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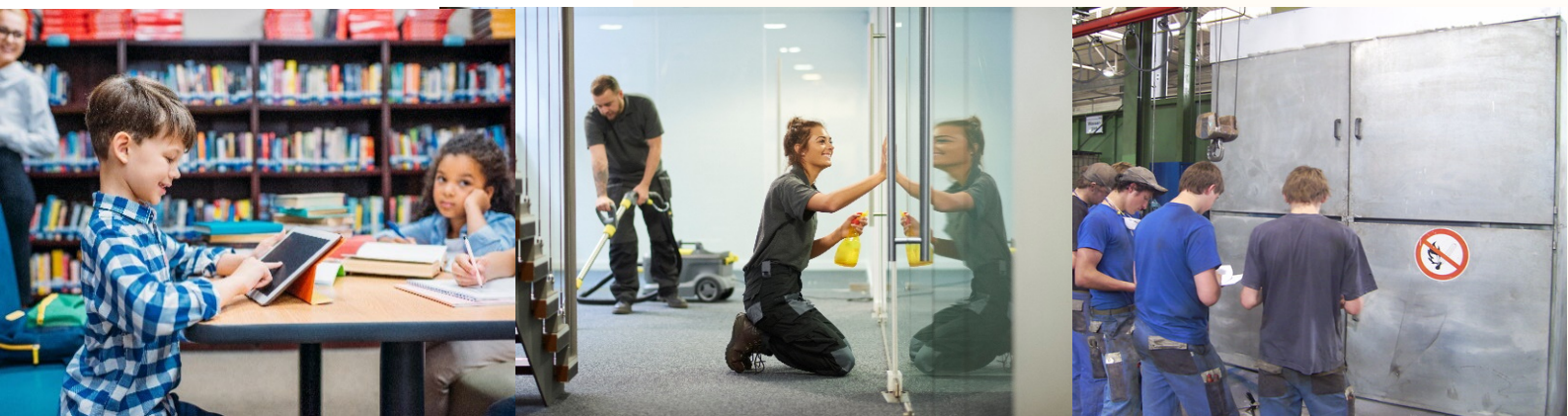


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Musculoskeletal disorders among children and young people: prevalence, risk factors, preventive measures

A Scoping Review

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Table of Contents

List of figures and tables.....	4
Executive summary	5
Main conclusions	5
What did we find?	6
What did we do to find this?	11
What further research is required?	12
1 Introduction.....	14
1.1 Background.....	14
1.2 Aim of the project.....	14
2 Methods.....	15
2.1 Definition of the research questions — concepts and key elements.....	15
2.2 Systematic search for relevant studies.....	17
2.3 Study selection	20
2.4 Data extraction and processing.....	20
2.5 Collating, summarising and reporting the results	22
2.5.1 Quantitative analysis of prevalence values	22
2.5.2 Qualitative compilation of results on risk factors and interventions.....	22
3 Results	24
3.1 Search and selection process	24
3.2 Prevalence of MSDs among children and young people	26
3.2.1 MSD prevalence per gender.....	26
3.2.2 MSD prevalence per MSD location	28
3.2.3 MSD prevalence per age	30
3.2.4 MSD prevalence per country	30
3.2.5 MSD prevalence grouped by publication year.....	35
3.3 Risk factors related to MSDs.....	37
3.3.1 MSD risk factors in children and adolescents before entering the labour market.....	38
3.3.2 Work-related risk factors in young workers	50
3.3.3 Sports injuries	53
3.4 Preventive measures or intervention strategies	54
3.4.1 Prevention of MSDs in children and adolescents.....	54
3.4.2 Prevention of MSDs in young workers	57
3.4.3 Prevention of sports injuries	59
4 Discussion	61
4.1 Methodology of literature search and data processing	61
4.2 Prevalence estimation	62
4.3 Evidence on MSD risk factors	63

4.3.1	MSD risk factors in children and adolescents	63
4.3.2	Work-related MSD risks in young workers	65
4.4	Efficacy of preventive measures or intervention strategies	67
4.5	Conclusion	68
5	Research gaps and recommendations	70
	References	72
	Annex 1: Search terms and search strings	91

List of figures and tables

Figure 1	PRISMA flow chart documenting the systematic selection process	24
Figure 2	Classification of included studies according to population and study content	25
Figure 3	Percentages of children and young people with MSDs before and after entering the labour market (data published between 2010 and 2021) grouped by gender.	27
Figure 4	Percentages of children and young people with MSDs before and after entering the labour market (data published between 2010 and 2021) grouped by MSD locations.	29
Figure 5	Percentages of children and young people with MSDs before and after entering the labour market (data published between 2010 and 2021) grouped by midpoint age.....	30
Figure 6	Median percentages of children and young people with MSDs before and after entering the labour market (data published between 2010 and 2021) grouped by country.	34
Figure 7	Percentages of children and young people with MSDs before and after entering the labour market (data published between 2010 and 2021) grouped by year of publication.	37
Figure 8	Risk factors for MSDs in children and young people identified in this review.....	38
Figure 9	Percentage of workers reporting different musculoskeletal disorders in the past 12 months, by age group, EU-28, 2015. Source: EU-OSHA (2019)	63
Table 1	Key concepts of research question (1) on prevalence and risk factors (CoCoPop type)	16
Table 2	Key concepts of research question (2) on interventions (PICO type).....	16
Table 3	Selection criteria for the key concepts and elements of research questions (1) and (2).....	17
Table 4	List of literature databases included in the search.....	18
Table 5	Tools for the search of 'grey literature'	18
Table 6	Initial list of key institutions considered in the search of 'grey literature'	19
Table 7	Pre-labour market and work-related risk factors for MSDs analysed or identified in the studies (number of studies/reviews in brackets, multiple answers possible).....	25
Table 8	Percentages of children and young people with MSDs before and after entering the labour market (data published between 2010 and 2021) grouped by gender	26
Table 9	Percentages of children and young people with MSDs before and after entering the labour market (data published between 2010 and 2021) grouped by MSD locations	28
Table 10	Percentages of children and young people with MSDs before and after entering the labour market (data published between 2010 and 2021) grouped by country	31
Table 11	Percentages of children and young people with MSDs before and after entering the labour market (data published between 2010 and 2021) grouped by year of publication.....	35

Executive summary

Main conclusions

This literature review focuses on musculoskeletal disorders (MSDs) among children and young people, paying special attention to young workers. The objective of the review is to identify the prevalence of and main risk factors for MSDs and the main preventive measures or intervention strategies.

In many cases, MSD problems begin in childhood, when inappropriate postures are combined with little sports activity (Rodríguez-Oviedo et al. 2018). Suffering from musculoskeletal pain in childhood or adolescence increases the risk of having it as an adult (Kovacs et al. 2011), possibly through the development of maladaptive beliefs, behaviours and attitudes related to the earlier pain events (Michaleff et al. 2014). The already high prevalence of MSDs among children (Calvo-Muñoz et al. 2013, Kamper et al. 2016b) raises the issue of young workers coming into the workplace with pre-existing musculoskeletal problems that have the potential to be exacerbated by work. If MSDs in children can be prevented, entry into a cycle of recurring episodes may be delayed and the prevalence of adult MSDs may be decreased (Hill and Keating 2015).

This report shows how important it is to adopt a 'life course' approach to studying musculoskeletal conditions and musculoskeletal health. Such an approach has the potential for a better understanding of how and why musculoskeletal conditions occur over the life course and how musculoskeletal health can be promoted. Its adoption 'improves prevention for all workers (young and older), and reduces the damage to workers' health while limiting early exit from work and improving the sustainability of work in jobs that have high physical demands' (Belin et al. 2016). In this context, the lifelong impact of musculoskeletal pain needs to be considered.

We found the prevalence of MSDs to be already quite high in schoolchildren and young people (7 to 26.5 years old), with ~30 % on average suffering from an MSD. However, apprentices and young workers or students (15 to 32 years old) show a slightly higher average prevalence of MSDs of ~34 %.

There are several reasons for the rather high prevalence rates in children and young people. MSDs can be caused by acquired, individual or congenital risk factors. Most of the acquired risk factors, i.e. physical, psychological, socioeconomic and environmental risk factors, are largely preventable.

A considerable number of preventable, non-work-related risk factors have been suggested to be associated with a higher risk of MSDs in children and adolescents: malnutrition and overweight; very low and very high levels of physical activity, leisure activities or poor sleep; smoking and alcohol consumption; bad or incorrect postures caused by extended sitting, excessive use of electronic devices, backpack loads or playing an instrument; sports injuries; mental health problems; social status; and weather conditions. However, current studies show inconsistent results, and currently no definite evidence supports the association of most of these factors with a higher risk of MSDs in children and young people. This could certainly also be attributed to the limitations of some of the existing studies.

Work-related risk factors for young workers comprise physical workload, long-term unnatural working positions, repetitive work, working under pressure, bullying, job insecurity, professional challenges and extreme weather conditions. There is a lack of studies on young workers in occupations with high exposure to noise, vibration, heat or cold, and to physically demanding work factors such as working in awkward positions, handling heavy loads and repetitive work. Nevertheless, studies that examined specific sectors and occupations (e.g. professional musicians and workers in the health care sector) found young workers to be at high risk of developing MSDs.

Established interventions to prevent or reduce MSDs involve education, physical exercises, manipulative therapy and ergonomic measures. In general, education is effective in increasing knowledge, sensitivity and awareness regarding musculoskeletal discomfort and pain in children as well as in young people. However, increased knowledge does not necessarily lead to improved behaviour. Physical exercises are promising interventions to prevent or reduce musculoskeletal discomfort. Yet, sustainable effects can only be achieved by strict adherence to these exercise regimes. Ergonomic equipment combined with physical exercise also showed a positive effect in the prevention or reduction

of MSDs. Manipulative therapy seems to be effective in children or young people with long-lasting or chronic pain.

In summary, irrespective of scientific evidence on the contribution of certain factors to the risk of developing MSDs, the prevalence among children, adolescents and workers is quite high. There is an urgent need for early promotion of musculoskeletal health in children and young people. Maintaining long-term adherence to a combination of education, physical training and ergonomic measures promises the best results in sustainably preventing or reducing MSDs for (working) life.

What did we find?

Prevalence of MSDs among children and young workers

Studies indicate that even children and young people are experiencing MSDs. The prevalence of MSDs in children and young people (7 to 26.5 years old) who are still going to school, college or university, etc. and who have not yet entered the labour market is quite high at ~30 % (pre-labour market prevalence).

The average prevalence in young workers (15 to 32 years old) who have entered the labour market is slightly higher, at ~34 % (work-related prevalence).

Whereas in the pre-labour market, the prevalence among girls is considerably higher than among boys, this varies in young workers according to the level of exposure.

In both pre-labour market young people and young workers, the prevalence is comparable between the countries considered. When considering the publication year of the corresponding studies no time trends over the past 10 years were detected.

Risk factors for MSD development

Generally, MSDs can be caused by acquired or congenital risk factors, or by other diseases. In this review we investigated only acquired, preventable and individual risk factors. Acquired risk factors are those that are largely preventable, namely physical, psychological, socioeconomic and environmental risk factors. In the studies we identified, a considerable number of preventable and individual risk factors for developing MSDs in children and young people was analysed.

Pre-labour market MSD risk factors in children and adolescents

Many factors have been suggested to be associated with a higher risk of developing MSDs or aggravating an already existing MSD in children and adolescents. Within the framework of this scoping review, we identified the following potential risk factors for MSDs in children and adolescents:

- physical factors:
 - nutrition and weight:
 - nutrition
 - body weight
 - lifestyle:
 - physical (in)activity
 - leisure activities
 - sleeping habits
 - smoking
 - alcohol consumption

- bad or incorrect postures:
 - extended sitting
 - use of electronic devices
 - backpack load
 - playing an instrument
- sports
- mental health/psychosocial factors
- socioeconomic factors
- environmental conditions
- individual factors:
 - gender
 - age/pubertal status.

In the following sections, the results of the studies are summarised.

Physical factors

Nutrition and weight

Nutrition. A direct association between vitamin D deficiency and fracture risk in children could not be shown. Dairy calcium and protein intakes seem to have limited effects on bone mineral density and fractures.

Body weight. Overall, the evidence suggests that an increased body mass index (BMI) is correlated with a higher risk of developing MSDs in children and adolescents. Overweight and obese children have a higher risk for lower extremity injuries or pain in particular. Estimates for the association between BMI and back or neck pain are inconsistent. There is weak evidence that overweight and obese children have a higher risk for back or neck pain. Incorrect body postures are more frequent among children and adolescents who are overweight and obese.

Lifestyle

Physical (in)activity. In general, both extremes of activity levels (i.e. very low and very high levels of physical activity) are associated with back pain or increased injury risk in children and adolescents, while moderate physical activity might be protective. Moreover, there were positive correlations between levels of activity, bone health and self-esteem.

Leisure activities. Playground-related injuries and leisure activities still lead to high numbers of injuries in children.

Smoking. The association between lower back pain in adolescents and tobacco consumption is controversial. There is a definite link, but pain is causing adolescents to smoke rather than vice versa. Adolescents suffering from back pain are more likely to smoke.

Alcohol consumption. No association was found between alcohol consumption and back pain.

Lack of sleep. There is a positive association between lack of sleep and back pain in children and adolescents. The quality of sleep seems to predict neck, lower back and shoulder pain.

Bad or incorrect postures

Extended sitting. A prolonged sedentary position, especially with incorrect posture, seems to be associated with lower back pain in children and adolescents, with a dose-response relationship between increased sedentary behaviour and unfavourable health outcomes.

Use of electronic devices. There seems to be an association between computer or smartphone use and musculoskeletal pain in children and adolescents, although only heavy computer use is significantly associated with neck, shoulder, hand/wrist or back pain. Reviews found the evidence for an association between moderate screen time and neck/shoulder or lower back pain to be insufficient.

Backpack load. The association between carrying school bags and back pain is debatable and seems to be weak. Schoolbag load, schoolbag carrying time and the way a backpack is carried have an inconsistent impact on back pain.

Playing an instrument. Musculoskeletal pain is highly prevalent among children and students playing musical instruments intensively.

Mental health/psychosocial factors

Depression, anxiety and distress may be important determinants in adolescent musculoskeletal pain.

Socioeconomic factors

The connections between socioeconomic factors (higher social class, education, residence) and MSDs in children and adolescents were found to be inconsistent. It appears that in the long run low socioeconomic status might be a risk factor for the onset of musculoskeletal pain, although clearly the relationship is complex.

Environmental factors

One study demonstrated that warm temperatures could increase the fracture risk in children.

Individual factors

Gender. On average, musculoskeletal pain is more common in girls than in boys. Generally, there is a positive association between female gender and back pain.

Age. Prevalence increases from childhood to adolescence, with a further increase in young adulthood.

Work-related risk factors for MSDs in young workers

Our search for scientific literature revealed that most studies regarding work-related MSD risk factors are performed in adults without discussing separate age groups (e.g. young people). Only very few studies, focusing on certain occupational sectors such as health care or professional music, explicitly addressed young workers.

Within the framework of this scoping review, we identified the following work-related risk factors for MSDs in young people:

- physical factors:
 - physical workload
 - long-term unnatural working positions that are occupation-/industrial sector-related (e.g. health care professionals, musicians)
- psychosocial factors
- socioeconomic factors
- environmental conditions
- individual factors:
 - gender.

The results of the studies and reviews are summarised as follows.

Physical factors

Physical workload. High physical demands, awkward trunk postures or extraordinarily long working hours are associated with musculoskeletal problems in young workers.

Occupation/industrial sector related. There is a lack of studies on occupations with high exposure to noise, vibration, heat or cold, and to physically demanding work factors such as working in awkward positions, handling heavy loads and repetitive work. Instead, only two small clusters of studies were identified that researched specific sectors, most notably professional musicians and workers in the

health care sector. In both sectors young workers are at high risk of developing MSDs, mainly as a result of long-term unnatural working positions.

Psychosocial factors

Psychosocial factors such as job insecurity, work-family imbalance and exposure to hostile work environments have an influence on MSD prevalence in young workers. Low back pain-related sick leave turns out to be associated with an unstimulating psychosocial work environment.

Socioeconomic factors

In one study, associations between workers' perceived connection to their trade union and neck or back pain were identified in young workers: the higher the perceived connection to the union of unionised apprentices, the lower the odds of reporting neck and back pain.

Environmental factors

Extreme environmental conditions (e.g. high temperatures) increase the risk of occupational injuries among young workers.

Individual factors

Gender. Relationships between gender and MSD risk in young workers correspond to varying exposures that differ between sectors and tasks.

Sports as a risk factor for MSDs in children and young people

Furthermore, sports were identified as a risk factor for both child and young amateur athletes and child and young professional athletes. In general, exercise has many positive effects on health, but some of the positive effects are lost on account of sports injuries. The reported injuries range from knee injuries (anterior cruciate ligament injury, meniscus) and fractures, concussion and muscle injuries to lower back pain and other injuries. A concern regarding the long-term consequences of youth sports injuries is the risk of developing osteoarthritis at a young age.

Preventive measures

Most MSDs caused by physical or psychosocial factors are preventable and manageable. The available studies show that health can effectively be improved by various types of interventions: education (e.g. school curricula, education sessions, presentations, materials or courses aimed at changing knowledge, attitudes and skills), exercises (e.g. movement or muscle strengthening programmes, physical syllabi, mind-body techniques, gym lessons and exercise training), manipulative therapy (e.g. physiotherapy activities, soft tissue treatment, chiropractic manipulation and correction of habitual positions), ergonomic measures (specially designed seats, desks, computer accessories or lifting equipment and adjustment of the worker's environment), orthopaedic aids/protective equipment and sports injury prevention programmes (warm-up, exercises and neuromuscular training):

- prevention of MSDs in children and adolescents:
 - prevention or reduction of musculoskeletal pain:
 - education
 - physical exercise
 - manipulative therapy
 - ergonomics
 - prevention of injuries/accidents:
 - education
 - physical exercise
- prevention of MSDs in young workers:
 - prevention or reduction of musculoskeletal pain:

- education
 - physical exercise
 - psychophysical re-education
 - biofeedback
 - manipulative therapy
 - ergonomics
- prevention of work-related injuries:
 - education
 - neuromuscular training
- prevention of sports injuries:
 - education
 - warm-up programmes, exercises
 - neuromuscular training
 - protective equipment.

In the following, the findings on interventions' effectiveness are summarised.

Prevention of MSDs in children and adolescents

Prevention or reduction of musculoskeletal pain

Education

In general, education (e.g. school curricula, education sessions, presentations, materials, courses aimed at changing knowledge, attitudes and skills) is effective in increasing knowledge and awareness about musculoskeletal discomfort and pain in both children and young people. Nevertheless, increased knowledge does not necessarily lead to improved behaviour; therefore, the efficacy of school-based educational programmes alone in preventing MSDs is poor.

Exercise

Exercises (e.g. movement or muscle strengthening programmes, physical syllabi, mind-body techniques, gym lessons and exercise trainings) are promising interventions that have rapid success in the prevention or reduction of MSDs. For sustainable effects, long-term adherence should be encouraged.

Manipulative therapy

When education or exercise interventions are applied, adding manipulative therapy (e.g. physiotherapy activities, soft tissue treatment, chiropractic manipulation and correction of habitual position) does not have added value. Nevertheless, manipulative therapy may be effective in children with long-lasting or chronic pain.

Ergonomics

Ergonomic equipment (specially designed seats, desks, computer accessories or lifting equipment) in addition to training has a positive effect. The combination of these two measures is an example of a good practice or intervention that can easily be transferred to other activities and occupational applications.

Prevention of childhood accidents

Accidents and injuries can effectively be reduced by injury prevention education programmes and moderate physical activity.

Prevention of MSDs in young workers

Prevention or reduction of musculoskeletal pain

Studies on professional musicians and health care professionals demonstrate that various training programmes are useful to improve musculoskeletal symptoms and learn basic ergonomic principles. In both professions, musculoskeletal pain is highly prevalent, and educational, physical and ergonomic interventions improve quality of work and life. It was proposed by many authors that MSD prevention programmes should be promoted early in education and training. Although there is a lack of comparative studies on young people in many sectors, conclusions from the health care or professional music sectors could be mainstreamed or transferred into other sectors as examples of good practice.

Prevention of workplace injuries

The results of the few studies identified suggest that there could be advantages in strengthening occupational safety and health as well as in neuromuscular education. One approach could be to widely teach occupational safety and health skills in a comprehensive approach as part of vocational diplomas.

Prevention of sports injuries

There is increasing evidence that many sports-related injuries are preventable. Some risk factors (muscle performance, strength deficits, coordination or endurance) are modifiable, and therefore could be targeted in injury prevention programmes. The field of sports medicine, in which a vast number of studies (some of the highest quality) exist, shows that prevention of sports injuries is effective. Programmes developed in this sector can be applied to other areas. Knowledge gained from sports injury prevention could, for example, be transferred to sectors to help prevent work or leisure accidents.

What did we do to find this?

The extensive literature review conducted within the framework of this project was based on the principles of a scoping review. As a method of knowledge synthesis, scoping reviews have the potential to advance health care practice, policy and research. A scoping review 'addresses an exploratory research question aimed at mapping key concepts, types of evidence, and gaps in research related to a defined area or field by systematically searching, selecting, and synthesising existing knowledge' (Colquhoun et al. 2014). A scoping review is consequently less likely to address very specific research questions or to assess the quality of included studies. Nevertheless, scoping reviews search and select the literature in the same systematic way as systematic reviews.

In our review, there were two principal research questions: one on the prevalence of MSDs among children, young people and young workers and the associated MSD risk factors and one on preventive actions or interventions and their effects.

- (1) What is the prevalence of MSDs among children, young people, and young workers?
 - What is the prevalence of MSDs among children, young people and young workers exposed to certain risk factors?
 - What is the link between MSDs and risk factors in children, young people and young workers?
- (2) What is the effectiveness of actions or interventions to prevent MSDs or to promote good musculoskeletal health among children, young people and young workers compared with no action or a comparator intervention?

Our search was limited to papers published as of 2010 and to studies performed in Europe, Australia, Canada, Israel, New Zealand and the USA. We explicitly included systematic, scoping and narrative reviews published as of 2010 to capture summaries of research conducted before 2010 and/or in other countries. The search identified 7 896 articles, of which 596 articles were eligible for this scoping review, with 52 on the prevalence of MSDs, 448 on risk factors and 96 on interventions.

We screened and selected all identified studies according to defined inclusion/exclusion criteria. The entire study selection process was documented and presented in a PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) flow chart (Moher et al. 2009; Moher et al. 2015; Liberati et al. 2009). For the selected studies, we extracted and documented the bibliographical data, including

publication type and country of the study, and data on population group and age, type of disease, disease location, described risk factors and applied interventions. To support the greater breadth of our scoping review, both qualitative and quantitative study designs were included. As scoping reviews are designed to provide an overview of the existing evidence base regardless of quality, we did not formally assess the methodological quality of the included studies.

We conducted an explorative statistical analysis to determine the extracted prevalence values. While we always grouped and compared pre-labour market and work-related prevalence values, we also investigated differences between MSD locations, gender, midpoint ages, countries and years of publication.

We investigated which risk factor(s) were analysed in the individual studies, extracted the studies' findings on the corresponding impacts and compiled these by describing and summarising the main study results.

Regarding the focus of interventions, we assigned the studies to one of six categories: (1) educational measures, (2) physical exercises, (3) manipulative therapy, (4) ergonomic measures, (5) neuromuscular training and (6) protective equipment/orthopaedic aids. We extracted and compiled the studies' results narratively.

What further research is required?

This literature review shows that MSDs in children and young workers in industrialised countries are of high importance, with prevalence estimates of about 30–34 % on average. However, the reported prevalence of MSDs varies greatly according to the different studies (0.5–91%). This is mainly explained by limitations related to the methodology or data used. We — as well as the authors of the included studies or reviews — had to cope with several methodological challenges in MSD research, which mostly came down to inconsistencies in (1) defining what counts as musculoskeletal pain, (2) limiting the time in which the pain must have occurred and (3) choosing outcome measures. This impedes comparison and/or analysis of the findings from different studies. We recommend at least having a systematic way of recording musculoskeletal pain and injuries to improve the quality of the available data, and this should serve as a basis for identifying risk factors and developing prevention programmes.

Many risk factors could be identified, but for most of them no consistent results could be found. There is currently no evidence available for the association between most potential factors and a higher risk of MSDs in children and young people. In fact, for most of the factors, different studies with similar designs and methodological quality have led to contradictory conclusions. This is partly because there is a lack of high-quality studies investigating risk factors for MSDs in children and in young adults.

The group of young workers is difficult to describe in many respects. Many studies investigate workers in general and do not focus on young workers. The subgroup of young workers is only rarely addressed in specific studies. However, having studies focusing on this group of workers is of great importance, as young workers still have their whole working lives before them. Although heavy lifting in health care workers, strained body postures in dentists and excessive practising in musicians undoubtedly constitute exemplary work-related risk factors, it is astonishing that no studies were identified in other sectors and/or occupations that are known for heavy physical work and which employ many young people (e.g. construction, agriculture). There is a lack of studies on professions with high exposure to noise, vibration, heat or cold, and professions with physically demanding work factors. Therefore, future research needs to target sectors (in the framework of prevention schemes/interventions or research) in which young workers are at the highest physical risk of suffering from MSDs. Moreover, little is known about the impact of psychosocial, socioeconomic and environmental factors on MSDs in young workers. These factors are relevant in sectors with higher levels of job insecurity (precarious jobs) or hostile work environments, and more research is needed. Altogether, better knowledge of young workers (on work-related MSDs and on OSH in general) is very important when it comes to the promotion of sustainable musculoskeletal health across the working life course.

There are only a few low-quality studies addressing the topic of prevention in this field. Preventive measures to address many of the risk factors identified are available and their efficacy has been proven, but child- or youth-oriented implementation is still insufficient. Regarding the labour market, there is an urgent need for prevention campaigns and interventions to focus on children. In general, prevention

campaigns and interventions should systematically integrate a life course approach to MSD prevention, which means that they should consider and control MSD risks across the entire workforce, irrespective of age.

Interventions involving a combination of actions (educational interventions and exercises) have a higher chance of being successful than standalone actions. This is even more important because there is a difference between improving our knowledge of the body's mechanics and changing our behaviour towards a healthy lifestyle. Yet, combined approaches (education plus training plus ergonomics) were not identified at all in the studies examined. We recommend interventions with a sectoral approach or those focusing on a specific population. Such targeted approaches allow the development of specific programmes or preventive measures (e.g. educational comic books, demonstrations plus exercises, classes on body posture as part of classes that teach young people to play a musical instrument).

In sports injury prevention, effective programmes have been developed that might be applied to other sectors. However, further research is needed to evaluate the detailed effect of the training measures, the effect of prevention programmes on different sports, the necessary number and duration of prevention programmes and the identification of athletes at risk, who are most likely to benefit from the successful application of prevention programmes. Concerning the evaluation of interventions' efficacy, studies should consider not only increasing knowledge as a key outcome but also behavioural change. Moreover, studies should investigate the psychological determinants of attaining the health behaviours sought. Long-term evaluation studies are currently missing, and those studies should assess whether behavioural change or knowledge gained at a young age is retained throughout a person's professional life.

In conclusion, this scoping review is in accordance with other reviews, which found methodological inconsistency and weakness in studies with widely varying results. To estimate the prevalence of MSDs in a more precise and nuanced way (e.g. for subpopulations such as teenage boys and girls or hairdressers aged 20–30 years), as well as the dose-response relationship between a certain risk factor and a certain MSD or the efficacy of a certain intervention programme, both systematic reviews and more high-quality studies are needed. Studies should be conducted on a large scale and should be of high quality to provide information to guide clinicians in the treatment of children, adolescents and young workers with MSDs. Additionally, those studies could support the development of evidence-based health promotion programmes targeting the prevention of musculoskeletal pain.

Furthermore, there is a need to use psychometrically, clinically meaningful and standardised outcome measures for pain, function, health care use and physical activity. Such standardisation will increase the clinical applicability of the research and facilitate the pooling of study results.

1 Introduction

1.1 Background

The European Agency for Safety and Health at Work (EU-OSHA) has been carrying out major research projects focusing on work-related musculoskeletal disorders (MSDs) during the period 2018–2021. The outputs of this activity will contribute to the Healthy Workplaces Campaign 2021-22 on MSDs, which is coordinated across the EU Member States by EU-OSHA. The work will include investigating the current situation and policy regarding MSDs in the workplace and their prevention and management, provision of good practice examples and development of practical resources. The research activities and the campaign take a holistic approach to the management of MSDs in the workplace, covering prevention, rehabilitation and return to work.

EU-OSHA is interested in adopting a ‘life course’ approach to studying musculoskeletal conditions and musculoskeletal health. This approach has the potential to gain a better understanding of how and why musculoskeletal conditions occur over the life course and how musculoskeletal health can be promoted. The adoption of such an approach ‘improves prevention for all workers (young and older), and reduces the damage to workers’ health while limiting early exit from work and improving the sustainability of work in jobs that have high physical demands’ (Belin et al. 2016). In this context, the lifelong impact of musculoskeletal pain needs to be considered. Existing statistics show that there is already a high prevalence of MSDs among children (Calvo-Muñoz et al. 2013, Kamper et al. 2016b). This raises the issue of young workers coming into the workplace with pre-existing musculoskeletal problems that have the potential to be exacerbated by work. The prevalence of MSDs among young people and young workers (those aged under 25) is not as high as for older age groups, but it remains quite high. Statistics show that the rates of disease reported among young workers is increasing (EU-OSHA 2010, 2020, 2007). EU-OSHA (2007) found that their situation is comparable to that of female workers; they often work in service sectors and are overexposed to MSD risk factors.

EU-OSHA therefore identified the need to prevent MSDs among children and young people and, above all, to promote good musculoskeletal health from an early age (from childhood). To provide EU-OSHA with actual information on the prevalence of, main risk factors for and preventive measures for MSDs, this literature review focuses on MSDs in children and young people, considering both pre-labour market prevalence (in schoolchildren and adolescents not yet in the labour market) and prevalence among young workers and young people in vocational training.

1.2 Aim of the project

The main objective of this research project was to carry out a literature review on MSDs among children and young people and young workers and to report on:

- MSD prevalence among children, young people and young workers, and the associated MSD risk factors; and
- the preventive actions and interventions and their effect on preventing MSDs or promoting good musculoskeletal health among children, young people and young workers.

The specific objectives of the project were to:

- increase knowledge and improve access to information on MSDs among children and young people (with a special focus on young workers);
- identify and present the main MSD risk factors;
- identify and report on the main preventive measures and intervention strategies to prevent MSDs and promote a good musculoskeletal health among children and young workers;
- identify gaps in knowledge and the need for further research; and
- provide information for the development of resources for the Europe-wide Healthy Workplaces Campaign 2020-22 on MSDs.

2 Methods

The extensive literature review conducted within the framework of this project was implemented based on the principles of a scoping review. As a method of knowledge synthesis, scoping reviews have the potential to advance health care practice, policy and research. A scoping review ‘addresses an exploratory research question aimed at mapping key concepts, types of evidence, and gaps in research related to a defined area or field by systematically searching, selecting, and synthesising existing knowledge’ (Colquhoun et al. 2014). At a general level, scoping studies might ‘aim to map rapidly the key concepts underpinning a research area and the main sources and types of evidence available, and can be undertaken as stand-alone projects in their own right, especially where an area is complex or has not been reviewed comprehensively before’ (Arksey and O'Malley 2005). A scoping review is consequently less likely to address very specific research questions or to assess the quality of included studies.

Scoping reviews search and select the literature in the same systematic way as systematic reviews. The methodology of scoping reviews is not as strongly laid down in guidelines as is the case for systematic reviews. Nevertheless, some methodological publications have become standard (Arksey and O'Malley 2005, Bragge et al. 2011, Daudt et al. 2013, Hidalgo Landa et al. 2011, Levac et al. 2010, Miake-Lye et al. 2016, Tricco et al. 2018). Arksey and O'Malley (2005) described five stages for conducting a scoping review:

- stage 1: definition of the research question(s);
- stage 2: systematic search for relevant studies;
- stage 3: study selection according to predefined inclusion/exclusion criteria;
- stage 4: data extraction and processing;
- stage 5: collating, summarising and reporting the results.

The method is guided by a requirement to identify all relevant literature regardless of study design. Therefore, scoping reviews specifically consider grey literature, which can also be sought using a systematic approach (Godin et al. 2015).

2.1 Definition of the research questions — concepts and key elements

There were two principal research questions: one on the prevalence of MSDs among children, young people and young workers and the associated MSD risk factors and one on preventive actions or interventions and their effects.

- (1) What is the prevalence of MSDs among children, young people and young workers?
What is the prevalence of MSDs among children, young people and young workers exposed to certain risk factors?
What is the link between MSDs and risk factors in children, young people and young workers?
- (2) What is the effectiveness of actions or interventions to prevent MSDs or to promote good musculoskeletal health among children, young people and young workers compared with no action or a comparator intervention?

These research questions were of the CoCoPop and PICO types. The first type (CoCoPop) is defined by three key concepts: condition (Co), context (Co) and population (Pop). The second type (PICO) is defined by four key concepts: population (P), intervention (I), comparator (C) and outcome (O).

Our specifications of the concepts are summarised in Table 1 and Table 2, respectively.

Table 1 Key concepts of research question (1) on prevalence and risk factors (CoCoPop type)

Key concept	Specification
Condition (Co)	MSDs
Context (Co)	MSD risk factors
Population (P)	Children, adolescents, pupils, students, young people, young workers

Table 2 Key concepts of research question (2) on interventions (PICO type)

Key concept	Specification
Population (P)	Children, adolescents, pupils, students, young people, young workers
Intervention (I)	Interventions to prevent MSDs
Comparator (C)	Population with no intervention
Outcome (O)	MSDs

Once the key elements were settled, we defined the corresponding search terms. For each key concept we collected fitting terms by considering team members' contributions, reviewing medical thesauri (Medical Subject Headings, MeSH; International Statistical Classification of Diseases and Related Health Problems — 10th revision, ICD-10) and screening highly relevant publications identified during a scoping exercise.

We performed the scoping exercise in PubMed to refine the specificity and sensitivity of the search strategy. We thereby considered papers published after 1999, but no other restriction was applied.

Firstly, we combined the collected terms and MeSH terms into a search string for each key concept separately. To test its specificity, each search string was applied separately in PubMed. For this purpose, we analysed the search results for their number, year of publication and available index data (headings). We assessed the relevance of selected search results by screening the abstract, keywords and MeSH terms. Secondly, we iteratively combined the key concepts to formulate the finalised search string. For this search string we also analysed the number, year of publication and indexes of hits as well as the relevance in a sample of search results. Additionally, we descriptively analysed the keywords and MeSH terms of all hits for relevant and irrelevant terms. Irrelevant references and irrelevant terms were analysed to determine why they were retrieved. If possible, we removed or replaced search terms, or otherwise combined them. If removal resulted into too many losses of relevant hits, we considered terms indicating the irrelevance of a paper to be used later for study selection (i.e. keywords such as drug names often indicate studies testing a medical treatment). The scoping exercise in PubMed resulted in the search questions retrieving about 2 500 references (publications between 2000 and 2021 with no further restrictions) for research question (1) and about 500 references for research question (2).

Afterwards, we tested a further approach to improve the sensitivity and specificity of the search string. Search results for the prevalence of MSDs in children and young people/workers in general were narrowed down by specifically searching for the prevalence in connection with a certain risk factor. The results obtained in this way showed a very high rate of relevant articles in terms of describing the prevalence of MSDs in children and young people/workers in connection with the corresponding risk factor. We therefore decided to apply this 'splitting' search strategy to research question (1).

The search string set up in PubMed was adapted to the syntaxes of other databases. The application of the adapted search string in the corresponding databases resulted in a high rate of relevant studies. Because of the unmanageably large quantity of relevant studies, we applied the following further restrictions:

- The study must have been performed in industrial countries in Europe, Australia, Canada, Israel, New Zealand and the USA, where conditions comparable to a European perspective are to be expected.
- The study must have been published in the period 2010-2021.

The finally applied selection criteria for the key concepts and further key elements (e.g. year and the language of publication, the place of study and the publication type) are given in Table 3.

Table 3 Selection criteria for the key concepts and elements of research questions (1) and (2)

Key concept	Inclusion	Exclusion
Condition (Co)	Prevalence of orthopaedic disorders, upper/lower limb/back/hand/arm/neck/shoulder disorders, pain or symptoms	Neuromuscular disorders, infectious diseases, tumour diseases, aneurysmal cysts, endocrine diseases, metabolic diseases, deformities, abnormalities, jaw diseases, rheumatic diseases
Context (Co)	Lifestyle, nutrition and weight, smoking, ergonomic arrangements, school bag, electronic devices, sports/protective gear, environment, accidents, psychosocial risk factors, work/occupation	Congenital risk factors, non-traumatic risk factors (infections, tumours)
Population (P)	Children, adolescents, young people, young workers, pupils, students (aged 6 years to 26 years)	Infants (< 6 years), adults (> 35 years old), older people, animals
Intervention (I)	Prevention, promotion, strategies, measures, education, training, interventions	Medication, surgery
Comparator (C)	Control group: no/other level of intervention	No control group
Outcome (O)	Effectiveness on prevalence and severity of orthopaedic disorders, upper/lower limb/back/hand/arm/neck/shoulder disorders, pain, or symptoms	Safety and efficacy of medical, surgery treatments, evaluation of diagnostic tests
Year of publication	≥ 2010	< 2010
Language	English	Language other than English
Place of study	Countries in Europe, Australia, Canada, Israel, New Zealand and the USA	Countries in Africa, Asia or South America
Publication type	Primary research studies (i.e. studies generating new data), systematic reviews, literature reviews, authority assessments	Books and book chapters, PhD theses, expert opinions, editorials, letters to the editor, extended abstracts, conference proceedings
Access	Full text	No full text available

2.2 Systematic search for relevant studies

Since our search was limited to papers published in 2010 and after and to studies performed in Europe, Australia, Canada, Israel, New Zealand and the USA (see section 2.1), we explicitly included systematic, scoping and narrative reviews published as of 2010 to capture summaries of research conducted before 2010 and/or in other countries. Nevertheless, it should be kept in mind that studies published before 2010 and national reports or scientific publications in languages other than English may have been missed here.

For the search to answer research question (1) we applied the ‘splitting’ approach, i.e. a series of search strategies designed to capture each potential risk factor (context) was performed. For the search to answer research question (2) we applied the ‘lumping’ approach, i.e. a single search to capture all interventions of interest was performed.

The search strategy allowed for searching the title, abstract, keywords and subject indexing terms (if available). We performed the search exclusively in English.

We selected search terms incorporating a wide variety of synonymous and related terms. We used truncation and wildcards where appropriate to capture different conventions in spelling and variation in the endings of terms. Search strings were combined by Boolean and proximity operators. We used MeSH terms in PubMed and in the Cochrane Library database. We applied ‘Subject Major Topics’/‘Subject Areas’ in CINAHL (see Table 4) and Scopus (Annex 1: Search terms and search strings).

We conducted the search for scientific literature and academic publications in the databases listed in Table 4.

Table 4 **List of literature databases included in the search**

Database	Web address	Searched on	No of results
Cumulative Index to Nursing and Allied Health Literature (CINAHL)	https://www.ebscohost.com/nursing/products/cinahl-databases	15.02.2021	2 697
Cochrane Database of Trials and Systematic Reviews (CDSR)	http://www.cochranelibrary.com	16.02.2021	77
Epistemonikos	http://www.epistemonikos.org	16.02.2021	2 214
PubMed (MEDLINE)	https://www.ncbi.nlm.nih.gov/pubmed	11.02.2021	1 644
PsycINFO	https://www.apa.org/pubs/databases/psycinfo/	17.02.2021	107
Scopus	https://www.scopus.com/home.uri	16.02.2021	938

The search for ‘grey literature’ was performed with the tools listed in Table 5.

Table 5 **Tools for the search of ‘grey literature’**

Tool	Web address	Searched on	No of results
Google Advanced Search	https://www.google.com/advanced_search	15.02.2021	118
Grey Matters	https://www.cadth.ca/resources/finding-evidence/grey-matters	17.02.2021	26
OpenGrey	http://www.opengrey.eu/	17.02.2021	7
Institutional Repository for Information Sharing	http://apps.who.int/iris/	18.02.2021	4

Additionally, we searched the websites of key institutions dealing with the topic 'OSH' (occupational safety and health) for 'grey literature' (see Table 6) from 17 to 18 February 2021.

Table 6 Initial list of key institutions considered in the search of 'grey literature'

Institution	Region	Web address	No of results
Centre for Research Expertise in Occupational Disease (CREOD)	Canada	https://creod.on.ca/	0
Centre of Research Expertise for the Prevention of Musculoskeletal Disorders (CRE-MSD)	Canada	https://uwaterloo.ca/centre-of-research-expertise-for-the-prevention-of-musculoskeletal-disorders/	0
EUROGIP	EU	https://eurogip.fr/en/	2
European Agency for Safety and Health at Work (EU-OSHA)	EU	https://osha.europa.eu/en	17
European Foundation for the Improvement of Living and Working Conditions (Eurofound)	EU	https://www.eurofound.europa.eu/	0
European Network Education and Training in Occupational Safety and Health (ENETOSH)	EU	https://www.enetosh.net	3
German Federal Institute for Occupational Safety and Health (BAuA)	Germany	https://www.baua.de	0
Health and Safety Executive (HSE)	UK	https://www.hse.gov.uk	0
Institute for Occupational Safety and Health of the German Social Accident Insurance (IFA)	Germany	https://www.dguv.de	0
Institute for Work and Health (IWH)	Canada	https://www.iwh.on.ca/	0
International Social Security Association (ISSA)	International	https://ww1.issa.int/home	0
Institution of Occupational Safety and Health (IOSH)	International	https://www.iosh.com/	0
National Institute for Occupational Safety and Health (NIOSH)	USA	https://www.cdc.gov/niosh/index.htm	4
Occupational Safety and Health Administration (OSHA)	USA	https://www.osha.gov/	0
Partnership for European Research in Occupational Safety and Health (PEROSH)	EU	https://perosh.eu	1

After the search in literature databases and the search for 'grey literature', we manually performed backward and forward reference searching within key publications.

2.3 Study selection

The screening and selection of studies, as well as the data extraction, were done using the reference management software Citavi 6.8¹ (except for extracting prevalence values, which was done in Microsoft Excel).

We screened and selected all identified studies according to the defined inclusion/exclusion criteria (summarised in Table 3). Studies were selected in two steps:

1. screening of titles and abstracts of the identified references and document exclusions;
2. screening of the full texts of the remaining manuscripts and documenting the inspection of the full texts and the fulfilment of the criteria.

The entire study selection process was documented and presented in a PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) flow chart (Moher et al. 2009, Moher et al. 2015, Liberati et al. 2009), see Figure 1.

With the aim of mapping relevant literature on the current situation in Europe, we searched and included both studies and reviews (of studies). Reviews published since 2010 were included to capture a summarised extent of the research performed so far. Studies published since 2010 were included to obtain the most recent research results. Since we were aware that a study might be included both as a separate publication and as the basis of one or multiple reviews, we checked for duplicates to be considered in the narrative compilation of study results.

To support the greater breadth of our scoping review, both qualitative and quantitative study designs were included.

As scoping reviews are designed to provide an overview of the existing evidence base regardless of quality, we did not formally assess the methodological quality of the included studies.

2.4 Data extraction and processing

For the selected studies, we extracted and documented the bibliographical data and information on the CoCoPop or PICO criteria and the other inclusion criteria (e.g. country of the study, publication type). Data extraction and processing was done with Microsoft Excel and R 4.0.4 (R Core Team 2021) considering the points below.

▪ Study objective

Considering the main aims and objectives of each study, we categorised them into three categories: studies on prevalence, studies on risk factors and studies on interventions.

▪ Prevalence

Studies mostly report prevalence values, but incidence values were also given for, for example, sports injuries and fractures. The explorative analysis of MSD prevalence in children and young people is based on prevalence values only. All prevalence values were converted to a percentage if needed. Note that one study can provide multiple prevalence values (e.g. for different age groups or MSDs), so that in this review the total number of extracted prevalence values (sample estimates) is larger than the total number of studies estimating prevalence.

In the qualitative compilation of study findings on risk factors, both incidence and prevalence values were considered.

▪ Labour market

Based on the young people's population group and age, we categorised each study as either before entering the labour market (pre-labour market) or after entering the labour market (work related). Sports

¹ Citavi 6.8.0.0 (2021). Copyright by Swiss Academic Software GmbH.

studies were not categorised by age group. Generally, this means that schoolchildren and young people in high school or college aged 6 years to 26.5 years were assigned to the pre-labour market category, while apprentices, young workers and university students were assigned to the work-related category.

▪ **MSD location**

We categorised the specific MSD described in the studies into one of four MSD locations according to the affected body part:

- 'back' (neck, upper and lower back);
- 'upper limbs' (shoulders, arms, elbows, hands, wrists);
- 'lower limbs' (hips, legs, knees, feet, ankles);
- 'unspecified' (general musculoskeletal complaints without specifying the location).

Category 'unspecified' was applied when the MSD in the studies was stated to be 'any MSD', 'musculoskeletal pain/discomfort' or 'multi-site musculoskeletal pain/discomfort'.

▪ **MSD period**

In the studies the subject was asked if they had 'ever had back pain in their life' or if they had 'had consistent back pain over a certain period during the last year' or if they were 'currently [experiencing] back pain'. For the quantitative analysis of prevalence values, we only considered pain being reported for a certain period in the recent past.

▪ **Risk factors**

We extracted the risk factors analysed in the studies or reviews and set up successive risk factor categories. Generally, we identified two objectives of studies/reviews: (1) to evaluate the evidence on the association between a certain risk factor and one or more MSD or (2) to evaluate the evidence on the association between various risk factors and a certain MSD. We accordingly assigned each study/review to one risk factor category or more.

▪ **Gender**

For each extracted prevalence we also tried to extract the corresponding gender. Where possible, the extracted prevalence values were thus categorised as 'male' or 'female'. However, not all studies grouped their subjects by gender. Therefore, a third category named 'all' was added, including all extracted prevalence values — those already grouped as 'male' or 'female' in addition to those that could not be grouped. In other words, the 'male' and 'female' categories are subsets of the 'all' category, but the latter includes additional prevalence values from studies that did not differentiate between 'male' and 'female'.

▪ **Country**

For each extracted prevalence we also extracted the country where the study took place. While this was possible in most cases, some studies provided data for groups of countries or regions such as Europe. Therefore, in addition to the all-country category, two categories named 'Europe' and 'global' were formed. As for the 'all' category for gender (see above), all European countries are subgroups of the 'Europe' category, but the latter also includes prevalence values from studies that investigated groups of European countries or European regions but did not differentiate between individual countries. Analogously, the same is true for 'global'; however, the only non-European countries that were included during the study selection process of this scoping review were Australia, Canada, Israel, New Zealand and the USA. In other words, the prevalence values for all European countries are subsets for both the 'Europe' and the 'global' categories, whereas 'global' just includes all prevalence values extracted in this review.

▪ **Midpoint age**

For each extracted prevalence we also tried to extract a corresponding age. In the ideal case we could extract a median or mean age per group from the publications. Yet, far more often only an age range was provided. In that case, we took the median of that range (e.g. 17 for the age range 13–21 years). It must be clear that the resulting values are therefore neither true mean ages nor median ages and they

should be interpreted with caution. This is why we explicitly refer to them as midpoint age here and investigate them only briefly to prevent overinterpretation.

2.5 Collating, summarising and reporting the results

2.5.1 Quantitative analysis of prevalence values

We conducted an explorative statistical analysis for the extracted prevalence values. While always grouping and comparing pre-labour market and work-related prevalence values, we also investigated differences between MSD location, gender, midpoint age, country and year of publication. Data analysis and visualisation of prevalence values was done with R 4.0.4.²

For all of the values except midpoint age, we estimated the median, mean, minimum and maximum prevalence per group. The median is the value separating the higher half from the lower half of a data sample, or 'the middle value', and the (arithmetical) mean is the sum of the values divided by the number of values. The median and the mean are both measures of the central tendency or 'the average' per group, but the median is more robust when it comes to outliers, which is why we prefer it over the (arithmetical) mean in this analysis. Furthermore, it was not always possible to extract the sample size for each extracted prevalence to calculate weighted means per group, as is often done in meta-analyses.

The minimum and maximum are the smallest and largest prevalence, respectively, and thus provide information on the dispersion or variability of extracted prevalence values in each group. One of the reasons we decided against other measures of variability, such as the standard deviation or interquartile range, is that the results for this analysis show quite a large variability (see section 3.2); this is important to realise and becomes very clear when looking at the minimum and maximum values. Moreover, we consciously decided to use boxplots and add scatter plots of all individual values to visualise the data. In comparison to bar plots (with error bars), these plots (Figure 3, Figure 4, Figure 7) allow the reader to get a more extensive feeling for the variability of the extracted prevalence values and see both the results and the data that the results are based on in the same figure.

Yet, we chose a different visualisation for the MSD prevalence per country. Because of the large number of countries and to potentially allow us to observe regional trends, we laid bar plots for each country over a map of Europe to roughly match their geographical position (Figure 6).

On account of the limited interpretability of the extracted midpoint age (see section 2.4), we decided against investigating it in the same manner as the other grouping factors. Accordingly, we only analysed it visually with a scatter plot (Figure 5).

Additionally, we investigated a potential trend in the prevalence values over time for midpoint age and year of publication, respectively, since these two could be taken as quantitative independent variables in a linear regression. We can already note, however, that none of these linear regression results are shown in section 3.2 because of the very poor goodness of fit (i.e. very small coefficient of determination, R^2) for all models.

2.5.2 Qualitative compilation of results on risk factors and interventions

We investigated which risk factors were analysed in the individual studies and assigned each study to one or more risk factor categories. Regarding the work-related classification of two population groups (pre-labour market population/young workers), the risk factors could accordingly be divided into pre-labour market and work-related risk factors. It should be noted here that pre-labour market risk factors are, in fact, non-occupational risk factors regardless of the population group or age. Nevertheless, within the framework of this scoping review we focused on the impact of these factors on children and young

² R Core Team (2020). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. <https://www.R-project.org/>.

people to assess the issue of pre-existing musculoskeletal problems before young people entered the workplace.

Within each category, we extracted the studies' findings on the corresponding risk factor impacts and compiled the data by describing and summarising the main study results.

Regarding the focus of interventions, the studies could be assigned to one of six categories: (1) educational measures, (2) exercises, (3) manipulative therapy, (4) ergonomic measures, (5) neuromuscular training and (6) protective equipment/orthopaedic aids. Educational interventions comprised school curricula, education sessions, presentations, materials and courses aimed at increasing knowledge, changing attitudes and building skills. Exercise interventions included movement or muscle strengthening programmes, physical syllabi, mind-body techniques, gym lessons and exercise training. Manipulative therapy involved physiotherapy activities, soft tissue treatment, chiropractic manipulation and correction of habitual positions. Neuromuscular training involves the application of biomechanical and neuromuscular principles aimed at improving sensorimotor control and achieving compensatory functional stability. Orthopaedic aids serve to stabilise, relieve or protect various bodily structures.

Within each category, interventions and preventive measures were identified, and the results of the studies were extracted and compiled narratively.

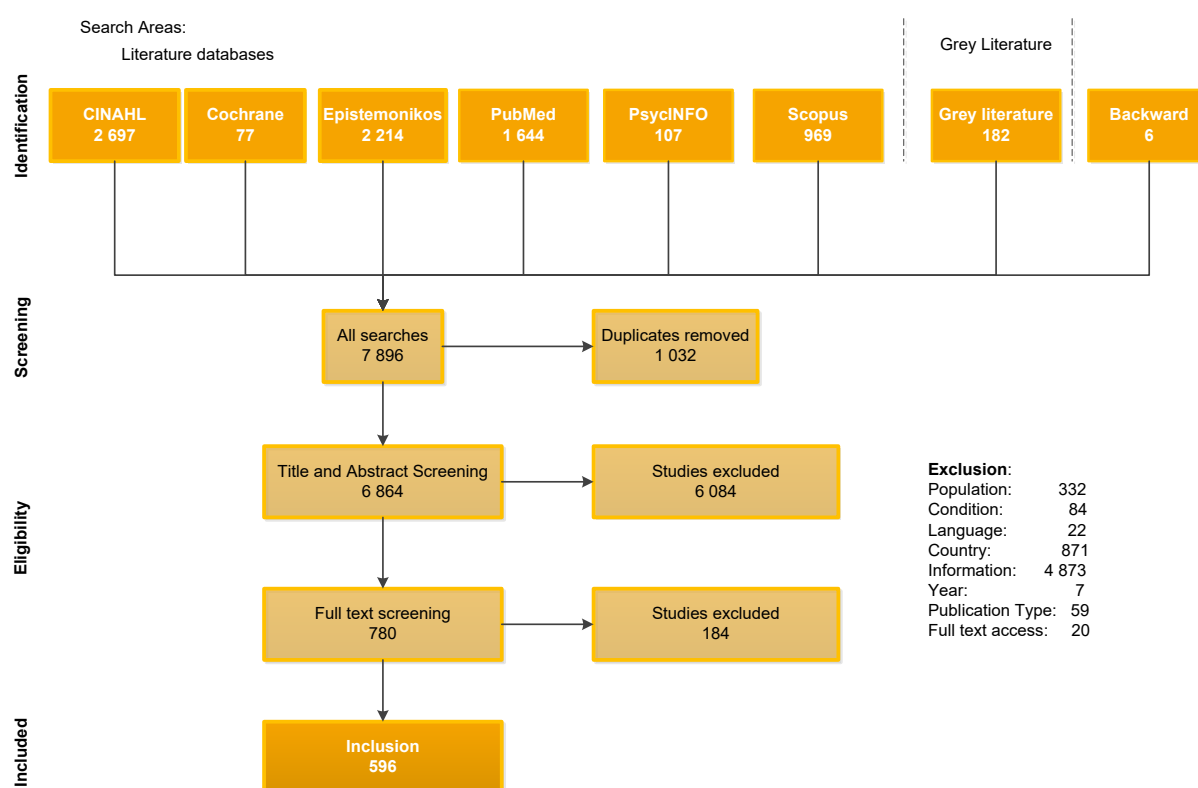
3 Results

3.1 Search and selection process

We identified 7 896 references in total, including 1 032 duplicates. The titles and abstracts of 6 864 references were screened, resulting in 6 084 references being excluded. Full text screening excluded a further 184 references. The remaining 596 references (141 reviews and 455 studies) were included as relevant for this literature review (Figure 1).

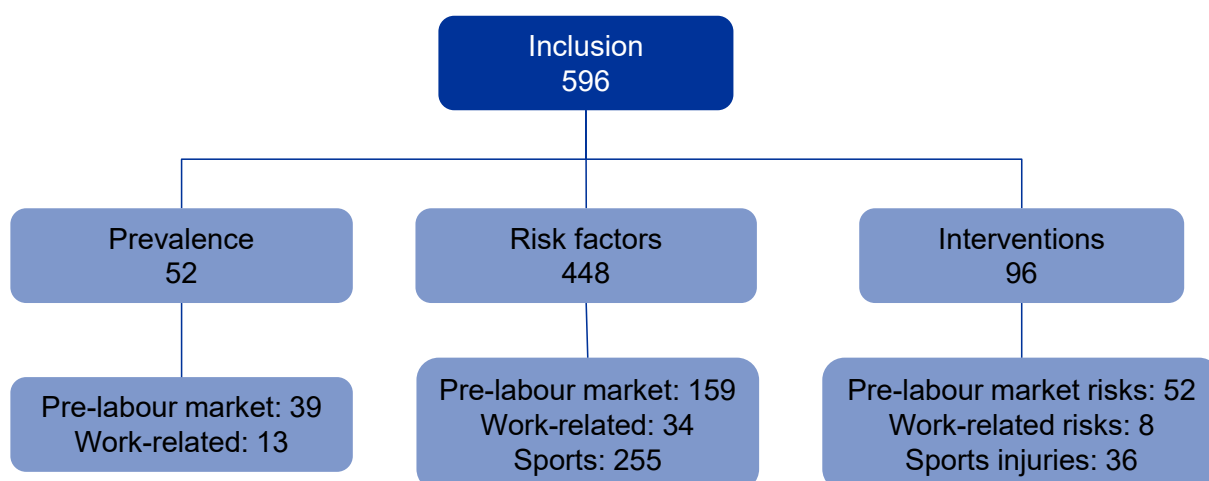
It should be kept in mind that our search was limited to (1) publications from 2010 onwards and (2) studies performed in Europe, Australia, Canada, Israel, New Zealand and the USA. Moreover, by limiting the search to publications in English, national reports or scientific publications in other languages may have been missed (see section 2.2).

Figure 1 **PRISMA flow chart documenting the systematic selection process**



The categorisation of the 596 included references according to study objectives and labour market resulted in (Figure 2):

- 52 studies/reviews analysing prevalence in children and adolescents (39 pre-labour market, 13 work-related);
- 448 studies/reviews analysing risk factors in children and adolescents (159 pre-labour market, 34 work-related, 255 sports-related);
- 96 studies/reviews on interventions to prevent MSDs or to promote good musculoskeletal health (52 to prevent pre-labour market risks, 8 to prevent work-related risks, 36 to prevent sports injuries).

Figure 2 **Classification of included studies according to population and study content**

Altogether, we could identify a large number of studies ($n = 448$) on risk factors for MSDs. The risk factors analysed by the studies or reviews are listed in Table 7. Some studies and most reviews analysed multiple risk factors.

Table 7 **Pre-labour market and work-related risk factors for MSDs analysed or identified in the studies (number of studies/reviews in brackets, multiple answers possible)**

Factor	Pre-labour market risk factors	Work-related risk factors
Physical	Nutrition and weight	Physical workload (9)
	Nutrition (17)	Occupation/industrial sector
	Body weight (38)	Medical professions (15)
	Lifestyle	Musicians (6)
	Physical activity (20)	
	Leisure activity (12)	
Psychosocial	Sleep habits (8)	
	Smoking (8)	
	Alcohol consumption (1)	
	Postural problems	
	Sedentary behaviour (15)	
	Use of electronic devices (19)	
Socioeconomic	Backpack load (21)	
	Playing an instrument (10)	
Environmental	Mental health factors (25)	Psychosocial factors (2)
	Socioeconomic factors (6)	Socioeconomic factors (1)
Individual	Environmental factors (1)	Environmental factors (1)
	Age (6)	Gender (4)
	Gender (7)	

However, with so many relevant risk factor studies, not every study found could be described in detail. Therefore, we decided to report the risk factors in a narrative matter. Especially in the field of sports as a risk factor for injuries (where $n = 255$ studies were found), only the topic's surface could be explored.

Additionally, we identified 96 studies describing preventive measures to counteract MSD risks and to improve the health of children and young workers. The interventions covered education (18), exercises (23), manipulative therapy (7), ergonomic measures (9), neuromuscular training (2), orthopaedic aids (1) and sports injury prevention (36). We also decided to report these interventions in a narrative matter.

3.2 Prevalence of MSDs among children and young people

Within the framework of this scoping review, we were able to extract 509 sample estimates for the prevalence of MSDs (MSD prevalence) from a total of 52 references (published from 2010 onwards and performed in Europe, Australia, Canada, Israel, New Zealand and the USA). In this section, we show the results of the explorative statistical analysis for these extracted prevalence values (see section 2.5.1 for details on the methodology). Overall, across all 509 prevalence values without any grouping, we found the average prevalence to be around 30 % (median = 30.0 %; mean = 32.6 %), which is quite high and in accordance with findings from the sixth (2015) wave of the European Working Conditions Survey (Parent-Thirion et al. 2017) for people under 25 (see Figure 9).

The following sections each focus on certain grouping factors and whether they have an influence on the MSD prevalence. While always grouping and comparing prevalence values of young people before and after entering the labour market, we also investigated differences between gender, MSD location, midpoint age, country and year of publication (see section 2.4 for details). We created the figures in a way that allowed a quick intuitive comparison of group averages on the one hand, while providing a comprehensive picture of the (variability of the) underlying data on the other. Additionally, summary statistics are displayed in corresponding tables (see section 2.5.1 for details). A summary of the insights that could be gained from the analysis of each grouping can be found at the end of each of sections 3.2.1–3.2.5.

It should be noted, however, that the variability of the extracted values is quite large, ranging from a minimum of 0.5 % to a maximum of 91.0 %. Unfortunately, the variability was consistently large across all grouping factors, which generally means that the estimated averages should be interpreted with caution. One reason for these fluctuations in prevalence estimates may have been the inconsistent definitions of MSDs and the wide variety of outcome measures. An example of this is that the subject may have been asked if they had ‘ever had back pain in their life’ or ‘had consistent back pain over a certain period during the last year’ or if they were ‘currently [experiencing] back pain’.

3.2.1 MSD prevalence per gender

Here we investigate whether the prevalence sample estimates extracted from a total of 52 publications suggests any differences between genders regarding the prevalence of MSDs in children and young workers.

When grouping the extracted MSD prevalence values by gender (‘female’, ‘male’, ‘all’), as well as separately considering whether the young people had entered the labour market or not, it was found that the average prevalence values per group range from 26 % to 38 %. Table 8 provides detailed information for the prevalence values of each group, which are also presented visually in Figure 3. As described in section 2.4, the ‘all’ group includes not only the extracted prevalence values from the ‘female’ and ‘male’ groups, but also the values from studies that did not differentiate between genders.

Table 8 Percentages of children and young people with MSDs before and after entering the labour market (data published between 2010 and 2021) grouped by gender

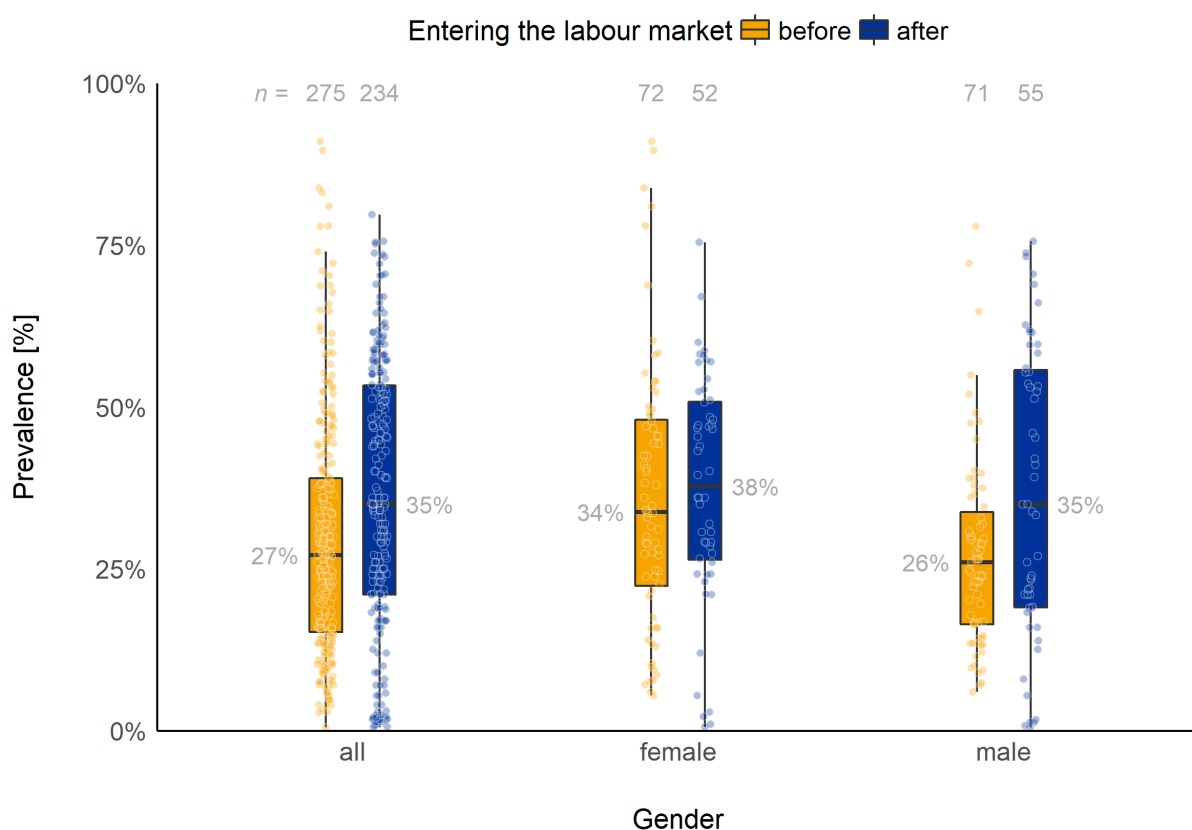
Gender	Entering the labour market	Number of sample estimates	Median (%)	Mean (%)	Minimum (%)	Maximum (%)
All	Before	275	27.1	29.7	0.5	91.0
All	After	234	35.0	36.1	0.5	79.7
Female	Before	72	33.8	36.2	5.4	91.0
Female	After	52	37.8	37.4	0.6	75.4

Gender	Entering the labour market	Number of sample estimates	Median (%)	Mean (%)	Minimum (%)	Maximum (%)
Male	Before	71	26.0	27.3	6.0	77.9
Male	After	55	35.0	36.7	0.5	75.6

Note: 'female' and 'male' are subgroups of 'all', but 'all' additionally includes prevalence values from studies that did not differentiate between genders.

Figure 3 **Percentages of children and young people with MSDs before and after entering the labour market (data published between 2010 and 2021) grouped by gender.**

Note: 'female' and 'male' are subgroups of 'all', but 'all' also includes prevalence values from studies that did not differentiate between genders. For each gender-labour market combination the number of extracted prevalence estimates is shown at the top and the rounded median is written besides the boxplot's median.



Each dot represents a prevalence extracted from a publication. For each 'Gender'-'Labour market' combination, (i) the number of prevalences extracted is shown at the top and (ii) the rounded median is written besides the boxplot's median

In summary, the following aspects can be pointed out, but it must be noted that the variability of the extracted prevalence values per group remains relatively large, which generally means that the estimated averages should be treated with caution. That said, we find that:

- (i) The average prevalence in people before entering the labour market in industrialised countries is already quite high, ranging from one quarter to one third of all people, depending on the gender (medians: all, 27 %; female, 34 %; male, 26 %).

- (ii) The average prevalence in people after entering the labour market is always slightly higher than those for people before entering the labour market (medians after vs before: all, 35 % > 27 %; female, 38 % > 34 %; male, 35 % > 26 %).
- (iii) The average prevalence in females is slightly higher than in males and all — especially for young people before entering the labour market (medians: female, 34 %; male, 26 %; all, 27 %).

3.2.2 MSD prevalence per MSD location

Here we investigate whether the prevalence sample estimates extracted from a total of 52 publications suggest any differences between the locations of the MSDs regarding the prevalence of MSDs in children and young workers.

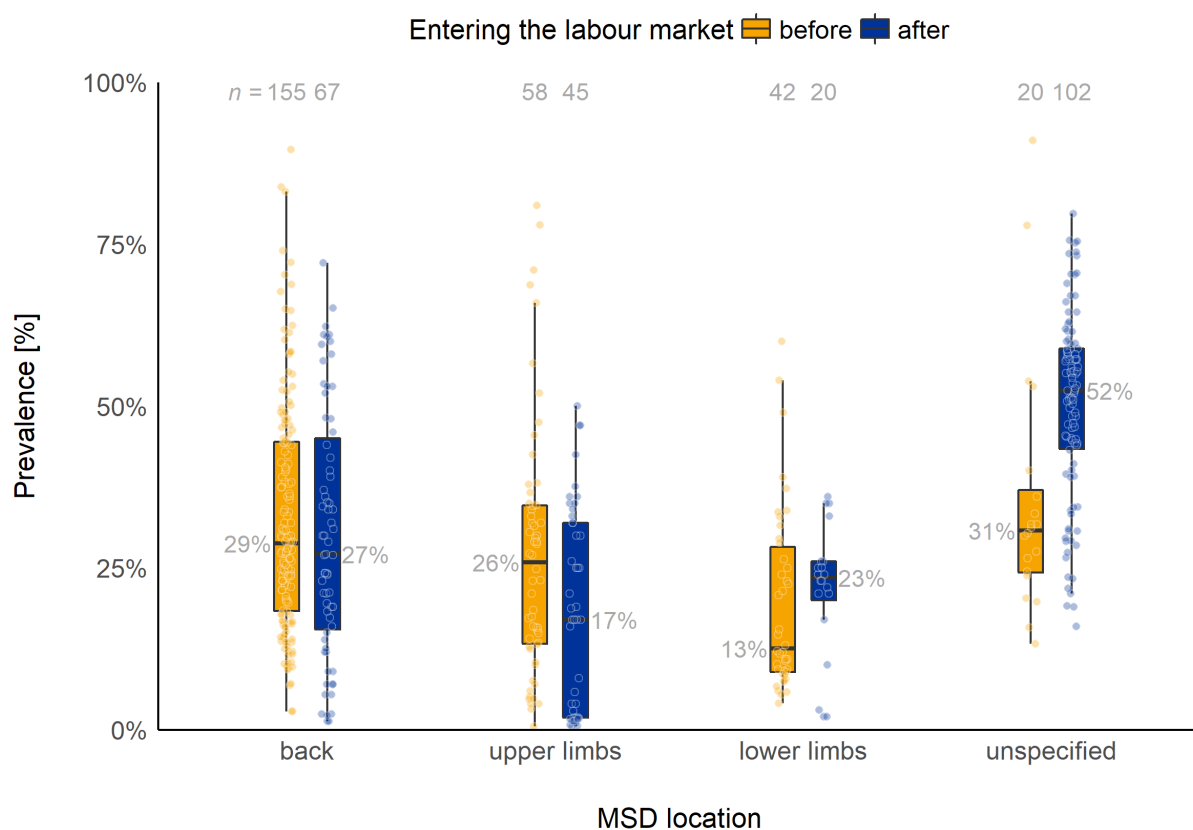
When grouping the extracted MSD prevalence values by their MSD location ('back', 'upper limbs', 'lower limbs' and 'unspecified'), as well as by separately considering whether the young people had entered the labour market or not, it was found that the average prevalence values per group range from 13 % to 52 %. Table 9 provides detailed information for the prevalence values of each group, which are also presented visually in Figure 4.

Table 9 **Percentages of children and young people with MSDs before and after entering the labour market (data published between 2010 and 2021) grouped by MSD locations**

MSD location	Entering the labour market	Number of sample estimates	Median (%)	Mean (%)	Minimum (%)	Maximum (%)
Back	Before	155	28.8	32.6	2.8	89.6
	After	67	27.1	30.3	1.3	72.1
Upper limbs	Before	58	25.9	27.2	0.5	81.0
	After	45	17.0	18.7	0.5	50.0
Lower limbs	Before	42	12.6	19.5	4.1	60.0
	After	20	23.5	21.7	2.0	36.0
Unspecified	Before	20	30.8	35.6	13.3	91.0
	After	102	52.4	50.3	16.0	79.7

Figure 4 **Percentages of children and young people with MSDs before and after entering the labour market (data published between 2010 and 2021) grouped by MSD locations.**

Note: each dot represents a prevalence extracted from a publication. For each MSD location-labour market combination the number of extracted prevalence estimates is shown at the top and the rounded median is written besides the boxplot's median.



Each dot represents a prevalence extracted from a publication. For each 'MSD location'-'Labour market' combination, (i) the number of prevalences extracted is shown at the top and (ii) the rounded median is written besides the boxplot's median

In summary, the following aspects can be pointed out, but it must be noted that the variability of the extracted prevalence values per group remains relatively large, which generally means that the estimated averages should be treated with caution. That said, we find that:

- (i) The average prevalence in people before entering the labour market is already quite high, except for MSDs grouped as 'lower limbs' (medians: back, 29 %; unspecified, 31 %; upper limbs, 26 %; lower limbs, 13 %).
- (ii) The average prevalence in people after entering the labour market is higher than that for people before entering the labour market for 'unspecified' and 'lower limbs', but comparable or even lower for 'back' and 'upper limbs' (medians after vs before: unspecified, 52 % > 31 %; lower limbs, 23 % > 13 %; back, 27 % < 29 %; upper limbs, 17 % < 26 %).
- (iii) The average prevalence values for most groups are around 15—30 %, with the striking exception of 52 % for the prevalence of 'unspecified' in people having already entered the labour market. This is emphasised by the fact that, at 16 %, this group also has the highest minimum prevalence.

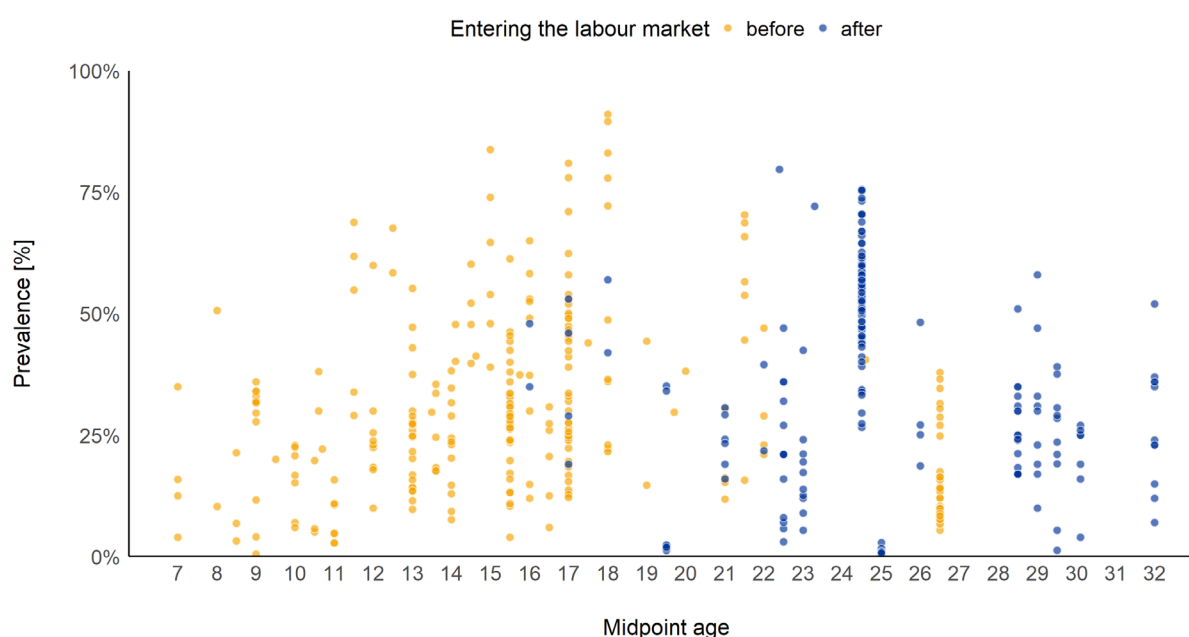
3.2.3 MSD prevalence per age

Here we investigate whether the prevalence sample estimates extracted from a total of 52 publications suggests any differences between the age regarding the prevalence of MSDs in children and young workers.

As described in section 2.4, there were limitations in extracting the age of each study's subjects, so the resulting extracted age values should be interpreted with caution. Accordingly, we refer to these values as the midpoint age and investigate them only briefly to prevent overinterpretation. That said, a visual representation of the MSD prevalence vs the midpoint age is shown in Figure 5.

Figure 5 **Percentages of children and young people with MSDs before and after entering the labour market (data published between 2010 and 2021) grouped by midpoint age.**

Note: each dot represents a prevalence extracted from a publication.



As can be seen, no significant trend becomes apparent — neither across the entire dataset, nor separately for young people before and after entering the labour market. This is confirmed by linear regression analyses (see section 2.5.1), the results of which are not shown here because of the very poor goodness of fit (i.e. very small coefficient of determination, R^2) for all models. For example, based on data for those aged 18 years old and under before entering the labour market, we fitted several regressions for multiple combinations of gender and location, yet none of the resulting models showed an R^2 larger than 25 %. However, all the fitted regressions were found to have positive slopes and thus upward trends from childhood to adolescence.

In summary, when accepting the limitations of the midpoint age as an age estimate (see section 2.4), there seems to be no clear trend between the MSD prevalence and the increasing age of children and/or young workers.

3.2.4 MSD prevalence per country

Here we investigate whether the prevalence sample estimates extracted from a total of 52 publications suggests any differences between the young people's country regarding the prevalence of MSDs in children and young workers.

Table 10 provides detailed information for the prevalence values of each country or region, which are also presented visually in Figure 6. As described in section 2.4, all European countries are subgroups

of the 'Europe' category, but the latter also includes prevalence values from studies that investigated groups of European countries or European regions, but which did not differentiate between individual countries. The same is analogously true for 'global', but keep in mind that the only non-European countries that were included during the study selection process of this scoping review were Australia, Canada, Israel, New Zealand and the USA.

Table 10 Percentages of children and young people with MSDs before and after entering the labour market (data published between 2010 and 2021) grouped by country

Country/ region	Labour market	Number of extracted prevalence estimates	Median (%)	Mean (%)	Minimum (%)	Maximum (%)
Global	Before	275	27.1	29.7	0.5	91.0
Global	After	234	35.0	36.1	0.5	79.7
Europe	Before	250	27.0	29.8	0.5	91.0
Europe	After	203	36.0	36.8	0.5	79.7
Australia	Before	7	40.2	35.7	22.3	47.8
Australia	After	14	20.3	26.2	5.4	73.5
Austria	Before					
Austria	After	8	52.2	36.9	3.1	60.7
Belgium	Before					
Belgium	After	6	37.7	39.8	18.7	62.7
Bulgaria	Before					
Bulgaria	After	1	57.2	57.2	57.2	57.2
Croatia	Before					
Croatia	After	2	45.8	45.8	44.7	46.8
Cyprus	Before					
Cyprus	After	2	52.8	52.8	45.3	60.3
Czechia	Before					
Czechia	After	4	49.9	48.5	39.0	55.1
Denmark	Before	29	29.6	28.7	0.5	60.0
Denmark	After	15	28.5	30.4	16.0	58.2
Estonia	Before					

Country/ region	Labour market	Number of extracted prevalence estimates	Median (%)	Mean (%)	Minimum (%)	Maximum (%)
Estonia	After	2	44.0	44.0	43.9	44.2
Finland	Before	75	16.8	22.9	4.0	91.0
Finland	After	15	42.0	34.6	1.3	70.5
France	Before					
France	After	8	2.3	25.5	0.5	72.1
Germany	Before	22	21.1	21.3	3.2	52.5
Germany	After	2	59.2	59.2	58.8	59.7
Greece	Before	1	22.1	22.1	22.1	22.1
Greece	After	3	58.7	59.3	57.2	61.9
Hungary	Before	1	12.5	12.5	12.5	12.5
Hungary	After	2	33.8	33.8	33.3	34.4
Iceland	Before					
Iceland	After	1	67.0	67.0	67.0	67.0
Ireland	Before	2	34.0	34.0	30.0	38.1
Ireland	After	2	51.4	51.4	50.3	52.4
Israel	Before					
Israel	After	3	60.0	57.7	52.0	61.0
Italy	Before	4	61.9	60.5	50.7	67.7
Italy	After	3	55.3	60.7	51.3	75.4
Lithuania	Before					
Lithuania	After	2	48.4	48.4	26.6	70.3
Luxembourg	Before					
Luxembourg	After	2	31.8	31.8	29.6	33.9
Malta	Before					
Malta	After	1	75.2	75.2	75.2	75.2
Netherlands	Before	19	12.2	13.1	2.8	30.4

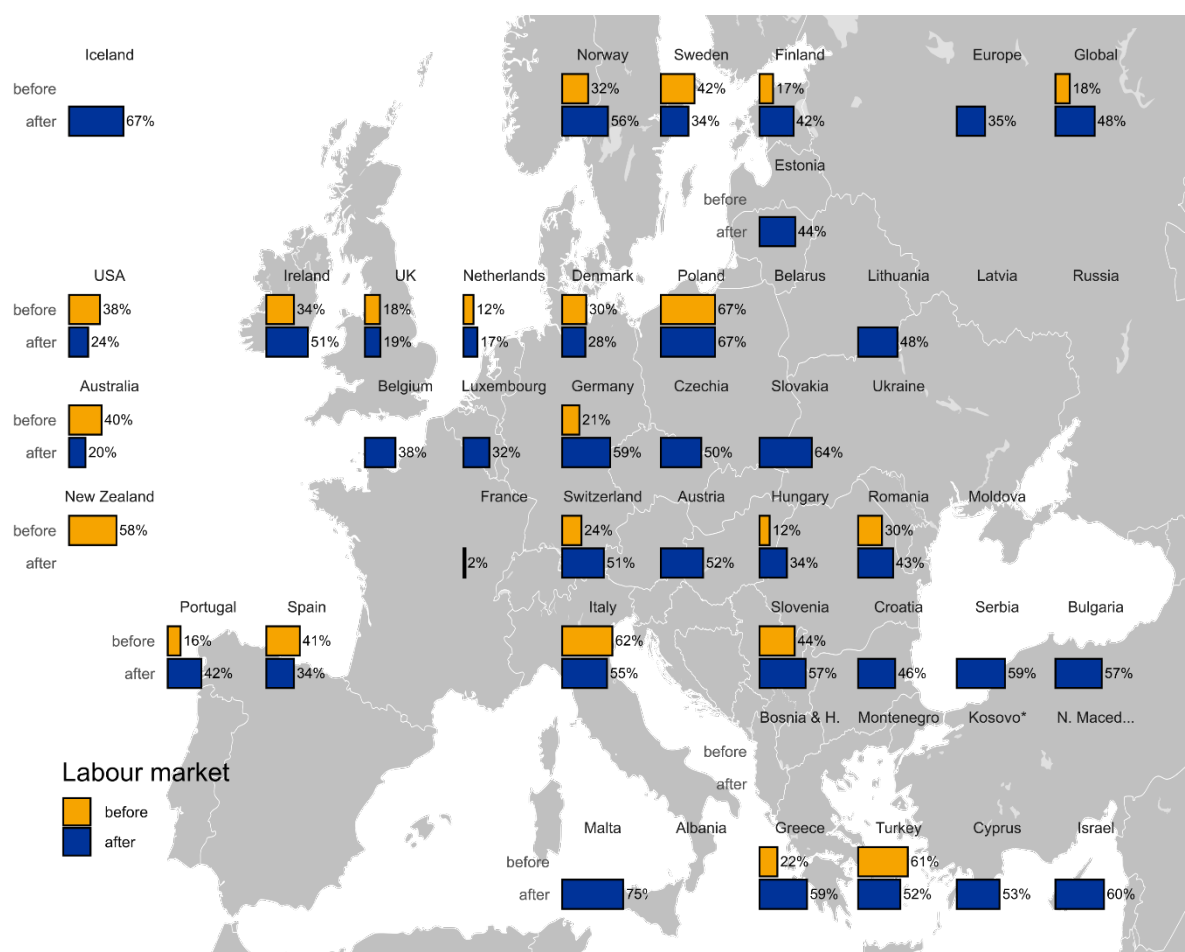
Country/ region	Labour market	Number of extracted prevalence estimates	Median (%)	Mean (%)	Minimum (%)	Maximum (%)
Netherlands	After	27	17.0	16.9	1.3	51.0
New Zealand	Before	1	58.4	58.4	58.4	58.4
New Zealand	After					
Norway	Before	41	32.0	36.2	4.0	81.0
Norway	After	4	56.4	57.2	40.1	75.6
Poland	Before	12	66.9	68.2	47.8	89.6
Poland	After	3	67.0	62.5	47.3	73.2
Portugal	Before	7	15.9	27.6	10.3	55.2
Portugal	After	2	41.7	41.7	39.2	44.2
Romania	Before	2	29.5	29.5	14.7	44.4
Romania	After	1	43.2	43.2	43.2	43.2
Serbia	Before					
Serbia	After	1	59.5	59.5	59.5	59.5
Slovakia	Before					
Slovakia	After	3	64.5	64.5	60.0	68.9
Slovenia	Before	2	43.5	43.5	43.0	44.0
Slovenia	After	3	56.9	62.2	55.9	73.8
Spain	Before	5	41.3	43.9	31.7	60.2
Spain	After	7	34.0	36.2	0.8	57.2
Sweden	Before	8	41.6	39.0	21.0	58.3
Sweden	After	14	34.0	32.6	8.0	52.4
Switzerland	Before	11	23.7	26.6	12.9	37.4
Switzerland	After	5	51.3	52.9	27.4	79.7
Turkey	Before	6	61.2	53.6	15.7	70.3
Turkey	After	4	52.1	49.1	34.0	58.3

Country/ region	Labour market	Number of extracted prevalence estimates	Median (%)	Mean (%)	Minimum (%)	Maximum (%)
UK	Before	3	18.5	19.9	15.5	25.7
UK	After	12	26.5	32.8	4.0	65.1
USA	Before	5	38.2	37.8	29.0	53.8
USA	After	12	23.6	27.6	10.0	58.0

Figure 6 **Median percentages of children and young people with MSDs before and after entering the labour market (data published between 2010 and 2021) grouped by country.**

Note: all European countries are subgroups of the 'Europe' category, but the latter also includes prevalence values from studies that investigated groups of European countries or European regions, but which did not differentiate between individual countries. The same is analogously true for 'global', yet the only non-European countries that were included during the study selection process of this scoping review were Australia, Canada, Israel, New Zealand and the USA.

*Under UN Security Council Resolution 1244/99



In summary, the following aspects can be pointed out, but it must be noted that for some countries the variability of the extracted prevalence values remains relatively large and, in some cases, only a few or no prevalence values could be extracted, which generally means that the estimated averages should be treated with caution. That said, we find that:

- (i) Across European countries, as well as for the 'Global' category:
 - a. the average prevalence in people before entering the labour market is already quite high (median: 27 %);
 - b. yet the average prevalence in people after entering the labour market is even higher (median: 36 %).
- (ii) Countries with relatively low median prevalence estimates are the Netherlands (12 % before, 17 % after), the United Kingdom (18 % before, 19 % after) and Denmark (30 % before, 28 % after).
- (iii) Countries with relatively high median prevalence estimates are Turkey (61 % before, 52 % after), Poland (67 % before, 67 % after) and Italy (62 % before, 55 % after).

3.2.5 MSD prevalence grouped by publication year

Here we investigate whether the prevalence sample estimates extracted from a total of 52 publications suggest any differences between publication years regarding the prevalence of MSDs in children and young workers.

When grouping the extracted MSD prevalence values per publication year, as well as separately considering whether the young people had entered the labour market or not, it was found that the average prevalence values per group range from 16 % to 64 %. Table 11 provides detailed information for the prevalence values of each group, which are also presented visually in Figure 7.

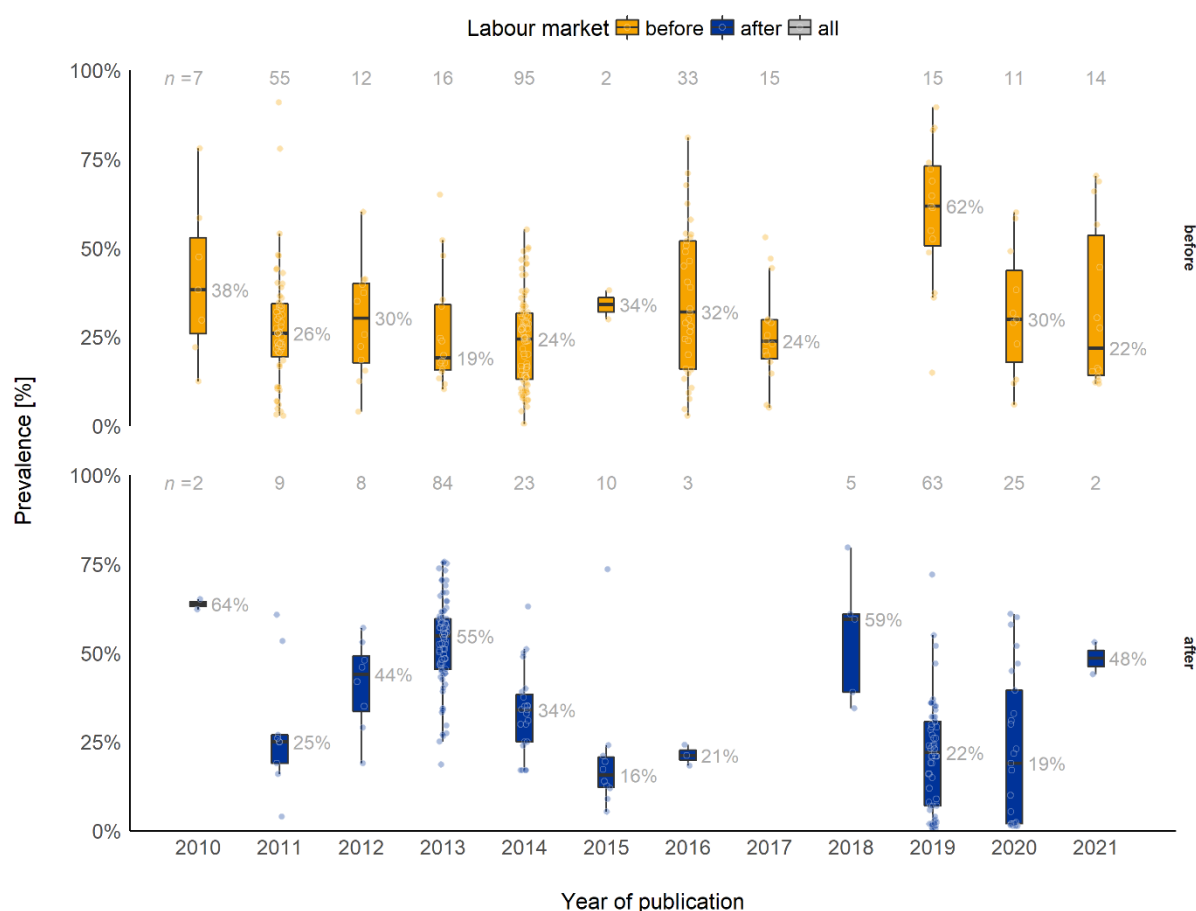
Table 11 **Percentages of children and young people with MSDs before and after entering the labour market (data published between 2010 and 2021) grouped by year of publication.**

Publication year	Labour market	Number of extracted prevalence estimates	Median (%)	Mean (%)	Minimum (%)	Maximum (%)
2010	Before	7	38.2	40.9	12.5	78.0
	After	2	63.7	63.7	62.3	65.1
2011	Before	55	26.0	27.7	2.8	91.0
	After	9	25.0	28.5	4.0	60.7
2012	Before	12	30.4	29.4	4.0	60.2
	After	8	44.0	41.1	19.0	57.0
2013	Before	16	19.0	26.4	10.3	65.0
	After	84	54.8	52.7	18.7	75.6

Publication year	Labour market	Number of extracted prevalence estimates	Median (%)	Mean (%)	Minimum (%)	Maximum (%)
2014	Before	95	24.4	23.6	0.5	55.2
	After	23	34.0	33.4	17.0	63.0
2015	Before	2	34.0	34.0	30.0	38.1
	After	10	15.6	20.8	5.4	73.5
2016	Before	33	32.0	35.3	2.9	81.0
	After	3	21.2	21.2	18.3	24.2
2017	Before	15	23.8	26.0	5.1	53.0
	After					
2018	Before					
	After	5	59.5	54.7	34.5	79.7
2019	Before	15	61.8	60.2	14.9	89.6
	After	63	22.0	21.0	0.5	72.1
2020	Before	11	30.0	31.9	6.0	60.0
	After	25	19.0	22.7	1.3	61.0
2021	Before	14	21.9	33.0	11.8	70.3
	After	2	48.5	48.5	44.0	53.0

Figure 7 **Percentages of children and young people with MSDs before and after entering the labour market (data published between 2010 and 2021) grouped by year of publication.**

Note: each dot represents a prevalence extracted from a publication. For each publication year-labour market combination the number of extracted prevalence estimates is shown at the top and the rounded median is written beside the boxplot's median.



Each dot represents a prevalence extracted from a publication. For each 'Year'-'Labour market' combination, (i) the number of prevalences extracted is shown at the top and (ii) the rounded median is written beside the boxplot's median

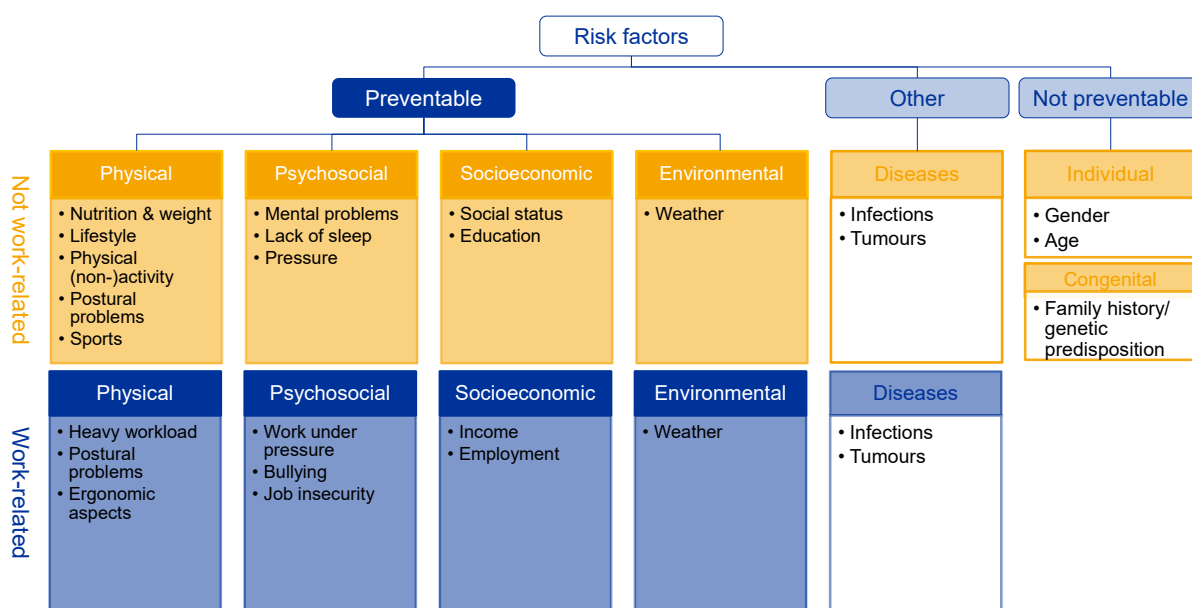
As can be seen, no clear trend becomes apparent — neither across the entire data, nor separately for young people before and after entering the labour market. This is confirmed by linear regression analyses (see section 2.5.1), the results of which are not shown here because of the very poor goodness of fit (i.e. very small coefficient of determination, R^2) for all models.

In summary, there seems to be no clear trend between the MSD prevalence in children and/or young workers and the respective study's publication year.

3.3 Risk factors related to MSDs

Generally, MSDs can be caused by acquired, individual or congenital risk factors or by other diseases. Acquired risk factors are those that are largely preventable, and these include physical, psychological, socioeconomic and environmental risk factors (Figure 8). Acquired risks are preventable, as they are connected to too little, tensed or excessive use of the musculoskeletal system. Congenital factors relate to family history and genetically determined MSDs. MSDs may also be triggered by infections or tumours.

Figure 8 Risk factors for MSDs in children and young people identified in this review



In this review we only investigated acquired, preventable and individual risk factors. We were able to identify 448 studies or reviews on this topic. Based on population group and age, we categorised 159 studies/reviews to analyse risks in children and adolescents before entering the labour market and 34 studies/reviews to analyse work-related risks in young people.

We considered 255 studies analysing sports-related injuries in young amateur and professional athletes to form a special category independent from labour market groups. We decided on this option because the aetiology of sports injuries is not differentiated between amateur and professional sports and because of the large number of studies. Sport has a unique status regarding the labour market, and a more in-depth analysis would also require distinguishing between the different disciplines. Nevertheless, sports injuries also have a negative impact on the work-related capabilities of children and young workers.

In the following sections, we show the narrative compilations of the main study results for each of the identified risk factors. The first subsection depicts pre-labour market risk factors for children and adolescents, and the second depicts work-related risks for young workers. The third subsection deals with sport as a risk factor for injuries in children and young people, whether amateur or professional athletes.

3.3.1 MSD risk factors in children and adolescents before entering the labour market

Studies indicate that children and young people are already experiencing MSDs. Unspecific pain of the back or limbs was previously believed to be uncommon in children (Beynon et al. 2019, Calvo-Muñoz et al. 2020). The reasons for this and the associated factors are the subject of current research. Many factors have been suggested to be associated with a higher risk of MSDs, including physical (e.g. reduced and excessive levels of physical activity, a sedentary lifestyle, excess body weight/obesity, schoolbag back load) or psychological (mental problems) variables. Notions that, for example, excessive schoolbag weights or permanent uneven body postures can trigger MSDs make clinical sense. However, studies reflect inconsistent results, and, for many suspected factors, the available evidence often does not support the notions.

Within the framework of this scoping review, we identified the following potential risk factors for MSDs in children and adolescents (see also Figure 8):

- physical factors:
 - nutrition and weight:
 - nutrition (6 reviews, 11 studies)
 - body weight (14 reviews, 24 studies)
 - lifestyle:
 - physical (in)activity (7 reviews, 13 studies)
 - leisure activities (12 studies)
 - sleep habits (3 reviews, 5 studies)
 - smoking (4 reviews, 4 studies)
 - alcohol consumption (1 review)
 - bad or incorrect postures:
 - extended sitting (6 reviews, 9 studies)
 - use of electronic devices (5 reviews, 14 studies)
 - backpack load (8 reviews, 13 studies)
 - playing an instrument (10 studies)
 - sports (76 reviews, 215 studies)
- mental health/psychosocial factors (6 reviews, 19 studies)
- socioeconomic factors (4 reviews, 2 study)
- environmental conditions (1 study)
- individual factors:
 - gender (3 reviews, 4 studies)
 - age/pubertal status (4 reviews, 2 studies).

The results of the studies and reviews are presented by risk factor and in a narrative way. The findings on the corresponding risk factor impacts are compiled by describing and summarising the main study results.

▪ Physical factors

Here, we compile the results of studies and reviews on physical risk factors (nutrition and weight, lifestyle, postural problems) for MSDs in children and adolescents.

Nutrition and weight

• Nutrition

Studies on the association between nutrition and MSDs focused on the influence of vitamin D or calcium and protein supply on bone health.

Vitamin D

Vitamin D therapy possibly reduces pain intensity and improves mobility and daily functioning in children with musculoskeletal/orthopaedic disorders, chronic recurrent pain and vitamin D deficiency (Blagojevic et al. 2016).

Seven studies analysed the association between vitamin D deficiency and fracture risk. Moon et al. (2014) concluded that there is insufficient evidence that a low vitamin D level increases childhood fracture risk. Overall, the relationship between vitamin D status and bone mass density is inconsistent; however, there is evidence suggesting that vitamin D supplementation in children might improve bone mass density. Contreras et al. (2014) did not find a relationship between vitamin D deficiency and fracture risk. Vitamin D status did not influence the occurrence of complications during fracture treatment (Gorter et al. 2016). There was no significant correlation with vitamin D level and mechanism of injury, but hypovitaminosis D was common among children with upper extremity fractures (James et al. 2013). Occurrence of a paediatric fracture was not associated with vitamin D levels in a study performed by Minkowitz et al. (2017). However, they did find children with lower vitamin D levels to be at higher risk

of more severe fractures. After controlling for age and daily sun exposure, higher fracture incidence was associated with serum vitamin D insufficiency (Thompson et al. 2017).

Händel et al. (2017) suggested that neonatal vitamin D status does not influence subsequent fracture risk in childhood. However, positive associations with bone mass were identified for milk, phosphorus, magnesium, potassium, protein, folate, calcium and vitamin D, while fat intake had a negative association, suggesting that osteoporosis prevention programmes need to start very early in life (Jones 2011).

McVey et al. (2020) found no association between bone mineral density and dietary vitamin D.

A direct association between vitamin D deficiency and fracture risk in children could not be shown.

Calcium and protein

A diet rich in calcium, potassium and protein was positively associated with measures of tibia bone mineral content and strength in recruits entering initial military training (Nakayama et al. 2019). Calcium from (fortified) dairy products increased bone mineral density by 0.7–1.8 % over 2 years, depending on the site of measurement, but there are currently no studies that have investigated the potential of dairy products to reduce fracture risk in children (van den Heuvel and Steijns 2018). On the basis of a systematic review of studies, fracture risk seemed to be associated with milk avoidance, high calorie intake, high cheese intake, high intake of sugar-sweetened beverages and not having been breastfed (Händel et al. 2015). Wallace et al. (2020) found only insufficient or limited evidence for the effect of dairy products on bone mass in infants and toddlers, children, adolescents and young adults.

However, healthy men and women who had been following religious fasting with lower dairy calcium and protein intakes and a lower dairy consumption than non-fasters did not differ in physical activity, height, bone mineral density and content or in prevalence of fractures. Therefore, periodic abstention from dairy products and, generally, animal products since childhood does not seem to compromise bone health in young adults (Rodopaïos et al. 2020).

McVey et al. (2020) found no association between bone mineral density and dietary calcium.

Dairy calcium and protein intakes seem to have limited effects on bone mineral density and fractures.

Others

A systematic review and evidence map demonstrated a lack of research into understanding the relationship between the Mediterranean diet and musculoskeletal health in all ages (Craig et al. 2017). Body composition and cardiorespiratory fitness mediate the association between the risk of eating disorders and bone health. These findings highlight the importance of maintaining a healthy weight and good cardiorespiratory fitness for the maintenance of good bone health in young adults (Garrido-Miguel et al. 2019).

- **Body weight**

Body weight was the most studied risk factor and was examined for its association with fractures, pain, posture problems and bone diseases.

Injuries/fractures

Several studies found a higher risk of injuries/fractures in overweight children and young people. Unintentional falls are the leading cause of non-fatal injuries and emergency department visits in this group (Adams et al. 2013). Childhood obesity is also associated with altered bone structure and bone mass accrual, triggering higher fracture rates (Ashley and Gilbert 2018). Overweight and obese children had statistically significantly higher odds of lower extremity injuries/pain than children with a normal weight, but no consistent association was observed between body mass index (BMI) and injuries/pain of the upper extremities (Adams et al. 2013, Pomerantz et al. 2010, Ferro et al. 2018). The

overweight/obesity rate was increased in girls with a fracture in either the upper limb or lower limb, while in boys it was only increased when they had a fracture in the lower limb (Valerio et al. 2012). Young men who had excessive body fat were 47 % more likely to experience a musculoskeletal injury and had a 49 % higher use of health care (Cowan et al. 2011). Children who were overweight in terms of both BMI and total body fat percentage showed the highest risk of sustaining lower extremity injuries (Jespersen et al. 2014). Obese children had a greater risk of extremity fracture than their non-obese counterparts (Kim et al. 2013a, Kim et al. 2016, Singer et al. 2011, Sabharwal and Root 2012). Obese individuals are more likely than non-obese individuals to seek treatment for osteoarthritis of the knee. Obese people have a higher risk of loss of reduction of forearm fractures, more severe supracondylar fractures and a higher likelihood of lateral condyle fractures. Obese individuals are more likely to have complications with femur fractures and they also have higher rates of foot and ankle fractures (Ashley and Gilbert 2018).

The study by Campbell et al. (2013) otherwise did not find increasing BMI to be associated with increased acute injury or bone fracture in children. The evidence of a significantly higher risk of developing an injury for overweight adolescents than normal weight adolescents was of very low quality (Paulis et al. 2014).

Overall, the evidence suggests that an increased BMI is correlated with a higher risk of developing MSDs in children and adolescents.

Pain

A higher BMI was significantly associated with lower back pain in adolescent males and females (Hershkovich et al. 2013). Compared with non-obese adolescents, obese individuals with any pain, knee pain and chronic regional pain reported more severe average pain (Deere et al. 2012). BMI in girls aged 16–18 years and boys aged 7–16 years can be used to predict lower back pain incidence at 18 years. In boys aged 16–19 years, a higher waist circumference was also associated with the incidence of lower back pain but not with its persistence (Mikkonen et al. 2013). Onan and Ulger (2021) and Paulis et al. (2014) showed a relationship between BMI and pain in the spine, particularly lower back pain. Obesity in children was associated with increased overall and lower limb musculoskeletal pain for which BMI was a stronger predictor than adiposity (Tsiros et al. 2014). A significantly higher rate of overweight and obesity was observed by Wilson et al. (2010) among young people with chronic pain than in a normative sample. Adolescents who are severely obese are more likely to have musculoskeletal pain that further limits their physical function and decreases their quality of life (Bout-Tabaku et al. 2015a).

Nevertheless, in their review Beynon et al. (2019) concluded that there were inconsistent estimates of association, with insufficient evidence to conclude that there is a relationship between BMI and back pain. In the eight studies that reported on BMI and back pain, three studies reported an increased prevalence, and five studies found no association. BMI showed no association with neck pain (Jahre et al. 2020). Moderate-quality evidence suggests that a high BMI is not a risk factor for the onset of musculoskeletal pain (Huguet et al. 2016) and no consistent results were found for this in relation to BMI, highlighted as important risk factors in previous literature (Øiestad et al. 2020).

Estimates for the association between BMI and back or neck pain are inconsistent. Thus, there is at best weak evidence that overweight and obese children are at higher risk of musculoskeletal pain.

Posture

Bout-Tabaku et al. (2015b) found significantly greater variability in knee alignment among females at higher BMI scores and greater valgus alignment in obese adolescents in late puberty. Progressive malalignment may predispose to pain and risk of early osteoarthritis. An increased BMI was correlated with a higher risk of developing lower extremity postural defects in children (Brzeziński et al. 2019). The results of Kim et al. (2019) indicate that obese children walk with increased patellofemoral loads in absolute terms and also relative to the area of the articulating surfaces, which probably contributes to the increased risk of knee pain in this population. The prevalence rates of incorrect body posture were

significantly higher among children and adolescents who are overweight and obese than among the group with a standard body mass. The most common postural deviations in obese children and adolescents were valgus knees and flat feet (Maciałczyk-Paprocka et al. 2017).

Incorrect body postures are more frequent among overweight and obese children and adolescents.

Bones

Mean BMI was significantly higher for patients with osteochondritis dissecans (OCD)³ of the knee, elbow and ankle than for patients without OCD (Kessler et al. 2018). A high BMI at 16 years old was associated with lumbar disc degeneration at 21 years old among young males, but not among females (Takatalo et al. 2013).

Lifestyle

Lifestyle risk factors included physical (in)activity, leisure activities, smoking and alcohol consumption and poor sleeping habits.

• Physical (in)activity

Findings showed that both extremes of activity level (i.e. very low and very high levels of physical activity) are associated with lower back pain. Guddal et al. (2017) found that a moderate level of physical activity level was associated with less neck and shoulder pain and lower back pain, and that participation in endurance sports may be particularly beneficial. Participation in technical sports was associated with increased odds of lower back pain, whereas team sports were associated with increased odds of lower extremity pain. Strength and extreme sports were related to pain in all regions. There is moderate evidence for the association between physical activity and lower back pain in children and adolescents (Kędra et al. 2020). Lunde et al. (2015) showed a weak trend towards decreasing lower back pain with moderate/high physical activity levels, but this association was not significant. It appears that vigorous or high levels of physical activity may be associated with back pain (Beynon et al. 2019). Aktürk et al. (2019) showed that the prevalence of MSDs was high among high school students, with a correlation found between low physical activity and back pain. A statistically significant relationship was found between experiencing upper/lower back pain and the participants' low physical activity levels. Cross-sectionally, participation in five or more different sport activities, compared with one sport, was associated with significantly less weekly lower back pain, but not with neck/shoulder pain (Kaartinen et al. 2019).

Higher body weight, inadequate levels of physical activity and depression were all independent predictors of back pain within the next 10 years of life. Furthermore, the adverse effects of body weight on back pain were not mitigated by physical activity (Brady et al. 2016). Symptoms of depression and screen-based activities increased the risk of neck and shoulder pain, while physical activity was protective (Myrtveit et al. 2014).

Conversely, Aartun et al. (2016) found objectively measured physical activity not to be associated with spinal pain. Physical activity showed no association with neck pain (Jahre et al. 2020). Physically inactive students declared back pain frequency similar to the frequency declared by their counterparts studying physical education (Kędra et al. 2017). No relationship was found between physical activity and lower back pain and no consistent results were found for lifestyle factors such as physical activity level and BMI, which were both highlighted as important risk factors in previous literature (Øiestad et al. 2020).

³ OCD is a joint condition in which bone underneath the cartilage of a joint dies because of a lack of blood flow.

Little or no physical activity was related to the risk of developing a poor body posture and weight problems (Andreea 2017).

Different modalities of physical activity had different injury risk factors. Low levels of habitual physical activity significantly increased injury risk, but it significantly declined with an increase in weekly exposure; the most active children had the lowest injury risk (Bloemers et al. 2012). Increased physical activity was associated with decreased fracture risk, probably in part due to beneficial gains in bone mineral density and muscle strength (Fritz et al. 2016a). Recreational, school and federated athletes had more injury occurrences, while subjects not participating in sports had a higher injury risk. Older subjects had more injuries. Early maturing girls that had just passed peak height velocity may be particularly vulnerable to the risk of sports injury because of the growing process (Costa e Silva et al. 2017).

Strong evidence was found for a positive association between muscular fitness and bone health and self-esteem. The evidence for an association between muscular fitness and musculoskeletal pain and cognitive ability was inconsistent/uncertain (Smith et al. 2014). Self-reported physical activity was not associated with disc degeneration (Takatalo et al. 2013).

In general, both extremes of activity level (i.e. very low and very high levels of physical activity) are associated with back pain or increased injury risk in children and adolescents, while moderate physical activity might be protective. There were also positive correlations between activity, bone health and self-esteem.

• Leisure activities

Leisure accidents are important causes of MSD injuries and fractures.

Despite current playground safety standards and guidelines, a large number of playground-related injuries continue to occur (Adelson et al. 2018, Tuckel et al. 2018, Bierbaum et al. 2018), with fractures of the upper limbs being the type of injury most often associated with a fall from playground equipment (43 %).

Furthermore, many holiday-related injuries sustained by children aged 19 years or under presented to emergency departments. The majority of injuries that occurred on holidays were classified as sports and recreation related (D'Ippolito et al. 2010).

Trampoline-related injury distribution included a higher percentage of fractures/dislocations, lower extremity fractures and surgical interventions (Doty et al. 2019, Korhonen et al. 2018). Furthermore, injuries and fractures were related to hoverboards (Ho et al. 2018), all-terrain vehicles (Hogue et al. 2015), falls from skateboards (Tuckel et al. 2019) and riding dirt bikes (Abdelgawad et al. 2013).

Adolescents with self-reported knee pain participate in more leisure time sports and this higher frequency of leisure time sports participation increases the risk of reporting knee pain (Rathleff et al. 2013).

Football (22 %), diving (20 %) and bicycle crashes (11 %) were the leading activities associated with cervical spine injury (Babcock et al. 2018); common injury patterns were subaxial fractures.

Playground-related and leisure activities still lead to high numbers of injuries in children.

• Sleep habits

A systematic review by Andreucci et al. (2017) concluded that sleep problems are not a general risk factor for musculoskeletal pain onset in children and adolescents (aged 6–19 years). Increased risk was found for some specific body regions and subgroups, but the evidence base was relatively weak and generally inconsistent.

A positive bidirectional association between back pain and insufficient sleep was confirmed by the review of Beynon et al. (2019). A 2-year follow-up survey among adolescents aged 15–19 years

concluded that insufficient quantity or quality of sleep at 16 years old predicted neck, lower back and shoulder pain, especially in girls (Auvinen et al. 2010). Gustafsson et al. (2018) followed a cohort of children aged 10–15. Findings were that daytime sleepiness predicts neck-shoulder pain later in adolescence and that a greater proportion of girls suffered from pain symptoms and daytime sleepiness compared with boys. Impaired sleep related to school pressure influenced the development of musculoskeletal pain in a study by Rolli Salathé et al. (2020).

Daytime tiredness was associated with having any musculoskeletal complaint (Hulsegge et al. 2011). Among boys, a high likelihood of musculoskeletal pains during follow-up was associated with insufficient sleeping time (Jussila et al. 2014). Sleeping problems were a risk factor for spinal pain (Szita et al. 2018).

Overall, the evidence would suggest that there is a positive association between lack of sleep and back pain in children and adolescents. Quality of sleep seems to predict neck, lower back and shoulder pain.

• Smoking

A review of Beynon et al. (2019) found ‘some relationship’ between smoking and back pain.

Gill et al. (2014) analysed bidirectional causal pathways between cigarette use and spinal pain in adolescents. They found that smoking at 14 years old predicted mid-back pain at 17 years old, and that back pain at age 14 was a significant risk factor for smoking at age 17. From a meta-analysis of 40 studies. Shiri et al. (2010) concluded that both current and former smokers have a higher prevalence and incidence of lower back pain than never smokers and that the association between current smoking and the incidence of lower back pain is stronger in adolescents than in adults. Adolescents and adults with chronic back pain or arthritis were more likely to smoke than those without chronic back pain or arthritis (Zvolensky et al. 2010). Two large, independent samples show that adolescents who experience back pain more frequently are also more likely to smoke, drink alcohol and report feelings of anxiety and depression (Kamper et al. 2019).

Smoking of at least four pack-years (number of packs of cigarettes smoked daily multiplied by years of smoking at the age of 19) was associated with disc degeneration among males but not among females (Takatalo et al. 2013).

Passive smoking does not appear to be a risk factor for lower back pain and does not seem to play a leading role in the aetiology of the condition (Kaspiris et al. 2010). Furthermore, even the heaviness of parental smoking (over 20 cigarettes a day) does not seem to alter the appearance of the disease.

No association was found between tobacco use and lower back pain by Minghelli et al. (2014), probably because of the small number of student smokers.

The association between lower back pain in adolescents and tobacco consumption is controversial. There is a definite link, but pain is causing smoking rather than vice versa. Adolescents suffering from back pain are more likely to smoke.

• Alcohol consumption

No association between alcohol consumption and back pain was found by Calvo-Muñoz et al. (2018).

Bad or incorrect postures

Extended sitting, excessive use of electronic devices, heavy backpacks or playing an instrument are risk factors for posture problems and pain. An important number of studies related to these risk factors and the importance of adopting good posture or alternating between postures.

• Extended sitting

Several studies revealed a dose-response relationship between increased sedentary behaviour and unfavourable health outcomes. Students with back pain spent more than 5 hours per day in a sedentary position and did so more often than students without back pain (Kędra et al. 2019). Higher durations/frequencies of screen time and television viewing were associated with unfavourable body posture (Carson et al. 2016). Maintaining a sitting position for a long time resulted in advanced asymmetries of the trunk and scoliosis and caused a decrease in lumbar lordosis and kyphosis of a child's entire spine (Drzał-Grabiec et al. 2015). Findings show reduced thoracic mobility in individuals who spend more than 7 hours/day sitting and undertake less than 150 minutes/week of physical activity (Heneghan et al. 2018). Among boys, a high likelihood of musculoskeletal pain during follow-up was also associated with a long periods of sitting and insufficient sleeping time (Jussila et al. 2014). The findings by Vierola et al. (2016) suggest that low cardiorespiratory fitness, high levels of sedentary behaviour and low body fat content are associated with increased likelihood of various pain conditions among prepubertal children.

Regarding postural habits, the data revealed that students who sit with their spine positioned incorrectly and who adopted an incorrect standing posture had a higher probability of developing lower back pain than those who did not (Minghelli et al. 2014, 2016). Remaining incorrectly seated for many hours greatly affects the spinal curvature in schoolchildren (Sainz de Baranda et al. 2020). Abnormal spinal posture and certain sitting positions were associated with back pain (Beynon et al. 2019).

For physical factors, there was a significant relationship between neck and lower back pain and the attributes of chairs (Trevelyan and Legg 2011). Lower back pain was significantly related to low desk height (as reported by students).

No association was found between sedentary time and neck and shoulder pain (Pirnes et al. 2020). There is unequivocal evidence that sitting and upper quadrant musculoskeletal pain are related in children and adolescents (Brink and Louw 2013).

A prolonged sedentary position, especially with incorrect posture, is associated with lower back pain MSDs in children and adolescents, with a dose-response relationship between increased sedentary behaviour and unfavourable health outcomes.

• Use of electronic devices

Musculoskeletal pain or discomfort in connection with computer or smartphone use is reported by various studies. Screen-based activities increased the risk of neck and shoulder pain (Myrtveit et al. 2014). Approximately half of the participants (53.8 %) of a study performed by Bubric and Hedge (2016) reported experiencing musculoskeletal discomfort when using a laptop. Gustafsson et al. (2017) found associations between excessive text messaging and reported musculoskeletal pain in the neck/upper back and shoulder/upper extremities and numbness/tingling in the hand/fingers for both men and women. Calvo-Muñoz et al. (2018) concluded in their review that the number of hours spent sitting (watching television, using computers, etc.) is a major determinant of lower back pain among children and adolescents, as has been shown to be the case among adults.

The musculoskeletal complaints among children and adolescents most commonly treated by physiotherapists were identified by Ciccarelli et al. (2016) as non-specific neck pain (84.2 %), thoracic postural pain disorder (76.2 %), non-specific lower back pain (69.3 %) and lumbar postural pain disorder (69.3 %).

People with a problematic amount of internet use were more likely to have a chronic condition and to report back pain (Suris et al. 2014). Smartphone use of over 6 hours in a typical day was found to have a statistically significant association with high musculoskeletal pain prevalence in the neck, shoulders and wrists/hands in comparison with the study reference smartphone use of 1–2 hours daily (Mustafaoglu et al. 2021). In a review on the risk factors associated with spinal pain in adolescent computer users, Kuo and Lee (2012) found positive associations between the duration of computer use and cervical pain: a weekly internet use of 42 hours or more predicted the occurrence of lumbar pain. A

computer use of 14 hours/week or more was associated with a moderate or severe increase in computer-associated musculoskeletal pain at all anatomical sites and moderate or severe inconvenience in everyday life due to lower back pain (Hakala et al. 2012).

It was estimated that 75 % of the world's population is hunched over their handheld devices for hours daily with their heads flexed forward. David et al. (2021) described 'text neck syndrome' as an emerging 21st century syndrome: text neck syndrome is more common in adolescents, who, for several hours a day and for numerous days a year, hunch over smartphones and personal computers more frequently than in the past. Adolescents who watched more television sat with a more flexed trunk posture (more slumped) and had lower back muscle endurance (Smith et al. 2010). Ciccarelli et al. (2011) found postures adopted when reading a book and writing with a pen to be more variable than postures adopted when performing electronics-based tasks.

In contrast, non-internet users were more prone to report frequent back pain (Bélanger et al. 2011) than occasional, regular or even heavy internet users. This finding was explained by the more physical workloads handled by non-internet users than by their peers who are still in high school. Drozda et al. (2011) did not find significant differences in computer use between adolescents with and without a history of back/neck pain and pain-free teenagers who watched television for significantly longer. Boys with back/neck pain performed physical work more frequently than pain-free boys. Straker et al. (2011) saw gender differences: an increased risk of neck-shoulder pain in males with increased computer use and a decreased risk of neck-shoulder pain in females with increased computer use.

However, results were inconsistent for the association of the duration of daily computer use with neck pain in a review by Jahre et al. (2020). In one review, Stiglic and Viner (2019) characterised the level of evidence for an association between screen time and neck/shoulder pain, headache and lower back pain as insufficient, and in another review Beynon et al. (2019) concluded that there were inconsistent estimates of associations between screen time and back pain.

Overall, there is at best weak evidence of an association between computer or smartphone use and musculoskeletal pain in children and adolescents; only heavy computer use is significantly associated with neck, shoulder, hand/wrist or back pain. In reviews the association between moderate screen time and neck/shoulder or lower back pain was assessed as insufficient.

• **Backpack load**

Several studies did not find associations between backpack load and musculoskeletal complaints. In a meta-analysis, Calvo-Muñoz et al. (2020) did not find an association between carrying school bags weighing more than 10 % of the person's bodyweight and lower back pain. Equally, there was no evidence of an increased association of lower back pain with carrying a backpack weight of more than 10 % of the student's body weight (Heuscher et al. 2010). The weight of the school bag and the way in which it was carried did not appear to have a statistically significant correlation with the appearance of back pain (Kaspiris et al. 2010). In 2016, Minghelli et al. found no statistically significant relationship between the presence of lower back pain and excessive backpack weight. This observation was explained by the care taken by students with lower back pain to minimise the pain; in other words, the lower back pain could have arisen because of carrying too much weight and, once the lower back pain was present, the student might be careful not to carry excess weight so as not to aggravate the symptoms. Likewise, Yamato et al. (2018) found evidence from five prospective studies that schoolbag characteristics such as weight, design and carriage method do not increase the risk of developing back pain in children and adolescents. The association between backpack weight or method of carriage and lower back pain was also inconsistent across studies included in the review by Calvo-Muñoz et al. (2018).

Furthermore, other backpack factors were assessed to be of no significance. In a study by Dockrell et al. (2015) none of the physical factors (absolute/relative schoolbag weight, carrying an additional item, duration of carriage, method of travel to school) were significantly associated with schoolbag-related musculoskeletal discomfort. Participants who carried backpacks heavier than 10 % of their body weight did not have more musculoskeletal pain or a lower pressure pain threshold than those who carried lighter

backpacks, although they did report greater fatigue (Hernández et al. 2020). Beynon et al. (2019) concluded inconsistent estimates of the association between backpack factors and back pain.

By contrast, Aprile et al. (2016) observed significantly increasing schoolbag-related pain with age. Girls reported significantly more frequent and more severe pain than boys. Interestingly, they noted that most of the studies reporting an association between carrying a schoolbag and pain were based on questionnaires, whereas those that did not find any such association were based on face-to-face interviews.

Students reporting back pain declared that their backpack was heavy more often than their counterparts who did not report back pain (Kędra and Czaprowski 2013). Subjects reported significant increases in back pain associated with backpack loads of 4, 8 and 12 kg (Neuschwander et al. 2010). Schoolchildren carrying the heaviest backpacks had a higher risk of back pain and a higher risk of back pathology, although this last result was not statistically significant (Rodríguez-Oviedo et al. 2012). The study by Minghelli et al. (2014) revealed that almost half of the students with lower back pain carried their backpacks improperly and that it therefore may be that the way a backpack is carried contributes to the development of lower back pain rather than carrying excessive weight. Carrying excess weight in backpacks was not statistically significantly related to lower back pain; these results are consistent with other studies (see above). Schoolbag weight was not significantly related to lower back pain, but carrying the bag on one shoulder was ($p < 0.05$) (Trevelyan and Legg 2011). No statistically significant relationship was found between carrying excess weight in backpacks and lower back pain, which is consistent with other studies (see above).

Differences in the weight of school bags after 1 school year influenced changes in body posture abnormalities, especially in rotation parameters. Asymmetric backpack straps was noticeably more common in the group of girls and the difference between straps may have an impact on some posturometric parameters (Brzęk et al. 2017). Furthermore, Kistner (2011) revealed statistically significant differences in postural angles and increased complaints of pain after walking with increased backpack loads. Increasing backpack loads significantly compressed lumbar disc heights measured in the midline sagittal plane and significantly increased lumbar asymmetry (Neuschwander et al. 2010). The added load of a backpack and the changes in spinal posture when carrying a backpack imposed considerable demand on internal tissues and probably results in considerable spinal loads (Suri et al. 2020). In a review, Perrone et al. (2018) identified some impacts of backpack loads, such as changes in posture (e.g. changes in spinal posture, lumbo-sacral angles and thoracic kyphosis), gait (increases in plantar pressure during foot-ground contact and increased double support), increases in physical discomfort and muscle activity, and increases in breathing rate.

The research by Minghelli et al. (2016) found no statistically significant association between scoliosis and incorrect postural habits and excessive weight of the backpack.

Overall, the evidence would suggest that the association between carrying schoolbags and back pain is debatable and weak. Schoolbag load, schoolbag carrying time and the way a backpack is carried have inconsistent impact on back pain.

• **Playing an instrument**

We found 11 studies analysing the prevalence of MSDs among children and students studying instrumental music. Musculoskeletal pain is highly prevalent (about 60–90 %) in music students (Rodríguez-Romero et al. 2016, Cruder et al. 2018, Ioannou and Altenmüller 2015, Kok et al. 2013, Nawrocka et al. 2014a, Nawrocka et al. 2014b, Stanek et al. 2017, Vinci et al. 2015, Wood 2014, Ranelli et al. 2014, 2011, Silva et al. 2018), mainly as a result of a higher number of upper extremity complaints. Playing instruments such as the violin for several hours a day leads to some changes in body posture in children (Cygańska et al. 2017). Studies found a gender difference, with girls more often affected than boys (Nawrocka et al. 2014b, Ranelli et al. 2011, Rodríguez-Romero et al. 2016). The type of instrument played (upper and lower strings, woodwind and brass) was significantly associated with all playing-related musculoskeletal problems in children (Ranelli et al. 2011). Soreness related to non-musical activities co-occurs significantly with playing problems in young instrumentalists (Ranelli et al. 2014).

Musculoskeletal pain is highly prevalent among children and students playing instruments intensively.

▪ **Mental health problems/psychosocial factors**

In the following, the results of studies and reviews on psychosocial risk factors for MSDs in children and adolescents are compiled.

Psychosocial factors were found to be associated with musculoskeletal pain (Gilkey et al. 2010, Hulsege et al. 2011, Jussila et al. 2014, Kamper et al. 2019, Myrtveit et al. 2014, Trevelyan and Legg 2011, Dolphens et al. 2016, Hugu et al. 2016). Adolescents with long-term multi-site pain had higher levels of distress and anxiety than those without or with only short-term multi-site pain. Associations were found in both genders, but the relationship between pain and distress was more pronounced among boys (Auvinen et al. 2017). The frequencies of psychological and social factors were significantly higher in adolescents with spinal pain than in those without (Batley et al. 2019). Psychological features, specifically psychological distress and emotional coping problems, were identified as potential risk factors or triggers for back pain in a review by Beynon et al. (2020). Borgman et al. (2020) found a significant association between having pain (headache, abdominal pain or back pain) and having depressive symptoms. Eckhoff and Kvernmo (2014) found a strong association between musculoskeletal pain sites and psychosocial problems. Anxiety/depression symptoms were the dominant factor associated with musculoskeletal pain, followed by negative life events and school-related stress. Psychosocial risk factors were uniquely significant predictors of upper and lower back pain (Erne and Elfering 2011). In both genders there were significant correlations between all the continuous pain and stress variables (Østerås et al. 2016). Spinal pain was a common complaint among young people and co-occurred with stress and poor general well-being (Stallknecht et al. 2017). Over 50 % of subjects reported lower back pain across grades, and both depression and somatisation were significantly positively associated with lower back pain (Robertson et al. 2017).

Any type of chronic pain, including chronic back or neck pain and frequent or severe headaches, was associated with any mental disorder, including affective, anxiety, behaviour, substance use and eating disorders (Tegethoff et al. 2015).

King et al. (2011) found that feeling sad was associated with pain in girls, but no psychological variables were associated with musculoskeletal pain in boys. Females reported more mental health difficulties than males, with strong relationships to back and neck pain (Rees et al. 2011). Externalising behaviour problems was associated with 'reporting lower back pain' and 'consultation for lower back pain' at baseline among both genders (Mikkonen et al. 2016).

The signs of attention deficit and hyperactivity disorder (anxiety and depression) were determined to be higher in children with extremity fractures than in those without fractures (Duramaz et al. 2019).

However, in their review Beynon et al. (2019) found some psychosocial factors (depression, anxiety and 'peer problems') to be associated with back pain while internalising, anxiety sensitivity, dysfunctional coping, and catastrophising were not associated with future back pain. Jahre et al. (2020) found inconsistent results for an association of neck pain with perceived stress.

On balance, therefore, the overall conclusion remains that mental health problems caused by, for example, depression, anxiety or distress may be important determinants of adolescent musculoskeletal pain.

▪ **Socioeconomic factors**

Four reviews and two studies analysed associations between socioeconomic risk factors and MSDs in children and adolescents.

In a US study (Ryan et al. 2013) two factors influencing paediatric bone fracture rates were found: race/education and large families. The poverty factor was not independently associated with fracture risk.

Lower levels of education, lower income and being unemployed were all associated with an increased prevalence of pain (Henschke et al. 2015). The prevalence of back pain was reported to be higher among students in private schools (Perrone et al. 2018).

Low socioeconomic status was identified as a risk factor for the onset of musculoskeletal pain in studies exploring long-term follow-up (Huguet et al. 2016). Those studies with a short follow-up (at 1 and 3 years) found no greater risk of developing musculoskeletal pain in children with lower socioeconomic status than in children with higher socioeconomic status. Those studies with a long follow-up (at 18 and 33 years) found a higher risk of developing musculoskeletal pain in children with lower socioeconomic status. Inconsistent results for the relationship between socioeconomic factors and back pain were reported in a review by Beynon et al. (2019). Seven studies reported positive associations between certain socioeconomic factors and back pain, whereas eight studies reported no association.

Lewandowski and Lukaszewska (2014) found that the living conditions in a rural and an urban environment in Poland posed no specific threat to the occurrence of spinal pain in young people.

With six very different papers and inconsistent results for the relationship between socioeconomic factors and musculoskeletal pain, it is difficult to draw any detailed conclusions. However, it appears that in the long run low socioeconomic status might be a risk factor for the onset of musculoskeletal pain, although clearly the relationship is complex.

▪ Environmental conditions

We identified only one study on the impact of environmental factors on MSDs in children and adolescents.

The effect of weather conditions on fractures in children aged less than 16 years was analysed by one Finnish study (Sinikumpu et al. 2017); the risk of a fracture was 3.5-fold higher on dry days than on rainy days. Warm temperatures (15–24.9 °C) increased the fracture risk 2.6-fold compared with cool (< 15 °C) days. The fracture incidence did not change according to the wind speed. The findings were similar throughout the school term and summer vacation.

▪ Individual factors

Most of the studies and reviews analysed the association between MSDs and the gender of children and adolescents. Additionally, some looked at the prevalence of development with age.

Gender

In 53 studies reporting on gender and back pain, 32 studies found a positive association with female gender and back pain, three studies found a higher prevalence of back pain in males and 18 studies found no association with gender (Beynon et al. 2019). Generally, there was a positive association between female gender and back pain.

Studies of pain in children and adolescents found that girls generally experience more pain than boys (Henschke et al. 2015). Most of the studies reported that musculoskeletal pain is more common in girls than in boys. Girls reported significantly more pain in the neck, shoulders, back and abdomen than boys, whereas boys reported significantly more knee pain than girls (King et al. 2011). Girls were also more than twice as likely to report recurrent back pain than boys (van Gessel et al. 2011). Females reported a higher 1-month prevalence of neck/shoulder pain than males (Straker et al. 2011). Girls had a higher risk of back pain and an increased risk with age was observed (Rodríguez-Oviedo et al. 2012). Gender was the risk factor with the highest risk ratio for lower back pain at some time in life (Sundell et al. 2019). Female gender and back pain at 14 years of age were strongly associated with lower back pain at 17 years of age (Smith et al. 2017). Girls were twice as likely to develop lower back pain than boys, and students in the older age group had a 50 % higher chance of developing lower back pain (Minghelli et al. 2014).

Risk factors for overuse knee injuries were being a girl, previous knee injury and participation in football, handball, basketball and rhythmic and tumbling gymnastics (Junge et al. 2016).

The backpack-induced reduction in lumbar range of flexion when moving quickly was larger in females than in males (Shojaei et al. 2018).

However, Jahre et al. (2020) found inconsistent results for the association between female gender and neck pain.

On average, musculoskeletal pain is more common in girls than in boys. Generally, there is a positive association between female gender and back pain.

Age

Beynon et al. (2019), Calvo-Muñoz et al. (2018), Henschke et al. (2015) and King et al. (2011) consistently found a higher prevalence of (back) pain as children advanced in age towards adolescence and young adulthood. Being over 12 years old was identified as a risk factor for non-specific spinal pain in a study by Szita et al. (2018). There also was an association between back pain and advanced pubertal status (Beynon et al. 2019).

Physical activity-related injuries increased with age in boys and in the higher maturity offset group in girls (Costa e Silva et al. 2017).

The prevalence of pain and injuries increases with advancing age in children as they approach adolescence and young adulthood.

3.3.2 Work-related risk factors in young workers

Our search for scientific literature revealed that most studies on work-related MSD risk factors are performed in adults without discussing separate age groups (i.e. young people). Only very few studies expressly addressed young workers.

These few studies focused on certain occupational sectors such as health care or professional music, probably because of increased awareness of MSDs in these sectors. The focus may also be triggered by easy access to these study populations. Although heavy lifting in health care workers, strained body postures in dentists and excessive practice in musicians undoubtedly constitute exemplary work-related risk factors, it is astonishing that no studies were identified in other sectors and/or occupations known for heavy physical work and in which many young people are employed (e.g. construction, agriculture). An EU-OSHA report on young workers (EU-OSHA 2007) described similar problems: 'Specific data on exposure of young workers are also hard to obtain, especially when it is to be more specific to sectors and occupations they are mostly employed in.'

Within the framework of this scoping review, we identified the following work-related risk factors for MSDs in young people (see also Figure 8):

- physical factors:
 - physical workload (nine studies)
 - occupation-/industrial sector-related factors (physical demanding work, poor working positions, ergonomic aspects):
 - health care professionals (2 reviews, 13 studies);
 - musicians (six studies)
- psychosocial factors (two studies)
- socioeconomic factors (one study)
- environmental conditions (one review)
- individual factors:
 - gender (one review, three studies).

The results of the studies and reviews are presented below by risk factor in a narrative way. Findings on the corresponding risk factor impacts are compiled by describing and summarising the main study results.

▪ Physical factors

Physical workload

Hanvold et al. (2014) and Lourenço et al. (2015) found a significant increase in neck and shoulder pain over time in the transition from technical school to working life. When compared with workers with low physical demands, those with repetitive and asymmetric demands or high and vibrational demands had an 80 % higher adjusted odds ratio of reporting neck/shoulder pain. High and vibrational demands were significantly associated with upper/lower back pain in comparison with low demands. It appears that certain types of work, such as white-collar work or manual work, may be associated with back pain (Beynon et al. 2019).

Adolescent girls and boys with high levels of exposure to awkward trunk postures, an overall physically demanding job with a high level of sustained muscle activity or significant exposure to biomechanical/ergonomic and video display unit risks had a higher likelihood of lower back pain incidence (Mikkonen et al. 2012, Hanvold et al. 2013, Russo et al. 2020). Male and younger workers who worked extraordinarily long hours (≥ 60 hours/week) also had higher prevalence of lower back pain compared with their counterparts who worked fewer hours per week (Yang et al. 2016). A forward bent posture during computer work in young females was associated with changes in fixation disparity (Mork et al. 2018).

High physical demands, awkward trunk postures or extraordinarily long working hours are associated with musculoskeletal problems in young workers.

Occupation- or industrial sector-related factors

Health care professionals

A high periodic prevalence of lower back pain (about 50–60 %) is reported among medical and nursing students, which is rather alarming considering their young age (Crawford et al. 2018, Horrell et al. 2010, Lövgren et al. 2014, Menzel et al. 2016, Moroder et al. 2011, Vujcic et al. 2018, Wong et al. 2021). Neck and upper back were the most common sites of problems reported (Penkala et al. 2018). Mental stress or psychological distress, sitting while studying at university, fatigue, incorrect posture and lack of exercise were associated with a higher prevalence of lower back pain (Wong et al. 2021, Vujcic et al. 2018, Mitchell et al. 2010). Nevertheless, the prevalence of lower back pain was not higher in medical students than in physically more active students, despite their sedentary lifestyle (Moroder et al. 2011).

Younger workers in health care support occupations had an increased risk of musculoskeletal problems (Yang et al. 2016).

Thumb- and other hand-related injuries are commonly reported among practising gastroenterologists (up to 20 %); females may be at particularly high risk (Austin et al. 2019).

MSDs also frequently occur among dentists and dental students (in about 40–50 %) (Kapitán et al. 2018, Kurşun et al. 2014, Netaneli et al. 2020, Warren 2010). In the dental profession there are many risk factors that combine and can contribute to the initiation and development of MSDs. These risk factors mainly include a long-term static position, forced unnatural posture during work, doing tasks with small instruments using a large force, a small working field with limited access, intensive lighting, noise and psychosocial stress. Another factor considered to be negative is a lack of adequate physical activity (Kapitán et al. 2018). Musculoskeletal pain often begins and continues to develop throughout dentistry studies (Kapitán et al. 2018). The most frequent sites of pain reported were neck, shoulders, lower back and upper back, hands and wrists (Kapitán et al. 2018, Kurşun et al. 2014, Netaneli et al. 2020). Exposure to biomechanical and psychosocial factors has independent and additive associations with

the high prevalence and costs of musculoskeletal disorders in dental hygienists and dental hygiene students (Warren 2010).

Musicians

Evidence that being a professional musician is a risk factor for musculoskeletal disorders and complaints and for the causal relationship between these factors remains low despite the large number of studies that have been performed (Rotter et al. 2020, Cruder et al. 2018). Activity of the forearm muscles while playing the piano was higher than that seen for computer keyboard workers (Baeyens et al. 2020). Musicians with prolonged symptoms of playing-related musculoskeletal disorders presented with higher prevalence of scapular and cervical motor control deficits (Silva et al. 2018). Pain was reported significantly more often by the musicians who did not comply with the recommended compensatory physical activities (Nawrocka et al. 2014a).

Other occupations

Younger workers in the construction industry, specifically masonry, in agriculture and hairdressers had an increased risk of musculoskeletal problems (Yang et al. 2016, Anton et al. 2020, Bradshaw et al. 2011).

There is a lack of studies in occupations with high levels of exposure to noise, vibration, heat or cold and to physically demanding work factors such as working in awkward positions, handling heavy loads and repetitive work, but two small clusters of studies were identified that researched specific sectors, most notably professional musicians and workers in the health care sector. In both sectors young workers are at high risk of developing MSDs.

▪ **Psychosocial factors**

Comparable to older workers, young workers who were exposed to a hostile work environment, work-family imbalance or job insecurity were more likely to report lower back pain (Yang et al. 2016, van Nieuwenhuyse et al. 2013). Findings by van Nieuwenhuyse et al. (2013) suggest that back-related sick leave is mainly taken by young workers who lack professional challenge. Moreover, low 'possibilities to develop skills' was responsible for a high proportion of lower back pain-related sick leave. Younger workers who reported job insecurity had the highest prevalence of lower back pain (36.2 %) compared with workers in the same age group who were exposed to other work-related psychosocial factors (work-family imbalance, exposure to hostile work environment) (Yang et al. 2016).

Psychosocial factors have an influence on MSD prevalence in young workers. Lower back pain-related sick leave is associated with an unstimulating psychosocial work environment.

▪ **Socioeconomic factors**

In a study focusing on the associations between unionisation and workers' health and well-being, Kim et al. (2013b) found significant associations between perceived union connection (workers' connection to their trade union) and neck pain or back pain. The higher the perceived connection to the union of unionised apprentices, the lower the odds of reporting neck and back pain.

▪ **Environmental factors**

A systematic review and meta-analysis (Fatima et al. 2021) suggested that the overall risk of occupational injuries among young workers (< 35 years) increased by 1 % for a 1 °C increase in temperature above reference values and by 17.4 % during heat waves.

▪ Individual factors

Gender

Male health care practitioners had an increased of for lower back pain, while female workers in the farming, fishing, forestry and health care support occupations had an increased likelihood of experiencing lower back pain (Yang et al. 2016). A high mechanical workload was associated with neck and shoulder pain among women, while a high level of shoulder muscle endurance capacity was associated with lower rates of neck and shoulder pain among men (Hanvold et al. 2014).

Female medical students demonstrated a higher lower back pain prevalence than their male counterparts (Wong et al. 2021, Vujcic et al. 2018) and the prevalence of pain is higher among female than among male dentists (Kurşun et al. 2014).

There are relationships between gender and MSD risk in young workers according to different exposures that vary between sectors and tasks.

3.3.3 Sports injuries

Sport is an important part of our society and has far-reaching positive effects on our health (e.g. prevention of obesity, metabolic diseases, osteoporosis and coronary heart disease). Unfortunately, some of these positive effects are lost as a result of sports injuries, which often have serious consequences, especially in childhood. A total of 57 review articles and an additional 198 original studies were found in our search on this topic.

Football (soccer) was the most commonly investigated sport ($n = 36$), followed by American football ($n = 23$), baseball ($n = 22$) and dancing ($n = 15$). Football is one of the most common sports worldwide; however, the injury rate is higher than in many other sports, and approximately over 80 % of injuries were sustained in people under the age of 24 (Koutures and Gregory 2010), highlighting its relevance for young people's health. In a systematic review, the injury incidence, prevalence and severity in high-level male youth football was investigated (Jones et al. 2019). The studies reviewed show a high probability of sustaining a time loss injury during a typical high-level youth football season. High-level youth players seemingly lose large portions of seasonal development time to injury. Pooled estimates for total incidence per 1 000 hours were 7.9 for older players (17 to 21 years), 3.7 for younger aged players (9 to 16 years), and 5.8 for youth players (9 to 21 years). Nearly one fifth (18 %) of all reported injuries were classified as severe, requiring > 28 days' recovery time, with muscle strain injury accounting for 37 % of all injuries sustained in high-level youth football (Jones et al. 2019).

The reported injuries range from knee injuries (anterior cruciate ligament injury, meniscus) to fractures, concussion and muscle injuries as well as lower back pain and other pain. One of the most common injuries is anterior cruciate ligament injuries, which have a steadily increasing incidence among adolescent athletes (Bram et al. 2020). The risk of anterior cruciate ligament injuries overall approached nearly 1 per 10 000 athlete-exposure for female athletes, who are almost 1.5 times more likely than male athletes to suffer an anterior cruciate ligament injury across all adolescent sports. A multisport female athlete was estimated to have a nearly 10 % risk of anterior cruciate ligament injuries over her entire high school or secondary school career. Specifically, male and female adolescents playing football, basketball, lacrosse and American football appeared at particular risk of injuries, a finding that can be used to target injury intervention (Bram et al. 2020).

Injuries specific to youth athletes are overuse injuries to the growth plates. Risk factors for physical injuries include periods of accelerated growth, chronological age, body size, training volume and previous injury. Muscular imbalances after accelerated growth periods predispose young athletes to overuse injuries. Modifiable risk factors such as flexibility, strength and training volume should be regularly monitored to prevent these injuries (Arnold et al. 2019).

A concern regarding the long-term consequences of youth sports injury is the risk of developing osteoarthritis at a young age. Based on the available evidence, a link between youth sports injuries, particularly acute injury of the knee and ankle, and osteoarthritis is likely. Early osteoarthritis development and intense participation in high-impact, high-stress elite sports at an early age also may

be associated, but a follow-up of elite athletes into their early adult years is needed to examine this relationship (Caine and Golightly 2011).

3.4 Preventive measures or intervention strategies

As the previous sections have showed, there is a large number of acquired MSD risk factors. MSDs caused by physical or psychosocial factors are preventable and manageable. This section discusses the available evidence on preventive measures to reduce the risks for MSDs in children and young people.

Within the framework of this scoping review, we were able to identify 96 studies or reviews on interventions to prevent MSDs or to promote a good musculoskeletal health among children, young people and young workers. The interventions covered educational measures (18), exercises (23), manipulative therapy (seven), ergonomic measures (nine), neuromuscular training (two), orthopaedic aids (one) and sports injury prevention programmes (36).

- prevention of MSDs in children and adolescents:
 - prevention or reduction of musculoskeletal pain:
 - education
 - physical exercise
 - manipulative therapy
 - ergonomics
 - prevention of injuries/accidents:
 - education
 - physical exercise
- prevention of MSDs in young workers:
 - prevention or reduction of musculoskeletal pain:
 - education
 - physical exercise
 - psychophysical re-education
 - biofeedback
 - manipulative therapy
 - ergonomics
 - prevention of work-related injuries:
 - education
 - neuromuscular training
- prevention of sports injuries:
 - education
 - warm-up programmes, exercises
 - neuromuscular training
 - protective equipment.

In the following section, the interventions are presented narratively in three sections: (1) prevention of musculoskeletal pain and accidents/injuries in children, (2) prevention of musculoskeletal pain and accidents/injuries in young workers and (3) prevention of sports injuries.

3.4.1 Prevention of MSDs in children and adolescents

In many cases, MSD problems begin in childhood, when inappropriate postures are combined with little sports activity (Rodríguez-Oviedo et al. 2018). Suffering from musculoskeletal pain in childhood or adolescence increases the risk of suffering as an adult (Kovacs et al. 2011), possibly through the

development of maladaptive beliefs, behaviours and attitudes related to the earlier pain events (Michaleff et al. 2014). If MSDs in children can be prevented, entry into a cycle of recurring episodes may be delayed and adult MSD prevalence decreased (Hill and Keating 2015). Hence, prevention campaigns and interventions should include children. Moreover, campaigns should already target young children to prevent MSDs in adolescence, the prevalence of which currently is comparable to that of adults (see section 3.2.3). The school setting offers the opportunity to deliver preventive interventions to a large number of children and has been used to address a range of public health problems (Orton et al. 2016). Young people living with persistent musculoskeletal pain described the absence of age-appropriate pain services and clearly articulated their perceptions on the role of, and opportunities provided by, digital technologies to connect with and support improved pain health care. Innovative and digitally enabled models of pain care are likely to be helpful for this group (Slater et al. 2016, Enz et al. 2021).

▪ Prevention or reduction of musculoskeletal pain

The results of studies/reviews analysing the effectiveness of education programmes, exercise interventions, physiotherapeutic or ergonomic measures on MSDs in children and students are collated in this section.

Education

Educational interventions comprised school curricula, education sessions, presentations, materials and courses aimed at increasing knowledge, changing attitudes and building skills.

Children are able to learn healthy daily life habits that might contribute to the prevention of future lower back pain (Vidal et al. 2011, Vidal et al. 2013). For the prevention of lower back pain, there is moderate-quality evidence to suggest that back education and promotion programmes are not effective in reducing lower back pain prevalence in children and adolescents, while exercise interventions appear to be promising for treating lower back pain in children and adolescents (Michaleff et al. 2014). A school-based educational back care programme resulted in increased back care knowledge up until adulthood, but the intervention did not change spinal care behaviour or self-efficacy (Dolphens et al. 2011). Handing out a comic book on the topic of backs slightly improved children's knowledge of appropriate methods for the prevention and management of lower back pain, and the effect remained significant 3 months after the intervention (Kovacs et al. 2011). An inexpensive intervention (a 1-hour presentation and demonstration of exercises) directed to reduce backpack weight and back pain had a positive effect in reducing both in schoolchildren (Rodríguez-Oviedo et al. 2018).

In general, education is effective in increasing knowledge and awareness about musculoskeletal discomfort and pain in children and young people. Nevertheless, increased knowledge does not necessarily lead to improved behaviour, which is difficult to achieve.

Exercise

Exercise interventions comprised movement or muscle strengthening programmes, physical syllabi, mind-body techniques, gym lessons and exercise training.

Regular exercise and education appear to reduce lower back pain episodes in children aged 8–11 compared with education alone (Hill and Keating 2015), but a comprehensive set of strategies considered to be important in encouraging children's adherence to exercise was not successful in sustaining the interest of more than half of the cohort (Hill and Keating 2016). Children who are overweight and obese and who participated in a 13-week exercise programme developed a better alignment of the head and lower limbs, improved their performance of fundamental movements and experienced global muscular strength gains; these improvements could contribute to the prevention of musculoskeletal disorders (Molina-Garcia et al. 2020). An exercise programme with 8 weeks' regular practice was effective in improving postural back pain, spinal alignment and inclination in university students with postural back pain (Çelenay and Kaya 2014). A 9-week progressive exercise therapy programme improved physical health and reduced the prevalence of cervical disability and lower back

pain in young adults with musculoskeletal pain (Rodríguez-Romero et al. 2019). The presence of a physiotherapist in the school context facilitated the acquisition of healthy postural habits; all adolescents perceived a decrease in back pain after taking part in a classroom programme (Blanco-Morales et al. 2020).

Movement training was more effective than hip strengthening in reducing pain in young adults with patellofemoral pain (Esquerre 2016). van der Heijden et al. (2016) found very low-quality but consistent evidence that exercise therapy for patellofemoral pain syndrome may result in a clinically important reduction in pain and improvement in functional ability and enhance long-term recovery.

A Pilates programme enhanced trunk endurance and extensibility in adolescents with a history of back pain (González-Gálvez et al. 2019). Statistically significant effects of the Pilates method combined with therapeutic exercise were obtained for pain reduction in children playing string instruments (Poncela-Skupien et al. 2020).

Discomfort associated with the modification of habitual postural behaviours was reduced after 3–4 months of regular training (Nowotny-Czupryna et al. 2013). Targeted diversification of physical and sport education syllabi focused on the improvement of the musculoskeletal system's functions in young female students, including body posture and the dynamic capacity of the spine and the muscle system, which led to significant changes in their overall body posture (Bendíková 2020). Daily use of a triangular dynamic cushion had a beneficial impact on children's lumbar proprioception (Fettweis et al. 2018). Furthermore, 4 weeks of deep cervical flexor training led to significant improvement in functional status and neck pain, but it did not improve head posture (Sikka et al. 2020). A significant improvement of posturometric parameters in younger school-aged children was achieved by an authorial programme, 'I Take Care of My Spine' (Brzek and Plinta 2016).

The results of a meta-analysis by Behringer et al. (2014) conclude that weight-bearing activities alongside a high calcium intake provide a practical, relevant method to significantly improve bone mineral content in prepubertal children, justifying the application of this exercise form as osteoporosis prophylaxis in this stage of maturity.

Physical exercises are promising interventions in showing quick successes in the prevention or reduction of MSDs; for sustainable effects strict adherence to exercises should be encouraged.

Manipulative therapy

Manipulative therapy comprised physiotherapy activities, soft tissue treatment, chiropractic manipulation and correction of habitual position.

Children experiencing spinal pain for a long time or those with co-occurring musculoskeletal pain before inclusion and a low quality of life at baseline tended to benefit from manipulative therapy, but adding manipulative therapy to advice, exercises and soft tissue treatment care in schoolchildren with spinal pain did not result in fewer recurrent episodes (Dissing et al. 2018, Dissing et al. 2019, Selhorst and Selhorst 2015). On the other hand, for adolescents with chronic lower back pain, spinal manipulation combined with exercise was more effective than exercise alone (Evans et al. 2018).

When education or exercise interventions are applied, adding manipulative therapy does not have added value. Nevertheless, manipulative therapy is effective in children with long-lasting or chronic pain.

Ergonomics

Ergonomics comprised specially designed seats, desks, computer accessories or lifting equipment.

The use of a high-density foam wedge on normal school seating reduced the intensity of back pain significantly, especially in the evenings (Candy et al. 2012). Dimensions for classroom furniture design are given by Oyewole et al. (2010); based on the need to accommodate at least 90 % of the population

of first graders in the USA, they propose furniture design dimensions for seat height (25.83–32.23 cm), seat depth (27.41–33.86 cm), seat width (17.91–23.29 cm), back rest (35.64–44.37 cm), arm rest (16.28–20.68 cm) and desk height (30.12–37.85 cm). Height-adjustable standing desks and pedagogical strategies significantly reduce or break up sitting time, but effects on musculoskeletal pain and discomfort are controversial (Contardo Ayala et al. 2016, Ee et al. 2018).

Students' use of notebook computers in class has increased as universities integrate technology into the classroom. Participatory ergonomics training and use of external notebook accessories (ergonomic chair, desktop monitor and notebook riser, wireless keyboard, mouse) may have significant health benefits for children who have daily exposure to computer use for school and leisure purposes (Jacobs et al. 2013, Jacobs et al. 2011). An adjustable chair and a notebook riser contributed to decreasing students' discomfort when combined with ergonomic training. The use of an external keyboard resulted in a reduction in neck and shoulder pain. Jacobs et al. (2011) warned that students are likely to enter the workforce with poor computing habits without some form of ergonomic intervention; they confirmed daily notebook computer use of 4 hours to be a risk factor.

Two interventions, Ergo Bucket Carrier and Easy Lift, for young people (and adults) to handle water/feed buckets on farms significantly decrease the magnitudes of risk of lower back disease (Fathallah et al. 2016).

Here we note that ergonomic equipment plus training have a positive effect. The combination of these two measures is an example of a good practice or intervention that can easily be transferred to other activities and occupational applications.

▪ Prevention of childhood accidents

There is some weak evidence that school-based injury prevention education programmes improve safety skills, behaviour/practices and knowledge (Orton et al. 2016). Studies found that 40 minutes of moderate physical activity every school day compared with 60 minutes of physical activity per school week almost halved the incidence of accidents and significantly enhanced total spine areal bone mineral density and muscle strength (Fritz et al. 2016a, Fritz et al. 2016b, Fritz et al. 2016c).

Accidents and injuries can be effectively reduced by the introduction of injury prevention education programmes and moderate physical activity.

3.4.2 Prevention of MSDs in young workers

Work-related MSDs due to abnormal positions maintained during work are very common, and already so among young workers. The problem of persistent musculoskeletal pain is big, and it imposes a substantial health and economic burden on young people and the broader community (Slater et al. 2016). Disorders are usually caused by postural distortion, prolonged static postures and repetitive movements while working. Early education of apprentices and students on ergonomic working postures is relevant for preventing unhealthy working postures in their professional careers and also to decrease the risk of MSDs in the future (Koni et al. 2018). Exercise therapy has also been investigated extensively, and there is evidence that it is effective for the prevention and treatment of lower back and cervical pain in young adults (Rodríguez-Romero et al. 2019).

Workplace injuries in young people raise public health concerns in Europe, the USA and Canada. Employment and working conditions are strong determinants of workplace injuries in young people, and occupational safety and health education programmes are developed to reduce their occurrence (Boini et al. 2017).

In summary, we identified only few studies covering prevention explicitly in young workers, whereas there are many more general studies on workers that do not specifically consider young people.

▪ Prevention or reduction of musculoskeletal pain

Education to increase knowledge, physical exercise and ergonomics are intervention measures that individually or in combination may prevent or reduce musculoskeletal pain in young workers. We identified studies analysing interventions explicitly targeting young musicians and young health care workers.

Musicians

A biopsychosocial course tailored to music students consisted of 11 classes on body posture while playing an instrument based on postural exercise therapy and performance-related psychosocial aspects. It was comparable, but not superior, to physical activity promotion in reducing disability (Baadjou et al. 2018). The majority of music students rated Alexander technique classes (constructive use of the self as an active method of 'psychophysical re-education') as beneficial for all factors, particularly for the reduction of play-related pain, posture, ability to release excess muscle tension, improvements in instrumental technique and improvements in performance level (Davies 2020). Providing music students with information about the most frequent medical problems in musicians, warm-up habits, postural hygiene, effective prevention strategies and different treatment options for these pathologies improved their body awareness by 91 % and the frequency of their injuries decreased by 78 % (Martín López and Farías Martínez 2013). A preventive curriculum given to student musicians during their first two semesters at university had a positive impact on students' performance and their attitude towards health, but did not have an effect on pre-existing physical symptoms (Zander et al. 2010). Cygańska et al. (2020) observed effective raising of the pain threshold of young musicians by two physio-prophylactic methods (chair massage and an original set of exercises).

Health care professionals

Forty-nine percent of dental students reported an improvement in pain symptoms after attending a training course on ergonomics and basic knowledge on postures and MSDs (Koni et al. 2018). Functional fitness training for dental hygiene students resulted in increased core endurance and improved execution of some movement patterns associated with good body mechanics (Parsons et al. 2019). Participation in a physical fitness course led to improved lower back health in dental students (Peros et al. 2011). Sonography students who specifically practised mindful sonography yoga and cueing indicated an improvement in mental health, stress levels and right upper extremity pain. Posture was improved with biofeedback training, while students who used biofeedback training, mindful sonography yoga and cueing demonstrated even greater improvements in posture (Butwin et al. 2017). To optimise ergonomics in the operating room, recommendations related to relaxation, movement and maintenance of ergonomic focus were proposed by Betsch et al. (2020).

The studies in these two sectors demonstrate that various training programmes were useful to improve musculoskeletal symptoms and to learn basic ergonomic principles. In both professions, musculoskeletal pain is highly prevalent, and educational, physical and ergonomic interventions improved quality of work and life. Many authors proposed promoting MSD prevention programmes early during education and training. Although there is a lack of comparative studies on young people in other sectors, these conclusions could be mainstreamed or used as examples of good practice and be transferred to other sectors.

▪ Prevention of workplace injuries

Only a few prospective analytical studies focusing on workplace injuries in young people have been published. Occupational safety and health education as well as neuromuscular training are measures used to prevent workplace injuries.

Young people starting their careers who reported having received occupational safety and health education at school had twice as few workplace injuries than those declaring not having received such education (Boini et al. 2017). A neuromuscular training and injury prevention counselling programme was effective in preventing acute ankle and upper extremity injuries in young male army conscripts and

could be useful for all young individuals (Parkkari et al. 2011). In a review, Gagnier et al. (2013) found that various types of neuromuscular and educational interventions appear to reduce the incidence rate of anterior cruciate ligament injuries by approximately 50 %.

The results of these studies suggest that there could be advantages to strengthening occupational safety and health education as well as neuromuscular education. One approach could be to widely and comprehensively teach occupational safety and health skills in vocational diplomas, as is done in France (Boini et al. 2017).

3.4.3 Prevention of sports injuries

Most evidence for prevention exists in the field of sports injuries. We found 16 original studies and 20 reviews describing interventions of preventive measures in young athletes. This is highly relevant, as over the past decade, there has been a growing number of young people participating in organised sports, both recreationally and competitively (Hanlon et al. 2020). Despite all the benefits resulting from participation in sports — such as improved body composition, cardiorespiratory function, increased strength, psychosocial well-being, weight control — participating in a sport with high physical demands may result in a greater risk of injury and therefore in an increase in health care costs and sick leave (Andreoli et al. 2018). However, there is increasing evidence that many sports-related injuries are preventable, as some risk factors (muscle performance, strength deficits, coordination, endurance) are modifiable, and therefore could be targeted in injury prevention programmes (Hanlon et al. 2020).

The causes of sports injuries are multifactorial. Over the last two decades, the progressive understanding of sports injury mechanisms has allowed the sports medicine community to identify many intrinsic and extrinsic risk factors (Emery et al. 2010, Arnold et al. 2017, Bram et al. 2020), some of which may be influenced in a targeted preventive manner. So far, too little attention has been paid to the effectiveness of prevention initiatives. It has been shown that up to about half of the sports injuries of the various joints (knee, hip, ankle, shoulder) can be avoided through targeted prevention and adequate training (Hübscher et al. 2010, Achenbach et al. 2018). Evidence is highest for the knee joint, where up to 67 % of anterior cruciate ligament injuries can be avoided in high-risk groups, such as adolescents and young female adults (Webster and Hewett 2018). Prevention concepts focusing on ankle injuries mainly target strength training or braces to optimise ankle stability. Regarding sport-specific prevention of these injuries (especially in football, handball, basketball and volleyball), an average relative risk of 0.53, and thus a significant reduction in ankle injuries, was described recently. The shoulder appears to be the least studied joint among those mentioned. The few studies identified showed a significant reduction in shoulder injuries in baseball and handball players. Prevention of hip diseases, such as femoroacetabular impingement and osteoarthritis, is still in its very beginnings, with promising early results. Preventive measures are able to reduce the frequency of muscle and tendon injuries, especially in explosive sports with a lot of sprinting and jumping. Hanlon et al. (2020) showed that prevention programmes also reduce several modifiable risk factors.

Other measures are protecting the young athlete from overload by regulating training, e.g. in baseball by restricting the number of allowed pitches (Zaremski and Krabak 2012).

Given that some antecedents of early adult-onset osteoarthritis may be traced to child and adolescent sports injury and related surgery, and perhaps intense training regimens, it follows that efforts to prevent sports-related joint injury should begin during childhood. Based on the results of recent research, programmes addressing prevention of youth sports injuries may provide rewarding results in osteoarthritis prevention (Caine et al. 2011).

The field of sports medicine, in which a vast number of studies (some of the highest quality) exist, shows that prevention of sports injuries works well and is, in fact, possible and effective. Programmes developed in this sector can also be applied to other areas, e.g. the mechanisms of sustaining an ankle sprain during work and sports are similar. Knowledge learned from sports injury prevention could be transferred, e.g. to the prevention of work or leisure accidents.

However, further research still has to be performed to evaluate the detailed effects of the training measures, the effect of prevention programmes on different sports, the necessary number and duration

of prevention programmes and identifying athletes at risk who would be most likely to benefit from the application of such prevention programmes (Stegé et al. 2014).

There is increasing evidence that many sports-related injuries are preventable, as some risk factors (muscle performance, strength deficits, coordination, endurance) are modifiable and therefore could be targeted in injury prevention programmes. The field of sports medicine, in which a vast number of studies (some of the highest quality) exist, shows that prevention of sports injuries works well and that it is, in fact, possible and effective. Programmes developed in this sector can also be applied to other areas. Knowledge learned from sports injury prevention could be transferred, e.g. to the prevention of work or leisure accidents.

4 Discussion

The overall goal of our review was to document the status of musculoskeletal health in children and young workers and to provide specific recommendations for preventive measures.

The main result we found is an already high prevalence of MSDs, of about 30 %, among children and young people. A vast number of potential risk factors have been investigated with mixed results. One of the main findings on prevention is that so far little attention has been paid to preventive measures counteracting MSD risks, especially in young people.

4.1 Methodology of literature search and data processing

We extracted information and data from studies and reviews that were identified and selected using an extensive systematic literature search according to the principles of a scoping review. Our aim was to map the current key knowledge on the prevalence of MSDs among children and young people on the one hand and on potential risk factors and preventive measures on the other hand.

We systematically searched for scientific literature in six electronic databases and for grey literature using Google and the websites of key institutions. To enable this, key concepts of the research questions and inclusion and exclusion criteria were specified.

As scoping reviews are designed to provide an overview of the existing evidence base regardless of quality, we did not formally assess the methodological quality of the included studies. However, a major problem in the identification of probable causes and risk of MSDs in children and young workers is the wide variation in the design and quality of the studies. High-quality studies were rare. More high-quality studies are urgently needed — a request that was also made by all the reviews we identified.

To manage the vast number of studies, our search was limited to (1) publications from 2010 onwards and (2) studies performed in Europe, Australia, Canada, Israel, New Zealand and the USA. We explicitly included systematic, scoping and narrative reviews published as of 2010 to capture summaries of research that was conducted before 2010 and/or in other countries. To further improve the extent of our scoping review, both qualitative and quantitative study designs were included. Nevertheless, it should be kept in mind that studies published before 2010 and national reports or scientific publications in languages other than English may have been missed here. The limitation regarding publication years, on the other hand, also offers an advantage, as recent studies reflect job profile and lifestyle changes in industrialised countries in more recent years.

Considering the main aims and objectives of each study, we formed three categories: studies estimating prevalence, studies describing risk factors and studies assessing interventions. In total, we identified 52 prevalence, 448 risk factor and 96 intervention studies (altogether 596 studies). With so many relevant studies, we decided to analyse the prevalence data quantitatively in an explorative approach and to report the risk factors as well as the interventions in a narrative way.

Based on the young people's population group and age, we categorised each study population as either having not yet entered the labour market (pre-labour market) or being in the labour market (work-related). This was done to compare pre-labour market with work-related prevalence. Children, schoolchildren and young people in high school or college aged 6 to 26.5 years were assigned to the pre-labour market category, while apprentices, young workers and university students were assigned to the work-related category. The population age in some studies was specified as median or mean age per group, but often only age ranges were provided. For some populations, an unambiguous assignment was not possible. This was especially true for athletes, which was the main reason why sports studies were not categorised by age.

Regarding the work-related classification of two population groups, the risk factors could accordingly be distinguished as pre-labour market and work-related risk factors. It can be argued that pre-labour market risk factors are basically non-occupational risk factors regardless of the population group or age. Nevertheless, within the framework of this scoping review, we focused on the impact of these factors on

children and young people to assess the issue of pre-existing musculoskeletal problems before coming into the workplace.

4.2 Prevalence estimation

Our estimates of the prevalence of MSDs among children and young people as well as risk factors for MSDs comprise results from various sources. Our review therefore gives a good overview of the general health of children and young workers, showing that even at this early age the rate of MSDs is quite high according to many studies. However, the reported prevalence of MSDs varies greatly between the different studies (0.5–91 %).

This can mostly be explained by the inconsistent definition of MSDs and the immense variation in study designs. We — and the authors of included studies or reviews — had to cope with several methodological challenges of MSD research, which mostly comes down to the inconsistency in (1) defining what counts as musculoskeletal pain, (2) limiting the time in which the pain must have occurred and (3) choosing outcome measures.

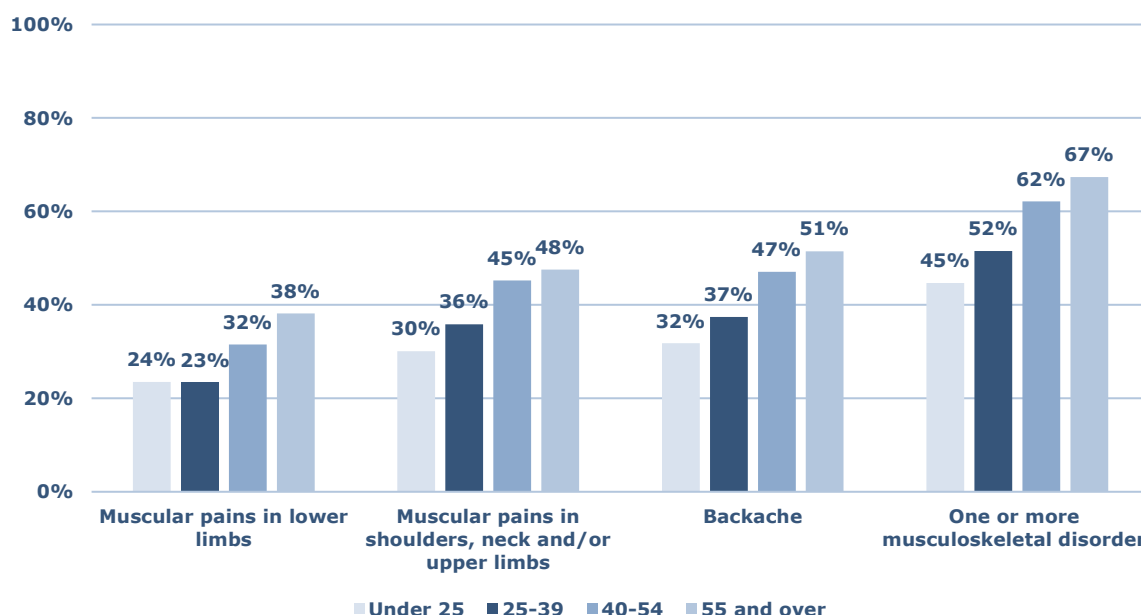
For this report, we categorised the specific MSDs described in the studies as one of three MSD locations according to the affected body part: ‘back’ (neck, upper and lower back), ‘upper limbs’ (shoulders, arms, elbows, hands, wrist) or ‘lower limbs’ (hips, legs, knees, feet, ankles). A fourth category ‘unspecified’ was applied when the MSD was stated to be ‘any MSD’ or ‘multi-site’. This pragmatic accumulation on the one hand facilitated the overall analysis of prevalence data across studies but on the other hand added to the variability of the data. Moreover, the pain duration was rarely specified in terms of units, but instead often referred to vaguely as ‘lifetime’, ‘last year’, ‘last months’ or ‘currently’. We therefore decided against differentiating between certain time periods and considered all pain reported for any time period in the recent past. This is important to remember, as the reported prevalence is not the current incidence, which is of course lower.

Regarding the analyses involving age (section 3.2.3), it must be clear that our extracted values are neither true mean nor median ages, which is why we explicitly refer to them as ‘midpoint age’. It should furthermore be noted that it was not always possible to extract the sample size for each extracted prevalence to calculate weighted means per group as is often done in meta-analyses. Therefore, these prevalence values should be interpreted with caution and should not be overinterpreted.

Our results show that the average prevalence of people after entering the labour market is always slightly higher than that for people before entering the labour market. This is not surprising considering a continuous increase in prevalence from childhood to young adulthood, but it supports the assumption that overuse in young workers is continuing.

Our average prevalence values for most MSD locations are around 15–30 %, with the striking exception of 52 % for the prevalence of ‘unspecified’ in people having already entered the labour market. This corresponds to the data of the sixth (2015) wave of the European Working Conditions Survey (Parent-Thirion et al. 2017), see Figure 9. In general, our results can partly be compared with those in Figure 9, taken from the sixth (2015) wave of the European Working Conditions Survey for people under 25 (EWCS, 2015). The results are similar to the averages found here: most MSD prevalence values are around 20–30 % and the lowest prevalence values are those for MSDs in the lower limbs. For comparison, Figure 9 displays analogous results originally presented in EU-OSHA (2019). When comparing these with the prevalence values in this report, a consistent picture regarding the trend towards increasing prevalence values with increasing age for all MSD sites becomes apparent. Moreover, it emphasises that MSDs are not simply non-existent before young workers enter the labour market, but instead seem to gradually develop at an even younger age.

Figure 9 **Percentage of workers reporting different musculoskeletal disorders in the past 12 months, by age group, EU-28, 2015. Source: EU-OSHA (2019)**



The comparison between different countries is difficult because of the varying number of available studies. Therefore, the respective results (section 3.2.4) should be treated with caution.

Alarming, we did not find a decreasing trend in prevalence over the last 10 years (section 3.2.5), which contrasts with the general improvements in health care. It could be because physical activity is decreasing, and body weight and unhealthy lifestyles are increasing. In addition, modern high-level medicine is more focused on cancers, cardiovascular problems and acute infectious diseases, and less on children or preventive measures. This report raises the attention that should be paid to the musculoskeletal health of our children and young workers.

4.3 Evidence on MSD risk factors

Altogether, we could identify many studies/reviews ($n = 448$) concerning risk factors for MSDs in children and young workers. Therefore, not every study found could be described in detail. Especially in the field of sports as a risk factor for injuries (255 studies were found), only the topic's surface could be explored. Therefore, we reported the risk factors in a narrative matter.

4.3.1 MSD risk factors in children and adolescents

In the studies we identified, a considerable number of risk factors for developing MSDs in children and adolescents were analysed. Remarkably, for most of them no consistent results were derived. There is currently no definite evidence supporting the association of most of these factors with a higher risk of MSDs in children and young people. In fact, for most of the factors, different studies with similar designs and methodological quality have led to contradictory conclusions (Calvo-Muñoz et al. 2018, Kamper et al. 2016a). This is partly because there is a lack of high-quality studies investigating risk factors for MSDs in children and young adults (Jahre et al. 2020, Calvo-Muñoz et al. 2018). The majority of studies are observational, cross-sectional or longitudinal and most do not start data collection before the onset of MSDs (Beynon et al. 2019).

In the studies identified, six groups of potential risk factors for MSDs in children and adolescents were discussed: physical, psychosocial, socioeconomic, environmental, individual and congenital.

Quite clearly, reviews (Beynon et al. 2019, Szita et al. 2018) and many studies concluded that the most likely risk factors or triggers for musculoskeletal pain are predominantly biological (gender, age,

congenital). It is likewise evident that injuries can be triggered by both low and very high levels of physical activity, e.g. by leisure activities or sports.

Nevertheless, considering most acquired, preventable risk factors, study results are not so clear; likely associations, weak significances or mixed results were found. Moreover, in many cases, limited research was observed.

Physical factors

The most discussed risk factors for MSDs were of a physical kind: nutrition and weight, lifestyle or postural problems. Although the results are inconsistent, overweight and obesity in general are health risks, especially for developing bad posture and for limiting mobility, thereby triggering musculoskeletal pain and sudden injuries. The long-lasting negative effects of overweight in the adult population have been well described, with increased risks for metabolic syndrome, hypertension, cardiovascular disease and the development of, for example, osteoarthritis of the knee.

Maintaining a healthy weight and good cardiorespiratory fitness is important for the maintenance of good bone health in young adults. Moderate physical activity is essential for good musculoskeletal health to build muscle strength, maintain flexibility, improve bone density and enable joint development. Moreover, it helps to maintain a healthy weight and to improve balance and coordination. Physical activity also enhances emotional well-being, which is directly linked to musculoskeletal health. Nevertheless, both extremes of activity levels can negatively affect MSDs. Interventions involving physical exercises and movement training are more important, to not only prevent MSDs but also promote good musculoskeletal health among children and young people. A minimum of physical activity seems to be necessary to maintain good health. This is also concluded in the latest recommendations of the World Health Organisation (Bull et al. 2020): 'In children and adolescents, physical activity confers benefits for the following health outcomes: physical fitness (cardiorespiratory and muscular fitness), cardiometabolic health (blood pressure, dyslipidaemia, glucose and insulin resistance), bone health, cognitive outcomes (academic performance, executive function) and mental health (reduced symptoms of depression) and reduced adiposity. It is therefore recommended that children and adolescents should do at least an average of 60 min/day of moderate-to-vigorous intensity, mostly aerobic, physical activity, across the week. Vigorous-intensity aerobic activities, as well as those that strengthen muscle and bone should be incorporated at least 3 days a week. In children and adolescents, higher amounts of sedentary behaviour are associated with detrimental effects on the following health outcomes: fitness and cardiometabolic health, adiposity, behavioural conduct/pro-social behaviour and sleep duration. It is recommended that children and adolescents should limit the amount of time spent being sedentary, particularly the amount of recreational screen time.'

No associations were found between smoking or alcohol consumption and MSDs.

There is a positive association between bad sleep habits and back pain in children and adolescents; therefore, lack of sleep should be prevented, particularly in children.

Bad or incorrect postures

Adopting good postures is important, as incorrect or excessive sitting or standing triggers tension, which consequently triggers musculoskeletal pain. Long school days and extensive screen time or smartphone use are predominantly sedentary activities that should be compensated for. Musculoskeletal pain is also highly prevalent among children and students playing instruments. Again, interventions involving physical exercises and movement training are needed to improve posture and reduce postural pain. It is important to recognise that there is no single posture that should be aimed for; rather, it is vital to change the posture often and to not stay in the same position for a long time.

However, some things commonly believed to be risk factors, such as carrying a school bag, were not found to be as dramatic as suggested at first sight. Schoolbag load, schoolbag carrying time and the way a backpack is carried showed inconsistent impacts on musculoskeletal pain, but again high-quality studies on this topic are rare.

Mental health/psychosocial factors

Depression, anxiety, stress and 'peer problems' were found to be associated with back pain, while other psychosocial factors were not. The overall conclusion remains that mental health problems may be important determinants in adolescent musculoskeletal pain. This is an important finding, as stress, depression or other psychological factors were not seen as problematic at a young age. There is an urgent need to apply interventions aiming to promote emotional well-being from an early age. In our review we found only very few studies addressing interventions to prevent psychological MSD risk factors in children or adolescents. This might be because psychological interventions are not primarily intended to prevent MSDs. However, evidence-based psychological treatments and interventions are available for children and adolescents with mental health needs (e.g. from the American Academy of Paediatrics).⁴

Socioeconomic factors

Regarding social health inequalities, not all children and young people are exposed to MSD risk factors in the same way. Some are exposed more and are accordingly more 'vulnerable' to suffering from MSDs. We found only a few studies and they showed inconsistent results, but it appears that in the long run low socioeconomic status might be a risk factor for increased prevalence of musculoskeletal pain.

Sports

Moreover, sports injuries, especially in high-level sports, constitute a major problem and counteract many of the positive aspects of sports. More education campaigns for children, parents, teachers and trainers should be conducted to improve health literacy and increase levels of general health. Especially concerning aspects are the long-term consequences of youth sports injuries, with the risk of developing osteoarthritis at a young age. Based on the available evidence, there is a link between youth sports injuries, particularly acute injuries of the knee and ankle, and osteoarthritis. Early osteoarthritis development may also be associated with intense participation in high-impact, high-stress elite sports at an early age, but follow-up studies of elite athletes into the early adult years are needed to further examine this relationship (Caine and Golightly 2011). Ultimately, more data are necessary to fully evaluate the long-term consequences of sports injuries in children (Caine and Golightly 2011).

4.3.2 Work-related MSD risks in young workers

Regarding work-related risk factors in young workers, the literature is especially difficult to evaluate. Whereas distinguishing between children and young people before they enter the labour market is easy, the group of young workers is difficult to describe in several respects. Many studies cover workers in general and do not focus on young workers. The subgroup of young workers is only rarely addressed in independent studies, which would be of great importance, as young workers still have their whole working lives before them. More or better knowledge of young workers (on work-related MSDs and also on OSH in general) is very important when it comes to the promotion of sustainable work across the work-life course. The cumulative nature of MSDs (as a result of long-term exposure to MSD risk factors) means that it is key to start preventing exposure to MSDs among young workers (in addition to prevention among older workers).

The fact that young workers are particularly exposed to MSDs risk factors has already been raised and addressed in several EU-OSHA reports.

In 2007, a report on young workers (EU-OSHA 2007) showed that they are exposed to a greater extent to noise, vibration, heat or cold and handling of dangerous materials, and also to physically demanding work factors such as working in awkward positions, handling heavy loads and repetitive work. Furthermore, the report showed that young workers tend to work under pressure, with tight deadlines and at high speeds. All these physical and psychosocial factors can increase the risk of these young workers developing MSDs.

⁴ <https://www.aap.org/en-us/documents/crpsychosocialinterventions.pdf>

In an 'occupational safety and health in figures' report on MSDs published in 2010 (EU-OSHA 2010) it was reported that young people are 'overexposed to MSD risk factors'. The high prevalence of young people complaining of MSDs is confirmed in a more recent report (EU-OSHA 2019).

Another publication (Belin et al. 2016) highlights the importance of occupational safety and health for achieving sustainable work across a person's working life and takes young workers into account: 'Adopting a life-course approach improves prevention for all workers, and reduces the damage to workers' health while limiting early exit from work and improving the sustainability of work in jobs that have high physical demands. This is key to promoting a longer working life and healthy retirement. Features of such an approach include:

- being aware that changes made to reduce risks for older workers (e.g. by excluding them from the more demanding aspects of jobs) might increase the risks for the other (younger) workers who have to take these tasks on instead.
- recognising that the cumulative nature of many injuries (e.g. some MSDs) means that reducing the incidence of these MSDs among older workers entails reducing exposures to MSD risk factors, such as excessively heavy manual work, for younger as well as older workers.'

Altogether, we identified 34 studies analysing work-related risk factors in young workers. These few studies focused on certain occupational groups such as those working in health care or professional music, probably because of increased awareness of MSDs in these sectors. The focus may have also been triggered by the easy access to these study populations. Although heavy lifting in health care workers, strained body postures in dentists and excessive practice in musicians undoubtedly constitute exemplary work-related risk factors, it is astonishing that no studies were identified in other sectors and/or occupations that are known for heavy physical work and in which many young people are employed (e.g. construction, agriculture). Therefore, future research needs to target sectors (in the framework of prevention schemes/interventions or research) in which young workers are most at risk of suffering from MSDs. These are usually sectors with higher levels of job insecurity (precarious jobs) and where physical working conditions are tougher (long working hours, high physical workload). Regular medical check-ups should be intensified, especially for hardworking people (e.g. construction) or other occupations at risk, to identify health problems at an early, reversible stage. An EU-OSHA report on young workers (EU-OSHA 2007) described similar problems: 'Specific data on exposure of young workers are also hard to obtain, especially when it is to be more specific to sectors and occupations they are mostly employed in'.

Regarding the studies identified, five groups of potential risk factors for MSDs in young workers were discussed: physical, psychosocial, socioeconomic, environmental and individual.

Physical factors

It is well known that high physical demands, awkward trunk postures or extraordinarily long working hours are associated with musculoskeletal problems in young workers. A report on young workers (EU-OSHA 2007) showed that they are exposed to a greater extent to noise, vibration, heat or cold and the handling of dangerous materials, and to physically demanding work factors, such as working in awkward positions, handling heavy loads and repetitive work. This was confirmed by the studies we identified for young workers with physically demanding occupations (i.e. health care professionals, musicians). It was shown that musculoskeletal pain often begins and continues to develop throughout apprenticeships or study. More education in and practice of preventive measures should be taught at that time. This is also supported by study findings in which pain was reported significantly more often by musicians who did not comply with the recommended compensatory physical activities.

Nevertheless, there is a lack of studies in other professions with high exposure to noise, vibration, heat or cold and to physically demanding work factors.

Psychosocial, socioeconomic and environmental factors

With only four relevant studies on young workers, our findings on psychosocial, socioeconomic and environmental factors are weak. Nevertheless, we identified a lack of professional challenges and job insecurity to be important psychosocial MSD factors for young workers. Interestingly, young workers' connection to their trade union was found to be connected to neck or back pain: the higher the perceived

connection to the union of unionised apprentices, the lower the odds of reporting neck and back pain. Increasing occupational injuries with increasing outdoor temperatures were observed among young workers.

Altogether, little is known about the impact of psychosocial, socioeconomic and environmental factors on MSDs in young workers, and more research is needed.

4.4 Efficacy of preventive measures or intervention strategies

While studies have highlighted physical, psychosocial, socioeconomic, environmental, individual and congenital risk factors for MSDs in children and young workers, there are only a few low-quality studies addressing the topic of prevention in this field. However, the available studies show that children's and young worker's health can effectively be improved by various types of intervention.

In 96 studies, we identified four main types of intervention:

- education (e.g. school curricula, education sessions, presentations, materials or courses aimed at increasing knowledge, changing attitudes and building skills);
- physical exercises (e.g. movement or muscle strengthening programmes, physical syllabi, mind-body techniques, physical education lessons and exercise training);
- manipulative therapy (e.g. physiotherapy activities, soft tissue treatment, chiropractic manipulation and correction of habitual position); and
- ergonomic equipment (e.g. specially designed seats, desks, computer accessories or lifting equipment, adjustment of worker's environment).

Generally, the concept of health interventions amounts to attaining a biomechanically healthy lifestyle through a good understanding of basic care-related principles, thereby reducing the burden of musculoskeletal pain (Dolphens et al. 2011). Educational programmes aim to improve knowledge and encourage behavioural change. Education turns out to be an effective strategy in improving the cognitive aspect of, for example, back care from childhood until adolescence (Dolphens et al. 2011). However, there is a difference between improving our knowledge of body mechanics and changing behaviour towards a healthy lifestyle, which is difficult to achieve. According to the theory of behavioural change, understanding a behaviour to be detrimental to one's health and becoming aware of the potential benefits of behavioural change are only the first two stages of change (Prochaska and Velicer 1997). Education should therefore be accompanied by active interventions (e.g. exercises). Interventions involving a combination of actions (educational interventions and exercises) have more chance of being successful than stand-alone actions. The maintenance of behavioural change should, for example, be supported by involving school-based education, parents, trainers, social media-based campaigns and others. In particular, the role of social media in health-related campaigns should be further explored in the future (Enz et al. 2021). Moreover, participatory (ergonomic) approaches (interventions, training) actively involving children, young people and young workers seem to have higher chances of success than ergonomic measures alone.

Regular exercise is recommended for the prevention of disease and for health promotion, and the effects of exercise diminish when exercise participation ceases (Hill and Keating 2015). Factors that contribute to the success of exercise programmes include establishing a routine, smooth integration into daily life and family involvement; interactive exercise demonstration, education, diagrams and written instructions; and exercise supervision, follow-up and behavioural techniques such as positive reinforcement and goal setting. In particular, new technologies such as step counters could be used to increase adherence to regular exercise. Systematic reviews report on the effectiveness of treatment and physical prevention interventions to alleviate low back pain in children and adolescents in the short term (Michaleff et al. 2014). Passive physiotherapeutic techniques aiming to increase the flexibility and elasticity of muscles and tendons (massage) as a complement to active therapies such as stretches or exercise are also recommended (Blanco-Morales et al. 2020, Dissing et al. 2018, Dissing et al. 2019), but these must be prescribed by a doctor and are much more costly than active exercises taught by, for example, sports teachers.

Measures such as ergonomic chairs and height-adjustable desks are generally acknowledged to promote musculoskeletal health in adults but are rarely found in classrooms. Ergonomics has also gained increasing recognition as an integral component of career longevity in many professions.

In summary, we found education to be effective in increasing knowledge and thus sensibility and awareness regarding musculoskeletal discomfort and pain in children and young people. However, the efficacy of educational programmes alone in preventing MSDs is poor. Exercises are promising interventions in showing quick successes, but for sustainable effects strict adherence is required. Manipulative therapy alone was found to be effective solely in children with long-lasting or chronic pain. Finally, ergonomic interventions clearly have a positive effect both at school and in the workplace.

Furthermore, it is important to develop interventions with a sectoral approach or focusing on a specific population. These targeted approaches allow the development of a specific type of training (comic book, demonstration plus exercises, classes on body posture while playing an instrument) or preventive measures. One of the most important questions, however, is how to motivate children in industrialised countries to be more physically active. Increased use of health care technology, such as fitness watches and step counters, might be a factor in increasing motivation, especially if coupled with incentives. Educating parents is also important. Digital technologies provide a mechanism by which to provide accessible, sustainable information about musculoskeletal pain and comorbid health conditions to this target population (Slater et al. 2016).

In many cases, MSD problems begin in childhood, when inappropriate postures are combined with little sports activity. Suffering from musculoskeletal pain in childhood or adolescence increases the risk of suffering as an adult. If MSDs in children can be prevented, entry into a cycle of recurring episodes may be delayed and adult MSD prevalence decreased. Without any form of intervention, students are likely to enter the workforce with poor health habits. Hence, labour market prevention campaigns and interventions should also include a focus on children. Policy-makers should systematically integrate a life course approach to MSD prevention, i.e. consider and control MSD risks across the entire workforce, whatever the worker's age. It particularly addresses the issue of young workers coming into the workplace with pre-existing musculoskeletal problems that have the potential to be exacerbated by work. Therefore, MSDs need to be prevented among children and young people and a good musculoskeletal health needs to be promoted from an early age (from childhood). The school setting offers the opportunity to deliver preventive interventions to many children and also to systematically collect data on MSD prevalence and risk factors in children. Schools or, more generally, the education sector should be involved in programmes to promote good musculoskeletal health. Early education is also relevant for apprentices and students, e.g. to prevent unhealthy working postures in their prospective professional career and to decrease the risk of MSDs in the future.

The fact that prevention can indeed work well can be seen in the field of sports medicine, in which a vast number of studies (some of the highest quality) exist, showing that prevention of sports injuries is in fact possible and effective (see section 3.4.3). Given that some antecedents of early adult-onset MSDs may be traced to child and adolescent sports injuries and related surgery, and perhaps intense training regimens, it follows that efforts to prevent sports-related joint injury should begin during the childhood years. Programmes developed in this sector can also be applied to other areas. Knowledge learned from sports injury prevention could be transferred to the prevention of leisure accidents. However, further research has to be performed to evaluate the detailed effect of the training measures, the effect of prevention programmes on different sports, the necessary number and duration of prevention programmes and the identification of athletes at risk (Stege et al. 2014)

From a health care sector viewpoint, today's high-level medicine focuses too much on the treatment of actual diseases and too little on their prevention. This leads to increasing financial problems due to rising costs for advancing technologies. Maintaining health in children and adolescents therefore also has an important economic aspect.

4.5 Conclusion

In summary, this scoping review provides a good overview of MSD prevalence, MSD risk factors and interventions to prevent or reduce MSDs in children and young people. We were able to map the current

key knowledge and to identify research gaps. This scoping exercise provides a solid base from which to carry out more specific systematic reviews, e.g. to obtain detailed prevalence estimations or in-depth evaluations of inconsistent study results on risk factors, or to assess the transferability to young people of interventions assessed in adults. It also indicates a requirement for further research in terms of high-quality studies, e.g. on the association of potential factors with a higher risk of MSDs in children and young people or on the effectiveness of interventions and preventive measures. Furthermore, this review identified a need to develop more complex, sustainable and long-term intervention programmes.

5 Research gaps and recommendations

This project has identified a number of gaps in the research, which need to be filled to better understand the aetiology of MSDs and to prevent them more effectively, both in children and young workers.

- There is a need to use psychometrically sound, clinically meaningful and standardised outcome measures for pain, function, health care use and physical activity. A more systematic recording of musculoskeletal pain and injuries in high-quality studies is recommended to improve the available data, increase the clinical applicability of the research, facilitate the pooling of study results and serve as a basis for identifying risk factors and developing prevention programmes.
- In order to estimate the prevalence in a more precise and nuanced way, to prescribe dose-response relationships between certain risk factors and certain MSDs more precisely and to assess the efficacy of certain intervention programmes, both systematic reviews and more high-quality studies are needed. In particular, there is a need for large-scale, high-quality studies to guide clinicians treating children and adolescents with MSDs and to inform the development of evidence-based health promotion programmes targeting the prevention of musculoskeletal pain.
- Considering that studies on risk factors in humans are inevitably observational studies, current developments on quality standards for this study type should be considered in future research.
- MSDs should be considered as permanent part of regular and systematic school-age screenings. This would allow for early detection of MSDs when they are still easily treatable before they become chronic or severe.
- Future research in young workers needs to target sectors with higher levels of job insecurity (precarious jobs) or work environments in which young workers are most at risk of suffering from MSDs. In particular, the role of psychological stress in young workers is insufficiently investigated and is of great importance for future generations.
- Many risk factors for MSDs in children and adolescents were found. However, one problem in many studies is the vast number of risk factors, which makes it difficult to investigate the role of isolated risk factors, as they are often confounded. Big data and artificial intelligence might give new insights into the detailed role of specific risk factors, which could then in turn be more specifically targeted through prevention programmes.
- Interventions involving a combination of actions (educational interventions, exercises, ergonomics) should be preferred over stand-alone actions. Moreover, interventions should have a sectoral approach or focus on a specific population. However, more research is necessary for specific sectors.
- The outcomes of prevention programmes must be better evaluated to increase the acceptance of these programmes. Additionally, economic analyses should also be performed to prove the cost-effectiveness of these programmes.
- Concerning the evaluation of interventions' efficacy, studies should consider not only knowledge growth but also behaviour change to be a key outcome and moreover elaborate on the psychological determinants of attaining the health behaviours sought. Furthermore, there is a lack of long-term evaluation studies assessing whether behavioural change or knowledge acquired when young is sustained in professional life.
- Current international clinical guidelines for the management of, for example, low back pain are restricted to evidence from studies performed on adult populations. While the effectiveness of many conservative treatments has been evaluated for adult populations, the spine of a child and adolescent is physiologically different from the adult spine (i.e. ligamentous laxity, bone composition, muscle mass) and therefore potentially responds differently to various interventions, movements and loading. Accordingly, there is reason to evaluate the efficacy of conservative interventions in this specific patient population.

- In general, many risk factors are positively influenced by a healthy lifestyle, e.g. healthy eating habits with normal body weight, regular physical activity (recommendations of the World Health Organisation). Some risk factors are well known (e.g. sports injuries, overweight, inactivity) and intervention would be possible (sports injury prevention programmes, weight loss, increased physical activity, etc.), but there is still a gap between knowledge and implementation. More efforts should therefore be placed on education and campaigns fostering physical activity, with the goal of increasing the health literacy of the population.
- Prevention campaigns and interventions should already address children and incorporate the use of social media, which is increasingly used by young people.
- Because of the importance of the health of children and young workers in the long run, the public health system should sponsor studies in this area.
- Cooperation with other policy areas (public health, education, safety of children) is needed to support a concerted approach to promote good musculoskeletal health among children and young workers.

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Annex 1: Search terms and search strings

Search terms for research question (1) exclusive plurals or different spellings

Key concept	Subcategory	Search terms MeSH terms	Search fields
Population (P)	–	children, adolescents, young workers, young people, youth, pupils, students, apprentices, trainees, teenager, younger population, schoolchildren	Title/Abstract/Keywords
Condition (Co)	Location	shoulder, elbow, arm, forearm, hand, wrist, finger, pelvis, hip, thigh, knee, ankle, leg, joint, foot, toe, neck, head, rib, back, spine, limb, muscle, trunk, extremity, tendon, sinew, ligament, capsule, bone, body, cervical spine, lumbar spine, spinal disc, vertebral disc, musculoskeletal	Title/Abstract/Keywords
Condition (Co)	Disorder	pain, ache, tension, damage, prolapse, cramp, syndrome, symptom, inflammation, deformity, degeneration, sprain, distortion, dislocation, luxation, contusion, torsion, injury, rupture, fracture, twist, posture, degenerative change, musculoskeletal disorder, overuse	Title/Abstract/Keywords
Condition (Co)	MSD meta data	Musculoskeletal Diseases, Musculoskeletal System, Musculoskeletal Pain, Pain	MeSH Terms
		epidemiology, injuries	MeSH Subheading
		pain, diseases, injuries, fractures	Subject Major
		Medicine, Nursing, Health Professions	Subject (area)
Condition (Co)	Prevalence	prevalence, risk, frequency, rate, occurrence	Title/Abstract/Keywords
Context (Co)	Risk factors	risk factors	Title/Abstract/Keywords
Context (Co)	Lifestyle	lifestyle, physical activity, movement, behaviour, behavioural, addiction, inactivity, sport, exercise, wellness, sitting, sedentary, sedentarism, standing, habit	Title/Abstract/Keywords
Context (Co)	Nutrition and weight	overweight, obesity, adiposity, BMI, nutrition, diet, calcium, water, hydration	Title/Abstract/Keywords
Context (Co)	Smoking	tobacco, smoke, smoking	Title/Abstract/Keywords
Context (Co)	Ergonomic arrangements	ergonomic, furniture, seating, chair, stool, bench, design, desk	Title/Abstract/Keywords
Context (Co)	School bag	backpack, schoolbag, satchel	Title/Abstract/Keywords
Context (Co)	Electronic devices	electronic devices, smartphone, mobile phone, cell phone, computer, tablet, laptop, notebook, PC, digital, workstation, information technology, video games, teleworking, office	Title/Abstract/Keywords
Context (Co)	Sport/protective gear	protective, footwear, clothing clothes, equipment, garment, apparel, gear, outfit, wear	Title/Abstract/Keywords

Key concept	Subcategory	Search terms MeSH terms	Search fields
Context (Co)	Environment	environment, environmental, light, noise, air quality, temperatures, oxygenation	Title/Abstract/Keywords
Context (Co)	Accidents	accidents	Title/Abstract/Keywords
Context (Co)	Psychosocial	stress, sleep, sleepiness, status, mental, anxiety, somatic, somatisation, emotional, wellbeing	Title/Abstract/Keywords
Context (Co)	Work/occupation	noise, vibration, heat, cold, dangerous, heavy, awkward, repetitive, pressure, tight, speed, kneeling, load, burden, lift, weight, strain, cumulative, immaturity, awareness, safety, carry, walk, squat, stand, hours, workplace	Title/Abstract/Keywords

Search string strategy for research question (1)

No	Key concept	Comments
#1	Population	
#2	Condition (Location)	
#3	Condition (Disorder)	
#4	#2 AND #3 (#2 W/2 #3)	all combinations location x disorder
#5	Condition (MSD meta data)	Major Topic, Subject, Term, Subject Area
#6	#4 AND #5/ Narrow #4 to MSD	MSDs at location x disorder
#7	Context (Prevalence)	
#8	#6 AND #7 (#6 W/2 #7)	prevalence of MSDs
#9	#1 AND #8	prevalence of MSDs in children and young people/workers
#10	Context (Risk factors)	
#11	#9 AND #10	risk factors (in general) of MSDs in children and young people/workers
#12	Context (Lifestyle)	
#13	#9 AND #12	lifestyle and risk of MSDs in children and young people/workers
#14	Context (Nutrition and weight)	
#15	#9 AND #14	nutrition, weight, and risk of MSDs in children and young people/workers
#16	Context (Smoking)	
#17	#9 AND #16	smoking and risk of MSDs in children and young people/workers
#18	Context (Ergonomic arrangements)	
#19	#9 AND #18	ergonomic arrangements and risk of MSDs in children and young people/workers
#20	Context (School bag)	

No	Key concept	Comments
#21	#9 AND #20	school bag and risk of MSDs in children and young people/workers
#22	Context (Electronic devices)	
#23	#9 AND #22	electronic devices and risk of MSDs in children and young people/workers
#24	Context (Sport gear/protective gear)	
#25	#9 AND #24	sport gear/protective gear and risk of MSDs in children and young people/workers
#26	Context (Environment)	
#27	#9 AND #26	environmental factors and risk of MSDs in children and young people/workers
#28	Context (Accidents)	
#29	#9 AND #28	accidents and risk of MSDs in children and young people/workers
#30	Context (Psychosocial risk factors)	
#31	#9 AND #31	psychosocial risk factors of MSDs in children and young people/workers
#32	Context (Work factors)	
#33	#9 AND #32	work factors of MSDs in children and young people/workers

Search terms for research question (2) exclusive plurals or different spellings

Key concept	Subcategory	Search terms MeSH terms	Search fields
Population (P)/Comparator (C)		children, adolescents, young workers, young people, youth, pupils, students, apprentices, trainees, teenager, younger population, schoolchildren	Title/Abstract/Keywords
Outcome (O)	Location	shoulder, elbow, arm, forearm, hand, wrist, finger, pelvis, hip, thigh, knee, ankle, leg, joint, foot, toe, neck, head, rib, back, spine, limb, muscle, trunk, extremity, tendon, sinew, ligament, capsule, bone, body, cervical spine, lumbar spine, spinal disc, vertebral disc, musculoskeletal	Title/Abstract/Keywords
Outcome (O)	Disorder	pain, ache, tension, damage, prolapse, cramp, syndrome, symptom, inflammation, deformity, degeneration, sprain, distortion, dislocation, luxation, contusion, torsion, injury, rupture, fracture, twist, posture, degenerative change, musculoskeletal disorder, overuse	Title/Abstract/Keywords
Outcome (O)	MSD meta data	Musculoskeletal Diseases, Musculoskeletal System, Musculoskeletal Pain, Pain	MeSH Terms

Key concept	Subcategory	Search terms MeSH terms	Search fields
Intervention (I)		prevention and control	MeSH Subheading
		pain, diseases, injuries, fractures	Subject Major
		Medicine, Nursing, Health Professions	Subject (area)
		intervention, prevention, care, education, program, training, supervision, safeguard, guideline, promotion	Title/Abstract/Keywords

Search string strategy for research question (2)

No.	Key concept	Comments
#1	Population/Comparator	identical to #1 for research question (1)
#2	Outcome (Location)	identical to #2 for research question (1)
#3	Outcome (Disorder)	identical to #3 for research question (1)
#4	#2 AND #3	all combinations location x disorder
#34	Outcome (MSD meta data)	Major Topic, Subject, Term, Subject Area
#35	#4 AND #34/ Narrow #4 to MSD	MSDs at location x disorder
#36	Intervention	
#37	#35 AND #36	interventions against MSDs
#38	#1 AND #37	interventions against MSDs in children and young people/workers

The European Agency for Safety and Health at Work (EU-OSHA) contributes to making Europe a safer, healthier and more productive place to work. The Agency researches, develops, and distributes reliable, balanced, and impartial safety and health information and organises pan-European awareness raising campaigns. Set up by the European Union in 1994 and based in Bilbao, Spain, the Agency brings together representatives from the European Commission, Member State governments, employers' and workers' organisations, as well as leading experts in each of the EU Member States and beyond.

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