Identification and prioritization of relevant prevention issues for work-related musculoskeletal disorders (MSD)

Work package 2

Attribution of the respective musculoskeletal disorders to occupational stress/risk factors

This report is the final report for Work Package 2 “Attribution of the respective musculoskeletal disorders to occupational stress/risk factors” within the “Identification and prioritization of relevant prevention issues for work-related musculoskeletal disorders (MSD)” project by the *Deutsche Gesetzliche Unfallversicherung* (DGUV, German Social Accident Insurance).

Work package 2 consists of three sub-projects which were carried out independently of each other:

Work package 2.1. Physical load factors:
e.g. manual material handling, forced postures, work with a high level of exertion/impact, repetitive activities, vibrations etc.

Work package 2.2. Mental stress factors:
e.g. stress, work uncertainty, job demand, job control, decision latitude etc.

Work package 2.3. Combined stresses of physical and psychological factors

Work package 2.1. Physical **load** factors: e.g. manual material handling, forced postures (overload and underuse), work with a high level of exertion/impact, repetitive activities with high frequency, vibrations.

Author: Dr. Elke Ochsmann
Institut für Arbeitsmedizin und Sozialmedizin, Medizinische Fakultät, RWTH Aachen, Pauwelsstrasse 30, D-52074 Aachen, Germany

Note: To improve readability only the masculine form is used in the following report.

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1. Introduction

Work package 2.1. aims to answer the following questions: Which occupational exposures/stressors/risk factors are associated with the respective musculoskeletal disorders? For which of these stressors/risk factors is the link to MSDs at least probable from a biomechanical and epidemiological point of view?

As already addressed in the discussion to Work Package 1, it is often difficult to attribute MSDs to specific risk occupations because nowadays many employees work in several occupations for short periods of time, and therefore “occupation-specific” MSDs resulting from one-sided occupational exposure over a long period of time may become less and less common. Given the current trend in employment policy with temporary employment contracts, increasing geographical and professional mobility and flexibility as well as an increased availability of temporary positions, it is expected that any preventive measures in the future will have to focus more and more on the individual activities performed and less on specific occupational categories. And while, as a result of this occupational diversification, the influence of physical load factors can vary, it is suspected that the influence of mental stress factors is increasing.

Work package 2 therefore investigates the link between

- physical loads and occupational MSDs (Work Package 2.1.)
- mental stressors and occupational MSDs (Work Package 2.2.)
- combined stresses of physical and mental factors and occupational MSDs (Work Package 2.3.).

In keeping with the three-strand approach to the topic in Work Package 2, the work package has been divided into the three sub-sections defined above. Work package 2.1. will therefore focus on the link between physical load factors and the occurrence of occupational MSDs.

2. Methodology

2.1. Review papers

2.1.1. Musculoskeletal Disorders and Workplace Factors - A Critical Review of Epidemiologic Evidence for Work-Related Musculoskeletal Disorders of the Neck, Upper Extremity, and Low Back (NIOSH report, Bernard, 1997 [1])

It was clear from previous literature reviews that the report by the US Department of Health and Human Services entitled “Musculoskeletal Disorders and Workplace Factors - A Critical Review of Epidemiologic Evidence for Work Related Musculoskeletal Disorders of the Neck, Upper Extremity, and Low Back” (NIOSH Report, Bernard, 1997) [1] is an extremely well constructed and well-founded review paper of the link between physical workplace factors and MSDs. This publication was issued by the National Institute for Occupational Safety and Health (NIOSH) (hereinafter referred to as: NIOSH report). As the findings of this review paper are also highly relevant to this research question, a summary of these findings is provided.

In this detailed report, articles from scientific “peer-reviewed”, epidemiological journals were methodically searched for and reviewed. New publications regarding MSDs and their risk factors, conference presentations and abstracts dealing with MSDs of the upper extremity or back, up-to-date text books, internally reviewed government reports or studies that had been carried out by the NIOSH and other documents were also included in the review. Reports from epidemiological studies were obtained by examining and reviewing government CD-ROM and online records. The literature research was performed in the following bibliographical computer databases: Grateful Med (includes Medline and Toxline), NIOSHTIC (NIOSH database) and CIS (International Labor Organization’s (ILO) occupational health database). The search strategy included the following keywords: occupation, repetition, force, posture, vibration, cold, psychosocial, psychological, physiological, repetition strain injury, repetitive strain injury, epidemiology, etiology, cumulative trauma disorders, MSDs (neck, tension neck syndrome, shoulder, rotator cuff, elbow, epicondylitis, tendinitis, tenosynovitis, carpal tunnel, de Quervain’s, nerve entrapment

syndrome, vibration, back pain and sciatica, manual material handling). Relevant foreign language citations quoted in English in the text were included in this review paper together with literature from the authors' own collections. This search strategy identified over 2,000 studies in total. Over 600 studies were included in the detailed review process.

When presenting the findings it is important to categorize the studies used in order to rate the evidence of any link between exposure at the workplace and the musculoskeletal disorders.
The evaluation criteria used are outlined below:

- The exposed and referent collectives had to be well defined.
- Studies were included if they contained musculoskeletal disorders of the neck region, the upper extremity and the back, and these had been determined by previously well-defined, explicit criteria.
- In terms of exposure, studies were included if they evaluated the exposure in such a way that the influence of repetition, force, extreme joint postures, static loads or vibrations and lifting could be accurately assessed.
- In terms of the study design, collective-based studies, case-control studies, cross-sectional studies, longitudinal cohort studies and case series were included.

Once the quality of the individual epidemiological studies had been classified by the NIOSH examiners, the evidence was evaluated to determine whether it was strong enough to associate a relevant risk factor with a MSD. When evaluating this link, the examiners took into account causality criteria in addition to quality and evaluation criteria. Studies that fulfilled all the evaluation criteria were taken into account before and to a greater extent than those which only fulfilled one evaluation criterion.
The evidence of a link between work factors and MSDs based on the epidemiological studies was then divided into the following four categories: strong evidence for work-relatedness (+++), evidence for work-relatedness (++), insufficient evidence for work-relatedness (+/0) and evidence that no effect from workplace factors can be assumed (-).

There is strong evidence of work-relatedness if a positive link between the risk factor and the MSD was observed in at least some of the studies in which chance, bias and confounding could probably be ruled out.
There is evidence of work-relatedness if a positive relationship between the risk factor and the musculoskeletal disorder was found in studies in which chance, bias and confounding were not the probable explanation.
Insufficient evidence for work-relatedness was assigned if the studies were of poor quality or the consistency or statistical power did not allow any conclusions to be drawn as to the existence or absence of a causal association.
Evidence that there was no effect from the workplace was assigned if sufficient studies consistently showed with considerable effect that the specific risk factor does not influence the occurrence of musculoskeletal disorders.

2.1.2. Criteria document for evaluating the work-relatedness of upper-extremity disorders [2]

Based on text references in scientific literature, another more recent review paper was identified by Sluiter et al. [2]. This highlights, in particular, MSDs of the upper extremity and evaluates the links between workplace factors and MSDs with evidence ratings. This paper also considers mental stress factors as causal factors and not just as confounders.

This review paper [2] was also compiled with the assistance of various international experts from the fields of occupational health, ergonomics, exposure measurements and epidemiology. The focus on MSDs of the upper extremity encompassed the following conditions: radiating neck pain, rotator cuff syndrome, lateral and medial epicondylitis, nervus ulnaris compression in the elbow region (cubital tunnel syndrome), radial nerve compression (radial tunnel syndrome), flexor extensor peritendinitis or tenosynovitis of the forearm region, De Quervain disease, carpal tunnel syndrome, nervus ulnaris compression in the wrist region: Guyon’s canal syndrome, Raynaud’s phenomenon and peripheral neuropathy in relation to hand-arm vibration, osteoarthritis of the upper extremity joints. To fulfill the requirements of this research project, searches were performed in scientific databases (Medline, EMBASE, NIOSHTIC, PsychINFO, SPORTSDiscus and Ergonomic Abstracts) and

the “grey” literature (1995-1998). The search terms used were: upper limb, upper extremity, arm, elbow, wrist, finger, neck, shoulder, musculoskeletal, repetitive strain injury, cervicobrachial, cervicothoracic, glenohumeral, thoracic outlet syndrome, rotator cuff, periarthritis, humeroscapularis, referred, symptoms. It was possible to limit the findings to 165 hits which were evaluated in terms of an “evident” link.

2.2. Own international literature research (review study)

In addition, our own research of international scientific literature was carried out, taking into account in particular the fact that new findings may have been produced since completion of the NIOSH report and covered in the review papers of recent years. Due to the short duration of the project, the focus here was once again placed on review papers from 2000 to the present.

A search was carried out in the PubMed and EMBASE databases for the following search terms: Musculoskeletal disorder [mesh term], occupational disease [mesh term] and the following terms for occupational activities: lift*, carry*, load, task*, mechanical stress, torsion, vibration, weight, manual transfer, dynamic load, moving load, limit load, critical load, squatt*, crouch*, kneeling, hoist*, raise, draw, pull, push, tug*, move, tow, sit stand, lie, hold, transport, uphold, bank, bend, flex, bearing, posture, overload, overhead, crawl, heel, climb, hammer, knock, beat, turn, repetition, repetitive movement, squat, high frequency.
As in Work Package 1 the search terms were linked to search terms relating to prevalence/incidence and risk (Boolean: AND). Limits: Reviews, humans, language: English, German.

A total of 561 reviews were identified in this way. The abstracts from all the hits were then examined and evaluated in terms of their relevance to this issue. Of the hits, 91 reviews were initially deemed to be relevant to the issue. Due to the high number of hits for the project duration and given the fact that the two review papers also included covered original literature up to 1998, it was decided to look at reviews from 2000 to the present. A total of 36 relevant reviews were thus included in the evaluation.

Firstly, the quality of the reviews was assessed in accordance with the AMSTAR criteria for the evaluation [3]. These are

a) the existence of an a priori design

b) information about the number of the databases searched and the search terms used

c) what period of time the search was performed for

d) how many reviewers processed the hits

e) whether there is a list of the selected and non-selected articles

f) whether there is a table of the selected articles

g) the extent to which the study collective is described

h) whether the quality of the studies has been evaluated

i) the extent to which the quality of the studies has been taken into account in the findings

j) whether the authors have conducted their own evaluation

k) whether a conflict of interest has been stated.

This means that a total of 11 points can be assigned to a review. Many of the review articles identified here in this search are narrative reviews, which only attained a very low rating according to the AMSTAR criteria. They have, however, been included in the table nonetheless to provide as comprehensive a view as possible of the knowledge available.

3. Results

3.1. Results of the review papers

3.1.1. NIOSH report [1]

3.1.1.1. Musculoskeletal disorders of the neck

There were over 40 epidemiological studies investigating the link between physical workplace factors and musculoskeletal disorders of the neck and the neck/shoulder region available for the evaluation. These studies include some that fulfill the strict epidemiological criteria and deal with important points in such a way that causal

relationships can be deduced. The majority of the studies covers combinations of interacting workplace factors, though some studies also looked at specific workplace factors.

There is evidence of causality between repetitive activities with high frequency and MSDs of the neck and the neck/shoulder region. Most of the epidemiological studies that were reviewed in this paper define “repetitive work” for the neck region as an activity involving continuous arm or hand movements affecting the neck/shoulder musculature and causing stresses in the neck or shoulder region. Few studies investigated actual repetitive neck movements. Both of the studies that investigated repetitive neck movements did so by measuring the head position (frequency and duration of the movement), and these two studies fulfilled the strict epidemiological criteria and showed a strong association between the investigated influencing factors and MSDs of the neck and shoulder region. In the studies that defined repetitive work as continuous hand or arm movement affecting the neck and shoulder region, nine studies were of statistical significance with a positive association and overall had odds ratios higher than 3.0. Eight of the studies fulfilled all of the epidemiological criteria apart from the exposure criterion and these studies looked at repetitions for the hand or the wrist region and not for the neck. Of these studies, three provided results of statistical significance and also showed odds ratios of over 3.0; five showed insignificant odds ratios that were all below 2.0.

There is also evidence of a link between forceful movements and the occurrence of MSDs of the neck in the epidemiological literature. Most of the studies defined “forceful work” for the neck/shoulder region as forceful arm or hand movements generating loads for the neck/shoulder region. None of the studies investigated the link resulting from actual forceful neck movements. Of the 17 studies that investigated force as an exposure factor, there was a link of statistical significance in five studies, but no odds ratios were specified. Two studies found odds ratios of over 3.0, seven studies odds ratios between 1.0 and 3.0 and two studies found odds ratios of less than 1.0. Many of the studies that investigated the link between force and musculoskeletal disorders (where force was defined as a workload) can be found in biomechanical or ergonomics literature.

There is strong evidence that activities associated with a high level of static contractions, prolonged static loads or extreme working postures and affect the neck and shoulder musculature pose an increased risk of neck and shoulder MSDs. Consistently high odds ratios were found (12 studies of statistical significance with odds ratios over 3.0) which provide enough evidence to associate tension neck syndrome with static postures or static lifting work.
From an epidemiological point of view there are not enough studies to prove a link between vibration and neck disorders. At present it looks as though more information needs to be gathered in order to conclusively evaluate a possible causal link between vibration and musculoskeletal disorders of the neck. Few prospective studies that focused on the reduction of repetitive work strains and awkward postures have been able to prove that this has led to a decline in the incidence of neck MSDs and an improvement in the workers affected. This data indicates that there may be a causal link between the MSD and the workplace factors.

3.1.1.2. Musculoskeletal disorders of the shoulder

Over 20 studies investigating the link between workplace factors and MSDs of the shoulder were found. Generally speaking, these studies compared employees with higher levels of exposure to those with lower levels of exposure. Having analyzed all the studies and taking into account confounding, bias and the strengths and weaknesses of the studies, the following was concluded:
There is evidence of a positive association between highly repetitive activities and MSDs of the shoulder. This evidence, however, has important limitations: Only three of the studies referred specifically to the outcome of shoulder tendinitis, and these studies investigate the combined exposure to repetition with awkward shoulder posture or static shoulder strains. The other six studies, which noted a significantly positive association, primarily dealt with symptoms. There is insufficient evidence of a positive association between force and MSDs of the shoulder. On the other hand, there is evidence of a link between repeated or sustained shoulder postures with greater than 60 degrees of flexion or abduction and MSDs of the shoulder. The evidence here relates to both shoulder tendinitis and non-specific shoulder pain. The evidence of the link is strongest where a combined exposure to various physical factors was examined, e.g. holding a tool during overhead work. The association was

positive and consistent in the six studies that referred to a shoulder tendinitis diagnosis. Only one of the 13 studies observed no positive association between exposure and symptoms. These findings are consistent with the findings from biomechanical, physiological and psychosocial literature.
Evidence of a positive link between vibration and MSDs of the shoulder based on the epidemiological literature currently available was insufficient.

3.1.1.3. Musculoskeletal disorders of the elbow (epicondylitis)

Over 20 studies investigated the relationship between physical workplace factors (mostly in combination) and their link with epicondylitis.
The evidence of an association between repetitive work and elbow MSDs is insufficient. None of the studies that investigated repetitive work as a decisive exposure factor met the inclusion criteria.
There is evidence of a link between forceful work and epicondylitis. Studies measuring exposure on the basis of quantitative or semi-quantitative data proved a dose-effect relationship between epicondylitis and application of force. Eight of the studies fulfilled at least one criterion of the inclusion factors and showed links of statistical significance.
There were not enough studies to reach conclusions about whether posture factors alone are linked with the development of epicondylitis.
On the other hand, there is strong evidence of a link between a combination of risk factors (e.g. force and repetition or force and posture) and epicondylitis. Risk occupations include, for example, meat packers and construction workers. The only prospective study that investigated a combination of exposure factors found a particularly high incidence rate of epicondylitis (IR = 6.7) and also demonstrated a temporal link between physical exposure and epicondylitis.
The strong evidence for the combined factors is in keeping with evidence found in sports and biomechanical literature. It has also been suggested in non-epidemiological studies that forceful and repetitive contractions of the elbow flexor and extensor musculature increase the risk of development of epicondylitis. Data from both national and international epidemiological review papers have consistently noted that the highest incidence of epicondylitis occurs in occupations and fields of activity involving intensive manual work and which are highly demanding for

employees in varying environments, e.g. mechanics, butchers, construction workers and boilermakers. Apart from this data, some of the literature indicates that a high percentage of individuals with severe elbow pain cannot practice their occupations, and it is therefore reported that time off due to incapacity to work is higher amongst people with musculoskeletal disorders of the elbow than amongst people with other MSDs of the upper extremity.

3.1.1.4. Musculoskeletal disorders of the hand or wrist (tendinitis):

Eight epidemiological studies investigated the link between workplace factors and the occurrence of tendinitis in the hand/wrist region. Some of these studies fulfilled the four epidemiological criteria of this review. As a result, it was noted that there is evidence of an association between individual factors such as repetition, force and posture and the occurrence of hand/wrist tendinitis. There is strong evidence that occupations involving a combination of these risk factors (e.g. highly repetitive, forceful hand/wrist actions) increase the risk of occurrence of tendinitis in the hand/wrist region.

3.1.1.5. Carpal tunnel syndrome (CTS)

Over 30 epidemiological studies investigated the link between workplace factors and carpal tunnel syndrome (CTS). Some of the studies fulfilled all four inclusion criteria defined for this area.

There is evidence of a positive link between highly repetitive activities alone or in combination with other factors and the development of CTS. Further, there is evidence of a positive link between forceful movements and CTS. On the other hand, there is insufficient evidence of a link between CTS and extreme postures. The individual variations in the work methods of employees in the same occupations and the effect of varying anthropometry on posture are difficulties that were identified when attempting to define and characterize postures. Standardized laboratory studies in extreme hand postures supported the suspicion of a positive link between exposure and CTS. There is evidence of a positive link between activities that involve hand/wrist vibration and the occurrence of CTS.

There is strong evidence of a positive link between a combination of risk factors (e.g. force and repetition, force and posture) and the occurrence of CTS. This result is consistent with the findings of biomechanical, physiological and psychosocial papers. Data from random samples of the population consistently indicates that the highest rates of CTS are found in occupations and activities involving highly demanding, intensive manual work, e.g. meat packer, poultry processor, assembly line worker in the automotive industry.

3.1.1.6. Hand-arm vibration syndrome

Generally the studies show strong evidence of a positive link between hand-arm vibrations and the occurrence of vascular symptoms. The following occupations were affected in particular: lumberjack, stone mason, stone cutter, docker and paver. These workers were typically exposed to hand-arm vibrations with acceleration ranges of between 5 - 36 m/s^2. There is substantial evidence that the risk of hand-arm vibration syndrome increases with increasing intensity and duration of exposure to vibrating tools. There are also indications that the severity of the hand-arm vibration syndrome is associated with increasing exposure. As the intensity and duration of the exposure increases, the time between the beginning of exposure and the first symptoms decreases.

3.1.1.7. Low back disorders

Over 40 articles provided evidence with regard to the link between disorders of the lumbar spine region and the five physical workplace factors taken into consideration in this report. These were:
1) heavy physical labor
2) lifting and forceful movements
3) bending and twisting (awkward postures)
4) whole body vibration (WBV)
5) static work postures.
Many of the studies, however, also looked at the simultaneous effect of various workplace factors.

There is evidence of a positive link between the occurrence of back disorders and heavy physical work, even though the risk estimates were weaker than for lifting/vigorous movements and awkward postures and whole body vibration. This weaker causal link was probably due to imprecise characterization of the exposure.

There is strong evidence that disorders in the lumbar spine region are associated with workplace-related lifting and forceful movements. Of the 18 studies included in the analysis, 13 showed consistently positive links. Risk estimates of between 2.2 and 11.0 (OR) were deduced. Studies that used objective methods to describe the lifting in more detail showed risk estimates of over 3.0, and also found dose-effect relationships between exposure and disorders.

Adjusted odds ratios were calculated in most of these studies. Nevertheless it must be said that some of the relatively high odds ratios observed were somewhat unlikely due to confounding or other lifestyle effects. The findings observed here are consistent with biomechanical findings of investigations into the link between lifting and dynamic movements on the back tissue.

Furthermore, there was evidence that awkward postures at the workplace are associated with the occurrence of disorders in the lumbar spine region. The results were consistently positive with risk estimates above 3.0 in many cases. Dose-effect relationships were demonstrated.

There is strong evidence of an association between whole body vibration and the occurrence of MSDs in the lumbar spine region. Of 19 studies 15 showed positive associations with risk estimates of between 1.2 and 5.7 when subjective exposure measurements were performed, and between 1.4 and 39.5 when objective research tools were used. Once again, adjusted values were often specified here. Both experimental and epidemiological studies indicated that whole body vibration can, also in combination with other workplace factors, such as sitting for a long time, lifting and awkward postures, contribute to an increased risk of MSDs in the lumbar spine. It is possible that the effects of whole body vibration also depend on the source of exposure (e.g. vehicle type).

There is insufficient evidence of a link between static working postures and the occurrence of LBS MSDs. There were, however, only a very few studies that investigated the effect of static working postures and lumbar spine.

3.1.2. Criteria document for evaluating the work-relatedness of upper-extremity disorders [2]

In terms of evidence data, the authors limited themselves to the neck region, the shoulder and upper arm region, the elbow and forearm region and the wrist and hand region. Evidence was found here for various physical factors (Table 1).

Table 1: Evidence of links between physical workplace factors and the occurrence of MSDs of the upper extremity [2]

	Neck region	Shoulder and upper arm region	Elbow and forearm region	Wrist and hand region
Physical factors				
Posture in relation to duration/frequency or both	Evidence	Evidence	Evidence	Evidence
Force in relation to duration/frequency or both			Evidence	Evidence
Duration of repetitive movements	Evidence	Evidence	Evidence	Evidence
Vibrating tools			Evidence	Evidence
Combinations of the physical factors		Evidence	Evidence	Evidence
Cold				Evidence

This paper also highlights psychological risk factors (insufficient recovery time, high psychological demands, low level of social support) as risk factors and explains causality with evidence for all factors and all regions.

3.2. Own international literature research (review study)

3.2.1. Upper extremity

The findings are set out below according to body region. Most of the hits referred to MSDs of the upper extremity. It should be pointed out here, however, that many of the narrative reviews merely repeat the information provided by the NIOSH in its reviews. A total of 20 of the reviews found in the literature research deal with MSDs of the upper extremity.

3.2.1.1. MSDs of the neck or neck/shoulder region

Six papers refer to MSDs of the neck and the cervicobrachial region or the neck/shoulder region, or the neck and the upper extremity [4; 5; 6; 7; 8; 9; 10; 11]. In each case, purely in terms of localization, there is an overlap of MSDs of the upper extremity and MSDs of the cervical spine. The existing reviews were classified in the AMSTAR categories 0 to 8, i.e. there is a wide qualitative range. As far as the neck is concerned, the paper by Ariens et al. from 2000 is of particular interest [6] as it investigates a total of 40 papers relating to the development of MSDs of the neck. Evidence was cited here for the duration of a sedentary activity (OR 0.94-2.8) and for trunk rotation or bending (OR 1.8-1.9). Evidence for the other influencing factors investigated, such as neck flexion, extension, rotation, arm impact, arm posture, hand-arm vibration, workplace ergonomics and driving is deemed to be non-conclusive. Both the studies by Aptel [8] and Buckle [9] (AMSTAR 0) quote the NIOSH report, which cites evidence for repetitive movements, exertion and strong evidence for posture, but shows insufficient evidence for vibration impacts. Wahlström [7] (AMSTAR 1) investigated the occurrence of MSDs of the neck and upper extremity, especially for PC workstations, and found positive, albeit overall conflicting results with regard to shoulder flexion and abduction and an inner elbow angle of < 121 degrees. This information tends to refer to the shoulder region as opposed to the neck. Coté et al. [4] also look at possible risk factors for pain in the cervical spine region in great detail. They find positive associations with evidence for MSDs of the cervical spine and sedentary activity (OR >2.0), repetitive action and precision work (OR 1.3-1.4), neck flexion > 20° for over 70% of working hours (OR 1.7), keyboard position (OR 0.2), mouse position (no OR specified), telephone lodged on shoulder (no OR specified) and negative evidence for MSDs of the cervical spine and arm rests. They describe provisional evidence for physical environmental factors and awkward postures.

Evaluation:

Once again generally speaking from an epidemiological point of view evidence-based point of view, reference must be made to the NIOSH report [1]; there is evidence/strong evidence of risk factors in the form of repetitive movements, exertions and, in particular, posture. The review by Ariens [6] reveals that the

duration of the sedentary activity, as well as trunk rotations and bending should also be taken into account. Vibration impacts cannot be linked to the occurrence of MSDs of the neck and cervicobrachial region with adequate certainty. For prevention at PC workstations in particular, the results of the study by Wahlström [10] (risk factors: shoulder flexion & abduction, inner elbow angle < 121 °) and by Coté et al. [4] should be taken into account.

3.2.1.2. Shoulder MSDs

Eight papers (AMSTAR 0-6) dealt with shoulder disorders [5; 7; 9; 12; 8; 13; 14; 7]. Once again the evidence data here primarily quotes the NIOSH report from 1997 [1]. For example, it is stated that repetitive movements show epidemiological evidence, exertions show insufficient evidence, the span of joint movement shows epidemiological evidence, impact of vibrations on the other hand is associated with insufficient evidence. Walker-Bone's paper [12] (AMSTAR 6) also notes that there is evidence of a link between overhead work and the occurrence of shoulder disorders, whereas repetition is only implicated with probable evidence. More specifically with regard to the NIOSH report [1], papers that investigated a link between shoulder posture and bicep tendon tendinitis considered shoulder posture in flexion and abduction in particular as a risk factor. As far as supraspinatus tendinitis (rotator cuff tendinitis) is concerned, a link is also noted between rotary movements in the shoulder joint and occurrence of the disorder. Overhead work and load work with repeated pulling or lifting are also specified as risk factors. Yassi's work [14] (AMSTAR 1) associates thoracic outlet syndrome with flexion, exertion, repetitive reaching over shoulder level and prolonged carrying of side loads/carrying rucksacks. Mani and Gerr [13] as well as Wahlström [7] (both AMSTAR 1) associate trapezius myalgia in the shoulder region with sustained static postures of the neck, shoulder and back or prolonged static shoulder loads. There is, however, no evidence data for these links between risk factor and disorder, nor are any odds ratios or risk estimates stated.

Evaluation:

Therefore, the NIOSH report in particular is once again decisive for specifying evidence as regards the shoulder region. Repetitive movements and posture in

particular are implicated with the development of disorders. Further, the paper by Walker-Bone [12] also cites evidence for overhead work and probable evidence for repetition. As the paper by Walker-Bone [12] was compiled in 2003 after the NIOSH report of 1997, the more recent findings from Walker-Bone's paper should at least be taken into account and possibly further verified when planning preventive steps. The reviews provided no informative risk estimates for the shoulder region, making prioritization of measures difficult.

3.2.1.3. Elbow MSDs

A total of nine reviews [9; 10; 15; 12; 13; 16; 14; 17; 41] concerning MSDs of the elbow were found, which highlighted the link between occupational activities and disorders. Some of these look at MSDs of the elbow in general, others look more specifically at epicondylitis, and others again focus very specifically on lateral and/or medial epicondylitis. The two papers by Aptel [9] and Buckle [10], both classified as AMSTAR 0, dealt generally with MSDs of the elbow, and once again referred to the NIOSH report. For example, it explains that there is insufficient epidemiological evidence for repetitive movements; similarly there is insufficient epidemiological evidence for exertions and for the span of the joint movements, however, if at least two of the aforementioned risk factors are present, there is strong evidence that the workplace-related risk factors could be linked to the occurrence of elbow MSDs. Palmer's paper [15] (AMSTAR: 8) looks at the risk factors for the development of epicondylitis in more detail. It also specifies gender-specific odds ratios (OR). For example, working with raised arms in front of the body for over 75 % of working hours is linked to a significantly increased risk of the occurrence of epicondylitis in women (OR 4.0). Likewise, working with flexed or twisted hands for more than 75 % of the working hours is significantly higher for women, with an OR of 7.4. Repetitive arm movements for more than 75 % of the working hours also lead to a 3.7 times higher OR for the occurrence of epicondylitis of the elbow in women. Working with flexed or twisted hands and precision work of the upper extremity were also investigated as risk factors for men, with ORs here of between 3.2 and 5.2. Repeated turning and screwing during the occupational activity is associated with an OR of 2.1 for both sexes. The Walker-Bone papers from 2003 and 2005 [12;8], classified as AMSTAR 6 and 5, both specify strenuous manual work with a combination of force, repetition

and/or vibration as a risk factor for the occurrence of epicondylitis. The narrative reviews by Mani and Gerr [13], Moore [16], Yassi [14], Wainstein and Taylor [17], which were classified as AMSTAR group 1, specify other potential risk factors as follows, in addition to the factors mentioned above for elbow MSDs: Powerful grip with wrist extension, high hand holding power with repetitive movements in the hand and arm, repetitive rotary movements, sudden or sustained muscular stresses, repeated pronation-supination movement against resistance or without elbow extension, unusual actions, prolonged hammer use, forceful wrist extension or gripping with an outstretched arm. For medial epicondylitis in particular, it is also noted that, apart from the effect of force and repetitive movements, the potential causality between occupational activities and the development of medial epicondylitis is not well researched.

Evaluation:

In terms of evidence data, the NIOSH report is once again the soundest source, detailing considerable epidemiological evidence of a link between a combined occurrence of exertion and repetitive movement. In addition, however, the types of exposure mentioned in more detail, particularly as specified in the paper by Palmer [15] should be taken into account when planning preventive measures or further research activities on occupational MSDs of the elbow. As far as prioritization is concerned, women should avoid activities with flexed or twisted hands in particular (OR 7.4), men should avoid precision work of the upper extremity in particular (OR 5.2) and both sexes should avoid circular or screwing motions (OR 2.1) [15].

3.2.1.4. Hand or wrist MSDs

There are 14 papers in total on MSDs of the wrist [5; 7; 9; 10; 12; 13; 14; 15; 16; 17; 18;19; 20; 21]. Four of the papers concentrate on the general definition of “musculoskeletal disorders of the hand or wrist” [5;18;19]. The paper by Davis and Kotowski [5] (AMSTAR 2) links powerful forces, frequent repetition, awkward postures and hand-arm vibration with the occurrence of these MSDs. Malchaire et al. [19] (AMSTAR 2) also rate the evidence of a link between various exposure factors and the occurrence of hand and wrist MSDs. Overall they believe there is a link with repetition and physical workloads, but there is no link with various gripping

techniques, no link with duration of the exposure (working hours) and no link with exposure to vibration. Wahlström [7] (AMSTAR 1) investigated the link between hand and wrist MSDs, especially at PC workstations and listed extreme wrist positions, repetitive activities and the combination of repetitive activities and extreme working postures as risk factors. His review found a positive link between these factors and wrist MSDs in all the studies detailed. Keyserling's paper [18] (AMSTAR 1) provides no exact localization information about the MSDs investigated, however it is implied from the range of disorders specified that it is also dealing with hand/wrist MSDs. Without specifying the exact location or evidence data, the following risk factors are listed here: firm gripping, exertion with flexed or overextended wrist, exertion together with radial or ulnar deviation, exertion with pincer grip or fingertip pressure, repetitive exertion, dynamic effects of hand movement (acceleration), working with appliances operated by air pressure, keyboard work, work with gloves, work with elevated shoulders, torque and angular momentum of a pneumatic tool, grip type of a pneumatic tool, vertical and horizontal range of hand tool, weight of pneumatic tool.

Evaluation:

Malchaire [19] describes evidence of a link between repetition, physical workload on the one hand, and hand/wrist MSDs on the other. By contrast, the same review [19] found no evidence for grip type, working hours and vibration. For PC workstations the review describes positive associations between wrist position, repetition and a combination of the two factors with the occurrence of MSDs in the wrist region [7]. Further, other risk factors, as described by Keyserling [18] (see above) in more detail, have to be taken into account. Risk estimates are not available.

The following specific symptoms of the hand/wrist region will be listed and discussed below in brief:

DeQuervain, extensor carpi ulnaris tendinopathy, flexor carpi radialis tendinopathy, hand-am vibration syndrome, peritendinitis, dorsal tendon entrapment, tendinitis, tenosynovitis, trigger finger and hand-arm vibration syndrome.

Three of the papers (all AMSTAR 1) refer to DeQuervain syndrome [13; 14; 17]. Causes cited here are fast rotary movements, repetitive movements, ulnar deviation, thumb use, radial deviation, simultaneous radial abduction with abduction and

extension of the thumb. There is no rating of the level of evidence. Many of the studies found during the literature research also refer to tendon disorders in the hand and wrist region. They include tendinopathy, peritendinits, tendon entrapment, tendinitis, tenosynovitis and trigger finger. The papers by Aptel et al. [9] and Buckle and Deveraux [10] (AMSTAR 0) again make reference to the NIOSH report, citing evidence for repetitive movements, exertions, the span of the wrist movement. There is strong evidence for the existence of at least two of the aforementioned risk factors. Walker-Bone et al. [12] (AMSTAR 6) look at the interaction of high impact and a high number of repetitions in their review and report an increased risk of up to 29 times for the occurrence of tendinitis in the hand/wrist region. Likewise, the other papers provide no new findings compared to the findings already published in the NIOSH report in this respect. The Moore paper [16] (AMSTAR 1) specifically looked at peritendinitis and dorsal tendon entrapment. Blunt trauma, contusion, as well as unusual, repetitive actions are cited as risk factors for peritendinitis. Overstressing of the thumb, monotonous work, chronic trauma, thumb pressure during abduction and ulnar deviation and a firm grip combined with radial hand movements are cited as risk factors for dorsal tendon entrapment. So-called trigger finger is investigated in the papers by Wainstein and Taylor [17] (AMSTAR 1), Walker-Bone [12] (AMSTAR 6) and Mani and Gerr [13] (AMSTAR 1). Again, repetitive thumb and finger actions are specified as risk factors here, in particular where there is high impact. Repetitive pincer grip is specifically addressed, carried out at high speed and in a non-neutral wrist position, likewise hand vibration and the use of hand tools. With regard to the use of hand tools, the investigation into white finger disease, or hand-arm vibration syndrome, is also worth pointing out. Three papers in total made reference to this (AMSTAR 0-1) [10; 13; 21]. Vibration, or handling vibrating hand tools such as chainsaws, pneumatic hammers, drills, etc, as well as working in a cold environment are cited as exposure factors. Hand-arm vibration is, however, also associated with the development of joint disorders in the wrist region, for example, in Hagberg’s paper [20] (AMSTAR 4), however, the evidence here was rated as insufficient as there are inconsistent study findings with statistically insignificant ORs of between 0.82 -6.8.

Evaluation:

It can be noted with regard to tendon disorders and vascular disorders in the hand/wrist region that repetition, impact and posture should be considered risk factors for the development of musculoskeletal disorders in the hand/wrist region as there is evidence here of a causal link [9;10] (from NIOSH [1]). According to the data from Walker-Bone [12], the combination of high impact and repetition in particular is associated with an up to 29 times increased risk and should possibly be considered as a particularly significant “risk combination”. Palmer’s review [15] notes a significant link between grip strength and high frequency in repetitive actions (OR 5.5-17.0) in one of the papers included. This would support the conclusions reached by Walker-Bone. In terms of disorders of a hand-arm vibration syndrome nature, the literature research carried out here offers no new findings and only inconclusive evidence [20]. Again, this literature research provides no new indications of a link between MSD of the wrist/hand and the effect of vibration. As far as specific prevention and research measures for the hand/wrist region are concerned, the more detailed exposure data from the papers by Moore [16], Weinstein [17], Walker-Bone [12], Mani and Gerr [13] and Keyserling [18] should also be taken into consideration in the future.

3.2.1.5. Carpal tunnel syndrome (CTS)

Nine of the reviews in total provide information about a link between CTS and risk factors at work [7; 8; 9; 10; 12; 13; 14; 16; 22]. The AMSTAR classification of the reviews ranges from 0 to 6. Some of the papers also specify an evidence class. The two reviews with the highest classification, both of which by Walker-Bone et al. [8; 12], identify the following risk factors for carpal tunnel syndrome: Impact and/or repetition, hand or wrist vibration, awkward forearm, wrist or finger position. It is noted that the combined effect of force and repetition in particular is deemed to be a more significant influencing factor, whereas additional influences such as vibration or awkward position could *probably* influence the development of CTS. The other studies provide a narrative evaluation of a selection of literature which is not detailed any further. The studies by Aptel [9] and Buckle [10], both of which were classified in group 0 according to the AMSTAR criteria, however provide information about epidemiological evaluation of the risk factors. Both state that the link between carpal tunnel syndrome and repetitive movement is evidence-based, as is the link between

exertion and carpal tunnel syndrome. The link between vibration and the development of carpal tunnel syndrome is (at least from an epidemiological point of view) described as insufficient. Apart from this, it is noted that if at least two of the aforementioned risk factors converge (repetition, exertion, vibration), there is strong evidence of a link between exposure and carpal tunnel syndrome. These findings were taken from the NIOSH report. The reviews by Yassi [14] and Mani and Gerr [13], both of which were rated AMSTAR 1, also cite impact, vibration, repetition and mechanical stress as risk factors for CTS. Moore [16] (AMSTAR 1) details a link between CTS and different occupational risk factors, and highlights the various causes of CTS in more detail, for example CTS as a result of tenosynovitis, as a result of tendon-nerve tractions, as a result of tendon hypertrophy, as a result of tendon contact pressure, as a result of lumbrical retraction, as a result of hypertrophy of the transversal carpal ligament, and as a result of ischemia. The paper goes on to explain what types of exposure could lead to the causes of CTS listed above (see Table 16). Wahlström [7] only briefly touches on CTS in his review of PC workstation activity. Again, in this case the evidence is not rated. In terms of the review quality the study was only categorized as AMSTAR class 1.

Evaluation:

Most of the reviews researched in this case referred to the evidence data of the NIOSH report. To avoid redundancy, the findings of this will not be detailed again at this point. Virtually none of the reviews specifies risk estimates as regards exposure, it would therefore seem difficult to prioritize the influencing factors. The combined effect of forceful, repetitive movements in particular is cited by Walker-Bone et al. in two papers [8; 12] as being an especially significant form of exposure. The combined effect of vibration and awkward posture, on the other hand, is only cited as being a “probable” risk combination [12]. Again, in the detailed description of possible causal factors for CTS in Moore’s paper, the force factor and the repetition factor play an important role, distinguished here according to the effects of these types of exposure on the various anatomical structures of the hand (tenosynovitis, tendon-nerve traction, tendon hypertrophy, tendon contact pressure, lumbrical retraction, transverse carpal ligament hypertrophy, ischemia, wrist extension > 20°).

3.2.2. MSDs of the lower extremity

Only one paper (Davis and Kotowski [5], AMSTAR 2) deals generally with musculoskeletal disorders of the lower extremity and specifies walking on uneven and wet terrain and carrying heavy loads as risk factors here.

3.2.2.1. Hip osteoarthritis

Six studies in total investigated the link between occupational activity and the occurrence of hip osteoarthritis in more detail [5; 11; 23; 24; 25; 26]. These studies were assigned to AMSTAR classes between 2 and 10. Jensen's paper [23] (AMSTAR 9) cites heavy lifting as a risk factor for hip osteoarthritis (moderate to strong evidence), agricultural activities (moderate to strong evidence), activity as a construction worker (limited evidence), and climbing stairs or ladders (insufficient evidence). Lievense et al. [24] (AMSTAR 10) specify high physical workload (moderate evidence), frequent heavy lifting (> 25 kg) (moderate evidence) and agricultural activity for more than 10 years (moderate evidence) as risk factors for the development of hip osteoarthritis. The following risk factors are also mentioned, however, without specifying any association, risk or evidence rating: vibration, jumping, standing for a long time, walking over uneven ground and exposure to vibrations from driving a tractor. Five out of five studies cite at least one positive association for activities with high compressive forces affecting the hip joint. The other papers provide no further information about evidence [5; 11; 25; 26].

Evaluation:

The existing literature outlines the situation as follows: The link between hip osteoarthritis and heavy lifting/carrying is implied with moderate to strong evidence (OR 2.0-3.5), between hip osteoarthritis and agricultural work with moderate to strong evidence (OR 2.0-12.0), between hip osteoarthritis and work in the construction industry (OR 3.3) with limited evidence. The following other risk factors (however without evidence data, in some cases also without risk evaluation) were also specified: High physical workload (heavy work, OR: 1.5-9.3), climbing stairs (OR 2.3-12.5), whole body vibration, standing for a long time, walking on uneven ground, forced postures.

3.2.2.2. Knee osteoarthritis

Five of the papers identified here deal with knee osteoarthritis/meniscus injuries [11; 23a; 25; 26; 27]. Their AMSTAR values range between 5.5 and 9.0, therefore overall these are well constructed reviews from a methodological point of view. The study by McMillan and Nichols [27] (AMSTAR 7.5) cites evidence for the link between injuries, meniscectomy with kneeling or squatting with or without heavy lifting and the development of knee osteoarthritis. In 15 of 17 studies there was a positive association between kneeling and squatting with heavy lifting and knee osteoarthritis with ORs of between 1.9 and 7.31. Jensen's paper [23a] (AMSTAR 9) cites moderate evidence for heavy lifting with ORs between 1.9 and 14.3, moderate evidence for kneeling with ORs between 2.2 and 6.9 and moderate evidence for the combined effect of heavy lifting and kneeling/ squatting with ORs between 2.2 and 5.4. By contrast, the evidence for climbing stairs or ladders is rated as limited with an OR of 2.7. Schouten et al. [25] (AMSTAR 6) also find positive associations for the influencing factors named above, although no evidence ratings are specified. In addition to the risk factors mentioned above, the paper by Vignon et al. [26] (AMSTAR 6) also includes steep inclines, jumping and vibration, however the text does not state a positive/negative association nor a risk factor nor an evidence rating, which means that the evidence for these influencing factors cannot be evaluated on the basis of these papers. In addition, Walker-Bone and Palmer [11] (AMSTAR 5.5) each find a positive link between heavy physical work and knee osteoarthritis in four studies.

Evaluation:

Overall the following conclusions can be drawn from the findings for knee osteoarthritis: There is moderate evidence of a link between knee osteoarthritis and heavy lifting and carrying (OR 1.9-14.3); similarly, moderate evidence is described for kneeling and squatting as risk factors (OR 1.9-6.9); there is also moderate evidence for a combination of kneeling and heavy lifting (OR 2.2-5.4) and limited evidence of a link between climbing stairs/ladders and knee osteoarthritis with OR 2.5-2.7 for men and OR 5.1 for women. Other risk factors covered are: Walking for a long time, repeated bending of the knee, steep inclines, jumping, exposure to vibration, heavy work. No concrete risk factors or evidence data were provided here.

3.2.3. Low back disorders

As far as the spine is concerned, 15 review papers were identified which deal with back disorders [5; 11; 21; 28; 29; 30; 31; 32; 33; 34; 35; 36; 37; 38; 39;]. The only paper that looks at both neck and back pain is by Hansson and Jensen [39] and has been rated with AMSTAR value 6. The evaluations here regarding the link between risk factors and disease entity refer to the evaluation of time off work due to incapacity. The authors find a positive link between heavy lifting and carrying or stooped and rotated lumbar spine and the occurrence of neck or low back pain, rating the evidence as limited. In addition, they find a negative link between whole body vibrations and the occurrence of time off due to incapacity to work as a result of pain neck or low back, again rating the evidence as limited. The other papers, which are primarily limited to the lumbar spine, range between AMSTAR classes 0 and 9. The review by Marras [28] (AMSTAR 1) again refers to the NIOSH report [1]. Walters et al. carried out a meta-analysis [30] (AMSTAR 7) investigating the link between driving a forklift truck and low back pain. The authors calculated a meta-odds ratio of 2.3 for this link from seven high quality studies. By contrast Hartvigsen et al. [31] (AMSTAR 9) investigated the link between sedentary activity and the occurrence of low back disorders and found no conclusive evidence of a causal link for either exclusively sedentary activities or so-called “sedentary occupations”. The odds ratios for these links ranged between 0.4 and 2.1 in the evaluated studies. Fatallah et al. [32] (AMSTAR 1) describe (following evaluation of the studies available to them) provisional evidence of a link between stooped posture between 21° and 60° for more than 5 % of the working hours and the occurrence of low back pain, with the quality of the studies analyzed tending to be classed as low. Lis et al. [35] (AMSTAR 8) looked at the link between sitting and the occurrence of low back pain. In their evaluation of 24 studies they showed a link between sitting (> half a working day) and the occurrence of lumbar spine pain in ten studies, with the odds ratios varying between 0.7 and 9.0 making them somewhat disputed. The authors note that more recent studies on this issue have found no link between sitting and low back pain. The simultaneous effect of whole body vibration and sitting for over half of the working hours is considered to be a relevant influencing factor for the occurrence of low back disorders in seven out of eight studies. The odds ratios here range between 1.7 and 13.4 and the link is rated by the authors with strong evidence. The same

applies for the simultaneous effect of sitting for over half of the working hours and awkward posture. Four out of four studies evaluated show a positive link and the odds ratios range between 2.3 and 10.6, which means that the authors also deemed this link as having stronger evidence than sitting alone. Punnett et al. [36] (AMSTAR 0) specify prevalence odds ratios of between 1.3 and 8.1 for simultaneous exposure to stooped posture and rotary movements of the lumbar spine and the occurrence of lumbar spine pain, prevalence odds ratios of 1.3-3.3 for static postures, prevalence odds ratios of 1.5-9.0 for whole body vibrations and prevalence odds ratios of 1.5-3.1 for heavy lifting. The review by Seidler et al. [37] (AMSTAR 1) finds evidence of a positive link between manual material handling and low backpain. There is also evidence of a positive link between awkward postures (forward bending postures) and low back pain, as well as a positive link between whole body vibrations and low backpain. In the case of repetitive activities, it is assumed that there is limited evidence of a positive link with low backpain, sedentary activities are deemed to have a negative link with limited evidence. Shelerud [38] (AMSTAR 1) reaches a similar conclusion, specifying an increased risk for heavy work, static working postures (standing), heavy lifting, a significantly increased risk for bending and turning, an unclear situation for whole body vibration and a lower odds ratio for static sedentary working postures. Hartvigsen et al. [31] (AMSTAR 9) also investigated a dose-effect relationship between sitting and the occurrence of low backpain and do not find any positive link in the three studies that investigate this link. In this respect they deem the evidence of this link to be non-conclusive. The reviews by Keyserling [33] (AMSTAR 1) contain special accounts of certain risk factors. The influencing factors cited here are: forward bending, axial trunk rotation, single-handed lifting, lifting above shoulder level, lifting in restricted room for maneuver, heavy weight of object, horizontal shifting of centre of gravity when lifting, availability of handholds, frequency of repetition, length of shift, distance over which an object has to be lifted, pushed or pulled and dynamic effects of the lifting speed (acceleration of external weights and body parts).

Evaluation:

It can be concluded from the preceding reviews that there is strong evidence of a link between lifting/forceful work in particular and low back disorders. A prevalence OR of 1.5-3.1 is specified here. Awkward postures (trunk bending and rotation: OR 1.3-8.1,

static posture: OR 1.3-3.3 and heavy work were also deemed by the authors as showing evidence between the risk factor and the occurrence of low back disorders. The situation regarding whole body vibration is less clear, as in one case strong evidence is described, but in another there is ambiguity. Overall, however, it is more likely that whole body vibrations contribute to pain in the lumbar spine region (OR 2.13->3), particularly when whole body vibration is experienced in a sitting posture, such as when driving a forklift truck (Meta OR 2.3).

4. Discussion and recommendations

The scientific/epidemiological findings up to 1997 are covered very systematically in the NIOSH report on musculoskeletal disorders [1]. There is one further review paper up to 1998 [2]. Both of these papers neglect MSDs of the lower extremity. Since then, further work has been undertaken in certain areas to update scientific knowledge of the link between activities and MSDs. This literature research of more recent review articles has tried to take account of these endeavors. Unfortunately, further data about evidence ratings was provided in very few cases, which means that first and foremost “trends” can be identified from most of the more recent studies.

Therefore, this data, and especially the more recent literature research, has been used to identify particularly physically stressful types of exposure for which further study would seem useful or for which preventive measures might be useful. Prioritization in terms of the number of employees that could be affected has not yet been undertaken here:

1) Neck: Posture, in particular neck flexion >20° (OR 1.7), trunk rotation or bending (OR 1.8-1.9), sedentary activity (OR 1.0-3.0)
2) Shoulder: Combined stresses, in particular: Overhead work (with load), activities with flexion and abduction in the shoulder joint, rotary movements in the shoulder joint
3) Elbow: Combined stresses with effort, in particular: Forceful movements with flexed or twisted hands (women: OR 7.4), forceful precision work (men: OR 5.2), forceful turning and screwing (both sexes: OR 2.1)

4) Hand/wrist: Combined stresses of effort and repetition (up to 29 times increased risk), in particular grip strength and repetition (OR 5.5-17.0), cold exposure
5) Carpal tunnel syndrome: Here again the combined stresses of force and repetition seem to represent a particular strain, the combination of vibration and posture represents a possible strain
6) Hip osteoarthritis: Heavy lifting and carrying (OR 2-3.5), agricultural work (OR 2.0-12.0), work in the construction sector (OR 3.3), heavy work (OR 1.5-9.3), climbing stairs/ladders (2.3-12.5), unclear situation for whole body vibration
7) Knee osteoarthritis: Heavy lifting and carrying (OR 1.9-14.3), kneeling/squatting (OR 1.9-6.9), combination of kneeling/ squatting and heavy lifting (OR 2.2-5.4), climbing stairs/ladders (esp. women: OR 5.1)
8) Lumbar spine: Heavy lifting and carrying (OR 1.5-3.1), posture (OR 1.3-8.1), heavy work (no OR specified), and whole body vibration when seated (driving a forklift truck: meta OR 2.3).

As in Work Package 1, the TOP TEN risk activities for which successful prevention might be possible is compiled on the basis of the frequency of the disorders and assumed frequencies of the activities in the respective occupations:

1. Lumbar spine – heavy lifting and carrying
2. Lumbar spine – posture
3. Lumbar spine – heavy work
4. Lumbar spine – whole body vibration when seated
5. Neck/shoulder pain – sedentary activity with neck flexion > 20°
6. Shoulder MSDs – combined stress of force and posture or force and rotation
7. CTS hand/wrist MSDs – combined stresses of force and repetition
8. Epicondylitis – combined stresses of repetition and force or posture and force
9. Knee osteoarthritis – combined stress of force and posture
10. Hip osteoarthritis – heavy lifting and carrying

The study carried out here supports the conclusions reached by Hartmann and Spallek [40], who analyzed work-related MSDs. They note that there is still not enough sufficiently proven knowledge about the effects of the four most thoroughly investigated physical stresses (lifting and carrying, forced postures, repetition, vibration) and explain this as follows:

1. Even though the influence of weight loads at the workplace has been better researched than any other physical influencing factor, there are currently no sufficiently scientifically proven benchmarks for various age groups, men and women or people in different physical conditions. Even this review analysis, despite the fact that clear indications of a dose-effect relationship can be seen from the studies, does not reach any conclusions as regards benchmarks for weight loads at the workplace.
2. Although forced postures are increasingly being acknowledged as physical risk factors (and to some extent evidence for MSDs of the shoulder, wrist and back has to be accepted), they are very difficult to identify and assess by third parties and in most cases depend on individual factors relating to the employees, and can therefore only be recorded in a standardized way in a very few cases. This methodological problem could, amongst other things, contribute to the fact that in many cases forced postures fail to deliver adequate significant study results that could lead to greater evidence of this link. This was also highlighted in the discussions of the review articles investigated here on several occasions.
3. Repetitive stresses were identified epidemiologically as risk factors for the occurrence of MSDs, especially of the upper extremity. However, when it comes to prevention of these stresses it is important to note that repetitive stresses at low to moderate exposure frequency can be detected physiologically at muscle level at the earliest, but not reliably by the naked eye. This impedes preventive approaches.
4. The effect of vibrations can be well linked to MSDs from a biomechanical point of view and can even be substantiated with benchmarks to some extent. There is, however, still some lack of clarity when it comes to the simultaneous effect of vibration and posture in particular. Further research is required here.
5. Links between physical, mental and organizational stresses are only partially investigated. The multifactorial origin of the relevant disorders further impedes the analysis.

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