The Association Between Manual Handling Operations and Pain in the Hands and Arms in the Context of the 2018 BIBB/BAuA Employment Survey

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Title

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Abstract

Background: Manual handling operations (MHO) are tasks performed by hand that require a high frequency of repetitive and sometimes forceful movements of the hand and forearm. MHO are currently performed in a large number of workplaces in skilled and unskilled professions in the production and service sectors. MHO are considered a significant work-related health risk factor. The relationship between MHO and the occurrence of disorders of the upper extremities has already been established. MHO can cause diseases such as tenosynovitis of the forearm and carpal tunnel syndrome. This study aims to assess the current prevalence of exposure to MHO in the German workforce and to evaluate the relationship between MHO and the occurrence of disorders in the hands and arms.

Methods: The analysis was based on the German *2018 BIBB/BAuA Employment Survey*. For this specific analysis we included subjects aged between 15 and 66 who work at least 35 hours per week. The self-reported frequency of MHO (never; rarely; sometimes; often) was considered the exposure of interest and was stratified by gender and occupation. Prevalence ratios were used to report the relationship between MHO and self-reported pain in the hands and arms (robust log-linear Poisson regression). Adjustments were made for age, gender, actual weekly working hours, psychosocial workload, and other physical workloads. The regression analyses only considered complete cases.

Results: The analysis included 14,299 employees. Nearly 33% of the male and 31% of the female subjects reported that they often perform MHO. These workloads were often reported by respondents who work in the agricultural sector (men: 70%; women: 79%), in unskilled (men: 59%; women: 67%) and skilled manual occupations (men: 73%; women: 67%).

A higher frequency of self-reported MHO was clearly associated with a higher prevalence of hand complaints (PR 2.26 CI: 2.00 - 2.55) as well as arm pain (PR 1.73 CI: 1.55 – 1.92).

Conclusion: MHO are still frequent in many occupations. The association between self-reported frequencies of MHO and pain in the hands and arms shown here demonstrates the importance of MHO in the current German workforce and the necessity to further develop prevention strategies.

Keywords: Manual handling operations; musculoskeletal disorders; upper extremities; association; 2018 BIBB/BAuA Employment Survey

Background

The relationship between work-related manual handling operations (MHO) and the occurrence of musculoskeletal disorders in the hands and forearms is well established [1-3]. However, the literature does not provide a unique definition of MHO. Typically, MHO are described as tasks performed by hand, which includes work activities that demand manual skills; highly repetitive sequences of hand and arm movement; and/or operations that require high degrees of hand and arm force [4]. MHO are characterized by a repetitive as well as static strain of the muscles and ligamental structures. The strain these tasks place on the body depends on the intensity of the required effort, the range of motion as well as the duration and frequency of the movements. MHO is a common physical workload among the European and German working population. In 2017, Eurofound conducted the sixth *European Working Conditions Survey* [5], which reported that 33% of women and 30% of men surveyed answered that performing MHO is a major part of every working day. A similar percentage stated that MHO made up 25% - 75% of their working time.

The European Agency for Safety and Health at Work (EU-OSHA) reported that between 61 and 63% of employees were exposed to repetitive hand or arm movements for at least a quarter of their working time across the EU-28 states between 2005 and 2015 [6]. In Germany, data on MHO are collected regularly through the *BIBB/BAuA Employment Surveys*. Conducted every six to seven years, these surveys aim to collect data on the working population to map the current working situation in Germany. For this purpose, data is collected on vocational training and education, working conditions, health conditions, and complaints. Asked about manual handling operations during the *2012 BIBB/BAuA Employment Survey*, 43.5% of men and 40.5% of women responded that they often perform manual work, which includes manual skills, high sequences of movement, and operations that require a high degree of force [7]. On the other hand, 13.8% of men and 18.8% of women responded that they "often" experienced pain in their hands during or after work.

A high degree of repetitive strain to the hand-arm system can cause degenerative structural changes in the muscles and tendons of the arms and hands, and may lead to specific diseases, for example carpal tunnel syndrome (CTS) [1-3, 8, 9]. Disorders such as CTS and tendonitis of the hands that are caused by work-related, repetitive MHO are recognized as occupational diseases by law in Germany as well as in other countries. In this context, the German statutory accident insurance approved CTS as an occupational disease in 304 out of 1,033 cases in 2018 [6, 10].

The etiology of musculoskeletal disorders is considered to be multifactorial [11]. Such other factors besides MHO are related to disorders, complaints, or pain in the hands. There is evidence that other types of physical workload, such as the manual lifting of heavy loads [1-3, 8] and overhead work [1, 9], are risk factors for disorders in the hands and forearms. Furthermore, it has been shown that MHO is also related to physical exposures such as

89 hand-arm vibrations [1, 2, 8] and climatic aspects [12-15]. Individual factors, including age [3,
90 16], gender [17, 18], being overweight [16, 19, 20] and the patient's smoking behavior [21],
91 are also described as risk factors for pain in the hands and arms. In some cases, psychosocial
92 factors [8, 22] and the socioeconomic status [23, 24] have also been shown to be related to
93 musculoskeletal disorders of the hands and arms.

94 The continuous change of current workplaces and the high numbers of employees who
95 perform MHO demand that we provide updated information on the distribution, the impact
96 and the consequences of MHO to the health of employees in today's workplaces. Therefore,
97 this study aimed to describe the self-reported prevalence of exposure to manual handling
98 operations in the current German workforce based on the *2018 BIBB/BAuA Employment*
99 *Survey* and to investigate the relationship between the intensity of manual handling
100 operations and the prevalence of pain in the hands and arms to estimate the current
101 percentage of pain prevalence attributable to MHO.

102 Methods

103 Study design and study population

104 The study was part of the F2456 project of the Federal Institute for Occupational Safety and
105 Health (BAuA). The study is a secondary analysis using the data of the *2018 BIBB/BAuA*
106 *Employment Survey* with an emphasis on exposure to physical workloads and its association
107 to musculoskeletal disorders. The *2018 BIBB/BAuA Employment Survey* was based on
108 telephone interviews and used a cross-sectional study design. German-speaking people aged
109 15 and older who work more than 10 hours per week were included in the survey [25]. BAuA
110 entrusted social research company Kantar Public with the conduct of standardized
111 telephone interviews between October 2017 and April 2018. The sampling strategy of the

survey used a dual frame sampling approach, which included landline and cell phone numbers to reach a wide range of participants. To increase the availability of the employees, the interviews were mainly conducted in the afternoons, evenings, and on weekends. The survey covered several confounders such as age, gender and key aspects of social-economic status. Other epidemiologically relevant facts, including smoking behavior, body weight and height, were not part of the questionnaire and could therefore not be used. Overall, 20,012 employees were interviewed and included in the *2018 BIBB/BAuA Employment Survey*.

For this paper, the study population was reduced to persons of working age – between 15 and 66 years of age – who work in fulltime jobs (normal working hours of 35 hours per week or more).

Response variables: hand and arm pain

Employees were asked about the occurrence of a range of pains and complaints related to or experienced after work, in different regions of the musculoskeletal system, that occurred within the past 12 months, with possible answers being “yes” and “no”. The answers relating to hand and arm pain were used as separate outcomes of interest.

Explanatory variables: manual handling operations and covariates

Furthermore, participants were asked about different aspects of their current working conditions. The frequency of manual handling operations was assessed via the following question: “Do you perform work with your hands that includes intensive manual work, fast sequences of movement, or requires high levels of force?” (Author’s translation). Participants could give one of four categories as a response, namely “never,” “rarely,”

135 “sometimes,” or “often”. If respondents refused to answer, this was treated as a missing
136 answer and was excluded from the analysis.

137 The question regarding the manual lifting of heavy loads was different for men and women
138 with respect to the absolute weight of the load lifted (men: 20 kg or more; women: 10 kg or
139 more). Other physical exposures at the workplace were examined in a similar manner to
140 MHO; only “overhead work” was indirectly derived and used in the regression models as a
141 binary dummy variable. This variable was generated based on the answers related to the
142 frequency of work performed in awkward body postures. Similar to the manual lifting of
143 loads, employees were asked to state whether their work required them to “never,”
144 “rarely,” “sometimes,” or “often” work in awkward postures such as bending, working
145 overhead, or kneeling or squatting. If interviewees answered “often,” they were
146 subsequently asked in which of these awkward postures they often worked. A binary dummy
147 variable was then developed from the combination of these answers (never or often works
148 overhead). Important confounders such as age (years) and gender (male; female) were
149 surveyed at the beginning of the interview. Actual working time per week (hours) included
150 overtime, extra work, and on-call service. Working hours in other part-time jobs were not
151 considered.

152 To assess the psychosocial workload, a score was calculated based on the Kroll index [26] .
153 This index represents the psychosocial workload of employees and considers different
154 psychosocial aspects, which were covered in the *2018 BIBB/BAuA Employment Survey*.
155 Subcategories of the psychosocial workload index include psychological stress, social
156 burdens and temporal involvement. These sub-indices were calculated by totaling the points
157 of the corresponding single items according to the answers given. The sub-indices of the
158 three subcategories were totaled and then divided by the maximum number of achievable

points of all validly answered individual items. The average of the three scores of the subcategories were interpreted as the psychosocial workload index; this index ranges from 0 to 100 points.

The occupations of the participants in the *2018 BIBB/BAuA Employment Survey* available in the dataset had been coded in accordance with a German classification of occupations. We grouped the coded job titles and assigned them to twelve main occupational groups using the job classification published by BLOSSFELD in 1985 [35] (Production: agricultural occupations; unskilled manual occupations; skilled manual occupations; technicians; engineers; Service: unskilled services; skilled services; semiprofessions; professions; Administration: unskilled commercial and administrational occupations; skilled commercial and administrational occupations; managers)

Data privacy and ethics

In March 2017, the BAuA ethics committee approved the design and methods of the *2018 BIBB/BAuA Employment Survey*. The dataset was provided in an anonymized manner. All personally identifiable information was removed from the dataset.

Statistical methods

The study used descriptive statistics and inference statistical approaches. Absolute and relative frequencies have been presented for the categorical variables, while the arithmetic mean and standard deviation (SD) have been provided for numeric variables. Generally, the descriptive statistics for all items used are shown stratified by the four categories of self-reported frequency of MHO (never, rarely, sometimes, and often). We reported the

182 prevalence of the exposure variable MHO stratified by gender and for all Blossfeld
183 occupational groups.

184 Loglinear Poisson regression analyses with robust variance estimation (generalized linear
185 models, SPSS 25®, GENLIN) were conducted to assess the association between MHO und
186 hand and arm complaints. The effect estimates were interpreted as prevalence ratios (PR).
187 The marginal means of the outcome prevalence are provided for the exposure categories
188 "never," "rarely," "sometimes," and "often". The calculation of these means was based on
189 post-estimations using the results of the fully adjusted regression Model 5. As a result, we
190 have provided the adjusted prevalence stratified by the self-reported frequency of MHO,
191 assuming that influencing variables are evenly distributed [27]. The difference of the
192 adjusted prevalence between the exposure categories can be interpreted as the absolute
193 proportion of the prevalence which is attributable to the exposure.

194 An a-priori literature search [1-3, 8, 9, 12-24] was conducted to identify essential factors that
195 may impact the outcome. In addition to MHO, the following cofactors that were available in
196 the dataset were included: age; gender; weekly working time; overhead work; manual lifting
197 of heavy loads; "cold, heat, wet humidity, draught"; and psychosocial workload. The
198 covariates were added to the regression models block by block:

199 - Model #1: MHO only;
200 - Model #2: #1 with age, gender;
201 - Model 3: #2 and weekly working time;
202 - Model #4: #3 and overhead work, manual lifting of heavy loads, "cold, heat, wet
203 humidity, draught";
204 - Model #5: #4 and psychosocial workload).

This study will focus on two of these five models: the unadjusted Model 1, which only includes MHO as an exposure of interest, and the fully adjusted Model 5, which includes all listed variables.

To assure each regression model has the same number of participants, only complete cases were considered. We selected datasets which were complete with regard to the exposure of interest, the two selected outcomes of interest (arm and hand pain) and all covariates. As a result, cases with missing variables have been excluded [28].

The metric variables were centered (invalue minus constant value) to reach a meaningful interpretation of the intercept as to the prevalence of the outcome in non-exposed subjects [29]. Thereby the interpretation of the marginal means (adjusted prevalence) refers to a male subject aged 45, with a mean working time of 40 hours per week and a mean psychosocial workload index of 38.9 points. For the categorical variables, the SPSS GENLIN procedure assumes cofactors have been equally distributed. The post-estimation of the prevalence of hand and arm complaints for all categories of exposure to MHO was based on the results of the regression models and allowed for adjusted estimates of the outcome prevalence per exposure category with 95% confidence intervals (95% CI). Syntax-based statistical calculations were conducted using IBM SPSS Statistics 25.

Results

Study population

The *2018 BIBB/BAuA Employment Survey* included 20,012 subjects. After applying the inclusion criteria, the sample size was reduced to 14,414 subjects. Of these, 14,375 employees responded to the question on hand pain, and 14,372 to the question on arm

228 pain. Considering these two outcomes as well as all other variables included in the
229 regression analyses, 14,299 cases with complete datasets were available and used for the
230 analyses. Nearly sixty-two percent (8,809) of the analyzed sample of 14,299 employees were
231 men; 38.4% (5,490) were woman. The mean age of the subjects was 46.7 (SD 11.1);
232 respondents reported a mean actual working time per week of 43.8 (SD 7.6) hours. The
233 mean of the psychosocial workload index based on Kroll (2011) was 38.9 (SD 11.8) index
234 points (see Table 1).

235 ## Unadjusted prevalence of manual handling operations

236 A share of 32.6% of men and 31.1% of women indicated that they often perform MHO.
237 Employees who reported that they often perform MHO also often lifted heavy loads (41.1%),
238 often worked overhead (12.9%) or reported that they often work under cold climatic
239 conditions, in heat, wet humidity, or draught (34.2%).

240 Men and women employed in occupations in the agricultural sector (e. g., farmers and forest
241 workers), in unskilled manual occupations (e. g., construction helpers and road builders) or
242 in skilled manual occupations (e. g., electricians and carpenters) reported that they
243 frequently executed MHO. Another large and important occupational group that is often
244 exposed to MHO is women in semiprofessions (e. g., physiotherapists). The distribution of
245 the prevalence of manual handling operations in occupational sectors stratified by gender is
246 provided in Table 2.

247 ## Crude prevalence of hand and arm complaints

248 The crude prevalence of self-reported hand pain within the past 12 months is 14.2%. Hand
249 pain is generally more common in women than in men (17.8% vs. 11.9%).

250 For both genders the prevalence increased in relation to the self-reported frequency of
251 manual handling operations. Nearly 11.4% of women who reported that they “never”

252 perform MHO experienced hand pain within the previous 12 months. In women, the
253 prevalence also increased over the following categories of frequency of MHO, with 12.6% in
254 the category “rarely,” 15.2% in the category “sometimes,” and 30.2% in the category
255 “often.” Men demonstrated a similar trend. The prevalence of a self-reported, 12-month
256 prevalence of hand pain increased from 5.0% for men who reported that they “never”
257 perform MHO, to 8.0% and 11.1% for men who were “rarely” and “sometimes” exposed, and
258 to 22.3% for men in the highest exposure category (Table 1).

259 Regarding arm pain, the second outcome, 17.4% of subjects reported that they had suffered
260 such complaints within the past 12 months. Generally, women more frequently expressed
261 the occurrence of arm pain than men (21.0% vs. 15.2%). There was a strong increase in the
262 prevalence of arm pain in relation to the self-reported frequency of manual handling
263 operations from 10.6% in subjects who were never exposed to manual handling operations
264 to 29.9% in subjects who were often exposed. This increase of prevalence related to the
265 exposure to manual handling operations was true for men as well as for women (Table 1).

266

267 Association between manual handling operations and hand complaints

268 There was a strong association between MHO and hand pain in the unadjusted as well as in
269 the adjusted models. All models showed a strong increase of the PR related to the increase
270 of the self-reported frequency of MHO. In comparison to the adjusted models, the estimated
271 association tended to be higher in the unadjusted model. According to the latter, subjects in
272 the category “rarely performs MHO” had a 1.21-fold (CI 1.02 – 1.43) increased risk of
273 suffering hand pain compared to subjects in the reference group who reported that they
274 “never perform MHO”. Based on the unadjusted model, the risk of hand pain increased 1.60-
275 fold (CI 1.38 – 1.86) to 3.25-fold (CI 2.45 – 3.60), respectively, for employees who stated that

they “sometimes” or “often” perform MHO. After adjustment for confounders (age; gender; weekly working time; manual lifting of heavy loads; overhead work; and cold; heat; wet humidity; draught), the association between MHO and pain in the hands remained high. Employees who reported that they “rarely perform MHO” had a higher probability of self-reported pain in the hands within the last 12 months. The prevalence of hand pain in the group of employees who “sometimes” perform MHO was 1.34 (CI 1.15 – 1.57) times higher compared to subjects who “never” perform MHO. The prevalence ratio rose to 2.26 (CI 2.00 – 2.55) for subjects who reported that they “often” performed MHO (Table 3). Other relevant physical workloads and exposures, such as working in extreme climatic conditions, were considered in the fully adjusted model. The relative risk for hand pain was associated with a high frequency of self-reported manual lifting of heavy loads (often: PR 1.34 CI 1.18 – 1.52), overhead work (PR 1.39 CI 1.23 – 1.56), and often working under difficult climatic factors (PR 1.50 CI 1.34 – 1.67) (Table 3). Compared to men, women showed a higher probability of self-reported hand pain within the past 12 months (PR 1.59 CI 1.47 – 1.72). The probability of reported hand pain increased by a factor of 1.10 (CI 1.07 – 1.15) per ten years of age. The adjusted prevalence was estimated based on the results of the fully adjusted Model 5. Employees who “often” performed MHO had the highest prevalence of hand pain (25.9% CI 24.0% - 28.0%). In employees who “sometimes,”, “rarely,” or “never” performed MHO, the prevalence of pain in the hands was 15.5% (CI 13.5% - 17.6%), 13.4% (CI 11.4% - 15.8%) and 13.4% (CI 11.4% - 15.8%), respectively. Therefore, if we compare subjects who “never performed MHO” to subjects who “often performed MHO,” nearly 12.5 % of the total percentage of hand pain prevalence is attributable to the MHO workload.

Association between manual handling operations and arm complaints

Similar to the results for hand pain as an outcome, we were able to prove a strong association between the self-reported frequency of manual handling operations and the prevalence of arm pain in the unadjusted as well as in the adjusted models. Regarding the unadjusted model the prevalence of arm pain increased 1.11-fold (CI 0.96 - 1.29) in subjects who reported that they are rarely exposed to MHO; 1.50-fold (CI 1.32 - 1.70) in those who were sometimes exposed; and 2.77-fold (CI 2.54 - 3.02) in subjects who were often exposed, comparted to subjects who were never exposed. The association was less characteristic if confounder variables were included in the regression model. Considering the fully adjusted Model 5 the prevalence ratio was 1.73 (CI 1.55 - 1.92) in the highest exposure category (often) and 1.16 (CI 1.02 - 1.33) in subjects who reported that they are sometimes exposed to manual handling operations. For other work related exposures (manual lifting of heavy loads; overhead work; climatic exposures; psychosocial workload; actual weekly working hours) and individual factors (age; gender) we find nearly the same associations to the self-reported frequency of manual handling operations as for hand pain (Table 4).

The adjusted prevalence of arm pain in subjects who never, rarely, sometimes, or often performed MHO was estimated based on regression Model 5 with 16.1% (CI: 14.6% - 17.9%), 16.1% (CI: 14.0% - 18.5%); 18.7% (CI: 16.7% - 21.0%); and 27.9% (CI: 26.0% - 29.9%), respectively. The percentage of arm pain prevalence attributable to the MHO workload is nearly 11.8% when comparing subjects who “never performed MHO” to subjects who “often performed MHO.”

Discussion

The study aimed to assess the exposure prevalence of manual handling operations (MHO) and the association between MHO and self-reported pain in the hands and arms using the data of the *2018 BIBB/BAuA Employment Survey*. The results show that the prevalence of pain in the hands and arms within the past 12 months strongly increased in relation to the self-reported frequency of manual handling operations (MHO) in men and women. However, pain in the hands and arms is generally more common in women than in men. On the other hand, the results demonstrate that MHO is still a significant risk factor in the German working population. One third of all employed women and men reported that they “often” performed MHO. These highly exposed employees also reported that they are often exposed to other related physical or environmental risk factors such as manual lifting of heavy loads, overhead work or difficult climates. Most employees who worked in the agricultural sector (such as farmers and forest workers) and in unskilled manual occupations (such as construction helpers and road builders) or skilled manual occupations (such as electricians and carpenters) “often” performed manual handling operations.

We were able to show a strong association between the self-reported frequency of MHO and hand and arm pain in the unadjusted and as well as in the adjusted models. After adjusting for relevant confounders, the prevalence ratio for the categories “sometimes” and “often” remains high. The relationship between the self-reported frequency of MHO and hand and arm pain is generally more pronounced for hand pain than for the less specific outcome of “arm pain”. According to the results of the regression models, the model-based adjusted prevalence of hand and arm pain increases with the self-reported frequency of manual handling operations.

344 It must be considered that the implemented analysis is based on a cross-sectional-study; it is
345 therefore not possible to provide causal statements.

346 One advantage of the study is the large study population of 20,012 employees. Nearly 47.4%
347 of reachable employees (n = 42,188) participated. A comparison of responders to non-
348 responders is complicated, as no basic information (age; education) is available for 5.1% of
349 them.

350 Although the percentage of men and women is equally distributed within the German
351 population [30], men were more prevalent than women in our study population. This may be
352 explained by the inclusion criteria applied to this analysis: employees who work less than 35
353 hours per week had been excluded. As a result, many women were not considered in the
354 analysis.

355 When interpreting the results, we must consider a healthy worker effect [31]. This effect can
356 impact all categories of MHO. It should be taken into account that employees who remain in
357 occupations with high workloads of MHO adapt to their working conditions, whereas
358 employees with health conditions are more likely to leave the workplace or switch to less
359 exposed fields of work. Therefore, the real effect estimates of MHO with regards to the
360 prevalence of hand pain may be higher.

361 Another consideration is that the *2018 BIBB/BAuA Employment Survey* covered a wide range
362 of work-related aspects, with only a relatively short timeframe available for the interviews.
363 This limited the ability to derive specific and multifarious information on individual
364 exposures and outcomes. For example, requirements of manual handling operations were
365 only covered by one short question with a limited spectrum of answers. MHO, however, is
366 related to a wide range of different physical demands, including heavy physical work and
367 precise manual work. In the survey, different requirements (high dexterity; applying great

368 strength with the hands and arms; repetitive activities) of manual work are covered by one
369 question. To understand which activity has the strongest influence on the hands and
370 forearms, the workload assessment needs to be based on objective workplace risk
371 assessments and measurements. Obtaining sufficient information on work-related exposure
372 is one of the most challenging quality problems epidemiological studies face. In their review,
373 da Costa et al. 2010 [3] discussed how studies that investigate the risk factors for the
374 development of work-related musculoskeletal disorders should report exposure levels in
375 detail. They added that if repetition is identified as a risk factor, the number of repetitions
376 necessary for it to become a risk should be reported as accurately as possible. The
377 expenditure required to obtain information on exposure in such detail is immense. Even in
378 ergonomic field studies, which perform deep ergonomic workplace evaluations with regard
379 to MHO [32, 33], exposures are only assessed at a workplace level, not for individual
380 employees, and not retrospectively. Since such deep exposure assessments are not
381 applicable in large telephone surveys such as the *2018 BIBB/BAuA Employment Survey*, we
382 have to consider the limitations of information related to self-reported exposure. It is also
383 necessary to discuss the wording of the questions on work-related exposures and health
384 outcomes in BIBB/BAuA Employment Surveys. Employees were only able to choose between
385 the categories “never,” “rarely,” “sometimes,” and “often” to rate the intensity of manual
386 handling operations and other work-related aspects. The categories employed here cannot
387 be linked to an actual time of exposure or an absolute frequency per day. Employment
388 surveys conducted in other countries, such as Denmark, Norway, and Spain, on the other
389 hand, obtain information on parts of the working day [34].
390 However, surveys can assess the outcome in a more differentiated manner. When asked
391 whether they had experienced pain in the hands within the last 12 months, participants only

392 had the option of answering with “yes” or “no.” It is not possible to rate the intensity or
393 frequency of reported pain within the last 12 months in this manner. We can also assume
394 that the ability to remember pain episodes and intensities varies [35]. On the other hand,
395 the questions on health outcomes should be improved. The anatomical regions of “hands”
396 and “arms” are not sufficiently specific to obtain precise information on complaints in hands,
397 forearms, elbows, and shoulders. The general wording of the question is unfortunately
398 conditional to the occurrence of pain while at or after work. At this point, we suggest a more
399 specific and unconditional operationalization of health outcomes in BIBB/BAuA Employment
400 Surveys.

401 The study is further limited by the fact that the survey does not cover other important
402 occupational factors for hand pain, such as hand-arm vibrations, or important individual
403 factors, such as body height, body weight, and smoking behavior of employees; these can
404 therefore not be considered.

405 Poisson regression with robust variance estimation was chosen to directly estimate the
406 prevalence ratio as a directly interpretable effect estimate, although the outcome variable is
407 binary and would implicate a logistic regression approach. According to Barros and Hirakata
408 (37), analyses that use Poisson regression with robust variance estimation produce the same
409 results as analyses that use binomial logistic regression. The investigation of Chen, Shi (38)
410 also shows that a robust variance estimation can handle outliers. This allows us to consider a
411 relatively large number of confounders within the models.

412 Due to the low number of misses, we chose a complete-case analysis and assumed that
413 missing values occurred completely at random [28]. The sixth *European Working Conditions*
414 *Survey*, conducted by Eurofound in 2017 [5], and the *2012 BIBB/BAuA Employment Survey*
415 report a similar prevalence of MHO. Moreover, the results of the study support the idea that

the German working population is still frequently exposed to MHO. Furthermore, the prevalence of pain in the hands deviates just slightly from the results of the earlier BIBB/BAuA Employment Survey in 2012. The findings additionally coincide with the results of Balogh et al. 2019 [18], namely that there is a higher prevalence of disorders in the hand among women. The different ways of assessing MHO make it difficult to compare the results of this study to others. The estimated high positive association between MHO and pain in the hands for the adjusted model are in accordance with the findings of the systematic reviews of Palmer et al. and van Rijn et al.[1, 2].

Conclusion

In conclusion, the results presented here show that manual handling operations are still a significant occupational exposure in the German workforce. The *2018 BIBB/BAuA Employment Survey* confirmed the known association between MHO and pain in the hands in current working conditions. Employees who “often” perform manual handling operations are especially affected. Therefore, the necessity of prevention measures for occupational groups that often execute MHO is high. These groups include employees in the agricultural sector, services as well as unskilled and skilled manual occupations. The results of this study can be used to justify needs for prevention, to focus on highly affected occupations and to optimize preventive approaches. By setting policies and implementing them within companies, we can reduce the negative impact of MHO on the health of employees. In light of the attributable fraction among the exposed, the results suggest a reduction target of nearly 10 points for said pain if the (self-reported) frequency of manual handling operations were to be reduced from “often” to “never.”

List of abbreviations

BAuA: Federal Institute for Occupational Safety and Health, BIBB: Federal Institute for Vocational Education and Training, CI: confidence interval, EU-OSHA: European Agency for Safety and Health at Work, MSD: musculoskeletal disorders, PR: prevalence ratio, SD: standard deviation

Declarations

Ethics approval and consent to participate

The BAuA ethics committee approved the study (EK007_2017 date d January 9, 2017).

Consent for publication

Not applicable.

Availability of data and materials

The dataset (no. ZA7574) supporting the conclusions of this article is available as scientific-Use-File and can be requested at „BIBB – Bundesinstitut für Berufsbildung - Forschungsdatenzentrum“ (Postfach 201264; 53142 Bonn; Germany; fax number: +49 – (0)228 – 107 – 2020)). The dataset will be available as ftp-download after approved application.

Competing interests

The authors declare that they have no competing interests.

Funding

The study is part of the F2456 project of the Federal Institute for Occupational Safety and Health (BAuA) and focuses on physical working exposures and complaints of the

musculoskeletal system. Further information is available online at: www.baua.de/DE/Aufgaben/Forschung/Forschungsprojekte/f2456.html.

Authors' contributions

FL and CM did the conception of the work, FL and MS prepared the data for analysis, CM and FL analyzed the data, all authors worked on the interpretation of data, CM and FL prepared the manuscript; MS, CM reviewed the manuscript. All authors read and approved the final manuscript.

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Additional material

Additional material is not included.

475 # Tables

476 Table 1: Description of the study population stratified by the self-reported frequency of
477 manual handling operations.

478

		Self-reported frequency of manual handling operations				
		Never	**Rarely**	**Sometimes**	**Often**	**Total**
Manual handling operations						
*** All participants (n (row%)**		6119 (42.8%)	1677 (11.7%)	1922 (13.4%)	4581 (32.0%)	14,299 (100.00%)
*** Men (n (row%))**		3476 (39.5%)	1183 (13.4%)	1276 (14.5%)	2874 (32.6%)	8809 (100.0%)
*** Women (n (row%))**		2643 (48.1%)	494 (9.0%)	646 (11.8%)	1707 (31.1%)	5490 (100.0%)
Age (years, mean (SD))		47.6 (10.7)	46.4 (11.2)	46.0 (11.3)	45.8 (11.5)	46.7 (11.1)
Women (%)		43.2%	29.5%	33.6%	37.3%	38.4%
Weekly working hours (mean (SD))		43.5 (6.8)	44.2 (7.4)	43.8 (8.1)	44.0 (8.4)	43.8 (7.6)
Psychosocial workload index (index points, mean (SD))		36.4 (10.5)	39.0 (11.4)	40.3 (12.3)	41.6 (12.7)	38.9 (11.8)
Prevalence of hand pain (%)	Male	5.0%	8.0%	11.1%	22.3%	11.9%
	Female	11.4%	12.6%	15.2%	30.2%	17.8%
	All	7.8%	9.4%	12.4%	25.3%	14.2%
Prevalence of arm pain (%)	Male	7.5%	10.3%	15.2%	26.5%	15.2%
	Female	14.6%	15.2%	17.2%	34.0%	21.0%
	All	10.6%	11.7%	15.9%	29.3%	17.4%
Manual lifting of heavy loads (col%)	Never	76.9%	32.6%	26.1%	21.8%	47.2%
	Rarely	16.2%	49.2%	29.2%	19.0%	22.7%
	Sometimes	4.4%	9.8%	28.0%	18.1%	12.6%
	Often	2.5%	8.3%	16.6%	41.1%	17.4%
Overhead operations (%)	Yes	0.2%	1.6%	4.1%	12.9%	5.0%
Cold; heat; wet humidity; draught (col%)	Never	80.1%	41.9%	37.5%	34.0%	55.1%
	Rarely	8.7%	28.9%	15.8%	12.6%	13.3%
	Sometimes	7.4%	15.8%	30.3%	19.2%	15.3%
	Often	3.8%	13.4%	16.4%	34.2%	16.4%

479 Legend: row %: row percentage, col %: column percentage, %: percentage, n: absolute
480 number, SD: standard deviation

481

Table 2: Prevalence of manual handling operations stratified by the BLOSSFELD occupational groups and gender.

BLOSSFELD occupational group	Self-reported frequency of manual handling operations					
	Never (row%)	Rarely (row%)	Sometimes (row%)	Often (row%)	Total (row%)	No. of subjects
Men (n = 8770)						
Agricultural occupations	5.3%	7.0%	17.6%	70.1%	100.0%	187
Unskilled manual occupations	11.7%	10.7%	18.1%	59.4%	100.0%	673
Skilled manual occupations	4.1%	6.7%	16.4%	72.7%	100.0%	1207
Technicians	28.2%	17.1%	20.1%	34.6%	100.0%	621
ENGINEERS	55.7%	19.1%	14.5%	10.7%	100.0%	768
Unskilled services	19.2%	16.6%	20.1%	44.1%	100.0%	866
Skilled services	29.8%	15.5%	19.2%	35.5%	100.0%	547
Semiprofessions	40.8%	17.6%	17.8%	23.9%	100.0%	574
Professions	54.6%	12.6%	12.9%	19.9%	100.0%	533
Unskilled commercial and administrational occupations	42.8%	15.3%	16.7%	25.2%	100.0%	222
Skilled commercial and administrational occupations	66.9%	12.5%	8.0%	12.6%	100.0%	1575
Managers	71.4%	13.0%	6.7%	8.8%	100.0%	997
All men	**39.4%**	**13.4%**	**14.5%**	**32.7%**	**100.0%**	**8770**
Women (n = 5473)						
Agricultural occupations	8.1%	1.6%	11.3%	79.0%	100.0%	62
Unskilled manual occupations	12.3%	7.8%	13.0%	66.9%	100.0%	154
Skilled manual occupations	8.6%	4.9%	19.8%	66.7%	100.0%	162
Technicians	34.2%	10.5%	12.1%	43.2%	100.0%	190
Engineers	59.9%	16.1%	11.7%	12.4%	100.0%	137
Unskilled services	24.6%	9.4%	13.4%	52.7%	100.0%	224
Skilled services	26.1%	11.9%	14.2%	47.8%	100.0%	464
Semiprofessions	38.2%	10.1%	17.5%	34.2%	100.0%	1419
Professions	59.8%	10.8%	10.2%	19.1%	100.0%	528
Unskilled commercial and administrational occupations	42.8%	7.0%	11.1%	39.1%	100.0%	271
Skilled commercial and administrational occupations	65.4%	8.0%	7.4%	19.2%	100.0%	1332
Managers	80.6%	5.7%	3.8%	10.0%	100.0%	530
All women	**48.1%**	**9.0%**	**11.8%**	**31.1%**	**100.0%**	**5473**
All men and women	**42.8%**	**11.7%**	**13.5%**	**32.0%**	**100.0%**	**14,286**

Legend: row %: row percentage.

487 Table 3 Relative risk of **hand pain** as a prevalence ratio (PR) with a 95% confidence interval
488 (95% CI) in unadjusted Model 1 and fully adjusted Model 5. The following confounder variables
489 were included in the fully adjusted model: gender; manual lifting of heavy loads; overhead
490 work; climatic factors; age; actual weekly working hours; and an index for psychosocial
491 workload based on Kroll (2011). The regression models include N = 14,299 subjects (complete
492 case analysis).

Exposure of interest and covariates	Categories / Units	Unadjusted PR (95%-CI) for hand pain (Model 1)	Adjusted PR (95%-CI) for hand pain (Model 5)
Manual handling operations	Often	3.254 (2.945-3.595)	2.260 (2.002-2.551)
	Sometimes	1.602 (1.383-1.855)	1.343 (1.149-1.571)
	Rarely	1.206 (1.015-1.433)	1.172 (0.981-1.400)
	Never (ref.)	1 (Ref.)	1 (ref.)
Manual lifting of heavy loads	Often		1.341 (1.183-1.520)
	Sometimes		1.149 (1.003-1.317)
	Rarely		0.959 (0.844-1.089)
	Never (ref.)		1 (ref.)
Overhead work	Often		1.386 (1.229-1.563)
	Rarely (ref.)		1 (ref.)
Cold; heat; wet humidity; draught	Often		1.496 (1.340-1.669)
	Sometimes		1.191 (1.056-1.343)
	Rarely		0.985 (0.856-1.133)
	Never (ref.)		1 (ref.)
Age	Per years		1.010 (1.007-1.014)
Gender	Female / Man (ref.)		1.587 (1.464-1.721)
Actual weekly working hours	Per hour		0.988 (0.982-0.994)
Psychosocial workload index (Kroll 2011)	Per Index-Point		1.012 (1.009-1.016)

493 Legend: ref.: reference group, PR: prevalence ratio, 95%-CI: 95% confidence interval
494

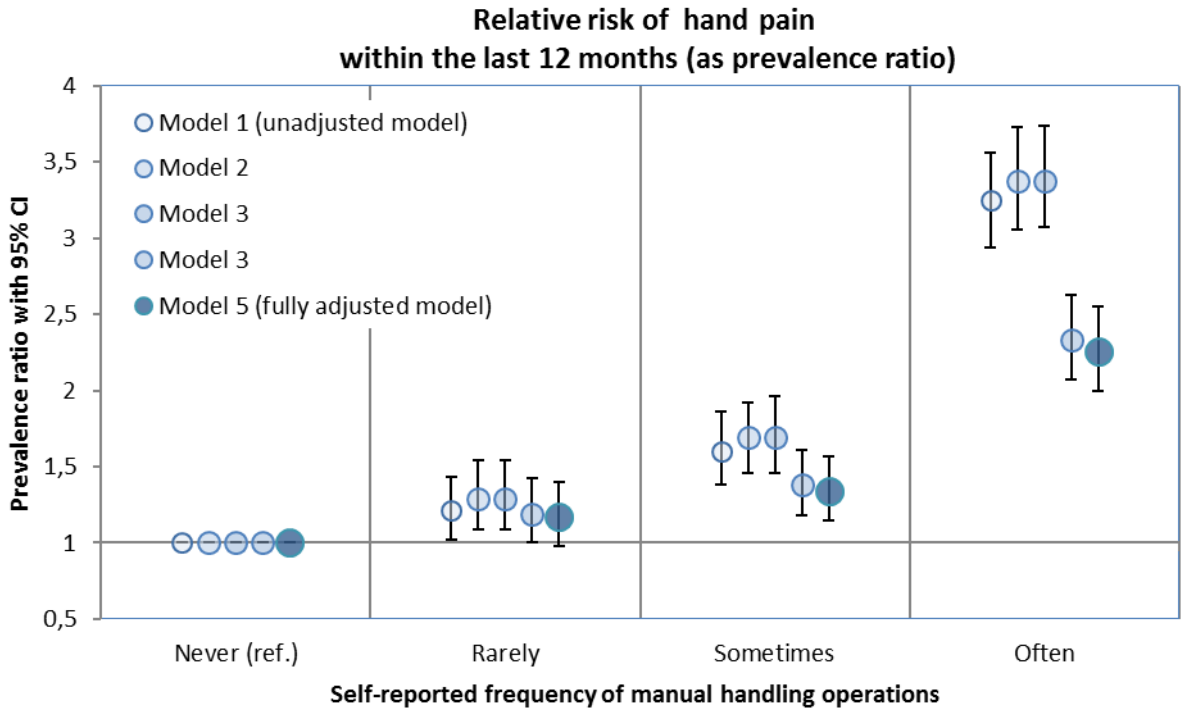
495

496 Table 4: Relative risk of **arm pain or complaints** as prevalence ratio (PR) with a 95%
497 confidence interval (95% CI) in the unadjusted and fully adjusted Model 5. The following
498 confounder variables were included in the fully adjusted model: gender; manual lifting of
499 heavy loads; overhead work; climate factors; age; actual weekly working hours; and an index
500 for psychosocial workload based on Kroll (2011). The regression models include N = 14,299
501 subjects (complete case analysis).
502

Exposure of interest and covariates	Categories / Unit	Unadjusted PR (95%-CI) for arm pain (Model 1)	Adjusted PR (95%-CI) for arm pain (Model 5)
Manual handling operations	Often	2.773 (2.545-3.020)	1.728 (1.552-1.923)
	Sometimes	1.501 (1.323-1.703)	1.162 (1.015-1.330)
	Rarely	1.111 (0.956-1.291)	0.996 (0.855-1.159)
	Never (ref.)	1 (Ref.)	1 (ref.)
Manual lifting of heavy loads	Often		1.590 (1.420-1.781)
	Sometimes		1.205 (1.063-1.366)
	Rarely		1.063 (0.951-1.190)
	Never (ref.)		1 (ref.)
Overhead work	Often		1.296 (1.166-1.440)
	Rarely (ref.)		1 (ref.)
Cold; heat; wet humidity; draught	Often		1.657 (1.500-1.830)
	Sometimes		1.297 (1.166-1.442)
	Rarely		1.048 (0.925-1.188)
	Never (ref.)		1 (ref.)
Age	Per year		1.020 (1.016-1.023)
Gender	Female / Man (Ref.)		1.458 (1.357-1.567)
Actual weekly working hours	Per hour		0.987 (0.981-0.992)
Psychosocial workload index (Kroll 2011)	Per Index-Point		1.011 (1.008-1.014)

503 Legend: ref.: reference group, PR: prevalence ratio, 95%-CI: 95% confidence interval
504

505 Figures



506

507 Figure 1: Relative risk of self-reported of hand pain or complaints stratified by the self-
508 reported frequency of manual handling operations. Prevalence ratios presented for the
509 unadjusted Model 1 and the adjusted regression Models 2 to 5 (reference category = "Never
510 performs manual handling operations").

511

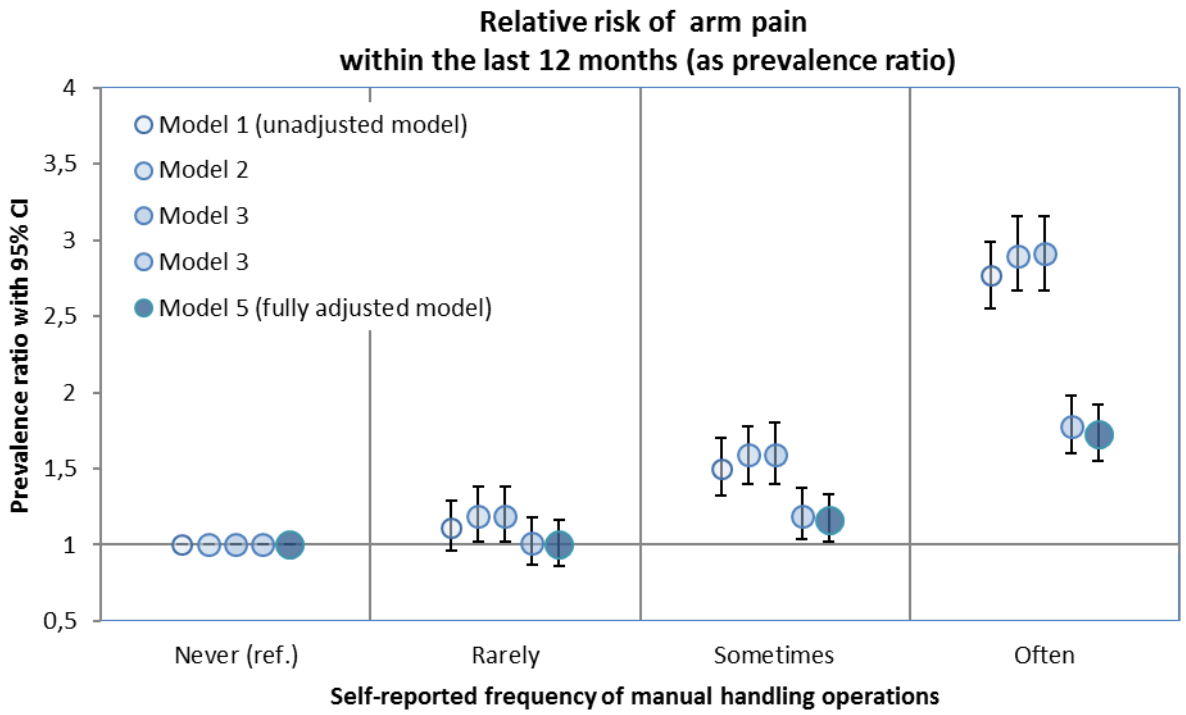


Figure 2: Relative risk of self-reported of arm pain or complaints stratified by the self-reported frequency of manual handling operations Prevalence ratios presented for the unadjusted Model 1 and the adjusted regression Models 2 to 5 (reference category = “Never performs manual handling operations”).

References

[1] Palmer KT, Harris EC, Coggon D. Carpal tunnel syndrome and its relation to occupation: a systematic literature review. Occup Med (Lond) 2007; 57:57-66. doi: 10.1093/occmed/kql125.

[2] van Rijn RM, Huisstede BM, Koes BW, Burdorf A. Associations between work-related factors and the carpal tunnel syndrome--a systematic review. Scand J Work Environ Health 2009; 35:19-36. doi: 10.5271/sjweh.1306.

[3] da Costa BR, Vieira ER. Risk factors for work-related musculoskeletal disorders: A systematic review of recent longitudinal studies. Am J Ind Med 2010; 53:285-323. doi: 10.1002/ajim.20750.

[4] Steinberg U, Liebers F. Manuelle Arbeit ohne Schaden. Grundsätze und Gefährdungsbeurteilung [Manual work without harm - principles and risk assessment]. Dortmund: BAuA; 2014. https://www.baua.de/DE/Angebote/Publikationen/Praxis/A55.html (06.07.2020).

[5] Eurofound. Sixth European Working Conditions Survey – Overview report (2017 update). Luxembourg: Publications Office of the European Union; 2017. https://www.eurofound.europa.eu/publications/report/2016/working-conditions/sixth-european-working-conditions-survey-overview-report (06.07.2020).

[6] Crawford JO, Davis A. Work-related musculoskeletal disorders: why are they still so prevalent? Evidence from a literature review - European Risk Observatory Report. Luxembourg: Publications Office of the European Union, European Agency for Safety and Health at Work; 2020. https://osha.europa.eu/de/publications/work-related-musculoskeletal-disorders-why-are-they-still-so-prevalent-evidence (26.06.2020).

[7] Wittig P, Nöllenheidt C, Brenscheidt S. Grundauswertung der BIBB/BAuAErwerbstätigenbefragung 2012 Männer/Frauen in Vollzeit mit den Schwerpunkten Arbeitsbedingungen, Arbeitsbelastungen und gesundheitliche Beschwerden [Basic analysis of the 2012 BIBB/BAuA employment survey fro men/women in full-time jobs and focusing on working conditions, workloads and health complaints]. Dortmund, Berlin, Dresden: Federal Institute for Occupational Safety and Health (BAuA); 2013. https://www.baua.de/DE/Angebote/Publikationen/Berichte/F2417-2.html (06.07.2020).

[8] Bernard BP, Putz-Anderson V. Musculoskeletal disorders and workplace factors: a critical review of epidemiologic evidence for work-related musculoskeletal disorders of the neck, upper extremity, and low back. Cincinnati: National Institute for Occupational Safety and Health (NIOSH); 1997. https://www.cdc.gov/niosh/docs/97-141/default.html (07.06.2020).

[9] da Costa JT, Baptista JS, Vaz M. Incidence and prevalence of upper-limb work related musculoskeletal disorders: A systematic review. Work 2015; 51:635-44. doi: 10.3233/WOR-152032.

[10] DGUV. DGUV-Statistiken für die Praxis 2018 - Aktuelle Zahlen und Zeitreihen der gewerblichen Berufsgenossenschaften und Unfallversicherungsträger der öffentlichen Hand [DGUV statistics for practice 2018 - Current figures and time series of the industrial accident insurence companies and the accident insurance companies of the public sector]. Berlin: Deutsche Gesetzliche Unfallversicherung (DGUV); 2018. https://publikationen.dguv.de/zahlen-fakten/ueberblick/3673/dguv-statistiken-fuer-die-praxis-2018 (06.07.2020).

[11] World Health Organization. Identification and control of work-related diseases: report of a WHO expert committee. Geneva: World Health Organization; 1985. https://apps.who.int/iris/handle/10665/40176 (06.07.2020).

[12] Hildebrandt VH, Bongers PM, van Dijk FJ, Kemper HC, Dul J. The influence of climatic factors on non-specific back and neck-shoulder disease. Ergonomics 2002; 45:32-48. doi: 10.1080/00140130110110629.

[13] Warrender WJ, Henstenburg J, Maltenfort M, Lutsky K, Beredjiklian PK. Seasonal Variation in the Prevalence of Common Orthopaedic Upper Extremity Conditions. J Wrist Surg 2018; 7:232-6. doi: 10.1055/s-0037-1612637.

[14] Piedrahíta H, Punnett L, Shahnavaz H. Musculoskeletal symptoms in cold exposed and non-cold exposed workers. Int J Ind Ergon 2004; 34:271-8. doi: 10.1016/j.ergon.2004.04.008.

[15] Pienimaki T. Cold exposure and musculoskeletal disorders and diseases. A review. Int J Circumpolar Health 2002; 61:173-82. doi: 10.3402/ijch.v61i2.17450.

[16] Roquelaure Y, Ha C, Rouillon C, Fouquet N, Leclerc A, Descatha A *et al*. Risk factors for upper-extremity musculoskeletal disorders in the working population. Arthritis Rheum 2009; 61:1425-34. doi: 10.1002/art.24740.

[17] Treaster DE, Burr D. Gender differences in prevalence of upper extremity musculoskeletal disorders. Ergonomics 2004; 47:495-526. doi: 10.1080/00140130310001638171.

[18] Balogh I, Arvidsson I, Bjork J, Hansson GA, Ohlsson K, Skerfving S, Nordander C. Work-related neck and upper limb disorders - quantitative exposure-response relationships adjusted for personal characteristics and psychosocial conditions. BMC Musculoskelet Disord 2019; 20:139. doi: 10.1186/s12891-019-2491-6.

[19] Capodaglio P, Castelnuovo G, Brunani A, Vismara L, Villa V, Capodaglio EM. Functional limitations and occupational issues in obesity: a review. Int J Occup Saf Ergon 2010; 16:507-23. doi: 10.1080/10803548.2010.11076863.

[20] Shiri R, Pourmemari MH, Falah-Hassani K, Viikari-Juntura E. The effect of excess body mass on the risk of carpal tunnel syndrome: a meta-analysis of 58 studies. Obes Rev 2015; 16:1094-104. doi: 10.1111/obr.12324.

[21] Al-Bashaireh AM, Haddad LG, Weaver M, Kelly DL, Chengguo X, Yoon S. The Effect of Tobacco Smoking on Musculoskeletal Health: A Systematic Review. J Environ Public Health 2018; 2018:1-190. doi: 10.1155/2018/4184190.

[22] Mansfield M, Thacker M, Sandford F. Psychosocial Risk Factors and the Association With Carpal Tunnel Syndrome: A Systematic Review. Hand (N Y) 2018; 13:501-8. doi: 10.1177/1558944717736398.

[23] Putrik P, Ramiro S, Chorus AM, Keszei AP, Boonen A. Socioeconomic inequities in perceived health among patients with musculoskeletal disorders compared with other chronic disorders: results from a cross-sectional Dutch study. RMD Open 2015; 1:e000045. doi: 10.1136/rmdopen-2014-000045.

[24] Mackenbach JP, Stirbu I, Roskam AJ, Schaap MM, Menvielle G, Leinsalu M, Kunst AE, European Union Working Group on Socioeconomic Inequalities in H. Socioeconomic inequalities in health in 22 European countries. N Engl J Med 2008; 358:2468-81. doi: 10.1056/NEJMsa0707519.

[25] Rohrbach-Schmidt D, Hall A. BIBB/BAuA Employment Survey 2018 Version 1.0. Bonn: BIBB (Federal Institute for Vocational Education and Training); 2020. https://www.bibb.de/veroeffentlichungen/de/publication/show/16563 (23.11.20202).

[26] Kroll LE. Konstruktion und Validierung eines allgemeinen Index für die Arbeitsbelastung in beruflichen Tätigkeiten anhand von ISCO-88 und KldB-92 [Construction and Validation of a General Index for Job Demands in Occupations Based on ISCO-88 and KldB-92]. Methoden, Daten, Analysen 2011; 5. doi: http://dx.doi.org/10.25646/1580.

[27] Eckey HF, Kosfeld R, Rengers M. Multivariate Statistik: Grundlagen - Methoden - Beispiele. Wiesbaden: Gabler Verlag; 2013.

[28] Pigott TD. A review of methods for missing data. Educational research evaluation 2001; 7:353-83.

[29] Fahrmaier L, Kneib T, Lang S. Regression - Modelle, Methoden und Anwendungen [Regression - models, methods and applications]. Berlin, Heidelberg, New York: Springer; 2007.

[30] DESTATIS. Bevölkerung im Wandel - Annahmen und Ergebnisse der 14. koordinierten Bevölkerungsvorausberechnung [Changing population - Assumptions and results of the 14th

coordinated population projection]. Wiesbaden: Statistisches Bundesamt (DESTATIS); 2019. https://www.destatis.de/DE/Presse/Pressekonferenzen/2019/Bevoelkerung/pressebroschuere-bevoelkerung.pdf (07.06.2020).

[31] Li CY, Sung FC. A review of the healthy worker effect in occupational epidemiology. Occup Med (Lond) 1999; 49:225-9. doi: 10.1093/occmed/49.4.225.

[32] Klussmann A, Liebers F, Gebhardt H, Rieger MA, Latza U, Steinberg U. Risk assessment of manual handling operations at work with the key indicator method (KIM-MHO) - determination of criterion validity regarding the prevalence of musculoskeletal symptoms and clinical conditions within a cross-sectional study. BMC Musculoskelet Disord 2017; 18:184. doi: 10.1186/s12891-017-1542-0.

[33] Klussmann A, Gebhardt H, Rieger M, Liebers F, Steinberg U. Evaluation of objectivity, reliability and criterion validity of the key indicator method for manual handling operations (KIM-MHO), draft 2007. Work 2012; 41 Suppl 1:3997-4003. doi: 10.3233/WOR-2012-0699-3997.

[34] Tynes T, Aagestad C, Thorsen SV, Andersen LL, Perkio-Makela M, Garcia FJP *et al*. Physical working conditions as covered in European monitoring questionnaires. BMC Public Health 2017; 17:544. doi: 10.1186/s12889-017-4465-7.

[35] Pearce N, Checkoway H, Kriebel D. Bias in occupational epidemiology studies. Occup Environ Med 2007; 64:562-8. doi: 10.1136/oem.2006.026690.

Figures

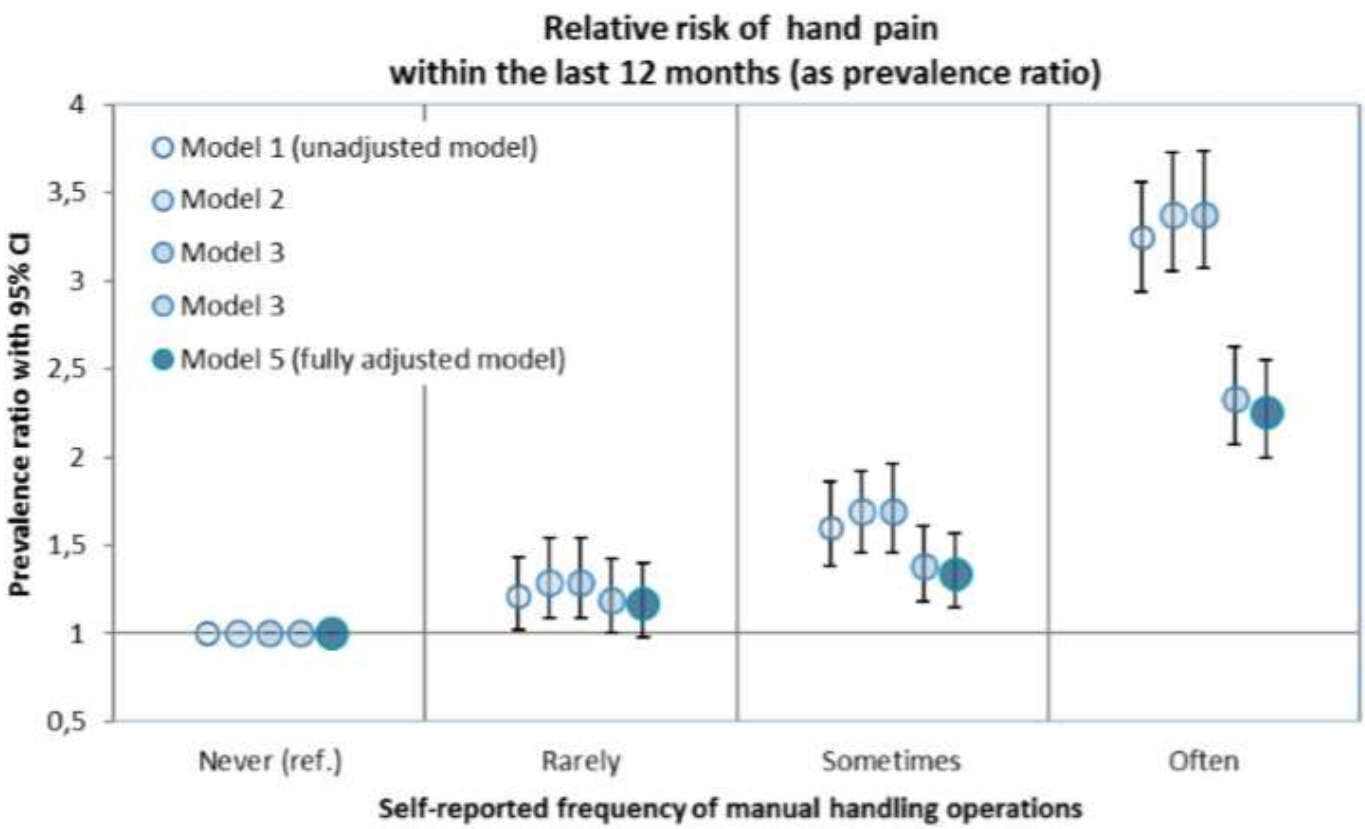


Figure 1

Relative risk of self-reported of hand pain or complaints stratified by the self- reported frequency of manual handling operations. Prevalence ratios presented for the unadjusted Model 1 and the adjusted regression Models 2 to 5 (reference category = “Never performs manual handling operations”).

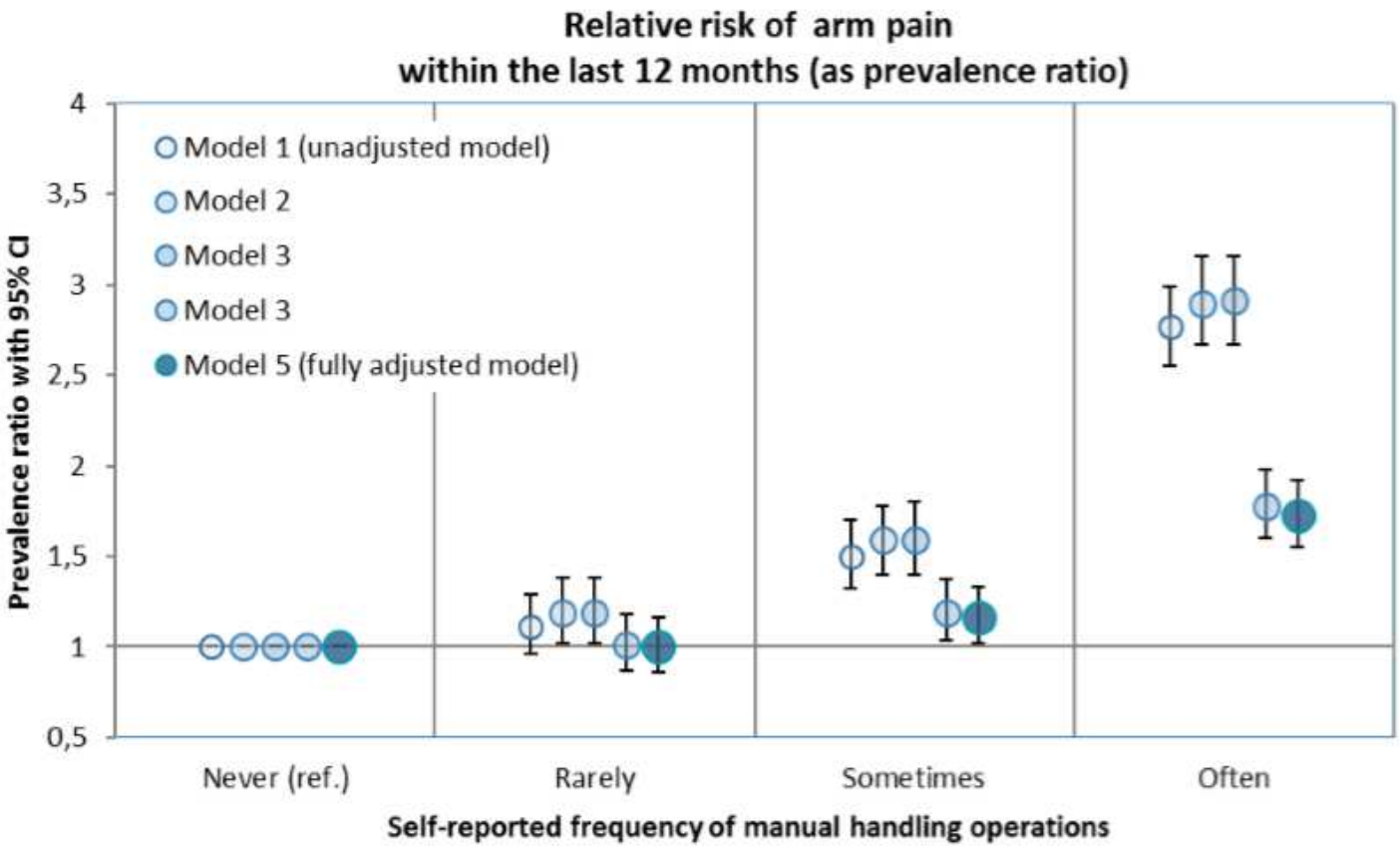


Figure 2

Relative risk of self-reported of arm pain or complaints stratified by the self- reported frequency of manual handling operations Prevalence ratios presented for the unadjusted Model 1 and the adjusted regression Models 2 to 5 (reference category = “Never performs manual handling operations”).