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The effect of lifting during work on low back pain: a health impact assessment based on a meta-analysis

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ABSTRACT

Lifting at work is considered an important risk factor for low back pain (LBP). However, contradictory findings have been reported, partly because frequency, duration and intensity (ie, the weight of the load) of lifting have not been systematically considered. This has hampered developments of threshold values for lifting. The aims of this study were: to assess the effect of lifting during work (quantified in duration, frequency or intensity) on the incidence of LBP and to quantify the impact of these relationships on the occurrence of LBP in occupational populations exposed to lifting. We searched in PubMed and EMBASE.com for longitudinal studies assessing the effect of occupational lifting on LBP incidence. For each study, the exposure–response slope of the association was estimated by loglinear regression analysis. When possible, a meta-analysis on these slopes was conducted. In a health impact assessment, the effects of the pooled exposure–response relationships on LBP incidence was assessed. Eight longitudinal studies were included. Pooled estimates resulted in ORs of 1.11 (1.05 to 1.18) per 10 kg lifted and 1.09 (1.03 to 1.15) per 10 lifts/day. Duration of lifting could not be pooled. Using these ORs, we estimated that lifting loads over 25 kg and lifting at a frequency of over 25 lifts/day will increase the annual incidence of LBP by 4.32% and 3.50%, respectively, compared to the incidence of not being exposed to lifting. Intensity and frequency of lifting significantly predict the occurrence of LBP. Exposure–response relationships show that lifting heavy loads may have a substantial impact on musculoskeletal health of the working population. This information may direct the development of occupational lifting guidelines and workplace design for LBP prevention.

INTRODUCTION

With a global lifetime prevalence of approximately 40%,[1] low back pain (LBP) causes a considerable burden on (working) society.[2] Besides, negative effects for workers, consequences of LBP include productivity-loss at work,[3] sickness absence[4] and disability.[5] Several individual, psychosocial and physical work-related factors have been identified as potential risk factors for LBP.[6–11] For one of the most studied physical risk factors, lifting at work, contradictory results have been reported. Whereas numerous systematic reviews have shown an effect of lifting on the occurrence of LBP,[8 10] others have contradicted these conclusions, finding conflicting[12] or even no evidence for lifting as causative factor for the occurrence of LBP.[13] The latter statement was presented as current interpretation in recent overviews,[14 15] which has led to an intense debate in several letters questioning the scientific quality of the earlier mentioned reviews.[16–23] Therefore, controversy remains regarding the importance of lifting for the occurrence of LBP.

Nevertheless, the possible effect of lifting on LBP can potentially be explained by the high mechanical loads (eg, low back moments or spinal compression forces) on the low back during lifting.[24 25] Lifting is a dynamic and highly variable type of physical exposure that can be quantified in duration, frequency and intensity (ie, the weight of the load lifted), that all contribute differently to mechanical low back load. For example, it has been shown that the intensity of lifting highly affects the magnitude of the loads on the low back.[25] In addition, even with no or small loads lifted, mechanical low back loading can be substantial as a result of acceleration of the upper body and upper extremities.[26] As a result, when a lifting task is executed at a fast pace (ie, with high frequency), loads on the lower back can almost double compared to a situation in which the task is executed with a low frequency.[27] Therefore, various exposures to lifting tasks can affect mechanical load on the low back in different ways.[25 28] Quantifications of lifting (expressed in duration, frequency and intensity) should therefore be considered to appreciate the exposure–response association of lifting and LBP.[29] Such quantifications can be a key issue in developing occupational lifting guidelines and workplace design for LBP prevention.

Several directives for lifting at the workplace have been developed, such as European[30] and international directives.[31] According to these directives, 25 kg is an acceptable weight limit when lifting optimally. This limit, however, decreases when the lifting situation is non-optimal (ie, large horizontal or vertical load distances, asymmetry, high frequency or inappropriate coupling of the load). Except for some minor differences, these directives are based on the NIOSH lifting equation,[32 33] which presents a recommended limit as a combination of frequency and weight that can be lifted by approximately 90% of adult persons without harmful effects. These effects are primarily based on psychophysical evaluation of the influence of lifting on self-perceived work load or fatigue within a few hours. Therefore, the ability of these directives to protect against LBP risks has been questioned.[34 35] Besides, current directives do not assess long-term consequences, which has hampered the development of threshold limit values distinguishing between healthy and unhealthy lifting exposure at work.[36] In addition, a lack of insight into exposure–response relationships between lifting and LBP has also complicated current attempts to demonstrate that a reduction in biomechanical exposure at work will contribute to a decrease in LBP occurrence.[37 38]

In the past few years, several sound systematic reviews have presented exposure–response relationships for occupational lifting and LBP,[9–11] even considering the influence of methodological characteristics (such as study design, participation and reliability of the exposure and the response) on the magnitude of the reported association.[8] However, these reviews have not expressed a pooled risk estimate in quantified units of exposure to lifting (in terms of intensity, frequency or duration) nor evaluated its impact on musculoskeletal health in the workforce. Therefore, the first aim of the current study was to assess the effect of exposure to lifting during work (in terms of loads lifted, frequency of lifts per hour, and duration of lifting activities) on the incidence of LBP. The second aim of the study was to quantify, through a health impact assessment, the potential impact of these exposure–response relationships on LBP in occupational populations with specific lifting exposures as a basis for the development of threshold limit values.

METHODS

Search strategy

To identify all relevant publications, we performed systematic searches of the literature written in English in the bibliographic databases of PubMed and EMBASE.com from inception to April, 2014. Search terms included controlled terms from MeSH in PubMed, EMtree in EMBASE.com as well as free text terms. Search terms expressing 'lifting' were used in combination with search terms comprising 'work-related' and terms for 'LBP' (search strategies in both data-bases are provided in online supplementary appendices 1 and 2, respectively). Lists of references of all included full-text articles were also screened for additional papers.

Two reviewers (PC and VG) independently screened all potentially relevant titles and abstracts for eligibility. If necessary, the full-text article was checked for eligibility criteria. Differences in judgment were resolved through a consensus procedure. Studies were included if they met the following criteria: The article describes an original prospective study (ie, no intervention studies, reviews, editorials or letters), in which the effect of occupational lifting (quantified in terms of duration, frequency or intensity) on the incidence of non-specific LBP was expressed in an appropriate risk estimate (ie, OR, relative risk (RR) or prevalence ratio (PR)). Full-text versions of the selected articles were obtained for data extraction and quality assessment.

Data extraction and quality assessment

Two reviewers (PC and VG) independently assessed all selected papers for data extraction and methodological quality. In case of a disagreement, consensus was reached during a meeting. If agreement could not be reached, a third reviewer (AB) decided on the matter. For data extraction, the following variables of each included paper were obtained: first author and year of publication, study population (ie, number of subjects in the analysis, age, gender, occupation and country), study design (ie, duration of the follow-up period and confounding factors), health effects (ie, response definition, baseline prevalence and incidence during follow-up period), exposure parameters (ie, duration, frequency or intensity of lifting) and risk estimate (eg, OR or RR). When multiple modalities of lifting (ie, lifting with a forward bent back or above shoulder level) were presented in the selected papers, only lifting activities with the highest occurrence were chosen for further analysis.

For methodological quality assessment, five criteria based on available, well accepted sources[39 40] were used (see online supplementary appendix 3). Items were scored positive, negative or unclear in case insufficient information was available. A high-quality study was defined by positive scores on over 50% of the items.

Meta-analysis and a health impact assessment

In order to combine results of included studies in a meta-analysis, small differences in definition of exposure and health outcomes were accepted.[41] For each study, an exposure–response relationship was calculated by a loglinear regression analysis:

$$y = e^{\alpha+\beta X+\log(N)} \quad (1)$$

In equation 1, y is the number of workers reporting a first episode of LBP (incidence), X is the exposure metric of interest and N is number of subjects in the particular study population. Model parameters were retrieved from the original studies, as presented in online supplementary appendix 4. Since studies have used categories of exposure, the midpoint of an exposure category was used as average exposure, for example 15 kg for a 10–20 kg exposure category. For the highest exposure category with an unbounded upper value a measure was chosen to reflect a meaningful estimate. This measure was chosen based on expert judgments, for example, lifting loads above 25 kg was set at 30 kg. In the loglinear regression analysis a single intercept was used that reflects the annual incidence of LBP without exposure. This also forces the exposure–response relation through the origin by the assumption that those workers without exposure to lifting could not have an increased incidence of LBP attributed to lifting, as is customary in regulatory risk assessment processes. This procedure allowed us to estimate the slope and CI of the exposure–response relationship within each study, which represents the increase in OR or RR per unit of exposure to lifting. When y and/or N were not presented in the selected paper, slopes were estimated using exposure categories and ORs.

In the meta-analysis, the slopes of individual studies were pooled by reciprocal weighting by the variance of the slope in a random effects model due to heterogeneity across studies. Pooled risk estimates, expressed in ORs and 95% CIs, were calculated for the effect of frequency (expressed in 10 lifts per day) and intensity (expressed in 10 kg of lifting) of lifting on LBP. The reported incidence of LBP among non-exposed participants was also pooled using the reported annual incidence of LBP among workers without lifting activities. This was carried out, in accordance to the pooling of ORs, by pooling using reciprocal weights of the size of the unexposed study population. In 7 of 8 studies, LBP was defined as any episode in the past 12 months, whereas in one study LBP in the past month was used as proxy for annual incidence of LBP.[42]

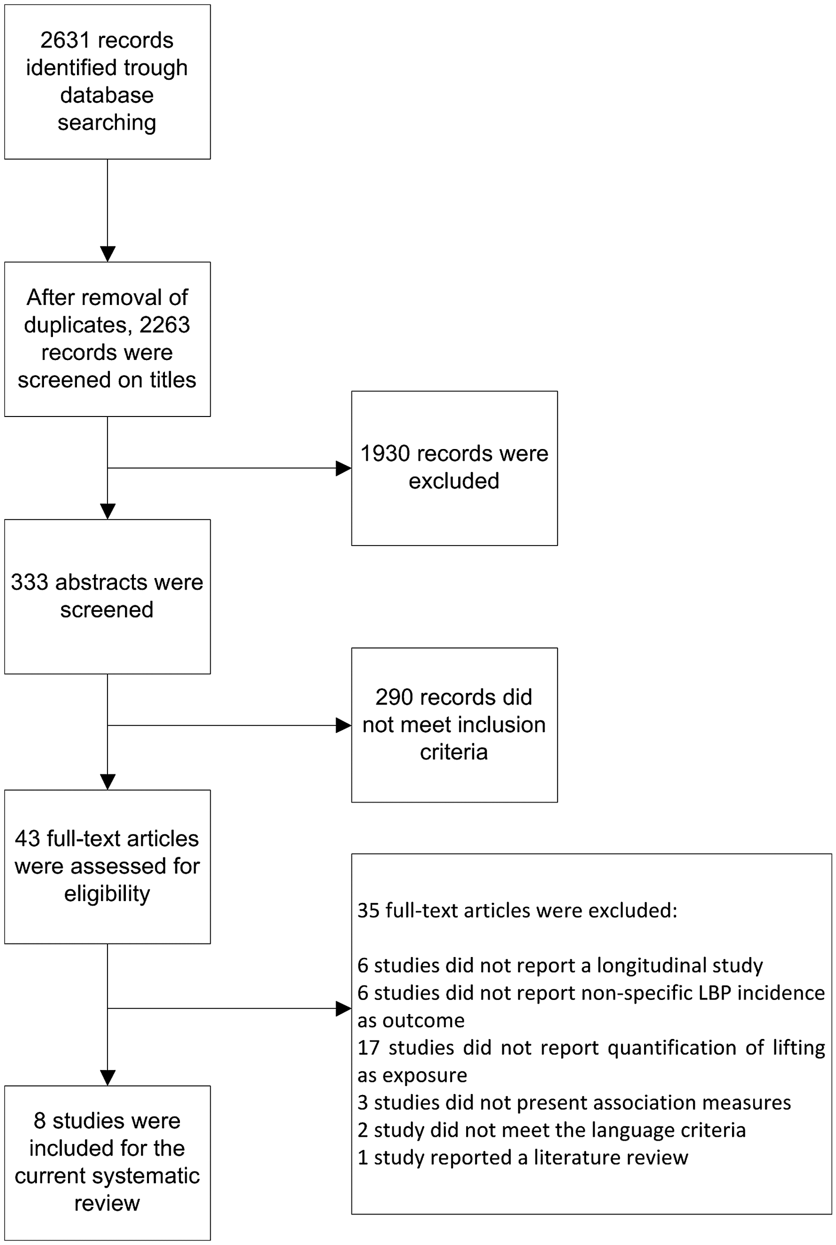
In a health impact assessment, using equation 1, the pooled annual incidence of LBP among non-exposed participants was combined with the pooled ORs of lifting loads more than 25 kg per day and more than 25 lifts per day. The extra incidence of LBP among workers lifting more than 25 kg, or performing more than 25 lifts per day was compared to the incidence of workers not being exposed to lifting across the observed range in pooled annual incidence and ORs. Also, publication bias was examined through visual inspection of funnel plot asymmetry depicting the SE of the OR plotted against the OR of all included studies for intensity (expressed in 10 kg) and frequency of lifting (expressed in 10 lifts per day).

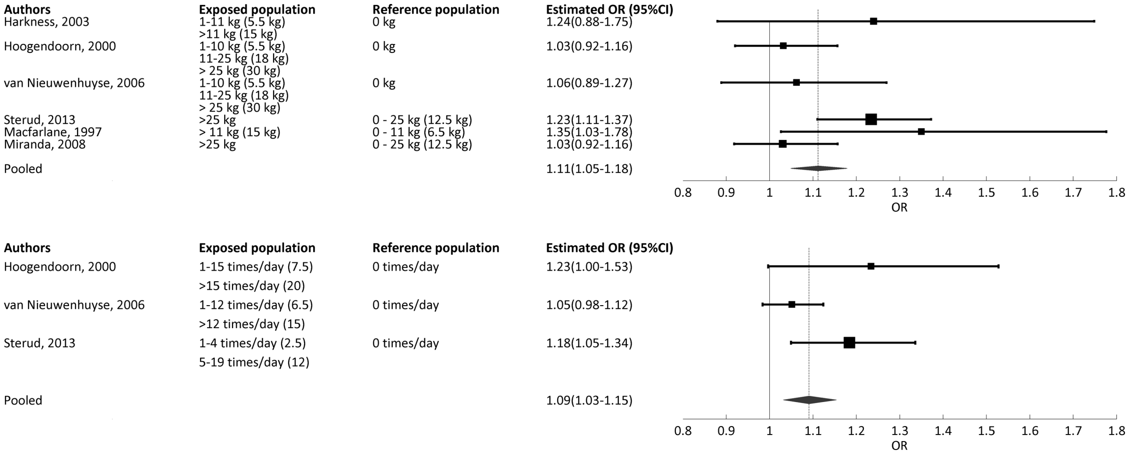
RESULTS

The flow chart of the search and selection process is presented in figure 1. The literature search generated a total of 2631 references, of which 1094 in PubMed and 1537 in EMBASE.com. After removing duplicates, 2263 unique references remained that were screened on their titles for inclusion. During this procedure, 1930 records were excluded, resulting in 333 records for full-text abstract screening. Based on this screening, another 290 studies were excluded. Subsequently, 43 full-text articles were assessed for their eligibility. A total of 35 of these studies were excluded for several reasons: 17 studies did not quantify exposure to lifting, six studies did not use non-specific LBP incidence as relevant outcome, six studies did not have a prospective design, three studies did not present interpretable risk estimates, two studies did not meet the language criteria and one study was a literature review. Eventually, 8 original prospective studies that described the effect of lifting (quantified in duration, frequency and/or intensity) on non-specific LBP incidence,[42–49] were included for further analysis. No additional studies were included based on reference lists in included articles. Information of all studies included is summarised in online supplementary appendix 4, while the quality of these studies is described in online supplementary appendix 5.

Figure 2 presents six studies on intensity of lifting with ORs varying between 1.03 and 1.24 for 10 kg loads, resulting in a pooled OR of 1.11 (95% CI 1.05 to 1.18) per 10 kg of lifting.[42 44 46–49] Three studies presented exposure–response information for 10 lifts per day with ORs between 1.05 and 1.23, resulting in a pooled OR of 1.09 (95% CI 1.03 to 1.15) per 10 lifts per day.[44 48 49] One study on frequency of lifting and LBP among nurses did not provide a comparable exposure

Figure 1 Flow chart depicting the procedure of selection of relevant papers.





Authors	Exposed population	Reference population	Estimated OR (95%CI)
Harkness, 2003	1-11 kg (5.5 kg) >11 kg (15 kg)	0 kg	1.24(0.88-1.75)
Hoogendoorn, 2000	1-10 kg (5.5 kg) 11-25 kg (18 kg) > 25 kg (30 kg)	0 kg	1.03(0.92-1.16)
van Nieuwenhuyse, 2006	1-10 kg (5.5 kg) 11-25 kg (18 kg) > 25 kg (30 kg)	0 kg	1.06(0.89-1.27)
Sterud, 2013	>25 kg	0 - 25 kg (12.5 kg)	1.23(1.11-1.37)
Macfarlane, 1997	> 11 kg (15 kg)	0 - 11 kg (6.5 kg)	1.35(1.03-1.78)
Miranda, 2008	>25 kg	0 - 25 kg (12.5 kg)	1.03(0.92-1.16)
Pooled			1.11(1.05-1.18)

Authors	Exposed population	Reference population	Estimated OR (95%CI)
Hoogendoorn, 2000	1-15 times/day (7.5) >15 times/day (20)	0 times/day	1.23(1.00-1.53)
van Nieuwenhuyse, 2006	1-12 times/day (6.5) >12 times/day (15)	0 times/day	1.05(0.98-1.12)
Sterud, 2013	1-4 times/day (2.5) 5-19 times/day (12)	0 times/day	1.18(1.05-1.34)
Pooled			1.09(1.03-1.15)

Figure 2 Associations of lifting intensity (upper part of the figure) and lifting frequency (lower part of the figure) and the incidence of low back pain. In the table (left panel), exposure categories, reference categories and estimated risks (ORs) per study as well as the pooled risk are shown. In the right panels, a forest plot depicts the effect found in all studies as well as the pooled effect for all studies.

metric.[43] Two studies reported positive associations between duration of lifting and occurrence of LBP, but exposure definitions were too different to conduct a meta-analysis.[45 46]

Five out of 8 studies described the annual incidence of LBP among workers without any exposure to lifting with a lowest value of 8.9%[44] and a highest value of 20.8%.[47] The pooled annual incidence was 18.4% (95% CI 17.6% to 19.2%), which was strongly dominated by the study with the highest reported incidence that contributed 41% to the combined study population.

The health impact assessment in table 1 shows that among workers who regularly lift loads above 25 kg, the incidence of LBP would increase by 4.32% compared to workers not being exposed to lifting, which is a relative increase of almost 25%. The sensitivity analysis for lifting intensity with differences in incidence of LBP among unexposed groups and differences in magnitude of exposure–response relationships estimated a 1.00–7.57% increase in annual incidence of LBP as a result of lifting more than 25 kg. For workers who regularly lift loads more than 25 times per day the incidence of LBP would increase by 3.50% compared to workers not being exposed to lifting, which is a relative increase of about 20%. The sensitivity analysis showed for lifting more than 25 times per day, an increase in annual incidence of LBP ranging from 0.63% to 6.52%.

Regarding publication bias, visual inspection of the funnel plot (figure 3) suggested some degree of asymmetry with some larger studies reporting lower ORs than smaller studies.

DISCUSSION

The current study aimed (1) to assess the effect of exposure to work-related lifting (in terms of duration, frequency or intensity) on the incidence of LBP, and (2) to quantify the potential impact of these relationships on the incidence of LBP in occupational populations with a variety of lifting activities. Our findings showed significant exposure–response relationships for intensity and frequency of lifting with LBP incidence. We were not able to conduct a meta-analysis on the effect of lifting duration on LBP incidence, but individual studies showed that longer duration of lifting was associated with a higher LBP incidence.

Table 1 Health impact assessment for the effect of intensity of lifting (upper panels of the table) and frequency of lifting (lower panels of the figure)

		Observed incidence (%) OR					Extra incidence (%) due to lifting OR		
		Lower CI	Pooled estimate	Higher CI			Lower CI	Pooled estimate	Higher CI
		1.05	1.11	1.18			1.05	1.11	1.18
Lifting intensity									
Incidence lowest value	8.73	9.72	11.08	12.60	Incidence lowest value	8.73	1.00	2.35	3.87
Incidence pooled estimate	18.42	20.27	22.73	25.40	Incidence pooled estimate	18.42	1.86	4.32	6.98
Incidence highest value	20.77	22.80	25.47	28.34	Incidence highest value	20.77	2.03	4.70	7.57
Lifting frequency									
Incidence lowest value	8.73	9.36	10.62	12.04	Incidence lowest value	8.73	0.63	1.90	3.31
Incidence pooled estimate	18.42	19.60	21.91	24.42	Incidence pooled estimate	18.42	1.19	3.50	6.00
Incidence highest value	20.77	22.07	24.59	27.29	Incidence highest value	20.77	1.30	3.82	6.52

Based on pooled OR and incidences, observed incidence associated with lifting more than 25 kg and more than 25 lifts per day are shown (left panels). Furthermore, the expected extra incidence in LBP of workers with such lifting activities as compared to those not being exposed to lifting is shown (right panels).
LBP, low back pain.

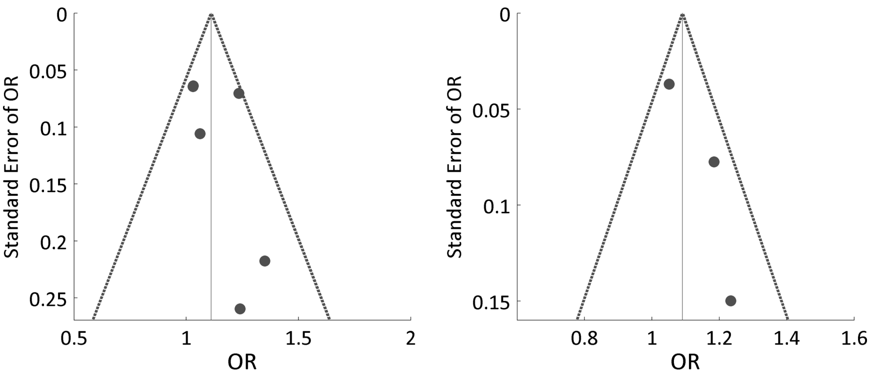


Figure 3 Funnel plot for intensity (left figure) and frequency of lifting (right figure). Dots represent the individual study estimates while the vertical line depicts the summary effect. Diagonal dashed lines represent the pseudo 95% CI.

Interpretation of results

Our results are in line with earlier reviews showing adverse effects of lifting on LBP.[8 10 11] However, these reviews have summarised the overall effects by comparing exposed workers with unexposed workers, treating exposure as a dichotomous characteristic. Such approach limits comparability across studies due to different definitions of the exposure variable of interest. In our approach, we first established the exposure–response association within each study, making full use of available information on trends demonstrating that with an increasing exposure category the likelihood of LBP increased. By introducing a common exposure metric, expressed by kg of load or frequency of lifts, these exposure–response associations could be pooled across all studies. Hence, the pooled exposure–response relationship presents a linear expression of the change in effect, that is, the incidence of LBP, caused by different levels of exposure, that is, weight of loads and frequency of lifting. This risk assessment might form the basis for occupational health policies.

A first consideration in these policies will be the interpretation with respect to possible existence of a no observed adverse effect level (NOAEL). Our risk assessment predicted that regularly lifting loads of more than 25 kg will result in an extra annual incidence of LBP of approximately 4.3%, which is a relative increase of 25%. Lifting weights above 25 kg is often used as a limit beyond which lifting is regarding as unsafe, for example in European[30] and international directives.[31] However, our risk assessment also predicted that lifting below this level will still increase the annual incidence of LBP, which mirrors observed risks in several longitudinal studies.

A second consideration is whether exposure guidelines can sufficiently capture the complex exposure patterns at the workplace with its strong variation in lifting characteristics within and between workers. Current guidelines focus strongly on maximum weights in combination with frequency of lifts, whereas workplaces surveys have shown that lifting activities encompass different weights being lifted with different frequencies over varying distances. Epidemiological studies will have limited discriminatory power to identify all combinations of lifting characteristics that may increase the occurrence of LBP. Thus, the translation of epidemiological evidence on exposure–response relationships into health policies will lack some specificity and precision.

A third important consideration is agreement on what should be considered as a biologically significant adverse effect. The longitudinal studies in our meta-analysis most often have defined LBP as the occurrence of any spell of pain in the past 12 months. Do we consider a couple of hours of pain as a relevant biological effect? Several studies have reported that a substantial proportion of participants with an episode of acute LBP will eventually develop chronic LBP, with a maximum of about half of the workers progressing to chronic LBP.[50] Moreover, this chronic non-specific LBP significantly predicts sickness absence[4] and work disability.[5] In the transition from acute pain to chronic pain, exposure to lifting at work plays a role.[51] Hence, occupational lifting is not only a risk factor for incident LBP but also a prognostic factor for aggravation of LBP and subsequent influence on sickness absence[4] and work disability.[5] This indicates the substantial impact of incident LBP on the burden of disease in the working population. A linked issue is how to define the acceptable risk criteria, for example is one LBP case among 100 workers per year an acceptable risk or among 10 000 workers per year?

A fourth consideration is whether compliance with a lifting guideline will reduce the occurrence of LBP. So far, most work-related interventions on lifting (eg, by providing lifting training or using assisting lifting devices) have not been successful on a large scale.[37 38] In general, interventions studies have not demonstrated very well that the ergonomic intervention under investigation has reduced exposure to lifting at the workplace, and through this reduced exposure has caused a significant reduction in the occurrence of LBP.[29] The exposure–response relationships present theoretical benefits of an intervention, but the resilient nature of work processes and organisations might hamper complete elimination of harmful lifting activities.[38] Thus, intervention studies should quantify the achieved reduction in exposure to lifting in order to provide insight how effective a particular intervention can be.

Given all the above, risk assessments can be improved by using better quantitative information on the effects of exposure to intensity and frequency of lifting on the incidence of LBP in specific occupational populations. Given the large number of studies on lifting and LBP, it is disappointing that only 8 studies presented sufficient information on exposure to lifting for analysis of a pooled exposure–response relationship. Therefore, more studies assessing the effect of lifting, quantified in intensity, frequency or duration, on LBP are needed.[29] Studies should assess the separate and combined effects of frequency and intensity of lifting on LBP, since the available evidence does not allow to disentangle both aspects of lifting which form the basis of the well-known risk evaluation captured in the NIOSH lifting equation.[32 33]

Methodological considerations

In the current study, only those longitudinal cohorts providing information on quantitative exposure information (duration, frequency and intensity) and their effects on LBP incidence were included. These studies, in which measurement of the exposure precedes that of the health effect, provide the opportunity to assess the actual causality regarding LBP.[52] Overall, studies included in this meta-analysis were of high quality, with only one included study scoring *unclear* on their description of the population and two included studies scoring *unclear* on their outcome description. A meta-analysis was performed to increase power and to obtain more reliable risk estimates. Despite these methodological advantages, some sources of bias cannot be excluded. For example, exposure as well as outcome of most studies were assessed using self-reports. Although the use of these self-reports is well accepted, the validity of such exposure estimates has often been questioned, as these are highly subjective and often based on crude categorisation, thereby limiting the accuracy.[53 54] Therefore, in future studies, more objective measurements should be obtained to improve estimates of lifting and subsequent mechanical work load. Such measurements can, for example, contain structured observations or more recently developed techniques, such as inertial sensor or automated marker-less posture tracking methods.[55 56]

A number of assumptions were made when conducting the described meta-analysis. First, as in the NIOSH equation,[32 33] the effect of exposure to lifting on LBP was assumed to be linear with an increasing risk of LBP with increasing exposure. However, there are indications that statistical models that anticipate a non-linear association of mechanical exposures and LBP are better able to identify risk associations.[45] Studies have suggested U-shaped associations,[57] quadratic[58] and fourth order weighting[59] of loads, polynomially calculated loads,[60] and spline function for exposure–response associations[45] in order to gain better information on exposure–response associations. Unfortunately, the available evidence in this systematic review was based on too few studies to investigate alternatives for the currently chosen linear association between exposure and response. This might have biased our results. Future research should therefore fill this gap by exploring alternative methods of describing exposure–response associations.

In meta-analyses, outcomes that are too diverse should not be combined. We assumed some random heterogeneity in the meta-analysis, but small differences in definition of exposure and LBP were accepted.[41] In general, the longitudinal studies that we selected were comparable as they mostly described self-reported exposures and incidence of LBP symptoms. There were some differences between the selected studies in definition of exposure, primarily due to differences in categorisation. Since our procedure required an estimation of the exposure–response relationship within each study before pooling results across studies, these differences will have had little influence on comparability of studies. Although studies used different LBP questionnaires, most studies had a similar recall period of 12 months and comparable description of ache and pain. A pooling of study results, as performed in our meta-analysis, seems therefore justified. A related issue is the potential presence of publication bias which would result in overestimation of the exposure–response association. Visual inspection of the funnel plots (figure 3) shows some larger studies reporting lower ORs than smaller studies. Publication bias, if present, may have led to some overestimation of association of lifting and LBP. However, the number of studies was too small to establish or refute publication bias.

It was assumed that several risk estimates (eg, OR and RR) can be interpreted equally, which may be questioned especially when the outcome of interest is common, such as LBP.[61] These assumptions may therefore have caused some inaccuracy in the pooled estimation of the risk, potentially influencing the reliability of our inferences. Another source of bias in the pooled OR stems from the fact that all publications selected are of Western countries, while there may be different exposure–response associations in developing countries.[62] Finally, as mentioned above, the number of included studies in this analysis was modest and this will have influenced the pooled estimates and associated CIs. The observed variation in the meta-analysis guided the sensitivity analysis of the health impact assessment, as presented in table 1. This synthesis of available information presents a more balanced view of the available evidence in epidemiological studies than a qualitative evidence synthesis on the level of evidence for existence of an association between lifting and LBP.

CONCLUSION

The meta-analysis and subsequent pooled risk estimates demonstrated that intensity and frequency of lifting were significantly associated with annual incidence of LBP. Exposure to lifting more than 25 kg or lifting more than 25 times per day can potentially lead to increased annual incidences of LBP by 4.3% and 3.5%, respectively. This information is of importance in decision-making on occupational lifting directives or workplace design for LBP prevention.

Contributors PC and VG conducted the search for literature and data extraction of all included papers. VG, ASAMvdB, JHvD, MHWF-D, AJvdB and AB analysed the data and reviewed the manuscript for important intellectual content. AB is guarantor.

Competing interests Some authors were members of the committee on Working Conditions of the Netherlands Health Council. The findings and conclusions in this article reflect the opinions of the authors and should not be construed to represent a statement of the Netherlands Health Council. The official report can be obtained from the website of the Health Council of the Netherlands: http://www.healthcouncil.nl/publications/healthy-working-conditions/manual-lifting-work

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