3–5 days per week by office workers [11]. Other papers have also investigated different kinds of exercise and working populations; for example, da Costa & Vieira [12], in their review, highlighted mixed findings but demonstrated some beneficial effects of stretching in preventing work-related musculoskeletal disorders. Moreover, Martinez [13], in his review, affirmed that the implementation of a workplace exercise program is of great value both for employees, who will improve their quality of life, and for the company, given that workers will be more satisfied.

Finally, the significant impact of physical demands at work on the development and persistence of WMSDs is widely recognized. While some individuals can continue working despite having MSDs, for others, it could be a diminished work ability, increased sick leave, and premature withdrawal from work [14]. Therefore, the main purpose of our study is to determine the effectiveness of exercise interventions (type, frequency, duration) in contributing to the primary and secondary prevention of WMSDs in manual workers.

2. Methods

The review protocol was initially registered on PROSPERO under the ID: CRD42022302772, and the review was written following the structure given by the PRISMA statement [15]. A systematic search was conducted on PubMed, Scopus, CINAHL, Web of Science and EMBASE using a search string composed of MeSH terms and free keywords identified by reading relevant papers on the subject, such as Stevens et al. [16] and Gram et al. [17]; the full search string used on PubMed was also used on the other search instruments by adapting the syntax and accounting for their thesauri or lack thereof (All search strings are available in the supplementary material A).

Eligibility criteria were established using the PICO-S reporting system [18]:

- Population: Employees engaged in manual labor tasks and exposed to biomechanical overload risk factors (e.g., material handling, repetitive movements of upper arm), from 18 to 65 years old. Studies that included both manual and office workers were excluded, as were studies exploring nurses, doctors, and other healthcare professionals, given that they are included in a different risk assessment category.
- Intervention: Non-acute physical activity (PA) interventions.
- Comparator(s): Employees exposed to different modalities of physical activity and/or no intervention.
- Outcome(s): Any evaluation of pain and/or functional impairment, with evaluations of physical functioning and health-related quality of life as secondary outcomes, with pre-post intervention measurements of the outcome (Standardized mean of difference measures).
- Study type: Pilot study, RCT, non-RCT, exploratory study, Randomized pilot trial.

We only included papers written in English and did not impose a publication year restriction in the criteria. The first round of searches was conducted in November 2021, and all records retrieved were uploaded on Rayyan (https://www.rayyan.ai/) [19], deduplicated, and screened by title and abstract. We then retrieved all papers that met our eligibility criteria and that were available and read the full-text articles for definitive inclusion. The screening process was conducted independently by F.F. and B.V., and disagreements were resolved by discussion with P.D.

Backward and forward Citation searching was also conducted on the included papers (on PubMed and Scopus), although no additional articles could be retrieved.

The same two authors extracted data from the included papers using an adapted version of the Cochrane data collection form (template form available in the supplementary materials):

- Study identifiers: title, first author, year, journal, study ID.
- Type of study (blinding, randomization, group homogeneity).
- Participants (number of participants, age, sex, workplace).
- Type of intervention (modality and setting).
- Exercise intervention parameters and duration (weeks).
- Comparison group intervention and/or control group data.
- Withdrawals and exclusions.
- Main outcome and measurement (methodology used and numerical measures).
- Secondary outcomes, if there were any.

The included studies were then divided between "pain and disability", "Health-related physical fitness," and "Cardiological parameters" outcomes and based on the typology of intervention received: "resistance training", "stretching and mobility training", "comparison of different interventions between groups", and a catch-all "other" category.

The quality of the studies was analyzed by V.B. and F.F. using a nine-criteria checklist adapted from the Cochrane Collaboration Back Review

Group [20], and studies with a positive (+) score in at least 5/9 items were considered as "high-quality".

Pain and disability outcomes were further split into "pain" (VAS measures, NMQ, etc.), "disability" (DASH, SPADI, etc.), and "effort" (RPE measures) outcomes.

Only the studies that included an intervention group and a true control group (not performing some physical activity) were included in the meta-analysis. Data was prepared on a standard Excel sheet (Microsoft 365, 2017) for a three-level meta-analysis.

All pre/post outcome data were converted or estimated into means and standard deviations (SD), specifically, to estimate the mean and S.D. of the outcomes in "Moreira-Silva_2014," the methods outlined by Wan et al. [21] employed. The control groups in "Ludewig_2002" were combined using the formulas in the Cochrane Handbook [22], chapter 6, table 6.5.a. In contrast, the control group in "Weyh_2020" was split into 2 equal groups to match the two intervention groups (strength and endurance training, respectively) to avoid "double counts", as recommended in the Cochrane Handbook, chapter 23, section 3.4. Similarly, "Zebis_2011" was split into two entries as divided in the paper, "cases" and "non-cases" (sample characteristics and outcomes were already reported separately, and no data conversion was required).

Effect sizes (ES) for each outcome and their variance were estimated using the pooled pre-test S.D. described by Morris S.B. [23].

Pre and post-intervention correlation coefficients were calculated using the methods provided by the Cochrane Handbook, chapter 6, section 2.5.8 when enough data was available in a study (SD pre-intervention, SD of change from baseline), and the resulting coefficients were used to assign a correlation coefficient to all other studies.

To estimate the overall effect size, a three-level model, with a single ES nested at the study level, was fitted using the restricted maximum likelihood (REML) method. The use of a three-level model was tested using the information criteria AIC (Akaike information criteria), BIC (Bayesian information criteria), and AICc (AIC corrected) to support the use or rejection of a three-level structure. Sensitivity analysis was performed with different correlation coefficient imputations. The results for pain outcomes were aggregated at the study level (maintaining the same pooled estimate) to produce a readable forest plot.

Meta-regression was carried out on pain outcome data (due to the limited number of disability outcomes) by testing one moderator at a time and estimating their significance with the restricted maximum likelihood test. A subset analysis was conducted, including only the VAS outcomes. Heterogeneity was estimated using the Cochran's Q and I^2 statistics. All analyses were then repeated after excluding one study that reported extremely high ES.

The pooled ES were categorized as "small" (< 0.39), "moderate" (0.40–0.59), "large" (0.60–0.79), and "very large" (≥ 0.80). I^2 values smaller than 50% of 50 to 75%, and larger than 75% were considered to indicate low, moderate and substantial levels of heterogeneity. The statistical significance threshold was set at $p<0.05$. All statistical analyses were performed with the statistical software R, version 4.3.2 [24] and the metafor package [25].

3. Results

A total of 15,778 records were retrieved from the searches and, after deduplication and abstract screening, 85 papers were retrieved and assessed for inclusion: 5 were not available to us, 5 were only available as abstracts, 7 were not in English, 32 had the wrong population, 11 didn't include a physical activity intervention, 3 didn't include any outcomes of interest, and 4 chose a study design outside of our criteria. Ultimately, 23 papers were included in the review and 14 in the meta-analysis (Figure 1), and relevant data was extracted.

17 papers were classified as "high quality", with the "upper limb" study of Sundstrup et al. [26] receiving a perfect score, and 6 as "low quality"; the mean score was of 6.1±2.0 out of 9, showing an overall good quality of the included papers; the results of this analysis are summarized in Table B1, available in the Supplementary material B.

3.1. Descriptive Analyses

As many as 2,454 participants were analyzed across the included studies, with an overall mean

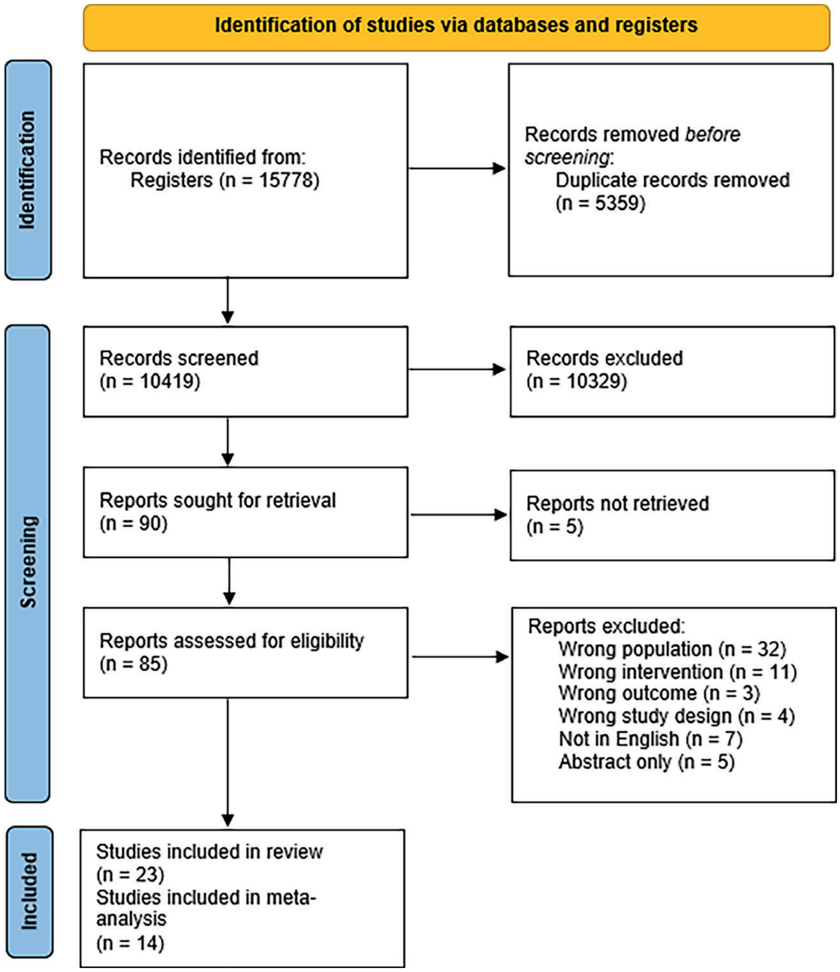

Figure 1. PRISMA Flowchart.

age of 41.58±9.39 years. 9 papers [27-35] implemented a resistance training intervention for a total of 1507 participants (1076 coming from Pedersen et al. [32] and Zebis et al., [33], 537 each); only one [36] carried out a pure stretching intervention, with 40 participants; 6 studies [26, 37-41] compared different intervention across multiple groups (356 participants total); finally, there were 7 more studies [17, 42-47] that implemented a number of other different or multimodal protocols, analyzing 551 participants overall. A summary of the studies' interventions and outcomes are available in the supplementary material B, in tables B2 and B3, respectively.

Mean (±SD) duration of intervention was 18±12.9 weeks (range: 6-47 weeks), with a mean frequency (when it was reported) of 3±1.2 days per week.

The RT interventions that were implemented were mainly specific training protocols, focusing on the shoulders, arms, and, to a smaller extent, spinal erectors. Only two studies with a RT intervention used a more general training approach, Rasotto et al. [31] and Gobbo et al. [27].

The stretching-only intervention applied by Bertozzi et al. [36] was aimed instead at the lumbar region and lower limbs.

The 7 papers with various interventions employed combined interventions of stretching and resistance training, or cryotherapy [45], or added compensatory exercises [47], and one carried out an exercise protocol based on a guidebook published by the Finnish Institute of Occupational Health [46].

Lastly, the interventions compared against each other in the papers with more than one intervention group are reported in Table B4, available in the Supplementary material B.

3.1.1. Effect on Pain

All included papers except for one [34] measured at least one outcome in the pain and disability domain, with 19 of those reporting at least one statistically significant ($p<0.05$) favorable pre-post difference in the intervention group(s).

The most prevalent pain outcomes measured were VAS (visual analogue scale) [48] and DASH (disability of the arm, shoulder, and hand questionnaire) [49] scores. Other outcomes relating to pain and/or disability and or work ability were used, such as: WAI (Work Ability Index) [50], SRQ (Shoulder Rating Questionnaire) [51], SPADI (Shoulder Pain and Disability Index) [52], NMQ (Nordic Musculoskeletal Questionnaire) [53], NPDS (Neck Pain and Disability Scale) [54], RPE during work activities, ODI (Oswestry Disability Index) [55] and BPI (Brief Pain Inventory) [56].

Specifically, 15 studies looked at outcomes relating to pain and disability in the upper limbs, shoulder and/or neck, with a mean duration of intervention of 17.5±12.8 weeks, using the VAS score or one or more of the scales listed above, that ask the participant about their pain in the last week or month, indicating more stable benefits, as opposed to acute effects, measured immediately post-training session.

3.1.2. Effect on HR-Physical Fitness and Cardiovascular Parameters

Among the included studies, 15 additionally measured health-related physical fitness and/or cardiovascular parameters, including the Senior Fitness Test, Hand grip and other physical strength tests, mobility assessments, resting heart rate and blood pressure measurements. 12 of those studies reported one or more statistically significant ($p<0.05$) favorable pre-post difference in the intervention group(s) for HR-physical fitness, and 1 reported a significant effect for cardiovascular parameters [39].

3.2. Meta-Analyses

When the first round of analyses was concluded, one study [43] was excluded because of the extremely high ES reported (4.62 and 5.52 for VAS of the shoulder and SPADI score, respectively), the lack of important information, such as the sample mean age and the timing of the intervention, and its overall poor quality (2/9). All analyses were then repeated without this study. The original analyses are available upon request. Only 3 papers included an "effort" outcome. Therefore, meta-analysis was conducted only on "pain" and "disability."

3.2.1. Effect on Pain

Exercise interventions resulted in a significant reduction in pain, with a pooled standardized mean change of 0.4339 (95% CI: 0.1267–0.7412, $p<0.01$), indicating a moderate effect of an exercise intervention on pain outcomes of workers employed in manual labor based on 49 unique outcomes nested in 13 studies, with a total sample size of 1,583 participants across studies. Information criteria and the likelihood ratio test support using a three-level model ($\chi^2=19.32$, $p<0.0001$).

Significant heterogeneity was found ($I^2_{pain}=93.2$ %), and variance decomposition reveals that 71.9% of the variance comes from heterogeneity between studies ($I^2_{level2}=21.4\%$, $I^2_{level3} = 71.9\%$).

The funnel plot (Figure B1, Supplementary material B) shows moderate asymmetry towards the null effect (each point is an outcome, outcomes from different studies are shown with different colors) and high heterogeneity between studies.

The data was then aggregated at the study level, maintaining the point estimates and confidence intervals, to produce the forest plot in Figure 2.

3.2.2 Effect on Disability

Exercise interventions resulted in a significant reduction in disability outcomes, as measured wit questionnaires and scales such as the DASH, NPDS-I, and WAI, with a pooled standardized mean change of 0.6279 (95% CI: 0.3983–0.8575,

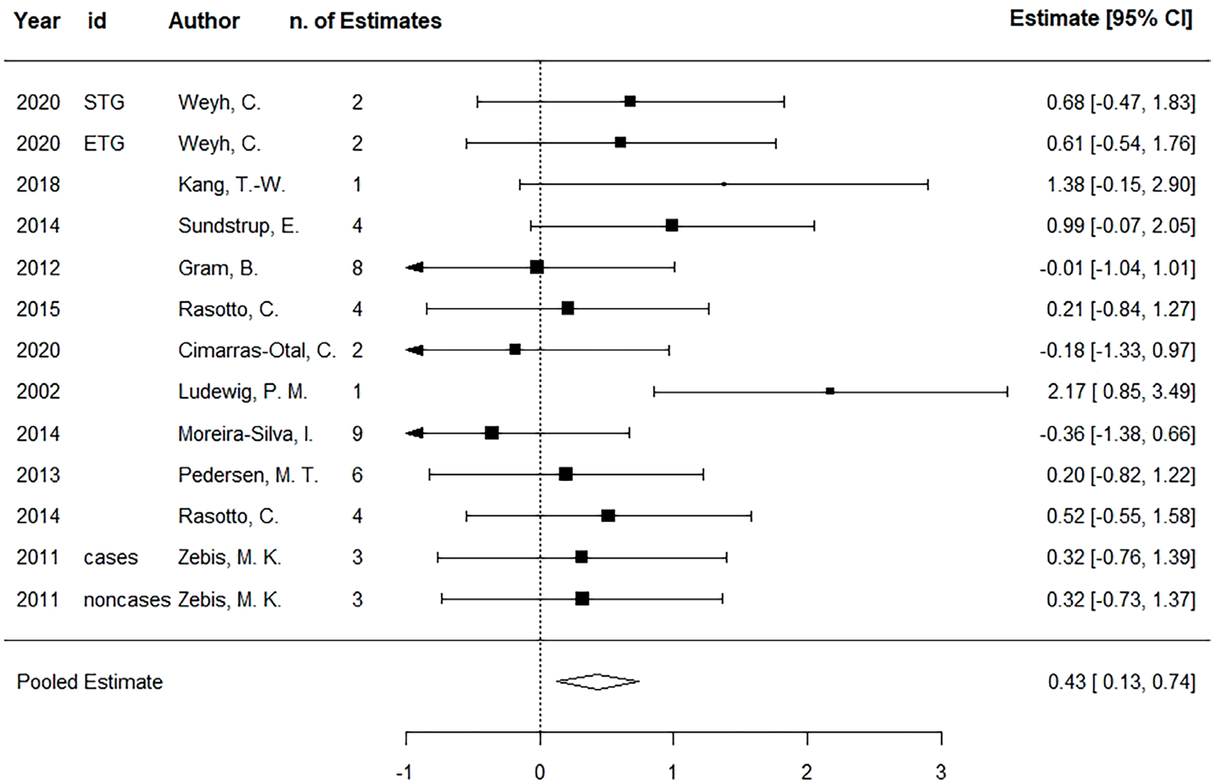

Figure 2. Forest plot for (aggregated) pain outcomes.

p<0.001), showing a large effect of exercise intervention on disability scores of workers employed in manual labor. Information criteria and the likelihood ratio test reject the choice of a three-level model (χ^2=2.34, p=0.13), therefore, a two-level random effect model was used to fit the model, with 15 outcomes coming from 9 studies, for a total of 1035 participants (Figure 3).

Significant heterogeneity was found for disability outcomes (Q=63.86, I^2=78%).

The funnel plot (Figure B2, Supplementary material B) shows slight asymmetry towards positive effects and high heterogeneity between studies.

3.2.3. Meta-Regression

The moderators tested were: year of publication, randomization (RCT or non-randomized), activity level (sedentary or active participants), mean age of participants, baseline differences between groups, type of intervention (strength, aerobic, combined or other modalities of training), duration and timing of the intervention, body part tested (neck, back, upper limbs, lower limbs, or whole-body). Among these, sex, age, and body part (whole body only) showed a significant effect.

Specifically, when comparing studies that included only men, only women, or both, men-only studies showed a pooled estimate of g=0.8279 (95% CI: 0.1916–1.4642, p=0.0108).

The mean age of participants had a significant moderating effect, with larger ES for studies that recruited older subjects (intercept ES=-5.8440, equivalent to a mean age of 0 years, increased by 0.1484 for each additional year of age; figure 4, cut at 30 years old for clarity).

Only pain outcomes relating to the whole body (such as averaged VAS results) had a significant effect on the model (p<0.001), however, this moderator had unbalanced classes, with tests for the upper

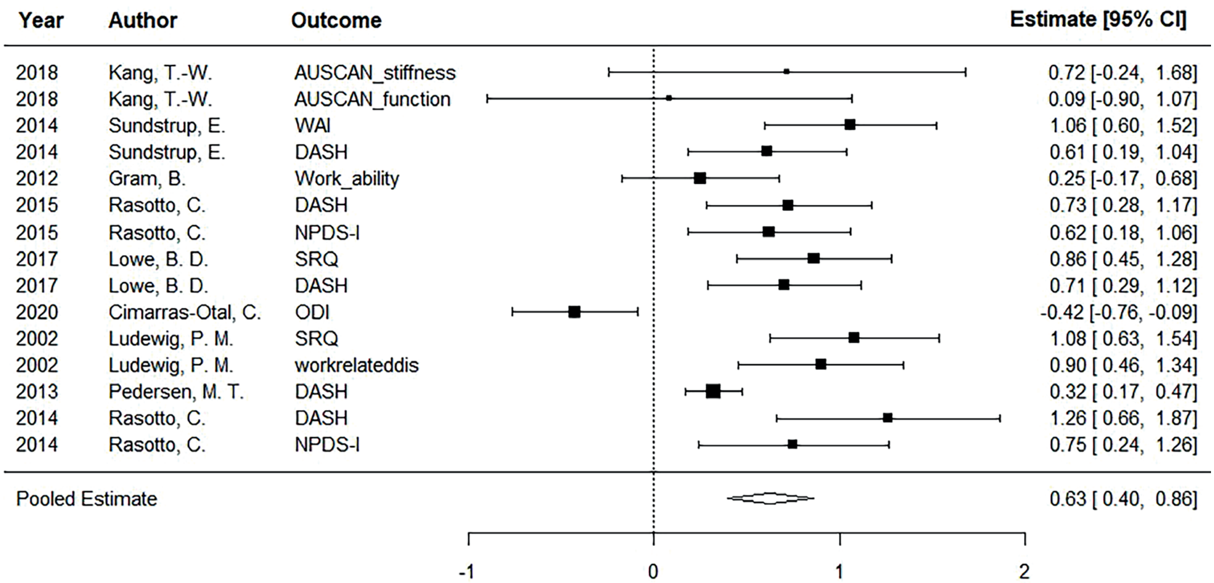

Figure 3. Forest plot for disability outcomes.

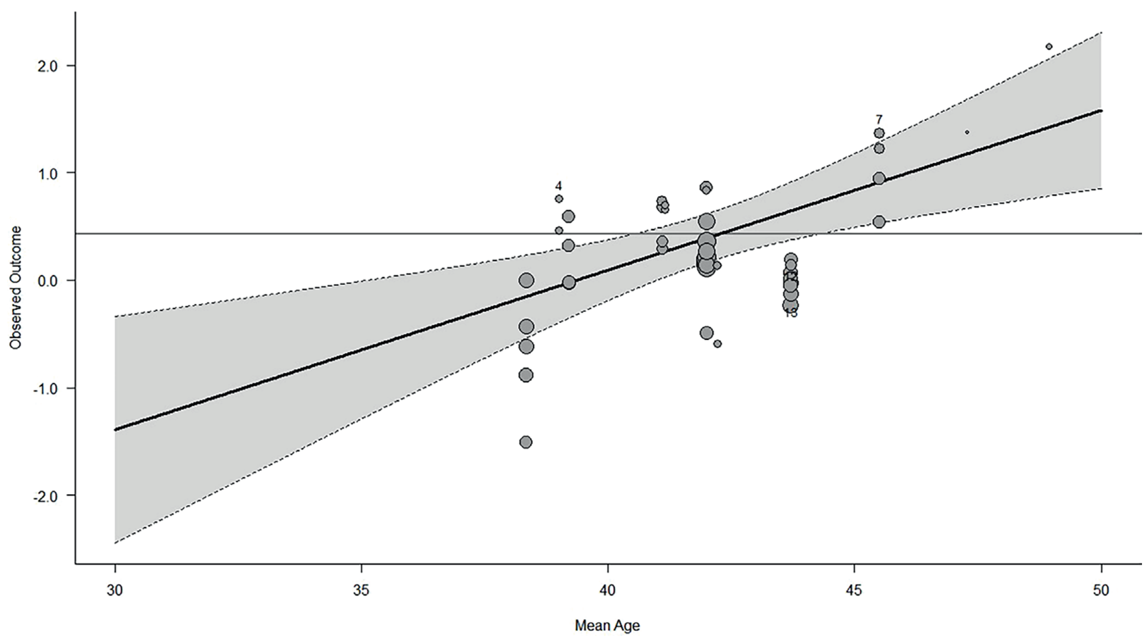

Figure 4. Regression line for Mean age. The grey horizontal line is set at 0.4339, the ES of the full model for pain. Each point represents an outcome, with larger points representing studies with heavier weight.

body comprising almost 50% of the pain outcomes (23 out of 49), undermining the usefulness of this particular result. Similarly, study quality was a significant moderating factor, with a pooled estimate of g=0.4984 (95% CI: 0.2097–0.7870, p<0.001) for studies of good quality (score≥5), and of g=-0.3558 for studies of poor quality.

Additionally, for the type of intervention, strength training displayed a trend towards significance (p=0.0503).

3.2.4. Subset Analysis

A subset of the dataset was constructed, including only measures of VAS results (16 outcomes nested within 5 studies, 271 total participants).

The pooled standardized mean change, based on a three-level model, was g=0.5866 (95% CI: 0.3102–0.8630, $p<0.0001$), showing a moderate-to-large effect of exercise intervention on the VAS score of workers employed in manual labor (Figure 5). This subset analysis shows much lower heterogeneity, with I^2=56%, with 44% of the total variation coming from between-studies heterogeneity (I^2_{level2}=11.54%, I^2_{level3}=44.39%). Information criteria and the likelihood ratio test support using a three-level model ($\chi^2 = 4.16$, $p < 0.05$). The funnel plot presents good symmetry (Figure B3, Supplementary material B).

4. Discussion

This systematic review aimed to assess the effect of physical exercise intervention on primary and secondary preventions in work-related musculoskeletal disorders. Data showed a moderate positive effect on various pain outcomes and a large effect on disability as measured with specific questionnaires, such as the DASH and the ODI. Results in this systematic review and meta-analysis are in accordance with those extracted by Moreira-Silva et al. [57], who conducted a meta-analysis and found moderate quality evidence of a positive effect of physical activity interventions on employees (without excluding papers based on work environment) on musculoskeletal pain in the neck/shoulder region, and only low-quality evidence for other sites of WMSDs (low-back, arms, wrist, etc.). A point of strength of the current systematic review is that, by limiting our population of interest to manual workers, we reduced heterogeneity in the participants' baseline conditions and exposure to work-related risk factors. Most of the included papers measured at least one outcome relative to pain and disability in the upper limb: this is not surprising, given that the shoulder has a high prevalence of WMSDs [58, 59]. Notably, instead, only 3 studies used questionnaires and scales directly investigating the lumbar region, another of the most common sites of WMSDs, and low back pain, such as the Oswestry disability index.

The main results of the meta-regression were the significant effects of sex and age:

The effect of exercise on pain appears to be greater in male workers. However, in the present meta-analysis, we could only compare studies recruiting only men versus studies that didn't impose

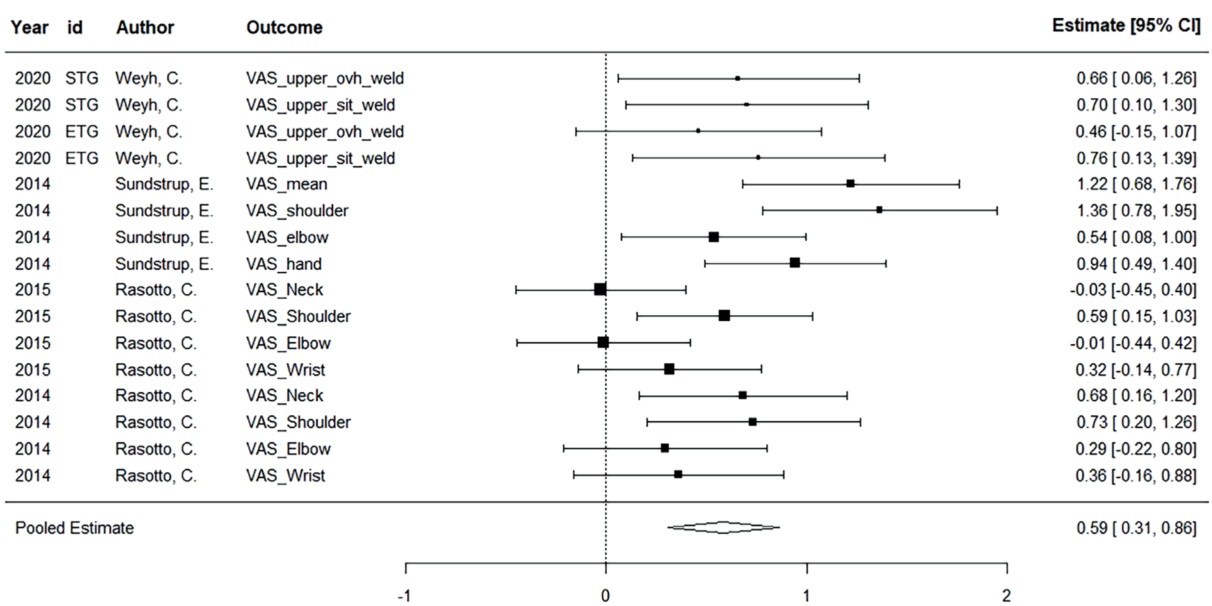

Figure 5. Forest plot for VAS outcomes.

a gender restriction on the participants. Only one study [35] was conducted on a female-only sample. This is part of the broader issue of the underrepresentation of women in both clinical and exercise trials [60-62]. More experimental trials are needed to characterize better the differences and needs of women involved in manual industrial work.

The significance of age as a moderator is less surprising. However, even though our inclusion criteria were set to include participants from 18 to 65 years old, it must be noted that in the included studies, the age range was much smaller, 28-48 years old, which somewhat limits the validity of the meta-regression data for this moderator.

As a side note, even though we imposed no restriction on publication year, all the included papers were published in the last 20 years, and more than 60% of them in the last decade. This hints at how recent the academic interest in the subject is and how many lines of research are open in this particular field. Indeed, in recent years, there has been a fast-growing trend in the number of RCTs evaluating the effectiveness of preventive interventions in occupational health [63].

We also looked at the effects on physical fitness and cardiovascular parameters, which, as was to be expected, were positively impacted in nearly all the interventions analyzed. It is also interesting to notice that there seems to be a qualitative correlation between significant effects on musculoskeletal pain and fitness, which would imply either a direct link between the two, as investigated by Ciolac & Rodrigues-da-Silva [64], or that more intensive exercise protocols could provide more significant results for pain and MSDs, that is, the improvements in HR-Physical fitness could be used as a proxy for exercise volume and intensity.

This leads to the first limitation of this review: the intervention protocols were at times poorly described, often lacking key training variables such as total volume or relative intensity (e.g., "The group sessions consisted of moderate worksite exercise based on a guidebook published by the Finnish Institute of Occupational Health"); other interventions were only loosely described by the objective or rationale of the exercise prescription or the muscles and joints involved in the exercise program (e.g., "nine easily-executed exercises to promote stretching and strengthening of soft tissues responsible for spinal stability, especially lumbar stability"). Furthermore, only 3 of the included papers reported attendance to the training program. This limited our ability to compare different interventions across studies and perform meta-regression on training variables. Future papers in this field should provide more accurate descriptions of training variables (volume, intensity, frequency, rest, exercise selection, etc.) in order to better compare interventions across studies, which in turn would allow us to extrapolate the data and provide more explicit recommendations for exercise prescriptions. This last point would also be of interest to the companies applying for these PE programs, as, with more data, it may be possible to derive the minimum effective training volume for the outcomes of interest (i.e., how little time could be spent on these programs to obtain a reduction in work-related injury risk).

The described interventions were generally of simple implementation and required little to no equipment: elastic bands, mats, and a small space to move safely in. All intervention types (resistance training, stretching, aerobic, multimodal, etc.) appeared similarly effective at reducing pain outcomes, with strength training showing a slightly greater effect.

The mean quality of the included papers was good nonetheless, and only 4 studies didn't implement a randomization process, which corroborates the findings of this systematic review. Noticeably, the studies with good quality showed a significantly higher effect on pain compared to the studies with poorer quality. A further study quality analysis could be conducted using tools more tailored towards PE studies, such as the TESTEX scale [65]; we would expect such an analysis to return worse results relative to study quality.

An interesting approach was used by Cheng & Hung [37], who compared clinical-based vs workplace-based "work-hardening" programs (which, again, were just generally described) as part of workers' rehabilitation after an injury. To the best of our knowledge, there are very few papers directly comparing the effects of PE intervention at the workplace against clinical or home-based

PE interventions. Workplace PE programs have the advantage of being easier to monitor, could have higher adherence if the exercise is performed as part of active breaks or shorter, additional PE breaks, and could be perceived by the workers as less time-consuming; therefore, future research investigating if their effects on pain, disability, and HR-physical fitness is comparable to "leisure time PE" could provide a foundation for suggesting their implementation to companies. Furthermore, workplace PE could supplement manual handling training, which was found to be largely ineffective and of questionable value [66, 67].

A second limitation of the current meta-analysis is the large heterogeneity present both for pain and disability outcomes. This could be ascribed in part to the large number of different scales and questionnaires employed and, in part, to the large variance of most of the outcomes, as can be gleaned from the forest plots in Figures 2, 3, and 5. This large amount of between-study variation reduced the certainty of the pooled estimate and the validity of its interpretation.

Another limitation is that even though the ability to exercise is free from acute musculoskeletal diseases was an inclusion criterion, only one study [33] performed separate analyses for "cases vs. non-cases" that is, participants with ongoing symptoms of WRMSDs and participants free of WRMSDs. Because of this, we can't differentiate between the prescription of an exercise program as primary vs secondary prevention for the development of WRMSDs. Future research could improve upon our work by performing separate analyses between healthy and symptomatic participants.

Visual inspection of the funnel plots (Figures B1, B2, B3, Supplementary material B) does not reveal clear asymmetries that could be interpreted as a sign of publication bias.

While the present review focused on WMSDs and the effects on HR-physical fitness, three of the included papers also measured outcomes relating to mental health, physical exercise and improved physical fitness are known to have a positive effect on mental health [68] in the general population, and their effect on the psychosocial well-being of workers has also been investigated in other fields, for example by [69] in teachers, by [70] in health care workers, and by [71] in office workers.

Particularly, Christensen and Justesen looked at Presenteeism (or "sickness presenteeism"), a relatively novel concept, loosely described as "attending work while ill", or sometimes conflated with its consequence of lost productivity for the company [72], even though there isn't a univocally accepted definition. For the individual, presenteeism usually means a slower recovery from illness, worse health outcomes, and a reduced quality of life. A future line of research could focus on investigating the effects of PA on reducing not just sick leaves [73] but sickness presenteeism as well, as advised in the closing remarks of the recent review on PA and presenteeism by Hervieux et al. [74]. Particularly, PA interventions could reduce costs for companies by reducing the time for recovery and symptoms of MSDs, thus lowering the economic burden of reduced productivity due to working while ill.

Finally, two of the included papers [28, 37] also measured outcomes regarding psychosocial factors, such as "Social support" and "Psychological demands, although in both cases, these factors were only measured at baseline and not at post-intervention. Psychosocial factors can have a significant influence on the worker's health and job performance and can play a role both in the development of WMSDs and the return to work after a WMSD is reported [75].

5. Conclusion

The results of this review provide an overview of the effectiveness of physical exercise programs in reducing musculoskeletal pain and disability in manual workers.

Based on these results, exercise programs seem to have a positive effect on pain and disability stemming from WRMSDs in manual workers. Even though most of the included studies were of "good quality", the substantial heterogeneity between studies limits the certainty of our conclusion. We believe that our results and recommendations could provide a starting point to guide future research in this field and, eventually, to update company policies and help disseminate the implementation of PE programs for manual workers.

Supplementary Materials: Supplementary material A: search strategies. Supplementary material B: additional tables and figures.

Institutional Review Board Statement: Not applicable.

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La Medicina del Lavoro

REVIEWS, COMMENTARIES, PERSPECTIVES

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The Role of Physical Exercise in the Prevention of Musculoskeletal Disorders in Manual Workers: A Systematic Review and Meta-Analysis

VALENTINA BULLO[1,2], FRANCESCO FAVRO[1], DAVIDE PAVAN[2], ALESSANDRO BORTOLETTO[1], STEFANO GOBBO[1,2,*], GIUSEPPE DE PALMA[3, 4], STEFANO MATTIOLI[5], EMMA SALA[4], LUCIA CUGUSI[6], ANDREA DI BLASIO[7], DAVID CRUZ DIAZ[8], DANILO SALES BOCALINI[9], MARCO BERGAMIN[1,2]

[1] Department of Medicine, University of Padova, Padova, Italy

[2] GymHub S.r.l., Spin-off of the University of Padova, Padova, Italy

[3] Occupational Health Unit – DSMC, University of Brescia, Brescia, Italy

[4] Occupational Health, Hygiene, Toxicology and Prevention Unit, University Hospital ASST Spedali Civili di Brescia, Brescia, Italy

[5] Department of Environmental and Prevention Sciences, University of Ferrara, Ferrara, Italy

[6] Department of Biomedical Sciences, University of Sassari, Sassari, Italy

[7] Department of Medicine and Sciences of Aging, G. d'Annunzio University of Chieti-Pescara, Chieti, Italy

[8] Department of Health Sciences, Faculty of Health Sciences, University of Jaén, Jean, Spain

[9] Laboratorio de Fisiologia e Bioquimica Experimental, Centro de Educacao Fisica e Deportos, Universida-Federal do Espirito Santo (UFES), Goiabeiras, Espírito Santo, Brazil

SUPPLEMENTARY MATERIAL A

Pubmed Search Strategy

1. "Exercise"[Mesh]
2. “Exercise”
3. “Physical Activity”
4. “Training Routine”
5. OR/1-4
6. “Musculoskeletal Diseases"[Mesh]
7. "Musculoskeletal Diseases"
8. "Work-related Musculoskeletal Disorders”

9. Job-Related
10. Injury
11. Illness
12. Pain
13. OR/10-12
14. 9 AND 13
15. Work-Related
16. Injury
17. Illness
18. Pain
19. OR/16-18
20. 15 AND 19
21. Pain
22. Neck
23. Hand
24. Wrist
25. Back
26. Musculoskeletal
27. “Upper Limb"
28. Intensity
29. Shoulder
30. MSK
31. OR/22-30
32. 21 AND 31
33. "Perceived"
34. "Exertion"

35. "Work"
36. AND/33-35
37. "Visual Analogue Scale"
38. VAS
39. OR/6-8,14,20,32,36-39
40. “Return to Work"[Mesh]
41. "Workplace"[Mesh]
42. "Workplace"
43. “Return to Work"
44. “Manual Labor”
45. “Blue Collar"
46. "Manual Handling of Loads"
47. Ergonom*
48. "Work Ability"
49. "Work Performance"
50. "Sick Leave"
51. "physically demanding work"
52. "Sickness Presenteeism"
53. "Sickness Absence"
54. "Assembly Work"
55. "Handwork"
56. OR/40-55
57. 5 AND 39 AND 56

EMBASE Search Strategy

1 exp exercise/

2 ("exercise" or "physical activity" or "training routine").mp. [mp=ti, ab, tx, ct, kw, ot, sh, hw, bo, bt, tn, dm, mf, dv, kf, fx, dq]

3 1 or 2

4 exp Musculoskeletal Diseases/

5 ("Musculoskeletal Diseases" or "work-related musculoskeletal disorders" or (job-related adj3 (injury or illness or pain)) or (work-related adj3 (injury or illness or pain)) or (pain adj3 (neck or hand or wrist or back or musculoskeletal or "upper limb" or intensity or shoulder or msk)) or ("perceived" adj3 "exertion" adj3 "work") or "visual analogue scale" or vas).mp. [mp=ti, ab, tx, ct, kw, ot, sh, hw, bo, bt, tn, dm, mf, dv, kf, fx, dq]

6 4 or 5

7 ("workplace" or "Return to Work" or "manual labor" or "blue collar" or "manual handling of loads" or ergonom* or "work ability" or "work performance" or "sick leave" or "physically demanding work" or "sickness presenteeism" or "sickness absence" or "assembly work" or "handwork").mp. [mp=ti, ab, tx, ct, kw, ot, sh, hw, bo, bt, tn, dm, mf, dv, kf, fx, dq]

8 exp return to work/

9 exp workplace/

10 7 or 8 or 9

11 3 and 6 and 10

CINAHL Search Strategy

S1 (MH "Exercise+")

S2 (MH "Musculoskeletal Diseases+")

S3 (MH "Work Environment+") OR (MH "Occupational-Related Injuries") OR (MH "Job Re-Entry")

S4 (MH "Exercise+") OR "exercise" OR "physical activity" OR "training routine"

S5 (MH "Musculoskeletal Diseases+") OR "Musculoskeletal Diseases" OR "work-related musculoskeletal disorders" OR (job-related AND (injury OR illness OR pain)) OR (work-related AND (injury OR illness OR pain)) OR (pain AND (neck OR hand OR wrist OR back OR musculoskeletal OR "upper limb" OR intensity OR shoulder OR MSK)) OR ("perceived" AND "exertion" AND "work") OR "visual analogue scale" OR VAS

S6 (MH "Work Environment+") OR (MH "Occupational-Related Injuries") OR (MH "Job Re-Entry") OR "workplace" OR "Return to Work" OR "manual labor" OR "blue collar" OR "manual handling of loads" OR ergonom* OR "work ability" OR "work performance" OR "sick leave" OR "physically demanding work" OR "sickness presenteeism" OR "sickness absence" OR "assembly work" OR "handwork"

S7 S4 AND S5 AND S6

Scopus Search Strategy

TITLE-ABS-KEY (("exercise" OR "physical activity" OR "training routine") AND ("Musculoskeletal Diseases" OR "work-related musculoskeletal (job- related W/3 (injury OR illness OR pain)) OR (work-related W/3 (injury OR illness OR pain)) OR (pain AND (neck OR hand OR wrist OR back OR musculoskeletal OR "upper disorders" OR limb" OR intensity OR shoulder OR msk)) OR ("perceived" W/3 "exertion" W/3 "work") OR "visual analogue scale" OR vas) AND ("workplace" OR "Return to Work" OR "manual labor" OR "blue collar" OR "manual handling of loads" OR ergonom* OR "work ability" OR "work performance" OR "sick leave" OR "physically demanding work" OR "sickness presenteeism" OR "sickness absence" OR "assembly work" OR "handwork")) AND NOT INDEX (medline)

Web of Science Search Strategy

TS=(("exercise" OR "physical activity" OR "training routine") AND ("Musculoskeletal Diseases" OR "work-related musculoskeletal disorders" OR (job-related NEAR/3 (injury OR illness OR pain)) OR (work-related NEAR/3 (injury OR illness OR pain)) OR (pain NEAR/3 (neck OR hand OR wrist OR back OR muscoloskeletal OR "upper limb" OR intensity OR shoulder OR msk)) OR ("perceived" NEAR/3 "exertion" NEAR/3 "work") OR "visual analogue scale" OR vas) AND ("workplace" OR "Return to Work" OR "manual labor" OR "blue collar" OR "manual handling of loads" OR ergonom* OR "work ability" OR "work performance" OR "sick leave" OR "physically demanding work" OR "sickness presenteeism" OR "sickness absence" OR "assembly work" OR "handwork"))

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Supplementary material B

Table B1: Studies quality summary.

Citation	Randomization procedure	Similarity of study groups	Inclusion or exclusion criteria	Dropouts	Blinding	Compliance	Intention-to-treat analysis	Timing of outcomes assessment	Follow-up	Results
AUTHOR	+/-									0/9
Weyh 2020	-	+	+	+	-	+	+	+	-	6/9
Moreira-Silva 2014	+	+	-	+	-	-	-	+	-	4/9
Sundstrup 2014, disability	+	+	+	+	-	+	+	+	+	8/9
Krüger 2015	-	+	+	-	-	-	-	+	-	3/9
Cimarras-Otal 2020	+	+	+	+	+	+	-	+	+	8/9
Ludewig	-	-	+	-	+	+	+	+	+	6/9

2002									
Rasotto 2014	+	+	+	+	+	+	-	+	-	7/9
Zebis 2011	+	-	+	+	-	+	+	+	+	7/9
Pedersen 2013	+	-	+	+	+	+	+	+	+	8/9
Rasotto 2015	+	+	+	+	-	+	+	+	-	7/9
Muñoz-Poblete 2019	+	+	+	+	+	+	-	+	+	8/9
Kang 2018, lowback	+	+	+	-	-	-	+	+	-	5/9
Camargo 2009	-	+	+	+	-	-	-	+	-	4/9
Gram 2012	+	-	+	+	-	-	+	+	-	5/9
Bertozzi 2014	-	+	+	-	-	+	+	+	-	5/9
Nurminen	+	+	+	+	-	+	+	+	+	8/9

2002										
Sundstrup 2014, upperlimb	+	+	+	+	+	+	+	+	+	9/9
Gobbo 2021	-	-	+	+	-	+	-	+	-	4/9
Kang 2018, finger	+	+	+	+	+	+	-	+	-	8/9
Cheng 2007	+	+	+	-	-	-	-	+	-	4/9
Malarvizhi 2017	-	-	+	-	-	-	-	+	-	2/9
Lowe 2017	+	+	-	+	-	+	+	+	+	7/9
Mesquita 2012	+	+	+	+	-	+	+	+	+	8/9

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Table B3: studies descriptions.

Study	Subjects and grouping, age	Training modality, program and intensity	Duration and frequency
Gobbo et al (2021)	22 (M) Age: 49.11 ± 7.58	1st-3rd wk: 10 min warm-up; resistance exercises for major muscular groups with elastic bands or free weights: squat, lunges, glute bridge, standing calf, floor press, upright row, lateral raise (5 sec reps), face pull (5 sec reps), external/internal rotation (5 sec reps), bicep curl, push down, crunches/plank; 10 min cool-down of stretching exercises. 4th-12th wk: 10 min warm-up; workout adapt for each participant with resistance and stretching specific exercises for neck, wrist, forearm, shoulders, and pelvic/hamstrings muscles: isometric neck flexion/extension (5 sec reps), lateral bending, wrist flexion/extension, forearm supination /pronation, shoulder mobility exercises in all directions, pelvic tilt/ hamstrings flexibility exercise; 10 min cool-down of stretching exercises.	12 weeks Hour: 5:00 p.m.
Cimarras-Otal et al (2020)	18 IG – intervention group: 10 (8 M, 2 F) CG – control group: 8 (4 M, 4 F) Age IG: 42.25 ± 7.28 Age CG: 42.20 ± 5.59	Compensatory exercises (displacement of workplace, cervical, spinal movement, handle loads, shoulder movement, use of tools). Three exercise levels of difficulty: starting level (1st-3rd wk), average level (4th-5th wk) and advanced level (7th-8th wk).	8 weeks
Weyh et al (2020)	77 ETG – endurance training group : 27 (M), 1 (F) STG – strength training group: 28 (M) CG – control group: 21 (M) Age ETG: 39 ± 10 Age STG: 42 ± 8	STG: 1st-12th wk: 3 sets of 20-25 reps at 55-60% 1RM 13th-24th wk: 3 sets of 10-15 reps at 70-75% 1RM 10 min of global warming before each session 60-sec break between each set. Chest or bench press, shoulder raises, seated row, dumbbell neck lift, fore-arm dumbbell curls, cable internal/external rotation, back extension, abdominal crunch/common crunches, leg press. ETG: 1st-12th wk: moderate intensity (65-75% HRmax), 30 min each 4 wk by 5 min up to 40 min, vigorous (75-85% HRmax) intensity stayed consequently at 20 min.	24 weeks STG: 2-3 d/w ETG: 3 d/w

	Age CG: 39 ± 11	13th-24th wk: moderate intensity (65-75% HRmax) once and vigorous intensity twice (75-85% HR max). Duration of vigorous intensity increased from 30 min each 4 wk by 5 min up to 40 min, moderate intensity keeps at 40 min. Cycling, jogging, (nordic-) walking. 24 hours rest, training volume increased every 4 wk by 10%.	
Muñoz-Poblete et al (2019)	105 IG – intervention group: 52 (M: 83.2%; F: 16.98%) CG – control group: 53 (M: 78.6%; F: 21.4%) Age IG: 29.03 ± 5.38 Age CG: 28.36 ± 5.42	Progressive resistance; training was bilateral, focusing on three areas of the body: scapular waist zone, shoulder zone, forearm-hand zone- started with a pre-tensioned rubber band, concentric contraction, isometric contraction (6 sec), eccentric contraction. Pause between each cycle (10 sec). Phase 1 (48 sessions): shoulder stabilizing muscles with three progressive levels of resistance using the Theraband of 4.6 kg, 6.3 kg and 8.5 kg for 16 sessions each. Phase 2 (36 sessions): three progressive levels of resistance, Theraband of 4.6 kg, 6.3 kg and 8.5 kg for 12 sessions each. Phase 3 (24 sessions): three progressive levels of resistance, Theraband of 4.6 kg, 6.3 kg and 8.5 kg for 8 sessions each. Women carried out the same protocol as men, but with a lower resistance, Theraband of 3.2 kg, 4.6 kg and 6.3 kg. The control group maintained a daily routine established by both companies consisting of stretching exercises. These exercises consisted of limb movements to stretch musculoskeletal tissues.	16 weeks 3 d/w 15 min
Kang et al (2018, finger)	29 (M) IG – intervention group: 15 CG – control group: 14 Age IG: 46.7 ± 4.6 Age CG: 47.9 ± 4.0	Paraffin bath therapy: temperature 50 °C, subjects dipped the affected hand into the paraffin, removed the hand, and waited for the layer of paraffin to harden and become opaque. Then they redipped the affected hand. These procedures were repeated 10 times. Later the affected hand was covered with a towel for 20 min. Finger exercise program: four exercises [finger stretch (1), roll into a first (2), make an "O-sign" (3), thumb abduction/extension (4)]. After the paraffin bath, exercise 2-6 for 15 reps, Intensity was determined through 10 RM. 1st-2nd wk: 10 reps 3rd-8th wk: 15 reps	8 weeks 5 d/w 30 min/d

Kang et al (2018, lowback)	24 SSG – stable surface group: 12 USG – unstable surface group: 12 Age SSG: 43.41 ± 5.96 Age USG: 42.83 ± 6.99	10-min hot pack treatment at 80 °C, 15-min interferential current therapy (2000–2500 Hz), and 5-minute ultrasonic treatment (0.8–1 MHz). Later, familiarization period (30 sec) of lumbar stabilization exercises. 5 min warm-up and stretching protocol, 20 min main (elbow-toe, back bridge, side bridge, curl up, 10-20 rep/set and 30 sec rest), 5 min cool down and stretching protocol. 1st-2nd wk: 3 sets, 10 reps 3rd-4th wk: 3 sets, 15 reps 5th -6th wk: 3 sets, 20 reps	6 weeks 5 d/w 30 min/d
Lowe et al (2017)	66 IG – intervention group: 37 CG – control group: 29 Age IG: 33.3 ± 8.61 Age CG: 37.4 ± 10.26	Resistance band (Therabands, The Hygenic Corporation, Akron, Ohio) strengthening movements and stretching/lengthening of the pectoralis and trapezius muscles. Stretches to be less than 30-sec.	12 months As many sessions per week as possible 15 min/d
Malarvizhi et al (2017)	30 (M) IG – intervention group: 15 CG – control group: 15	1st-2nd wk: free exercises, Codman's pendular exercises, wall climbing, sideways, circling and strengthening exercises for all the shoulder muscles with dumbbells (max 10 reps). 3rd-4th wk: strengthening exercises, external/internal rotators. 5th-6th wk: stretches, stretch for pectoralis minor, anterior/posterior shoulder, minimize awkward postures, handling tools (power tools create less torque than air tools, reducing forces).	6 weeks
Krüger et al (2015)	14 (M) IG – intervention group: 7 CG - control group: 7 Age IG: 26.4 ± .2 Age CG: 28.1 ± .5	Subjects were tested for their strength (1RM). Strength training for trapezius (shoulder press machine in a standing position), forearm extensor and flexor m, infraspinatus m, deltoid m., erector spinae m., biceps and triceps and abdominis m. 3 sets, 12-15 reps, 90" rest between exercises; 3' rest between sessions. Subjects exercised at an intensity of 70–75% of 1RM. Intensity was measured using RPE.	12 weeks 2 d/w, at the same time each day 60 min/d
Rasotto et al (2015)	60 (F) IG – intervention group: 30 CG - control group: 30 Age IG: 38.05 ± 6.07	1 month: first part (~8 minutes) included warm-up exercises at very low intensities; mobilization exercises of shoulder and upper limbs. 3 sets for each exercise Second part: strength training, 15 minutes, intensity was targeted between 5 to 7 on a perceived exertion scale of 0 to 10.	6 months 2 d/w 30 minutes

	Age CG: 40.32 ± 6.32	At the end of each training session, approximately 8 minutes were dedicated to the cool down, using six additional stretching positions maintained from 60 to 90 seconds. The CG received no intervention.	
Bertozzi et al (2014)	40 (70% F) IG - intervention group: 20 CG - control group: 20 Age IG: 42.7 ± 8.7 Age CG: 47.5 ± 7.5	The 20 participants allocated to the EG were further divided into four subgroups. They received the same intervention in 10 treatment sessions. The worker could choose when to perform them. The same group also performed a home exercise protocol. Simple postural exercises, relaxation, stretching and extension aimed at the lumbar spine and lower limbs. Same sequence of exercise to be able to perform the exercise also at home. The 20 participants allocated to the comparative group study performed the exercise protocol only at home. Pain intensity was measured with a 10-cm VAS.	5 weeks 2 d/w 1 hour
Moreira-Silva et al (2014)	70 (M, F) IG (TOI) - intervention group: 39 CG (TOR): reference group 31 Age IG: 38.8 ± 8.6 Age CG: 38.0 ± 6.9	The training sessions were given during work time. Stretching exercises: hands, wrists, elbows, shoulders, neck, and dorsal and lumbar regions. Strengths were included: lower extremities. Intimate to do some aerobic training at home.	6 months 3 d/w 10-15 min
Rasotto et al (2014)	68 (M) IG - intervention group: 34 CG - control group: 34 DROP OUT IG: 17 Age IG: 41.65 ± 8.26 Age CG: 40.88 ± 7.55	1st month: general exercise familiarization. Three parts in each training sessions: Warm up: 8', at very low intensity, mobilization of lumbar-, dorsal- and cervical-spine, shoulder and upper-limb. 3 sets x 5 reps, 30" rest between exercise. Strength exercises: 15', were performed with low weight dumbbells and elastic bands and were upper-limb abductions/adductions on transverse plane, shoulder flexions/ex- tensions, shoulder abductions/adductions, pushes forward, and lateral pushes. Intensity was set from 5 to 7 on a scale 0 to 10. Cool Down: 7 / 8', stretching positions maintained from 60 to 90 s. Stretching intensity was maintained at moderate intensity. Participants allocated in the CG were invited to continue in performing their normal daily activities.	9 months 2 d/w 30 min for session

Sundstrup et al (2014, disability)	66 (M, F) STG - strength training group: 33 (25M, 8F) ETG - ergonomic training group: 33 (26M, 7F) Age STG: 48 ± 9 Age ETG: 43 ± 9	STG performed supervised high-intensity strength training for the shoulder, arm, and hand muscles during 3 sessions of 10 minutes. Training intensity (loads) was progressively increased from 20 repetition maximum to 8 RM during the later phase. EG received ergonomic training addressing job-specific training where participants received appropriate guidance and training in how to correctly handle the individual work task stations.	10 weeks 3 d/w 10 min per session
Sundstrup et al (2014, upperlimb)	66 (M, F) RTG - resistance training group: 33 (25M, 8F) ETG- ergonomic training group:: 33 (26M, 7F) Age RTG: 48 ± 9 Age ETG: 43 ± 9	STG performed supervised high-intensity strength training specifically for the shoulder, arm, and hand muscles during 3 sessions of 10 minutes. The training program consisted of 8 exercises: 1 - 2: shoulder rotation in 2 planes with elastic tubing, 3 - 4: ulnar and radial deviation of the wrist using sledgehammers, 5: eccentric training of the wrist extensors using a FlexBar, 6: wrist flexion and extension by the use of a wrist roller, 7: flexion of the hand using a hand gripper, 8: extension of the hand and fingers using expand-your-hand bands. Training intensity (loads) was progressively increased from 20 RM to 8 RM during the later phase. EG received ergonomic training addressing job-specific training where participants received appropriate guidance and training in how to correctly handle the individual work task stations.	10 weeks 3 d/w 10 min per session
Pedersen et al (2013)	537 TG1 - training group 1: 282 (80% F) TG2 - training group 2: 255 (89% F) Age TG1: 42 ± 10 Age TG2: 42 ± 11	TG1 performed strength training for the shoulder, neck and arm with dumbbells (wrist extension, shoulder lateral raise, shoulder front raise, shoulder shrugs, reverse flies) 20 min, 3 times per week, for 20 weeks. Training loads were progressively increased from moderate loadings of 15-20 RM during the initial weeks to relatively heavier loadings of 8-12 RM during the final weeks. Adherence was quantified from questionnaire replies on training frequency at follow-up. After 20 weeks TG2 was offered the same training as TG1 did the first 20 weeks for half a year until January 2010. Participants in TG1 were allowed to continue training until 2010 but without supervision or any form of guidance. TG1 was not allowed to train, when TG2 had supervised training. However, they were allowed to train during working hours as previously and the management was positive to this continued training.	20 weeks - 1 year TG1: strength training 20' x 3d/w from 15-20 RM to 8-12 RM TG2: same as TG1 after 20 weeks

Gram et al (2012)	67 (M) EG - exercise group: 35 CG - control group: 32 Age EG: 44 ± 11.1 Age CG: 43 ± 10.0	All training sessions included 10-minute dynamic exercises for warm-up and aerobic capacity (increasing from ~50% to 70% estimated maximal workload) followed by 10 minutes with the individually tailored exercises. The intensity of the muscle strength training was approximately 60% 1RM, and the intensity of the aerobic capacity training was at least 70% of Vo2max. The intensify was measured and adjusted if needed 2 times during the 12-week training period. The control group was not offered exercise training, but was given a 1-hour lecture on general health promotion. Pain Intensity from 0 to 10 (BORG)	12 weeks 1 hour a week 3 x 20 minutes
Mesquita et al (2012)	98 (M) IG – intervention group: 57 CG – control group: 41 Age IG: 33.50 ± 8.17 Age CG: 27.40 ± 6.25	An isometric electronic dynamometer was used to measure the resistance (in seconds) and maximal isometric strength (in Kgf) of trunk flexors and extensors. This program included 9 easily-executed exercises to promote stretching and strengthening of soft tissues responsible for spinal stability, especially lumbar stability. This program was being executed daily for 8' ca, at the beginning of the working time, at the company facilities. To motivate the workers to adhere to the program and follow it, there were several training sessions and posters illustrating the exercise program to execute were distributed at the company facilities. The program efficacy was evaluated twice – at baseline and 11 months later. A physiotherapists visited the warehouse facilities every 15 days, to correct the exercises executions and to evaluate the programme efficacy. All evaluations were preceded by a 5 minute warming up, which involved some calisthenic exercises.	11 months 8 min daily on working days
Zebis et al (2011)	537 TG - training group: 282 (80% F) CG – control group: 255 (89% F) Age TG: 42 ± 11 Age CG: 42 ± 10	The intervention took place over a 20-week period with questionnaires sent out in January 2009 and June 2009. Training group used 1H/week during work hours for the specific training program. Experienced instructors introduced the program in small groups and then the subjects were allowed to train on individual basis or in self organized groups. TG performed high-intensity specific strength training locally for the neck and shoulder muscles with 4 different dumbbell exercises and 1 exercise for the wrist extensor muscles. The training regime consisted of three sessions per week, each lasting 20 minutes. After two introductory training sessions relative loadings were progressively increased - from 15 RM ~70% of maximal intensity at the beginning of the training period (week 1-12) - to 8-12 RM ~75-85% of maximal intensity during the later phase (week 13-20). Slow to moderate lifting velocity in EC and CC.	20 weeks 3 d/w > 20 min

		Participants in the control group received advice to stay physically active and were consulted once a week by a supervisor during the 20-week period. After the 20 weeks intervention period, the control group was offered an equivalent 20 weeks training period - i.e. 1 hour a week during work hours.	
Camargo et al (2009)	14 (M) Age: 31.93 ± 5.86	A standardized intervention consisting of cryotherapy, stretching, and strengthening exercises: trapezius, pectoralis minor and posterior shoulder stretching, lateral rotation, scapular retraction, serratus anterior, shoulder abduction strengthening exercises with bands. The intervention was performed for eight consecutive weeks, twice a week, on alternate days. All sessions were supervised by the same physiotherapist and completed during working hours in the physiotherapy room at the industry site. Stretch: 3 reps of 30'', rest 30" strength: 3 sets of 10 reps, rest 30" 20' of cryotherapy Progression of intervention program: Weeks 1-2; yellow band Weeks 3-4; red band Weeks 5-6; green band DASH and McGill Pain Questionnaire.	8 weeks 2 d/week, on alternate days
Cheng et al (2007)	94 CWH - Clinic-based work hardening training: 48 (35 M, 13 F) WWH - Workplace-based work hardening training: 46 (37 M, 9 F) Age CHW: 32.1 ± 10.33 Age WWH: 32.6 ± 10.13	Three sessions a week in both CWH and WWH group. The training content in the CWH group was comprised of mobilization activities for upper limb extremities, strength and endurance training as well as work simulation. In addition, it was also ensured that CWH group workers did not receive any workplace-based intervention such as on-site job analysis, job placement or liaison with the superior or employer. The Training for WWH was Static stretching methods for posterior, anterior and inferior shoulder structure are performed slowly. Shoulder stretch. Stretching exercises for the shoulder were used as warm up exercises to decrease the resistance of soft tissues. Static stretching methods for posterior, anterior and inferior shoulder structure are performed slowly and held for at least 15 s each time, one set of 10 stretches for each one.	4 weeks 3d/week

		Scapular control exercises (3 sets x 10 each) are closed chain exercises in which the hand of the injured shoulder is placed against the wal: Scapular elevation, depression, protraction and retraction, wall push-ups and knee push-ups. Strengthening isometric exercises (3 sets x 10 each) for shoulder (shoulder abduction, shoulder adduction, shoulder flexion, shoulder extension, shoulder external rotation and shoulder internal rotation) and specifically for rotator cuff muscle were started immediately after the scapular control exercises, and also progressive resistive dynamic exercises (holding a bottle of distilled water for 15 min) The training program was based on Phase 2 (the recovery phase) & Phase 3 (the functional phase)	
Ludewig et al (2002)	92 (M) IG – intervention group: 34 SCG - symtomatic control group: 33 ACG - asymptomatic control group: 25 Age IG: 48 ± 1.8 Age SCG: 49.2 ± 1.8 Age ACG: 49.4 ± 2.5	Subjects in the control groups received no intervention. Subjects returned after 8-12 weeks for follow up testing. Stretching: 2x30s each repetition and five repetitions each day. One for the pectoralis minor and one for the posterior shoulder. A muscle relaxation exercise for the upper trapezius was performed five times daily by having the subjects raise the arm overhead in the scapular plane without shrugging the shoulder. Relaxation was enhanced through visual input by performing the exercise in front of a mirror, or by proprioceptive input by placing the uninvolved hand on the active upper trapezius. Progressive RT: three days per week for two muscle groups. For the serratus anterior muscle, strengthening was performed supine by protracting the scapula and raising a handheld weight superiorly. Humeral external rotation was resisted with Thera-Band while subjects were in a standing position. Subjects were instructed to progress from an initial position of the arm close to their side, to a position of abduction of the arm. Week 1: 3x10 Week 2: 3x15 Week 3: 3x20 After achieving 3x20 repetitions for three consecutive sessions, subjects were to further progress their program by increasing weight resistance or Thera-Band tension (by shortening the band), and repeating the repetition sequence as described. Subjects were instructed that exercises may induce muscle fatigue but should not cause increased shoulder pain.	8 weeks daily for flexibility and stretching exercise 3 d/w for both strengthening exercises 3x10 week 1 3x15 week 2 3x20 week 3 (3 sessions) then increasing weight resistance or Thera-Band tension
Nurminen et al (2002)	260 (F)	The sessions lasted 60 minutes once a week during workhours and totaled 26 sessions over an 8-month period. The adherence to the intervention and the mode of exercise were rated on a participation form	8 months 1 d/w x 26 times 1h

	IG – intervention group: 133 CG – control group: 127 Age IG: 40.7 Age CG: 39.1	that the physiotherapist filled out after each session. Two additional 60-minute reinforcement sessions were arranged for the intervention group in the autumn of 1997 to promote physical activity. The group sessions consisted of moderate worksite exercise based on a guidebook published by the Finnish Institute of Occupational Health for promoting work ability and physical activity through group exercise. The program involved muscle strengthening, cardiovascular exercise, and stretching. The exercise intensity increased progressively, the mean of the perceived exertion rating being 7.8 (SD 4.7) in the spring at the third exercise session and 8.6 (SD 4.4) at tenth session, on a scale of 0–10.	Two additional 60' reinforcement sessions at 14 months

d/w: day/week;

Table B3: Studies outcomes.

Author (year)	**Group**	**Pain and disabilities**	**Health-related physical fitness**	**Cardiological parameters**
Gobbo et al (2021)	RT	L-VAS, 4.08 ± 3.08 to 4.22 ± 3.46 DASH, $p < .03$ * 20.69 ± 16.20 to 16.04 ± 12.95	2-minutes step test, $p < .01$ ** 76.29 ± 22.81 to 91.00 ± 22.50 Chair sit and reach R (cm), $p <.03$ * - 9.54 ± 11.31 to - 5.22 ± 10.64 Chair sit and reach L (cm), $p < .04$ * - 7.71 ± 11.58 to - 3.65 ± 10.02 Back scratch R (cm), - 0.86 ± 7.16 to 0.25 ± 7.67 Back scratch L (cm), - 4.90 ± 8.75 to - 3.55 ± 7.98 Handgrip test R (kg), $p < .01$ ** 42.81 ± 8.76 to 46.58 ± 7.87 Handgrip test L (kg), $p < .02$ * 40.63 ± 7.42 to 42.84 ± 5.89	
Cimarras-Otal et al (2020)	IG	ODI 17 ± 16.42 to 18.6 ± 14.67 BPI short form Pain intensity in last 24 hours (total) 3.9 ± 2.05 to 2.85 ± 2.3 Maximum pain 5.2 ± 2.74 to 4 ± 2.91 Minimum pain 2.3 ± 1.89 to 1.8 ± 1.99 Average pain 4.2 ± 2.3 to 3.3 ± 2.67 Pain at time of completion 3.9 ± 2.18 to 2.3 ± 2.36	General activities 4.9 ± 3.18 to 2.9 ± 2.85 Mood 3.4 ± 3.06 to 1.8 ± 2.44, $p <.05$ * Walking 1.1 ± 1.91 to 0.6 ± 1.07 Usual work 4.2 ± 3.26 to 3.1 ± 3.14 Relations with others 2 ± 2.67 to 1 ± 1.94 Sleep 3.6 ± 3.75 to 2.9 ± 3.21	

		Pain interference (total) 3.23 ± 2.48 to 2.03 ± 2.11, $p < .01$ **	Enjoyment 3.4 ± 3.13 t 1.9 ± 2.47 F/R test Flexion angle (°) 68.38 ± 9.47 to 75.94 ± 8.34, $p < .05$ * Flexion speed (°/sg) 31.33 ± 8.47 to 31.33 ± 9.25 FER spinalis (uV) 1.10 ± 0.97 to 0.90 +. 0.60	
	CG	ODI[a] 16.75 ± 13.09 to 12.25 ± 12.98 BPI short form Pain intensity in last 24 hours (total) 4.75 ± 1.16 to 3.44 ± 1.19, $p < .05$ * Maximum pain 7.63 ± 2 to 5.5 ± 2.33 Minimum pain 3.13 ± 2.03 to 2 ± 1.77 Average pain 5 ± 1.41 to 3.63 ± 1.51 Pain at time of completion 3.25 ± 1.67 to 2.63 ± 1.77 Pain interference (total) 3.91 ± 3.21 to 2.82 ± 2.04	General activities 4.38 ± 3.2 to 2.75 ± 2.66 Mood 4.88 ± 4.29 to 3.38 ± 3.54 Walking 3.5 ± 3.85 to 1.38 ± 2.5 Usual work 3.88 ± 2.95 t 3.13 ± 1.64 Relations with others 3.38 ± 3.85 to 1.75 ± 2.76 Sleep 3.5 ± 2.83 to 3.88 ± 3.36 Enjoyment 3.88 ± 3.91 to 3.5 ± 3.63 F/R test[c] Flexion angle (°) 74.32 ± 13.89 to 72.86 ± 12.56 Flexion speed (°/sg) 33.69 ± 10.47 to 22.56 ± 6.63 FER[e] spinalis (uV) 0.95 ± 0.33 to 1.07 ± 0.32	
Weyh et al (2020)	ETG	RPEmax (Borg) StOP: 16 ± 2 to 15 ± 2, $p \leq .05$* SiBP: 15 ± 1 to 13 ± 2, $p \leq .05$*	Erector spinae m. StOP: 6.1 ± 4.4 to 5.6 ± 2.9 SiBP: 7.9 ± 5.6 to 6.4 ± 3.9, $p \leq .05$*	SBPmax (mm Hg) StOP: 154 ± 16 to 158 ± 18 SiBP: 151 ± 19 to 143 ± 13

	Weight (kg) 92.0 ± 20.7 to 90.8 ± 20.0 BMI (kg/m^2) 29.3 ± 6.5 to 28.6 ± 6.2 Fat mass (%) 25 ± 7 to 23 ± 6, $p \leq .05$* Muscle mass (%) 54 ± 5 to 55 ± 5, $p \leq .05$*	VASmax (mm) StOP: 48 ± 23 to 40 ± 25 SiBP: 37 ± 21 to 26 ± 17 PCS (SF-36-score) 52.7 ± 4.8 to 52.4 ± 4.4 MCS (SF-36-score) 52.3 ± 4.0 to 53.2 ± 5.5	Infraspinatus m. StOP: 12.4 ± 4.9 to 11.7 ± 5.7, $p \leq .05$* SiBP: 11.7 ± 4.7 to 9.3 ± 4.3 Deltoideus m. StOP: 17.5 ± 7.8 to 17.2 ± 7.2 SiBP: 8.3 ± 5.1 to 6.5 ± 3.9 Pectoralis major m. StOP: 11.4 ± 6.8 to 11.9 ± 7.9 SiBP: 2.5 ± 3.5 to 3.1 ± 5.8 Extensor dig. long m. StOP: 14.3 ± 4.5 to 16.7 ± 6.6 SiBP: 6.8 ± 7.1 to 8.6 ± 5.4, $p \leq .05$* Biceps b. m. StOP: 2.6 ± 1.4 to 3.2 ± 2.3 SiBP: 5.3 ± 5.0 to 4.2 ± 2.9 Triceps b. m. StOP: 2.7 ± 1.6 to 3.1 ± 3.7 SiBP: 3.8 ± 3.8 to 3.5 ± 4.3 Arm flexion (Nm) 132.9 ± 34.0 to 138.1 ± 33.3 Arm extension (Nm) 70.5 ± 17.5 to 74.7 ± 21.6 Knee flexion (Nm) 201.4 ± 63.1 to 216.5 ± 71.3 Knee extension (Nm) 371.1 ± 111.6 to 399.5 ± 108.2 Trunk flexion (Nm) 151.8 ± 50.6 to 167.1 ± 57.9 Back extension (Nm) 259.2 ± 109.4 to 287.1 ± 91.8; $p \leq .05$*	DBPmax (mm Hg) StOP: 109 ± 13 to 105 ± 10 SiBP: 103 ± 11 to 97 ± 10 HRmax (beats/min) StOP: 98 ± 16 to 91 ± 11; $p \leq .05$* SiBP: 87 ± 16 to 80 ± 15; $p \leq .05$* EWT-duration (s) StOP: 439 ± 62 to 468 ± 31; $p \leq .05$* SiBP: 464 ± 50 to 476 ± 20 Maximum bicycle performance (W) 206 ± 34 to 226 ± 37; $p \leq .05$* Relative bicycle performance (WAg/BW) 2.3 ± 0.6 to 2.5 ± 0.6; $p \leq .05$*

	STG Weight (kg) 87.7 ± 12.0 to 88.2 ± 11.7 BMI (kg/m^2) 27.9 ± 3.5 to 28.0 ± 3.5 Fat mass (%) 23 ± 6 to 21 ± 5; $p \leq .05$* Muscle mass (%) 54 ± 4 to 57 ± 4; $p \leq .05$*	RPEmax (Borg) StOP: 16 ± 2 to 15 ± 2; $p \leq .05$* SiBP: 15 ± 2 to 14 ± 2 VASmax (mm) StOP: 50 ± 29 to 34 ± 27; $p \leq .05$* SiBP: 41 ± 24 to 30 ± 25 PCS (SF-36-score) 45.7 ± 7.8 to 52.0 ± 4.8 MCS (SF-36-score) 50.6 ± 8.6 to 53.2 ± 5.2	Erector spinae m. StOP: 5.7 ± 4.2 to 4.9 ± 2.5 SiBP: 6.9 ± 4.7 to 5.9 ± 3.9; $p \leq .05$* Infraspinatus m. StOP: 11.3 ± 7.3 to 8.4 ± 5.2; $p \leq .05$* SiBP: 9.7 ± 5.4 to 9.4 ± 7.0 Deltoideus m. StOP: 14.5 ± 4.6 to 12.0 ± 6.2 SiBP: 7.6 ± 6.4 to 6.2 ± 4.0 Pectoralis major m. StOP: 9.9 ± 5.2 to 12.0 ± 7.1 SiBP:.5 ± 2.4 to 6.1 ± 6.1; $p \leq .05$* Extensor dig. long m. StOP: 14.5 ± 6.2 to 14.7 ± 5.5 SiBP: 9.8 ± 5.2 to 9.6 ± 6.0 Biceps b. m. StOP: 4.7 ± 3.8 to 2.9 ± 2.5 SiBP: 6.0 ± 4.9 to 4.2 ± 3.2 Triceps b. m. StOP: 5.7 ± 3.9 to 4.4 ± 4.7 SiBP: 7.6 ± 4.3 to 6.5 ± 5.9 Arm flexion (Nm) 131.1 ± 24.9 to 135.9 ± 28.5 Arm extension (Nm) 75.1 ± 20.9 to 77.3 ± 19.1 Knee flexion (Nm) 188.4 ± 49.8 to 202.3 ± 53.7 Knee extension (Nm) 390.1 ± 92.8 to 416.2 ± 120.7 Trunk flexion (Nm) 143.1 ± 44.8 to 169.1 ± 60.5 Back extension (Nm)	SBPmax (mm Hg) StOP: 152 ± 24 to 150 ± 17 SiBP: 150 ± 23 to 150 ± 23 DBPmax (mm Hg) StOP: 103 ± 12 to 103 ± 10 SiBP: 100 ± 12 to 102 ± 18 HRmax (beats/min) StOP: 100 ± 16 to 95 ± 14 SiBP: 89 ± 15 to 84 ± 12 EWT-duration (s) StOP: 424 ± 67 to 458 ± 45; $p \leq .05$* SiBP: 471 ± 33 to 478 ± 11 Relative bicycle performance (WAg/BW) 2.5 ± 0.7 to 2.7 ± 0.6

			299.7 ± 93.0 to 373.2 ± 111.9; $p \leq .05$*	
	CG Weight (kg) 87.8 ± 17.1 to 88.2 ± 18.8 BMI (kg/m^2) 28.2 ± 4.5 to 28.2 ± 4.5 Fat mass (%) 23 ± 6 to 24 ± 6 Muscle mass (%) 54.6 ± 47 to 199 ± 43	RPEmax (Borg) StOP: 16 ± 3 to 16 ± 3 SiBP: 14 ± 4 to 15 ± 3 VASmax (mm) StOP: 48 ± 30 to 52 ± 28 SiBP: 39 ± 29 to 47 ± 26 PCS (SF-36-score) 50.8 ± 6.0 to 49.7 ± 7.3 MCS (SF-36-score) 51.4 ± 7.4 to 50.1 ± 9.2	Erector spinae m. StOP: 6.7 ± 5.2 to 6.7 ± 4.1 SiBP: 4.6 ± 3.0 to 6.8 ± 4.9; $p \leq .05$* Infraspinatus m. StOP: 12.0 ± 9.7 to 10.6 ± 6.1; $p \leq .05$* SiBP: 9.8 ± 6.2 to 10.5 ± 5.9 Deltoideus m. StOP: 16.5 ± 6.2 to 17.2 ± 7.2 SiBP: 9.5 ± 6.2 to 8.9 ± 4.0 Pectoralis major m. StOP: 12.0 ± 6.4 to 11.8 ± 6.4 SiBP: 2.7 ± 2.2 to 2.2 ± 1.9; $p \leq .05$* Extensor dig. long m. StOP: 16.2 ± 8.0 to 14.6 ± 6.8	SBPmax (mm Hg) StOP: 156 ± 27 to 157 ± 24 SiBP: 155 ± 24 to 152 ± 23 DBPmax (mm Hg) StOP: 107 ± 13 to 105 ± 10 SiBP: 107 ± 14 to 103 ± 12 HRmax (beats/min) StOP: 99 ± 14 to 95 ± 15 SiBP: 87 ± 11 to 84 ± 10 EWT-duration (s) StOP: 428 ± 77 to 428 ± 79 SiBP: 463 ± 47 to 463 ± 47 Maximum bicycle performance (W) 202 ± 47 to 199 ± 43

			SiBP: 8.9 ± 4.8 to 10.0 ± 7.2 Biceps b. m. StOP: 3.3 ± 2.9 to 4.1 ± 3.3 SiBP: 3.7 ± 2.5 to 4.2 ± 3.4 Triceps b. m. StOP: 4.2 ± 3.1 to 8.0 ± 9.2 SiBP: 4.9 ± 3.5 to 8.9 ± 8.6 Arm flexion (Nm) 129.1 ± 23.4 to 131.5 ± 18.1 Arm extension (Nm) 71.0 ± 23.4 to 67.8 ± 19.6 Knee flexion (Nm) 206.5 ± 59.8 to 208.1 ± 45.9 Knee extension (Nm) 409.6 ± 120.8 to 394.4 ± 122.6 Trunk flexion (Nm) 181.1 ± 70.9 to 162.3 ± 56.0 Back extension (Nm) 337.0 ± 126.9 to 303.0 ± 132.6	Relative bicycle performance (WAg/BW) 2.4 ± 0.5 to 2.4 ± 0.5
Muñoz-Poblete et al (2019)	IG	Pain intensity VAS 0–100 mm Upper limb 8.0 ± 7.1 to 5.4 ± 8.8; *p <.007* ** Neck 5.8 ±15.1 to 1.1 ± 5.4; * Right shoulder 10.9 ±21.1 to 8.5 ±20.3; Left shoulder 8.8 ± 21.2 to 6.5 ±15.9 Right elbow-forearm 6.7 ±12.9 to 4.3 ±14.2; *p <.016* * Left elbow-forearm	Everyday functional difficulties in the last week (%), *p < .112* to *p <.018* * None: 54.7 to 86.54 Few: 17.1 to 11.54 Moderate: 28.2 to 1.92 Substantial: - A lot: - Everyday working difficulties in the last week (%) None: 34.7 to 71.15 Few: 25.2 to 17.31 Moderate: 23.1 to 9.62 Substantial: 17.0 to 1.92 A lot: - Difficulty in performing work (%), *p < .303* to *p <.041**	

		4.8 ±13.2 to 5.3 ±16.4 Right wrist-hand 10.6 ±19.7 to 4.5 ±16.4; *p <.034 ** Left wrist-hand 6.2 ±16.4 to 1.1 ±5.4; *p <.013 ** Functionality initial DASH: 0–105 points 27.2 ±8.9 to 25.8 ±8.7; *p <.037 **	None: 49.1 to 78.85 Little difficulty: 14.2 to 3.85 Moderate difficulty: 9.8 to 3.85 Great difficulty: 26.9 to 9.62 Incapable: - to 3.85 Difficulty in performing work as well as you would wish (%) *p <.282* to *p<.021** None: 31.5 to 71.15 Little difficulty: 19.2 to 13.46 Moderate difficulty: 21.2 to 5.77 Great difficulty: 28.1 to 9.62 Incapable: -	
	CG	Pain intensity VAS 0–100 mm Upper limb 9.7 ± 10.4 to 10.4 ± 11.3; *p <.007 ** Neck 9.9 ± 18.9 to 6.6 ± 17.6; *p <.045 ** Right shoulder 12.4 ± 23.9 to 11.1 ± 21.9 Left shoulder 7.4 ± 16.7 to 6.6 ± 17.6 Right elbow-forearm 10.4 ± 19.9 to 12.8 ± 24.6; *p <.016 ** Left elbow-forearm 5.6 ±16.7 to 8.7 ±21.5 Right wrist-hand 13.9 ±26.0 to 12.2 ±25.5; *p <.034 ** Left wrist-hand 8.7 ±21.8 to, 10.9 ±20.8, p<.013 * Functionality initial DASH: 0–105 points 27.2 ±8.9 to 28.7 ±9.1; *p <.037 **	Everyday functional difficulties in the last week (%), *p < .112 to p <.018** None: 56.4 to 71.7 Few: 21.3 to 9.43 Moderate: 22.3 to 18.87 Substantial: - A lot: - Everyday working difficulties in the last week (%), None: 32.3 to 43.40 Few: 28.1 to 32.0 Moderate: 19.4 to 16.98 Substantial: 20.2 to 5.66 A lot: - to 1.89 Difficulty in performing work (%), *p < .303 to p <.041** None: 48.3 to 64.15 Little difficulty: 12.2 to 1.89 Moderate difficulty: 11.5 to 13.21 Great difficulty: 28.1 to 18.87 Incapable: - to 1.89 Difficulty in performing work as well as you would wish (%) *p <.282 to p <.021** None: 33.6 to 45.28 Little difficulty: 17.8 to 26.42 Moderate difficulty: 22.4 to 20.75	

			Great difficulty: 26.2 to 7.55 Incapable: -	
Kang et al (2018, finger)	IG	Pain 63.67 ± 9.42, to 42.07 ± 5.26, *p < .001*** Difference (pain, AUSCAN index) 21.6 ± 8.3	Hand grip strength 15.62 ± 2.96, p < .88 to 19.14 ± 3.88, *p < .001*** Stiffness: 56.33 ± 8.9, p < .64 to 42.47 ± 7.20, *p < .001 *** Physical function 67.73 ± 9.42, p < .91 to 50.93 ± 7.01 6.37, *p < .001***	
	CG	Pain 64.36 ± 9.36 to 56.50 ± 6.19 Difference (pain, AUSCAN index) 7.9 ± 5.5	Hand grip strength 15.46 ± 2.31, p < .88 to 16.04 ± 2.29, *p < .05 ** Stiffness 57.93 ± 9.34, p < .64 to 50.50 ± 9.20, *p < .001 *** Physical function 68.07 ± 6.72, p < .91 to 56.64 ± 5.26, *p < .001 ***	
Kang et al (2018, lowback)	IG	VAS: 5.1 ± 0.5 to 3.0 ± 1.0 p<0.05 pre-post and vs CG Owestry Disability Index: 36.8 ± 1.3 to 32.5 ± 1.5 p<0.05 pre-post and vs CG	Back muscle strength: 32.9 ± 2.7 to 34.6 ± 1.6 p<0.05 pre-post and vs CG Stork balance stand test: 13.1 ± 3.5 to 25.1 ± 6.1 p<0.05 pre-post and vs CG	
	CG	VAS: 5.0 ± 0.3 to 1.6 ± 0.3 p<0.05 pre-post Owestry Disability Index: 37.5 ± 2.0 to 24.4 ± 1.3 p<0.05 pre-post	Back muscle strength: 33.8± 1.3 to 40.4 ± 1.6 Stork balance stand test: 13.1 ± 1.4 to 33.1 ± 8.0 p<0.05 pre-post	

Lowe et al (2017)	IG	SRQ 83.8 ± 12.1 to 87.5 ± 12.3 DASH 12.1 ± 13.2 to 21.2 ± 11.8 Nordic questionnaire (% last 12 months) 64.5 to 54.9 Nordic questionnaire (% last 12 months) 22.3 to 25.7 Nordic questionnaire (% 7 days) 38 to 21.4		
	CG	SRQ 81.1 ± 12.3 to 74.0 ± 20.8 DASH 16.0 ± 12.0 to 21.2 ± 18.2 Nordic questionnaire (% last 12 months) 89.6 to 92.1 Nordic questionnaire (% last 12 months) 26.1 to 41.6 Nordic questionnaire (% last 7 days) 52.5 to 44.4		
Malarvizhi et al (2017)	IG (A)	VAS 5.87 ± .352 to 1.60 ± .507, $p < .000$*** SPADI 47.2893 ± 3.95766 to 10.5073 ± 2.90073, $p < .001$** EG (A) vs CG (B) VAS A: 1.60; B: 2.80; 2.20 ± .761, $p < .000$*** SPADI A: 10.507; B: 16.868; 13.688 ± 4.1919, $p < .001$**		

	CG (B)	VAS 5.80 ± .414 to 2.80 ± .414, $p < .000$*** SPADI 43.1240 ± 7.59179 to 16.8681 ± 2.51144, $p < .001$**		
Krüger et al (2015)	IG	Sitting position: Rating of Perceived Exertion during welding 14.50 ± .2 to 12.57 ± .20, $p < .05$ * Standing position: Rating of Perceived Exertion during welding 18.71 ± .57 to 16.44 ± .44, $p < .05$ *		Sitting position: Heart Rate (bpm) 74.57 ± 3.41 to 73.00 ± 4.34 Systolic Blood Pressure (mmHg) 134.43 ± 5.12 to 123.71 ± 4.56 Diastolic Blood Pressure (mmHg) 88.86 ± 5.51 to 84.86 ± 1.44 Lactate (mmol/L) .97 ± .14 to 1.16 ± .22 Standing position: Heart Rate (bpm) 84.29 ± 9.40 to 79.29 ± 4.87 Systolic Blood Pressure (mmHg) 143.86± 7.42 to 139.86 ± 4.79 Diastolic Blood Pressure (mmHg) 84.00 ± 9.05 to 92.71 ± 3.01 Lactate (mmol/L) 1.26 ± .13 to 1.36 ± .24

	CG	Sitting position: Rating of Perceived Exertion during welding 13.71 ± .68 to 14.00 ± .31 Standing position: Rating of Perceived Exertion during welding 18.86 ± .34 to 18.57 ± .43		Sitting position: Heart Rate (bpm) 74.86 ± 1.26 to 74.00 ± 1.91 Systolic Blood Pressure (mmHg) 130.71 ± 7.43 to 129.71 ± 3.64 Diastolic Blood Pressure (mmHg) 82.71 ± 3.73 to 89.00 ± 3.04 Lactate (mmol/L) .83 ± .06 to .86 ± .07 Standing position: Heart Rate (bpm) 85.43 ± 3.24 to 75.14 ± 2.41 Systolic Blood Pressure (mmHg) 136.14 ± 5.86 to 139.00 ± 4.55 Diastolic Blood Pressure (mmHg) 89.71 ± 3.61 to 95.43 ± 2.46 Lactate (mmol/L) 1.66 ± .29 to 1.42 ± .27
Rasotto et al (2015)	IG	VAS neck (cm) 4.09 ± 2.88 to 3.73 ± 2.65 VAS shoulder (cm) 2.39 ± 2.58 to 1.76 ± 2.56, $p < .05$* VAS elbow (cm) 1.07 ± 1.93 to 0.65 ± 1.19 VAS wrist (cm) 3.25 ± 2.51 to 1.70 ± 1.85	SH el 164.91 ± 7.25 to 170.12 ± 7.67, $p < .05$* SH ab 162.99 ± 13.42 to 170.05 ± 10.12, $p < .05$* FL head 44.75 ± 10.11 to 45.38 ± 7.48 EX head 54.73 ± 11.66 to 56.03 ± 11.99	

			LI head 35.80 ± 3.86 to 39.56 ± 3.66, $p < .05$* RO head 69.93 ± 11.48 to 74.02 ± 7.62, $p < .05$*	
	CG	VAS neck (cm) 4.81 ± 2.79 to 4.38 ± 3.00 VAS shoulder (cm) 2.03 ± 2.20 to 2.85 ± 2.41 VAS elbow (cm) 0.86 ± 1.51 to 0.51 ± 1.01 VAS wrist (cm) 4.36 ± 2.94 to 3.50 ± 2.55	SH el 167.60 ± 11.48 to 167.05 ± 16.48 SH ab 161.46 ± 16.83 to 160.20 ± 26.15 FL head 42.40 ± 12.50 to 42.59 ± 8.67 EX head 51.56 ± 11.41 to 48.68 ± 7.46 LI head 36.48 ± 5.05 to 37.87 ± 5.55 RO head 73.82 ± 8.39 to 67.60 ± 12.34	
Bertozzi et al (2014)	IG	Cervical VAS 3.9 ± 4.2 to 3.2 ± 3.7 Lumbar VAS 7.3 ± 2.3 to 7.3 ± 2.3 RMDQ 12.8 ± 4.7 to 7.3 ± 4.3 ODI 33.0 ± 17.8 to 20.6 ± 11.8 Difference within groups Cervical VAS -0.7 ± 0.8		

		Lumbar VAS -1.9 ± 0.3, $p < .05$* RMDQ -5.5 ± 1.0, $p < .05$* ODI -12.4 ± 3.6, $p < .05$*		
	CG	Cervical VAS 3.4 ± 3.7 to 3.1 ± 3.6 Lumbar VAS 7.3 ± 2.6 to 6.1 ± 2.4 RMDQ 13.2 ± 5.3 to 10.0 ± 5.2 ODI 39.3 ± 18.7 to 25.5 ± 18.9 <u>Difference within groups;</u> Cervical VAS -0.3 ± 0.8 Lumbar VAS -1.2 ± 0.4, $p < .05$* RMDQ -3.2 ± 1.1, $p < .05$* ODI -13.8 ± 3.7. $p < .05$*		
Moreira-Silva et al (2014)	Reference (TOR) Weight (kg) 68.7 ± 17.6 to 70.5 ± 20.4 BMI (kg/m2) 26.4 ± 3.5 to 27.0 ± 3.8 Weight status (%)	Neck 12 m (% yes) 19 ± 61.3 to 20 ± 64.5 Limit (% yes) 7 ± 22.6 to 6 ± 19.4 7 days (% yes) 9 ± 29.0 to 9 ± 29.0 Pain intensity 2 ± 5 to 3 ± 5 Shoulders		Blood pressure (mmHg) systolic 123.7 ± 14.3 to 127.0 ± 17.1 diastolic 75.5 ± 8.8 to 75.9 ± 10.7 MPVA (min/week) 180 ± 390 to 90 ± 135

	non-overweight 25.8 to 19.4 overweight 54.8 to 54.8 obese 19.4 to 25.8 Body fat (%) ; 30.17 ± 9.61 to 29.3 ± 9.8 Waist circumfer-ence (cm) 91.1 ± 11.8 to 92.7 ± 11.3	12 m (% yes) 18 ± 58.1 to 18 ± 58., Limit (% yes) 6 ± 19.4 to 5 ± 16.1 7 days (% yes) 9 ± 29.0 to 12 ± 38.7 Pain intensity 3 ± 6 to 3 ± 6 Elbows 12 m (% yes) 9 ± 29.0 to 10 ± 32.3 Limit (% yes) 5 ±16.1 to 4 ± 12.9 7 days (% yes) 6 ± 19.4 to 5 ± 16.1 Pain intensity 0 ± 5 to 0 ± 3 Wrists/hands 12 m (% yes) 21 ± 67.1 to 24 ± 77.4 Limit (% yes) 7 ± 22.6 to 8 ± 25.8 7 days (% yes) 11 ± 35.5 to 10 ± 32.3 Pain intensity 3 ± 5 to 4 ± 6 Dorsal region 12 m (% yes) 6 ± 19.4 to 4 ± 12.9 Limit (% yes) 2 ± 6.5 to 2 ± 6.5 7 days (% yes) 2 ±6.5 to 1 ± 3.2 Pain intensity 0 ± 0 to 0 ± 0, Lumbar region 12 m (% yes) 22 ± 71.0 to 23 ± 74.2 Limit (% yes) 9 ± 29.0 to 5 ± 16.1 7 days (% yes)		

		8 ± 25.8 to 8 ± 25.8 Pain intensity 3 ± 5 to 4 ± 4 Hips/thighs 12 m (% yes) 6 ± 19.4 to 9 ± 29.0 Limit (% yes) 3 ± 9.7 to 4 ± 12.9 7 days (% yes) 3 ± 9.7 5 ± 16.1 Pain intensity 0 ± 0 to 0 ± 4 Knees 12 m (% yes) 9 ± 29.0 to 11 ± 35.5 Limit (% yes) 6 ± 19.4 to 2 ± 6,5 7 days (% yes) 4 ± 12.9 to 4 ± 12.9 Pain intensity 0 ± 3 to 0 ± 3 Ankles/feet 12 m (% yes) 14 ± 45.2 to 16 ± 51.6 Limit (% yes) 4 ± 12.9 to 3 ± 9.7 7 days (% yes) 5 ± 16.1 to 10 ± 32.3 Pain intensity 0 ± 3 to 3 ± 7		
	Intervention (TOI) Weight (kg) 57.2 ± 15.2 to 67.3 ± 18.4 p<.194 BMI (kg/m2) 26.0 ± 6.8 to 25.0 ± 7.4 p<.194	Neck 12 m (% yes) 33 ± 56.4 to 20 ± 51.3 Limit (% yes) 11 ± 28.2 to 2 ± 5.1, *p<.004*** 7 days (% yes) 11 ± 28.2 to 9 ± 23.1 Pain intensity 3 ± 6 to ± 5 Shoulders 12 m (% yes)		Blood pressure (mmHg) systolic; 124.1 ± 12.5 to 122.7 ± 17.7 p<.477 diastolic 75.2 ± 10.3 to 74.7 ± 11.7 MPVA (min/week) 180 ± 390 to 150 ± 345

	Weight status (%) p<.739 non overweight 46.2 to 51.3 overweight 25.6 to 17.9 obese 28.2 to 30.8 Body fat (%) 28.24 ± 10.97 to 27.5 ± 11.5 p<.514 Waist circumference (cm) 90.3 ± 13.7 to 89.5 ± 12.3 p<.512	26 ± 66.7 to 28 ± 71.8 Limit (% yes) 7 ± 17.9 to 8 ± 20.5 7 days (% yes) 11 ± 28.2 to 12 ± 30.8 Pain intensity 4 ± 7 to 4 ± 5 Elbows 12 m (% yes) 10 ± 25.6 to 4 ± 10.3 Limit (% yes) 3 0 ± 7.7 to 3 ± 7.7 7 days (% yes) 5 ± 12.8 to 1 ± 2.6 Pain intensity 0 ± 1 to 0 ± 0, *p<.003*** Wrists/hands 12 m (% yes) 26 ± 66.7 to 24 ± 64.1 Limit (% yes) 15 ± 38.5 to 9 ± 23.1 7 days (% yes) 12 ± 30.8 to 10 ± 25.5 Pain intensity 4 ± 7 to 3 ± 6 Dorsal region 12 m (% yes) 8 ± 20.5 to 4 ± 10.3 Limit (% yes) 3 ± 7.7 to 1 ± 2.6 7 days (% yes) 2 ± 5.1 to 3 ± 7.7 Pain intensity 0 ± 2 to 0 ± 0, *p<.015*** Lumbar region 12 m (% yes) 24 ± 52.2 to 23 ± 59.0 Limit (% yes) 11 ± 28.2 to 0 ± 23.7 7 days (% yes) 12 ± 30.8 to 13 ± 33.3		

		Pain intensity 6 ± 7 to 4 ± 6 Hips/thighs 12 m (% yes) 7 ±17.9 to 8 ± 20.5 Limit (% yes) 3 ± 7.7 to 1 ± 2.6 7 days (% yes) 1 ± 2.6 to 1 ± 2.6 Pain intensity 0 ± 1 to 0 ± 0 Knees 12 m (% yes) 11 ± 28.2 to 17 ± 43.6 Limit (% yes) 3 ± 7.7 to 2 ± 5.1 7 days (% yes) 6 ± 15.4 to 8 ± 20.5 Pain intensity 0 ± 3 to 0 ± 3 Ankles/feet 12 m (% yes) 18 ± 46.2 to 16 ± 41.0 Limit (% yes) 5 ± 12.8 to 4 ± 10.3 7 days (% yes) 6 ± 15.4 to 10 ± 25.6 Pain intensity 1 ± 5 to 0 ± 6		
Rasotto et al (2014)	IG	VAS neck (cm) 3.08 ± 2.80 to 0.76 ± 1.31* to 1.54 ±1.91* VAS shoulder (cm) 1.12 ± 1.42 to 0.69 ± 1.07* to 0.20 ± 0.45* VAS elbow (cm); 0.44 ± 0.99 to 0.34 ± 1.08* to 0.00 ± 0.00* VAS wrist (cm)	SH el (degrees) 165.46 ± 8.92 to 171.38* ± 5.22 to 172.02 ± 6.45* SH ab (degrees) 158.69 ± 19.06 to 175.25* ± 6.60 ± 175.69 ± 5.92* EX head (degrees) 58.41 ± 14.84 to 58.41 ± 6.61* to 62.16 ± 6.68* FL head (degrees)	

		1.69 ± 2.33 to 0.63 ± 0.97* to 0.32 ± 1.12*	47.51 ± 13.42 to 54.45 ± 9.66* to 55.75 ± 5.02* LI head (degrees) 37.43 ± 6.35 to 39.70 ± 3.14 to 42.93 ± 1.86 RO head (degrees) 76.27 ± 5.78 to 78.77 ± 1.67* to 79.49 ± 2.75*	
	CG	VAS neck (cm) 1.96 ± 2.62 to 1.47 ± 1.99 to;2.38 ± 2.57 VAS shoulder (cm) 0.92 ± 1.66 to ;0.98 ± 1.62 to 1.12 ± 1.68 VAS elbow (cm) 0.24 ± 1.20 to 0.53 ± 1.74 to 0.08 ± 0.35 VAS wrist (cm) 1.06 ± 1.81 to 1.13 ± 1.57 to 0.69 ± 1.25	SHel (degrees) 169.21 ± 9.60 to 167.48 ± 9.06 to 167.96 ± 7.33 SHab (degrees) 164.67 ± 16.77 to 170.43 ± 11.22 to 167.72 ± 12.84 FLhead (degrees) 48.54 ± 9.12 to 45.23 ± 13.28 to 48.82 to 10.34 EXhead (degrees) 55.13 ± 10.91 to 54.52 ± 10.11 to 54.41 ± 9.26 LIhead (degrees) 40.72 ± 5.28 to 35.68 to 5.28 to 37.29 ± 5.22 ROhead (degrees) 73.64 ± 9.62 to 72.70 ± 9.48 to 72.75 ± 9.01	
	Average differences between groups	<u>T5 – T0</u> VAS neck (cm) IG - 2.32 ± 2.15 CG -0.49 ± 2.42* VAS shoulder (cm) IG -0.43 ± 1.26 CG 0.05 ± 1.70 VAS elbow (cm)	<u>T5 – T0</u> SH el (degree) IG 5.92 ± 5.59 CG -1.73 ±4.59* SH ab (degree) IG 16.56 ± 17.25 CG 5.75 ± 18.78* FL head (degree)	

		IG -0.09 ± 1.57 CG 0.29 ±1.8 VAS wrist (cm) IG - 1.05 ± 2.25 CG 0.06 ± 1.48* T10 – T0 VAS neck (cm) IG – 1.29 ± 2.72 CG -0.39 ± 2.51* VAS shoulder (cm) IG -0.94 ± 1.09* CG 0.17 ± 2.02 VAS elbow (cm) IG -0.43 ± 0.98 CG 0.16 ±1.12 VAS wrist (cm) IG - 1.40 ± 1.87 CG 0.39 ± 0.93*	IG 2.27 ± 4.67 CG -5.03 ± 5.19* EX head (degree) IG 0.00 ± 12.27 CG -0.61 ± 10.01 LI head (degree) IG 2.26 ± 4.66 CG -5.04 ± 5.19* RO head (degree) IG 2.51 ± 5.22 CG -0.93 ± 10.27* T10 – T0 SH el (degree) IG 7.03 ± 8.39 CG -0.99 ± 5.66* SH ab (degree) IG 15.07 ± 13.58 CG -1.73 ± 4.59* FL head (degree) IG 4.83 ± 4.38 CG -3.32 ± 4.93* EX head (degree) IG 1.89 ± 8.17 CG -0.36 ± 10.47 LI head (degree) IG 4.83 ± 4.39 CG -3.34 ± 4.93* RO head (degree) IG 3.25 ± 3.80 CG -0.73 ± 6.89*	
Sundstrup et al (2014, disability)	RT	WAI score: 0.3 (-1.1–1.7) Item 1: (0–10) 0.0 (-0.5–0.5) Item 2: (2–10) 0.4 (0.0–0.8) Item 3: (1–7) -0.2 (-0.6–0.3)	Baseline characteristics of the two intervention groups. (the same as Sundstrup et al, 2014, upperlimb)	

		Item 4: (1–6) 0.1 (-0.1–0.3) Item 5: (1–5) -0.2 (-0.6–0.0) Item 6: (1–7) 0.2 (-0.5–0.8) Item 7: (1–4) 0.1 (-0.1–0.4) Changes in work ability index (WAI) and single-item scores from baseline to 10-week follow-up (between group difference) Mean (95% CI), p-value WAI score: 2.3 (0.9–3.7), 0.012* Item 1: 0.5 (0.0–1.0) 0.18 Item 2: 0.7 (0.3–1.2) 0.003* Item 3: 0.1 (-0.3–0.6) 1.00 Item 4: 0.0 (-0.2–0.2) 1.00 Item 5: 0.2 (-0.1–0.5) 0.47 Item 6: 0.3 (-0.4–1.0) 1.00 Item 7: 0.3 (0.1–0.6) 0.021*	Work ability index (7–49): 39.2 ± 3 Item 1: Current work ability compared with the lifetime best (0–10): 7.3 ± 1.0 Item 2: Work ability in relation to the demands of the job (2–10): 7.5 ± 0.9 Item 3: Number of current diseases diagnosed by a physician (1–7): 5.6 ± 0.1 Item 4: Estimated work impairment due to diseases (1–6): 5.7 ± 0.4 Item 5: Sick leave during the past year (1–5): 4.7 ± 0.6 Item 6: Own prognosis of work ability two years from now (1–7): 5.5 ± 0.4 Item 7: Mental resources (1–4): 3.0 ± 0.5 Shoulder, elbow and hand pain intensity previous week (scale 0–10) 4.5 ± 1.2 Work disability (DASH work module; scale 0–100) 28.3 ± 13.8 WAI (7–49) 39.± 4 3 Item 1: 7.2 ± 1.0 Item 2: 7.5 ± 0.9 Item 3: 5.6 ± 0.9 Item 4: 5.7 ± 0.4 Item 5: 4.6 ± 0.6 Item 6: 5.7 ± 0.4 Item 7: 3.0 ± 0.5 Shoulder, elbow and hand pain intensity previous week (scale 0–10) 4.5 ± 1.2 Work disability (DASH work module; scale 0–100): 27.8 ± 13.8	
	ET	WAI score: -2.2 (-3.5– -0.8) Item 1: -0.5 (-0.9–0.0) Item 2: -0.3 (-0.8–0.1) Item 3: -0.3 (-0.7–0.1)		

		Item 4: 0.0 -(0.2–0.2) Item 5: -0.5 (-0.8– -0.2) Item 6: -0.3 (-0.9–0.3) Item 7: -0.3 (-0.5–0.0)		
Sundstrup et al (2014, upperlimb)	RT	Pre post difference (C.I.) Modified VAS (0–10) - Pain intensity: -1.8 (-2.3 to -1.2) DASH-W score (0–100) -6.5 (-13.2 to 0.1)	Shoulder rotation strength (N) 28 (19 to 36) Wrist extensor strength (N) 30 (18 to 42)	
	ET	Pre post difference (C.I.) Average pain intensity (0–10) -0.3 (-0.8 to 0.3) DASH-W score (0–100) 2.8 (-3.7 to 9.4)	Shoulder rotation strength (N) -10 (-18 to -2) Wrist extensor strength (N) -11 (-23 to 2)	
	Between group difference	Average pain intensity (0–10): -1.5 (-2.0 to -0.9) (< 0.0001)* DASH-W score (0–100) -8.8 (-15.6 to -2.0) (< 0.05)*	Shoulder rotation strength (N) 37 (28 to 45) (< 0.0001)* Wrist extensor strength (N) 42 (29 to 54) (< 0.0001)*	
Pedersen et al (2013)	TG1 DASH: 18,4 ± 21,5	Changes of pain within groups (Intention-to-treat) the last 7 days: Neck T2-1 (Diff. of least squares means): 0.31±0.12 *p<.008***, T3-1: 0.70±0.13, *p<.001**** T3-2: 0.38±0.13, *p<.004*** R-shoulder T2-1: 0.49±0.12, *p<.001**** T3-1: 0.92±0.13, *p<.001**** T3-2: 0.43±0.14, *p<.002*** R-hand		

		T2-1: 0.18±0.10, T3-1: 0.36±0.11, *p<.002***, T3-2: 0.18±0.12; lower back T2-1: -0.04±0.12, , T3-1: 0.42±0.14, *p<.002***, T3-2: 0.46±0.14, *p<.001****; DASH at T2-1: 5.19±0.95, *p<.001****, T3-1: 7.70±1.06, *p<.001****, T3-2: 2.51±1.08, *p<.021** <u>Changes within groups (cases only) of pain in the last 7 days:</u> Neck T2-1 (Diff. of least squares means): 1.70±0.24, *p<.001**, T3-1: 2.57±0.27, *p<.001****, T3-2: 0.87±0.27, *p<.002***, R-shoulder T2-1: 2.13±0.29, *p<.001**** T3-1: 3.38±0.32, *p<.001**** T3-2: 1.25±0.32, *p<.001**** Upper back T2-1: 1.62±0.30, *p<.001****, T3-1: 2.44±0.35, *p<.001****, T3-2: 0.82±0.35, *p <.020*** lower back T2-1: 0.78±0.27, *p<.005***, T3-1: 2.21±0.30, *p<.001****, T3-2: 1.43±0.30, *p<.001****		
	TG2 DASH: 15,1 ± 21	<u>Changes of pain within groups (Intention-to-treat) the last 7 days:</u> Neck T2-1 (Diff. of least squares means): 0.92±0.12, *p<.001**** T3-1: 0.85±0.13, *p<.001****, T3-2: -0.06±0.14,		

		R-shoulder T2-1: 0.90±0.12, *p<.001****, T3-1: 0.79±0.13, *p<.001****, T3-2: -0.11±0.14, p<.441*; R-hand T2-1: 0.53±0.10, *p<.001****, T3-1: 0.62±0.11, *p<.001****, T3-2: 0.08±0.12, p<.480*; lower back T2-1: 0.38±0.12, *p<.002***, T3-1: 0.48±0.13, *p<.001****, T3-2: 0.11±0.14, *p<.452*;* DASH T2-1: 9.96±0.97, *p<.001**, T3-1: 9.70±1.03, *p<.001**, T3-2: -0.26±1.10 <u>Changes within groups (cases only) of pain in the last 7 days:</u> Neck T2-1 (Diff. of least squares means): 2.76±0.24, *p<.001****, T3-1: 2.50±0.25, *p<.001****, T3-2: -0.26±0.27 R-shoulder T2-1: 3.23±0.30, *p<.001****, T3-1: 2.38±0.32, *p<.001****, T3-2: -0.84±0.34, *p <.014**;* Upper back T2-1: 2.91±0.30, *p<.001****, T3-1: 2.69±0.30, *p<.001****, T3-2: -0.22±0.33 Lower back T2-1: 2.52±0.30, *p<.001****, T3-1: 3.22±0.32, *p<.001****, T3-2: 0.70±0.35, *p<.048*;*		

Gram et al (2012)	EG (n = 35)	Perceived exertion at work (scale, 6–20) 13.4 ± 2.9 Self-rated productivity (scale, 0–10): 8.2 ± 1.5 (n = 35) Sick leave (d) last 3 months: 0.8 ± 1.4 (35) Pain intensity last 7 days (scale, 0–10): Neck: 1.3 ± 2.1 R Shoulder: 1.4 ± 2.3 L Shoulder: 1.0 ± 2.3 Shoulder dominant: 1.7 ± 2.7 Upper back: 1.3 ± 1.9 Low back: 2.7 ± 2.9 Hip: 1.0 ± 2.4 Knee: 1.9 ± 2.7 T0 (week 1-2) and T1 (week 11-12) measures, Based on Text Messages and Questionnaire for Each Study Group, Based on Intention-to-Treat Text Messages Neck–shoulder T0: 2.5 ± 2.4, difference T0−T1: −0.2 ± 1.9 Low back 2.4 ± 2.7 difference T0−T1: −0.5 ± 1.7 Hip–knee 2.3 ± 2.5 difference T0−T1: −0.1 ± 1.9 Work ability T0: 7.8 ± 2.4, difference T0-T1: 0.1 ± 3.1, Questionnaire (pooled data): Neck–shoulder 2.1 ± 2.8 difference T0−T1: −0.3 ± 1.9 Low back		

		2.7 ± 2.9 difference T0−T1: −0.2 ± 2.2 Hip–knee 2.1 ± 3.0 difference T0−T1: −0.1 ± 2.7 Work ability 7.8 ± 2.0 difference T0-T1: 0.4 ± 1.6 Work ability (scale, 0–10) 0.4 ± 1.6 Perceived exertion at work (scale, 6–20) 0.1 ± 2.2 Self-rated productivity (scale, 1–10) (total n = 64): −0.3 ± 2.1 (n = 34) Sick leave (d) last 3 months (total n = 64): 0.7 ± 2.2 (n = 35) Pain intensity last 7 days (scale, 0–10): Neck: −0.2 ± 1.5 Shoulder right: 0.0 ± 1.7 Shoulder left: −0.3 ± 2.4 Shoulder dominant: −0.3 ± 2.3 Upper back: −0.2 ± 1.6 Low back: −0.2 ± 2.2 Hip: −0.1 ± 3.0 Knee: −0.2 ± 2.7		
	CG (n = 32)	Work ability (scale, 0–10) 8.1 ± 1.9 Perceived exertion at work (scale, 6–20) 14.0 ± 2.4 Self-rated productivity (scale, 0–10) 8.8 ± 1.3 (n = 29)		

		Sick leave (d) last 3 months 2.0 ± 3.9 (n = 29) Pain intensity last 7 days (scale, 0–10) Neck: 1.4 ± 1.7 R Shoulder: 1.1 ± 1.7 L Shoulder: 0.8 ± 1.5 Shoulder dominant: 1.1 ± 1.7 Upper back: 1.2 ± 2.1 Low back: 2.6 ± 2.6 Hip: 0.8 ± 2.0 Knee: 1.6 ± 2.4 Text Messages Neck–shoulder 1.9 ± 1.8 difference T0-T1: 0.2 ± 1.0 Low back 2.5 ± 2.7 difference T0−T1: −0.5 ± 1.7 Hip–knee 2.0 ± 2.5 difference T0−T1: −0.1 ± 2.2 Work ability 8.4 ± 2.2 difference T0−T1: −0.7 ± 1.7 Questionnaire (pooled data): Neck–shoulder 2.1 ± 1.9 difference T0−T1: −0.2 ± 1.6 Low back 2.6 ± 2.6 difference T0-T1: 0.0 ± 2.3 Hip–knee 1.9 ± 2.5 difference T0−T1: −0.0 ± 2.1 Work ability 8.0 ± 1.9		

		difference T0−T1: −0.1 ± 1.3 Work ability (scale, 0–10) −0.1 ± 1.3 Perceived exertion at work (scale, 6–20) −0.3 ± 1.6 Self-rated productivity (scale, 1–10) (total n = 64) −0.1 ± 1.1 (n = 29) Sick leave (d) last 3 months (total n = 64) 0.1 ± 4.6 (n = 29) Pain intensity last 7 days (scale, 0–10): Neck: −0.2 ± 1.3 Shoulder right: −0.4 ± 1.0 Shoulder left: 0.1 ± 1.4 Shoulder dominant: −0.4 ± 1.0 Upper back: −0.2 ± 1.9 Low back: 0.0 ± 2.3 Hip: 0.2 ± 1.9 Knee: −0.3 ± 1.8		
	TOTAL (n = 67)	Work ability (scale, 0–10): 7.9 ± 2.0 Still able to perform the job in 2 years' time ("inconceivable," "not sure," "surely"), %: 3/12/85 Perceived exertion at work (scale, 6–20) 13.7 ± 2.7 Self-rated productivity (scale, 0–10) 8.5 ± 1.5 Sick leave (d) last 3 months 1.4 ± 2.9 Pain intensity last 7 days (scale, 0–10): Neck: 1.3 ± 1.9 R Shoulder: 1.3 ± 2.0 L Shoulder: 0.9 ± 2.0 Shoulder dominant: 1.4 ± 2.3		

		Upper back: 1.2 ± 2.0 Low back: 2.6 ± 2.7 Hip: 0.9 ± 2.2 Knee: 1.8 ± 2.6		
Mesquita et al (2012)	IG		SFle (Kgf) 72.07 ± 14.33 to 73.39 ± 14.42 RFle (Sec) 42.43 ± 15.58 to 44.31 ± 15.89 SExt (Kgf) 79.48 ± 15.94 to 83.29 ± 13.73, *p< .014*** RExt (Sec) 51.57 ± 17.60 to 58.69 ± 15.38, *p< .006*** Ratio 1.10 ± 0.25 to 1.16 ± 0.21; *p< .037**	
	CG		SFle (Kgf) 63.49 ± 20.94 to 58.81 ± 18.40, *p< .002*** RFle (Sec) 42.71 ± 19.45 to 45.17 ± 17.06 SExt (Kgf) 65.74 ± 18.42 to 61.90 ± 20.10, RExt (Sec) 62.41 ± 18.46 to 61.79 ± 18.97 Ratio 1.12 ± 0.30 to 1.08 ± 0.27	
Zebis et al (2011)	CG	Pain intensity in the neck and shoulder at baseline and follow-up for cases and non-cases, separately. Cases Neck: 4.6 ± 1.8 to 2.9 ± 2.3; n = 77 R shoulder: 4.7 ± 1.8 to 2.5 ± 2.6; n = 69	>30 days with Neck pain previous year (% of participants): 31% / >30 days with Right shoulder pain previous year (% of participants): 20% >30 days with Left shoulder pain previous year (% of participants): 13%	

		L shoulder: 5.0 ± 1.8 to 22 ± 2.6; n = 43 Non-cases Neck: 0.5 ± 0.7 to 0.8 ± 1.5; n= 175 R shoulder: 0.4 ± 0.7 to 0.5 ± 1.2; n = 183 L shoulder: 0.4 ± 0.7 to 0.5 ± 1.1; n = 209	Neck Pain intensity of 3 or more during previous week (% of participants): 31% Right shoulder Pain intensity of 3 or more during previous week (% of participants): 27% Left shoulder Pain intensity of 3 or more during previous week (% of participants): 17% Percentage of participants spending more than half of total work time: Sitting: 87% Standing: 37% Bend forward without arm- or hand-support: 9% Twisting or bending the back: 23% Hand at shoulder height or higher: 1% Performing physical strenous work: 10% Bent neck: 24% Hand twisted or flexed: 28% The same finger movements several times a minute: 57% The same arm movements several times a minute: 34% Static work posture: 48% Kneeling: 2% Other work-related characteristics: Weekly working hours: 35± 8 Years working in the same type of job: 15±11	
	TG	Pain intensity in the neck and shoulder at baseline and follow-up for cases and non-cases, separately. Cases Neck: 4.7 ± 1.6 to 1.8 ± 1.9; n = 95 R shoulder: 4.8 ± 1.7 to 1.4 ± 1.7; n = 76 L shoulder: 4.5 ± 1.5 to 0.9 ± 1.3; n = 46 Non-cases Neck: 0.6±0.8 to 0.5±1.3; n = 182 R shoulder: 0.6±0.8 to 0.5±1.2; n = 200	>30 days with Neck pain previous year (% of participants): 34% >30 days with Right shoulder pain previous year (% of participants): 27% >30 days with Left shoulder pain previous year (% of participants): 17% Neck Pain intensity of 3 or more during previous week (% of participants): 34%	

		L shoulder: 0.4±0.7 to 0.4±1.0; n = 231	Right shoulder Pain intensity of 3 or more during previous week (% of participants): 28% Left shoulder Pain intensity of 3 or more during previous week (% of participants): 17% Percentage of participants spending more than half of total work time: Sitting: 83% Standing: 41% Bend forward without arm- or hand-support: 11% Twisting or bending the back: 32% Hand at shoulder height or higher: 0% Performing physical strenous work: 14% Bent neck: 29% Hand twisted or flexed: 33% The same finger movements several times a minute: 65% The same arm movements several times a minute: 38% Static work posture: 51% Kneeling:0% Other work-related characteristics: Weekly working hours: 35±8 Years working in the same type of job: 16±12	
	DECLINERS		>30 days with Neck pain previous year (% of participants): 17% >30 days with Right shoulder pain previous year (% of participants): 6% >30 days with Left shoulder pain previous year (% of participants): 11% Neck Pain intensity of 3 or more during previous week (% of participants): 20% Right shoulder Pain intensity of 3 or more during previous week (% of participants): 8%	

			Left shoulder Pain intensity of 3 or more during previous week (% of participants): 14% Percentage of participants spending more than half of total work time: Sitting: 92% Standing: 42% Bend forward without arm- or hand-support: 14% Twisting or bending the back: 21% Hand at shoulder height or higher: 3% Performing physical strenuous work: 10% Bent neck: 19% Hand twisted or flexed: 30% The same finger movements several times a minute: 62% The same arm movements several times a minute: 33% Static work posture: 58% Kneeling: 3% Other work-related characteristics: Weekly working hours: 35±9 Years working in the same type of job: 12±12	
Camargo et al (2009)	IG 14 male workers	DASH score and DASH work score in 14 workers with SIS at pre- and post-intervention DASH score: Pre-intervention: 22.32 ± 16.80 Post Intervention: 9.64 ± 8.38 * Pre-Post Difference: 12.67 ±17.55 DASH work score Pre-intervention: 23.21 ± 18.90 Post Intervention;10.27 ± 11.91 * Pre-Post Difference: 12.94 ± 18.90 PRI category (max score) Sensory (34) Pre-intervention: 14.36 ±- 3.88 Post-Intervention: 8.50 ± 8.23 *		

		Affective (17) Pre-intervention: 5.00 ± 2.18 Post-Intervention: 1.71 ± 1.49 * Evaluative (5) Pre-intervention: 2.21 ± 1.25 Post-Intervention: 1.29 ± 1.14 Miscellaneous (12) Pre-intervention: 3.29 ± 1.64 Post-Intervention: 1.00 ± 1.24 * Total (68) Pre-intervention: 24.86 ± 6.72 Post-Intervention: 12.50 ± 11.55 *		
Cheng et al (2007)	CHW	SPADI 54.25 ± 12.07 to 40.50 ± 16.30, p*	Shoulder flexion (degree) 163.38 ± 10.98 Shoulder extension (degree) 38.85 ± 8.14 Shoulder abduction (degree) 163.23 ± 11.69 Shoulder external Rotation (degree) 56.56 ± 6.03 Shoulder internal rotation (degree) 66.77 ± 11.83 Leg lift (lbs) 43.66 ± 15.89 Arm lift (lbs) 34.16 ± 13.35 High near lift (lbs) 23.56 ± 9.35 Bilateral pushing (lbs) 21.18 ± 10.22	

			Bilateral pulling (lbs) 19.96 ± 9.03 Bilateral carrying (lbs) 14.06 ± 4.69 Unilateral lifting (affected hand) (lbs) 13.88 ± 5.32 Overhead tolerance (IS%) 54.04 ± 17.40 Pre–post differences in functional outcome Shoulder flexion (degree) 163.38 ± 10.98 to 169.79 ± 9.34, p* (between groups) Shoulder extension (degree) 38.85 ± 8.14 to 43.65 ± 7.84 Shoulder abduction (degree) 163.23 ± 11.69 to 166.72 ± 23.91 Shoulder external rotation (degree) 56.56 ± 6.03 to 59.58 ± 6.51 Shoulder internal rotation (degree) 66.77 ± 11.83 to 70.52 ± 11.82 Leg lift (lbs) 43.66 ± 15.89 to 51.60 ± 19.62 Arm lift (lbs) 34.16 ± 13.35 to 38.52 ±14.47, p* (between groups) High near lift (lbs) 23.56 ± 9.35 to 28.62 ± 10.54, p** (between groups) Bilateral pushing (lbs) 21.18 ± 10.22 to 24.41 ± 10.92	

			Bilateral pulling (lbs) 19.96 ± 9.03 to 23.73 ± 9.73 Bilateral carrying (lbs) 14.06 ± 4.69 to 26.46 ± 8.69, p* (between groups) Unilateral lifting (affected hand) (lbs) 13.88 ± 5.32 to 17.86 ± 6.55 Overhead tolerancea (IS%) 54.04 ± 17.40 to 76.61 ± 23.12, p* (between groups)	
	WWH	Pre–post-differences in SPADI 52.09 ± 10.89 to 31.54 ± 13.37	Shoulder flexion (degree) 166.63 ± 8.30, p* (between groups) Shoulder extension (degree) 40.98 ± 6.47 Shoulder abduction (degree) 165.65 ± 9.92 Shoulder external Rotation (degree) 57.93 ± 6.02 Shoulder internal rotation (degree) 66.41 ± 10.98 Leg lift (lbs) 44.58 ± 12.50 Arm lift (lbs) 37.35 ± 12.47, p* (between groups) High near lift (lbs) 25.09 ± 8.14, p** (between groups) Bilateral pushing (lbs) 22.92 ± 10.11 Bilateral pulling (lbs) 22.29 ± 9.95	

			Bilateral carrying (lbs) 15.65 ± 4.90, p* (between groups) Unilateral lifting (affected hand) (lbs) 14.17 ± 5.06 Overhead tolerance (IS%) 59.66 ± 14.83, p* (between groups) Pre–post differences in functional outcome; Shoulder flexion (degree) 166.63 ± 8.30 to 175.11 ± 5.92 Shoulder extension (degree) 40.98 ± 6.47 to 45.76 ± 5.67 Shoulder abduction (degree) 165.65 ± 9.92 to 173.48 ± 7.29 Shoulder external rotation (degree) 57.93 ± 6.02 to 61.09 ± 6.23 Shoulder internal rotation (degree) 66.41 ± 10.98 to 72.93 ± 9.16 Leg lift (lbs) 44.58 ± 12.50 to 56.66 ± 14.40 Arm lift (lbs) 37.35 ± 12.47 to 46.27 ± 14.09 High near lift (lbs) 25.09 ± 8.14 to 39.33 ± 12.63 Bilateral pushing (lbs) 22.92 ±10.11 to 27.50 ± 10.58 Bilateral pulling (lbs) 22.29 ±9.95 to 26.92 ±10.09 Bilateral carrying (lbs) 15.65 ± 4.90 to 31.85 ± 10.35	

			Unilateral lifting (affected hand) (lbs) 14.17 ± 5.06 to 19.77 ± 6.63 Overhead tolerance (IS%) 59.66 ± 14.83 to 23.80	
Ludewig et al (2002)	IG	SRQ score 65.9 ± 1.96 to 78.0±2.31 ** Satisfaction score 4.5±0.31 to 6.2 ± 0.35 * Work related pain 4.8 ± 0.28 2.8 ± 0.29 * Work related disability 4.1 ± 0.30 to 2.5 ± 0.29 * Change (pretest to post-test) scores and percent change scores in function and pain measures by group SRQ Difference score mean (17-100) 11.17 ± 2.83 ** SRQ % change (1-10) 19.23 ± 4.75 Satisfaction score (dsm) (1-10) 1.50 ± 0.33 Satisfaction score % change 43.61 ± 10.22 Work related pain questions (dsm) (1-10) -1.95 ± 0.28 Work related pain questions % change -29.99 ± 8.22 Work related disability questions (dsm) (1-10): -1.52 ± 0.35		

		Work related disability questions % change: -39.6 ± 5.06		
	SCG	SRQ score: 72.5 ± 1.99 to 71.1 ± 2.24 Satisfaction score: 5.0 ± 0.31 to 5.0 ± 0.34 Work related pain: 4.6 ± 0.28 to 4.1 ± 0.29 Work related disability: 3.8 ± 0.30 to 3.7 ± 0.29 Change (pretest to post-test) scores and percent change scores in function and pain measures by group SRQ Difference score mean (17-100): -1.56 ± 2.5 SRQ % change (1-10): -0.27 ± 3.72 Satisfaction score (dsm) (1-10): -0.09 ± 0.38 Satisfaction score % change: 12.45 ± 11.94 Work related pain questions (dsm) (1-10): -0.48 ± 0.34 Work related pain questions % change: 8.43 ± 8.69 Work related disability questions (dsm) (1-10): -0.09 ± 0.31 Work related disability questions % change: -3.43 ± 7.90		

	ACG	Means (standard error of mean) of outcome variables by group SRQ score: 93.8 ± 2.28 to 94.0 ± 2.64 * Satisfaction score: 9.1 ± 0.37 to 8.8 ± 0.40 * Work related pain: 1.3 ± 0.32 to 1.4 ± 0.34 * Work related disability: 1.3 ± 0.35 to 1.3 ± 0.34 * Change (pretest to post-test) scores and percent change scores in function and pain measures by group SRQ Difference score mean (17-100): 0.04 ± 1.45 SRQ % change (1-10): 0.36 ± 1.65 Satisfaction score (dsm): -0.36 ± 0.28 Satisfaction score % change: -3.03 ± 3.42 Work related pain questions (dsm): 0.08 ± 0.13 Work related pain questions % change: 2.34 ± 4.13 Work related disability questions (dsm): 0.03 ± 0.08 Work related disability questions % change: 12.8 ± 8.55		

Nurminen et al (2002)	IG	<u>Perceived work ability</u> WAI (mean): 7–49 points/7 items: 40.0 Work ability (%): good (37–43 points) or excellent (44–49 points) 73.7 Work ability compared with lifetime best: scale 0–10 (mean): 8.5 Work ability in relation to physical demands of the work (%): very good or rather good 76.7 Work ability in relation to mental demands of the work (%): very good or rather good: 82.7	<u>Health-related factors</u> Health status compared with that of persons of the same age (%): very good or rather good: 69.0 Prognosis of work ability with respect to health after 2 years (%): fairly sure able to do current job: 81.2 Prognosis of work ability during next 5 years with respect to musculoskeletal symptoms (%): no difficulties: 59.1 Mental resources (mean): 3 items: 9.5 Perceived well-being Stress (%): very much or rather much: 8.3 Job satisfaction (%): very good or rather good: 75.6 Life satisfaction (%): very good or rather good: 87.9	
	CG	<u>Perceived work ability</u> WAI (mean): 7–49 points/7 items: 39.8 Work ability (%): 75.7 Work ability compared with lifetime best: scale 0–10 (mean): 8.4 Work ability in relation to physical demands of the work (%): 77.4 Work ability in relation to mental demands of the work (%): 78.2	<u>Health-related factors</u> Health status compared with that of persons of the same age (%): 64.0 Prognosis of work ability with respect to health after 2 years (%): 82.9 Prognosis of work ability during next 5 years with respect to musculoskeletal symptoms (%): 60.3 Mental resources (mean): 3 items: 9.3 Perceived well-being Stress (%): 8.1 Job satisfaction (%): 71.8 Life satisfaction (%): 85.5	

Results are shown as mean ± standard deviation, or median (interquartile range), or change Δ

*Abbreviations: p <0.05 * within group comparison, ** between groups comparison*

Gobbo et al (2021)*: RT: resistance training, L-VAS: Low back Visual Analog Scale, DASH: Disabilities of Arm, Shoulder and Hand Score*

Cimarras-Otal et al (2020): IG: intervention group, CG: control group, ODI: Oswestry Disability Index, BPI: Brief Pain Inventory, F/R test: Flexion-Relaxation test, FER: Flexion-Extension Ratio

Weyh et al (2020): ETG: endurance training group, STG: strength training group, CG: control group, SiBP: sitting bended position, StOP: standing overhead position, BMI: Body Mass Index, BW: body weight, MCS: mental component summary, Nm: newton meter, PCS: physical component summary, DBPmax: maximum diastolic blood pressure, EWT: experimental welding task, HRmax: maximum heart rate, RPEmax: maximum rating of perceived exertion, SBPmax: maximum systolic blood pressure, VASmax: maximum visual analogue scale

Muñoz-Poblete et al (2019): IG: intervention group, CG: control group, VAS: visual analogue scale, DASH: Disabilities of Arm, Shoulder and Hand Score

Kang et al (2018, finger): IG: intervention group, CG: control group, BMI: body mass index, AUSCAN index: Australian/Canadian osteoarthritis hand index

Kang et al (2018, lowback): IG: intervention group, CG: control group, AUSCAN index: Australian/Canadian osteoarthritis,

Lowe et al (2017): IG: intervention group, CG: control group, SRQ: Shoulder Rating Questionnaire, DASH: Disabilities of Arm, Shoulder and Hand Score.

Malarvizhi et al (2017): IG: intervention group, CG: control group, VAS: visual analogue scale, SPADI: shoulder pain and disability index.

Krüger et al (2015): IG: intervention group, CG: control group.

Rasotto et al (2015): IG: intervention group, CG: control group, VAS: visual analogue scale, EL: elevation, AB: abduction, FL: flexion, EX: extension, LI: lateral inclination, RO: rotation

Bertozzi et al (2014): IG: intervention group, CG: control group, VAS: visual analog scale, RMDQ: Roland Morris Disability Questionnaire, ODI: Oswestry Disability Index

Moreira-Silva et al (2014): TOI: intervention group, TOR: reference group, BMI: body mass index, MVPA: moderate and vigorous physical activity

Rasotto et al (2014): IG: intervention group, CG: control group, VAS: visual analogue scale, EL: elevation, AB: abducion, FL: flexion, EX: extension, LI: lateral inclination, RO: rotation.

Sundstrup et al (2014, disability): RT: resistance training, ET: endurance training, WAI: work ability index, DASH: Disability of Arm, Shoulder and Hand Score.

Sundstrup et al (2014, upperlimb): RT: resistance training, ET: ergonomic training, DASH: Disabilities of Arm, Shoulder and Hand Score, VAS: visual analogue scale

Pedersen et al (2013): TG1: training group 1, TG2: training group 2, DASH: Disabilities of Arm, Shoulder and Hand Score.

Gram et al (2012): EG: Exercise group, CG: control group.

Mesquita et al (2012): SFle: Trunk flexors strength; RFle: Trunk flexors resistance; SExt: Trunk extensors strength; RExt: Trunk extensors resistance.

Ratio between trunk extensors/flexors strength.

Zebis et al (2011): TG: training group; CG: control group.

Camargo et al (2009): DASH: Disabilities of Arm, Shoulder and Hand Score; PRI: Pain rating index in the four different categories assessed using the Brazilian version of the McGill Pain Questionnaire.

Cheng et al (2007): CWH: Clinic-based work hardening training; Workplace-based work hardening training; SPADI: Shoulder Pain and Disability Index; Percent of Industrial Standard (%IS) is the evaluee's demonstrated ability as a percent of the Industrial Standard, where 100% and up indicates performance at or above the IS, while below 100% indicates performance below the IS.

Ludewig et al (2002): IG: intervention group; SCG: symtomatic control group; ACG: asymptomatic control group; SRQ: Shoulder Rating Questionnaire.

Nurminen et al (2002): IG: intervention group, CG: control group; WAI: work ability index

Table B4: List of papers with more than one intervention group, and relative interventions.

Paper ID	Intervention 1	Intervention 2
Cheng_2007	Clinical based work hardening training	Workplace based work hardening training
Sundstrup_2014_disability	Resistance training	Ergonomic training
Sundstrup_2014_upperlimb	Resistance training	Ergonomic training
Kang_2018_finger	Finger exercises	Paraffin bath
Kang_2018_lowback	Heat, current and ultrasonic treatments + unstable surface training	Heat, current and ultrasonic treatments + stable surface training
Weyh_2020	Resistance training	Endurance training

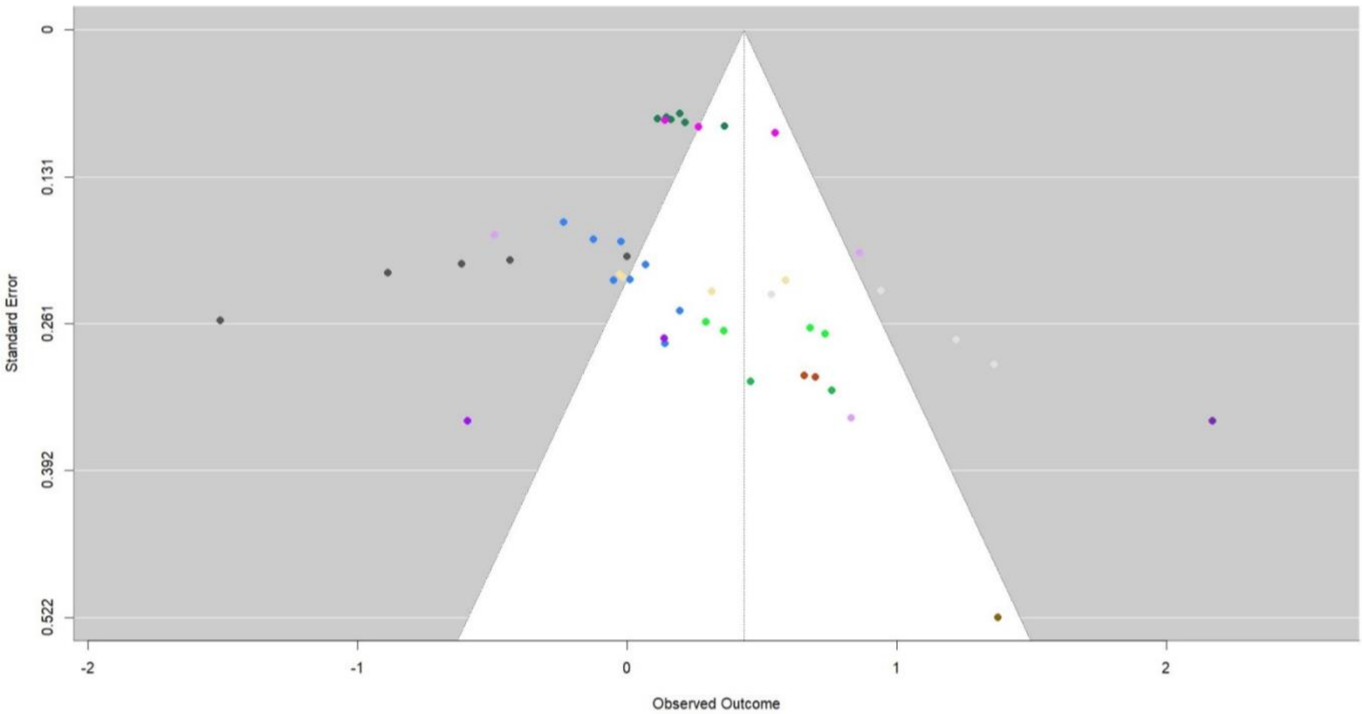

Figure B1. Funnel plot for pain outcomes, showing asymmetry towards the null. Different colors denote different studies.

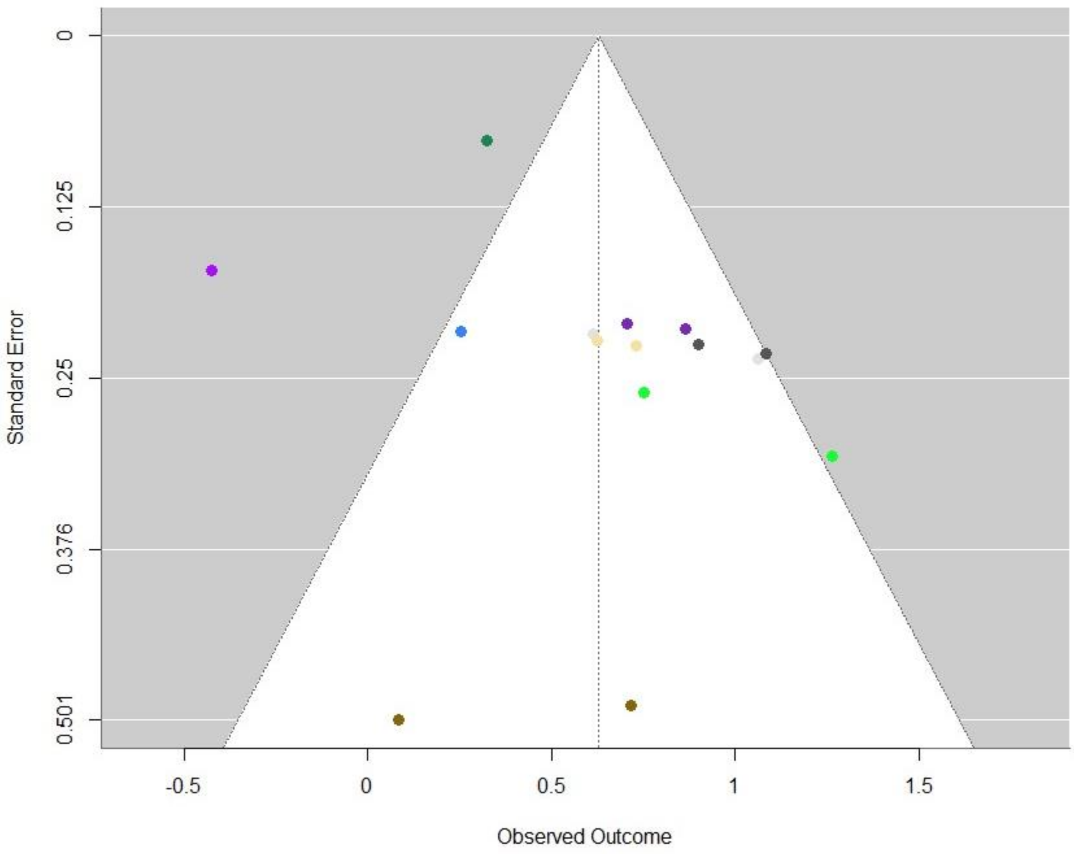

Figure B2. Funnel plot for disability outcomes, showing asymmetry towards positive effects. Different colors denote different studies.

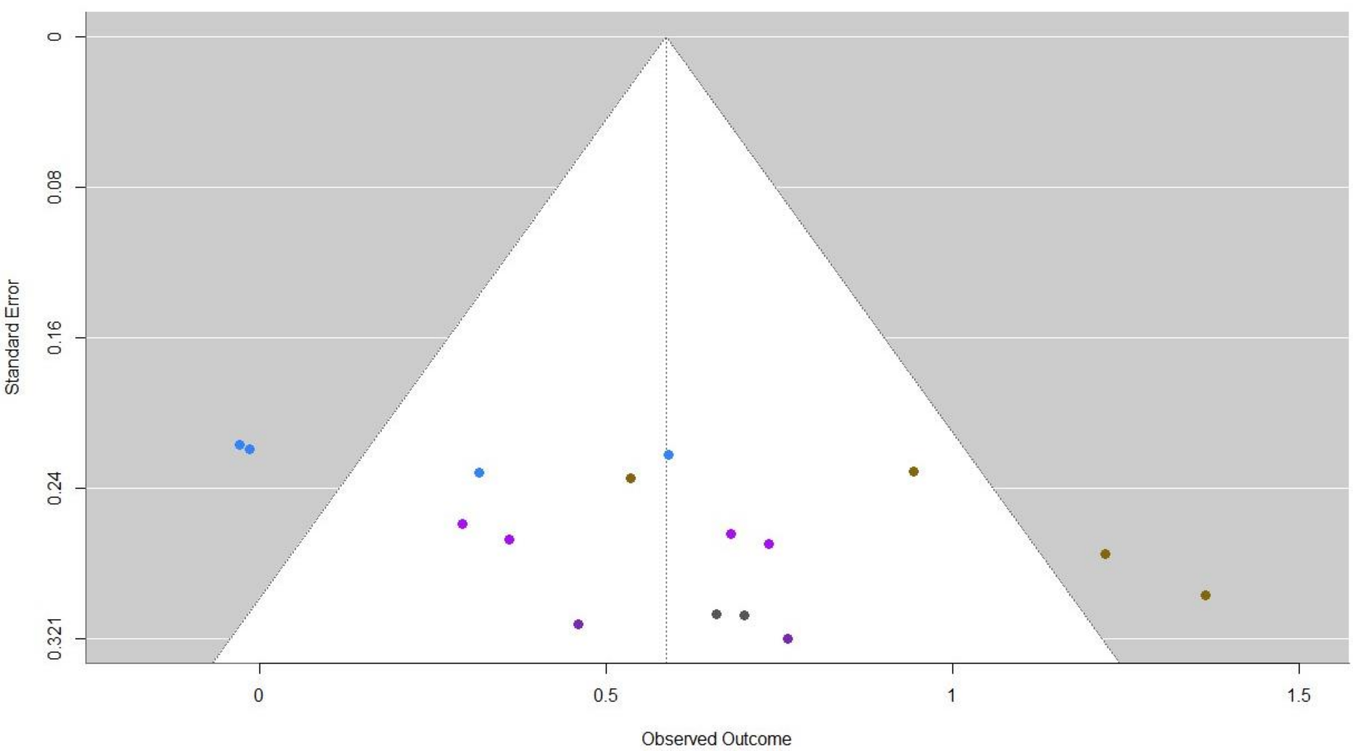

Figure B3. Forest plot for VAS outcomes, showing good symmetry. Different colors denote different studies.