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Work-site musculoskeletal pain risk estimates by trained observers – a prospective cohort study

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Work-related musculoskeletal pain (MSP) risk assessments by trained observers are often used in ergonomic practice; however, the validity may be questionable. We investigated the predictive value of work-site MSP risk estimates in a prospective cohort study of 1745 workers. Trained observers estimated the risk of MSP (neck, shoulder or low-back pain) using a three-point scale (high, moderate and low risk) after observing a video of randomly selected workers representing a task group. Associations of the estimated risk of pain and reported pain during a three-year follow-up were assessed using logistic regression. Estimated risk of neck and shoulder pain did (odds ratio, OR: 1.45 (95% confidence interval, CI: 1.01–2.08); 1.64 (95% CI: 1.05–2.55)), however, estimated risk of low-back pain did not significantly predict pain (OR: 1.27 (95% CI: 0.91–1.79)). The results show that observers were able to estimate the risk of shoulder and neck pain, whereas they found it difficult to estimate the risk of low-back pain.

Practitioner Summary: Work-related musculoskeletal pain risk assessments by observers are often used in ergonomic practice. We showed that observers were able to estimate shoulder and neck pain risk, but had difficulties to estimate the risk of low-back pain. Therefore, observers' risk estimates might provide a useful method for musculoskeletal pain risk assessments.

Keywords: musculoskeletal pain; longitudinal studies; prospective studies; risk estimates

1. Introduction

Work-related musculoskeletal pain (MSP), which often affects the lower back, neck or shoulder region (Picavet and Schouten 2003), is a great concern for society (Alexopoulos *et al.* 2004, Punnett *et al.* 2005). The high prevalence of MSP is associated with a loss of quality of life and high costs (e.g. medical costs, costs due to work absenteeism and costs due to a reduction of productivity while working during sickness, so-called presenteeism; Stewart *et al.* 2003, Bot *et al.* 2005, Lambeek *et al.* 2011). In addition to personal risk factors (e.g. age, gender; Leboeuf-Yde 2004, Côté 2012) and psychosocial risk factors (e.g. work pressure, social support and job satisfaction; Hartvigsen *et al.* 2004, van den Heuvel *et al.* 2005), several work-related physical risk factors were found to be associated with MSP. For example, trunk bending and twisting, lifting and whole body vibrations are associated with the occurrence of low back pain (LBP) (Hartvigsen *et al.* 2001, van Nieuwenhuysse *et al.* 2006, Tiemessen *et al.* 2008), whereas repetitive handling, extreme body postures (e.g. upper arm flexion and neck flexion), high forces or a combination of these factors are associated with neck and shoulder pain (Palmer and Smedley 2007, Côté *et al.* 2008, van Rijn *et al.* 2010).

An important issue when assessing physical risk factors for MSP in epidemiological research and ergonomic practice is to choose an appropriate method of measurement (David 2005, Burdorf 2010). Work-related risk factors can be assessed by self-reports, observations (i.e. subjective risk estimations or structured observations of exposure variables) and direct measurements (e.g. muscle activity measurements, goniometry and measurement of external forces). Self-reports have been used in numerous epidemiological studies (e.g. Balogh *et al.* 2001, Barrero *et al.* 2009a) and are easily applicable; however, their accuracy has been questioned (Balogh *et al.* 2004, Punnett and Wegman 2004). Therefore, in contrast to epidemiological studies, self-reports of workload are rarely used for evaluation in ergonomic practice (Hansson *et al.* 2001). Instead, subjective risk estimations by observers are frequently used. Although these observations have higher validity than self-reports, their validity is assumed to be lower than obtained by direct measurement (Spielholz *et al.* 2001, Takala *et al.* 2010). Regrettably, when moving from self-report to direct measurement, cost and measurement time increase while feasibility decreases (David 2005,

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Barrero *et al.* 2009b). Therefore, when selecting an appropriate measurement method in epidemiologic studies or in ergonomics practice, a trade-off between accuracy and feasibility should be considered.

When constructing a sound measurement strategy, besides choosing an appropriate measurement method, also the way of sampling exposure measurements (e.g. measuring over a single day or over multiple days) has to be chosen (Mathiassen *et al.* 2003) and either a group or an individual measurement approach should be adopted (Jansen and Burdorf 2003). Based on reviews, the predictive validity of measuring methods depends largely on the measurement strategy. For example, no differences in exposure-response associations for neck pain in studies using objective and subjective measurement methods (Fejer *et al.* 2006) have been reported, suggesting that objective measurements provide only limited additional predictive information, possibly as a result of inadequate or time-limited measurements (Palmer and Smedley 2007). Structured observations and direct measurements may lack accuracy when using a poor measurement strategy, whilst self-reports and subjective risk estimations can be useful, especially when efficient measurement strategies are needed. Despite the abovementioned suggestions, the predictive validity of subjective risk estimations is unknown. Therefore, in the present study, data from a prospective study were used to investigate whether MSP risk estimates of workers in the workplace by trained observers were predictive for MSP (LBP, neck and shoulder pain). If proven to be valid, such subjective assessments could be useful for risk assessments in ergonomics practice and epidemiological research.

2. Methods

2.1. Population

Data used in this study are part of the Study on Musculoskeletal disorders, Absenteeism and Health (SMASH) previously described in more detail (Hoogendoorn *et al.* 2000, Ariëns *et al.* 2001). In short, the study is a prospective longitudinal assessment of MSP risk estimation and personal characteristics by trained observers for a cohort of workers at baseline and then by self-administered annual questionnaires during a three-year follow-up. Workers were recruited from 34 companies in the Netherlands representing several industrial and service branches, including metal, computer software, chemical, pharmaceutical, food and wood construction industries, as well as insurance companies, childcare centres, hospitals, distribution companies and roadworker organisations. Thus, the study population included workers performing various tasks with a wide range of physical and mental workloads.

At baseline, 1990 of the invited 2048 workers participated in the study. A total of 1802 of the original 1990 participants completed all questionnaires. Forty-six workers were excluded because they were employed in their current job less than one year or worked less than 20 h a week. Eleven workers were excluded because they had had a paid job for a substantial amount of time at a company other than the one from which they were recruited. After exclusion, 1745 workers were eligible to participate in the current study on MSP risk estimations. The MSP risk estimation data were available for 1338 workers (Figure 1).

2.2. Data collection

At baseline, data were collected on personal factors (e.g. age and gender) by questionnaires and observers made MSP risk estimations as described in more detail in the next paragraph. At baseline and in a subsequent three-year follow-up, MSP prevalence (in the lower back, neck and shoulder regions) was assessed annually using a self-administered Dutch version of the Nordic Questionnaire for assessment of musculoskeletal symptoms (Kuorinka *et al.* 1987). Subjects were asked to indicate how often they had experienced neck, shoulder or low-back pain in the last 12 months: never, occasionally, regularly or prolonged. Musculoskeletal pain was defined when workers reported regular or prolonged pain in the 12 months prior to the completion of the questionnaire. Musculoskeletal pain during follow-up was defined as MSP in at least one of the three follow-up questionnaires. This definition of MSP was independent from MSP at baseline.

2.3. MSP risk estimation

For the risk estimations, workers were video-recorded at the workplace on four occasions, randomly selected over the course of a single workday. The duration of each video recording was 5–14 min depending on the variability of the worker's task. Observers allocated all workers to a total of 145 groups with similar tasks and physical loads based on the International Standard Classification of Occupations (1968). Videos of one fourth of the workers in each task group were randomly selected and were used for a structured observation protocol in which several

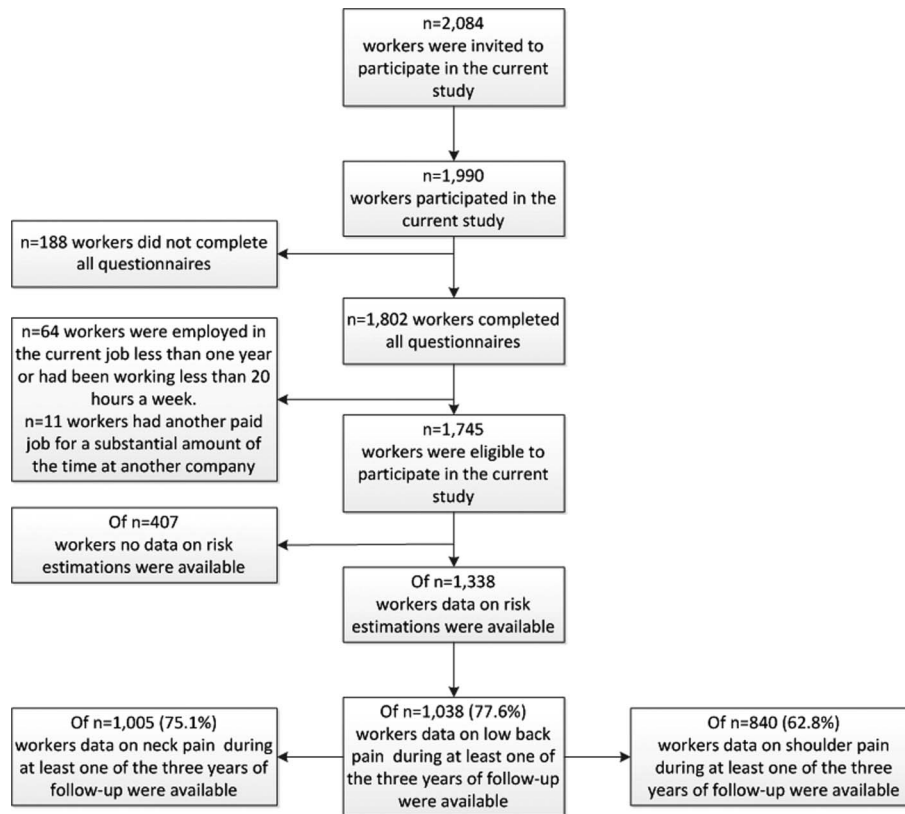


Figure 1. Flow chart of the workers' inclusion process.

kinematic exposure variables (e.g. trunk flexion angles and arm elevation angles) were assessed whilst replaying the video. After observing the video, the observers were asked: 'make an estimation of the risk of shoulder and neck pain and LBP respectively'. This estimated risk was expressed in three categories: low, moderate and high risk of pain. For all task groups, the modal estimated risk of the observed workers in a task group was assigned to all workers within that task group. This group approach has been shown to lead to efficient data collection that might even result in higher predictive individual estimates (Spielholz *et al.* 2001, Jansen and Burdorf 2003) than individual exposure assessment.

All video observations were conducted by a group of 31 well-trained and experienced research assistants with significant knowledge on human kinesiology, recruited from a group of students of the Faculty of Human Movements Sciences of the VU University Amsterdam. The observers were trained to minimise inter-observer variation and ascertain the repeatability of kinematics using a structured video-observation protocol. However, observers were not specifically trained in making risk estimations.

2.4. Statistical analyses

Crude associations between risk estimates of neck pain, shoulder pain and LBP, and the actual reported prevalence of pain during follow-up were assessed using logistic regression analysis. In each analysis, the estimated risk was considered as independent variable (on an ordinal scale categorised as low, moderate or high risk for MSP) and the prevalence of self-reported pain during the three years of follow-up (regardless of MSP at baseline) as a dichotomous dependent variable. Associations of estimated MSP risk (for shoulder pain, LBP and neck pain) and pain during the follow-up were assessed in two ways, resulting in a total of six logistic regression analyses; associations using the lowest risk score as a reference were assessed, as well as the association of risk estimates across the three risk categories. Since observers may have incorporated the effect of confounders (e.g. age and gender) into their MSP risk estimates, we decided not to correct for confounders in the present study. All statistical analyses were performed using SPSS (version 17.0.1).

3. Results

3.1. Population

The 1338 workers for who risk estimates were available had a mean age of 35.6 ± 8.8 years and 74% were male. For this group, data on the prevalence of MSP during at least one of the three years of follow-up were available for 1005 workers (neck pain), 1038 workers (LBP) and 840 workers (shoulder pain), which is 75, 78 and 63%, respectively (Table 1; Figure 1). Specifically, during at least one of the three years of follow-up, 334 (32%) workers reported neck pain, 528 (51%) workers reported LBP and 187 (22%) workers reported shoulder pain.

3.2. Associations

Associations of the estimated risk and the reported prevalence of neck and shoulder pain were significant (Table 2). Workers with estimated high risk of neck or shoulder pain had a significantly higher reported prevalence of neck and shoulder pain compared to workers with estimated low risk of neck and shoulder pain (odds ratio, OR: 1.45 (95% confidence interval, CI: 1.01–2.08) and 1.64 (95% CI: 1.05–2.55), respectively). Furthermore, there was a significant trend of MSP across the three levels of estimated risk for neck and shoulder pain (OR: 1.20 (95% CI: 1.00–1.43) and 1.28 (95% CI: 1.03–1.59), respectively). In contrast, workers with estimated high risk of LBP did not report a significantly higher prevalence of LBP compared to workers with an estimated low risk of LBP (OR: 1.27 (95% CI: 0.91–1.79)). The risk estimates of LBP across the three risk levels were also not significantly associated with the reported prevalence of LBP (OR: 1.14 (95% CI: 0.96–1.35)).

4. Discussion

4.1. Summary of findings and interpretation

The results of this study show that MSP risk estimates by trained observers were predictive for the occurrence of shoulder and neck pain, but not for LBP. Therefore, these estimates provide an assessment method that is crude, but useful for neck and shoulder pain risk assessment in ergonomics practice and in epidemiological studies.

Self-reports are often applied in epidemiologic studies while in ergonomic practice, subjective risk estimates by observers are more frequent. The subjective risk estimates are relatively cheap and easy to apply. However, it has been suggested that these estimates may be inaccurate because of the crude categorical scales (e.g. low, medium, high) often used (Spielholz *et al.* 2001, Burdorf 2010), among other reasons. Although there are appropriate methods to analyse these ordinal scales (Svensson 2001), categorisation is highly dependent upon a number of factors (e.g. the number of categories used, boundaries of these categories) affecting the accuracy of the measurement that can lead to an underestimation of risk associations (Lowe 2004, Kociolek and Keir 2010). Despite reported inaccuracies, we found that the subjectively estimated risk for neck and shoulder pain did predict the occurrence of pain in our study. This might be due to large number of subjects who were observed during a substantial period of their work time. This hypothesis is underlined by reviews presenting comparable (Fejer *et al.* 2006, Palmer and Smedley 2007) or even stronger exposure-response associations (Barrero *et al.* 2009a) in studies using subjective risk estimates compared to more objective measurement tools.

Our finding that risk estimates of LBP are not significantly associated with LBP prevalence corresponds with earlier studies questioning the accuracy of subjective risk estimates (e.g. Hansson *et al.* 2001, Balogh *et al.* 2004). The fact that observers were able to make risk estimates of shoulder and neck pain, but not of LBP, may not directly be attributable to a more complicated causal mechanism. The aetiology of MSP has only partly been revealed; it is highly likely that physical load as well as personal and psychosocial factors are involved. This holds not just for LBP, but also for neck and shoulder pain (Holmstrom *et al.* 1992, Hartvigsen *et al.* 2004, van den Heuvel *et al.* 2005, Eatough *et al.* 2012). More likely, physical loading of the lower back may be harder to assess through visual observation than the physical load on the neck and shoulder. Low-back load depends on a larger number of task variables (i.e. trunk posture, arm posture, load magnitude and load distance) than neck and shoulder load, which mainly depend on neck and shoulder flexion. The accuracy of assessing low-back load seems to be relevant since the risk of LBP was found to be associated with high low-back loads (Marras *et al.* 1995, Norman *et al.* 1998, Marras *et al.* 2010, Coenen *et al.* in press).

Table 1. Descriptive statistics (number of workers (n), gender, age (in years), number of working hours per week and years of employment in the current job) are reported in the upper rows. Self-reported pain is described in the lower rows.

	Neck pain			LBP			Shoulder pain		
	Study population	Drop-outs	Drop-outs	Study population	Drop-outs	Drop-outs	Study population	Drop-outs	Drop-outs
Descriptive statistics									
n	1338	333	300	1038	300	498	840	498	
Gender	$m = 992(74\%)$ $f = 340$	$m = 249(75\%)$ $f = 81$	$m = 219(74\%)$ $f = 78$	$m = 773(74\%)$ $f = 262$	$m = 219(74\%)$ $f = 78$	$m = 372(75\%)$ $f = 123$	$m = 620(74\%)$ $f = 217$	$m = 372(75\%)$ $f = 123$	
Age (years)	35.6 ± 8.8	34.5 ± 8.4	34.7 ± 8.9	35.8 ± 8.7	34.7 ± 8.9	35.1 ± 8.7	35.8 ± 8.8	35.1 ± 8.7	
Hours per week	38.2 ± 4.6	38.1 ± 4.5	37.9 ± 7.8	38.3 ± 4.7	37.9 ± 7.8	38.0 ± 7.8	38.3 ± 4.6	38.0 ± 7.8	
Years in job	9.6 ± 7.9	8.6 ± 7.5	8.8 ± 4.5	9.8 ± 7.9	8.8 ± 4.5	9.2 ± 4.7	9.8 ± 7.9	9.2 ± 4.7	
Baseline pain									
<i>Baseline</i>									
n	995	323	290	1028	290	488	828	488	
Pain	249 (25%)	64 (19%)	71 (24%)	396 (38%)	71 (24%)	43 (9%)	91 (11%)	43 (9%)	
Follow-up pain									
<i>FU-1</i>									
n	996			1015			832		
Pain	221 (22%)			239 (32%)			98 (12%)		
<i>FU-2</i>									
n	973			985			812		
Pain	205 (21%)			317 (32%)			77 (10%)		
<i>FU-3</i>									
n	970			981			824		
Pain	160 (16%)			273 (28%)			84 (10%)		
<i>At least one year of FU</i>									
n	1005			1038			840		
Pain	334 (32%)			528 (51%)			187 (22%)		

Notes: Number of workers who filled in the pain questionnaires and number of workers who reported pain at baseline in the three years of follow-up combined and during each of the three years of follow-up are reported. Percentages provided are the percentages of workers reporting pain (expressed as a percentage of the number of workers who filled in that specific questionnaire). Data of the group of workers who were eligible to participate in the current study (left column), of the groups of workers for whom data were included in the statistical analyses (for neck pain, LBP and shoulder pain, respectively) and those workers who dropped out the analyses (for neck pain, LBP and shoulder pain, respectively) have been described.

Table 2. Associations (odds ratios) for the risk estimates (low, moderate, high) of MSP and the prevalence of MSP during the three years of follow-up in the neck, lower back and shoulders.

Risk Factor	Pain	No pain	% Pain	OR 95% CI ¹	OR 95% CI ²
<i>Neck (n = 1046)</i>					
Low risk	58	144	29	Reference	1.20 (1.00–1.43)*
Moderate risk	137	286	32	1.19 (0.82–1.72)	
High risk	139	241	36	1.45 (1.01–2.08)*	
<i>Low-back (n = 1120)</i>					
Low risk	108	114	48	Reference	1.14 (0.96–1.35)
Moderate risk	233	243	49	1.01 (0.74–1.39)	
High risk	186	154	55	1.27 (0.91–1.79)	
<i>Shoulders (n = 872)</i>					
Low risk	43	194	18	Reference	1.28 (1.03–1.59)*
Moderate risk	83	291	22	1.29 (0.85–1.94)	
High risk	61	168	26	1.64 (1.05–2.55)*	

Notes: Both associations taking the lowest risk category as a reference category and associations across all three risk categories are reported. *denotes a significant association of the estimated risk and the reported pain. %pain, percentage of subjects with MSP within the groups of estimated risk of MSP; OR, odds ratio; CI, confidence interval. ¹Associations of three levels of risk using the lowest group as reference; ²associations across the three levels of estimated risk.

4.2. Methodological considerations

The results of the current study are based on a prospective cohort study of a large group of workers suggesting high methodological strength (Rothman and Greenland 2005). A limitation of the present study is that the workers were only observed for a single day, which could alter the reliability of the MSP risk estimates, since it has been shown that variation in work exposure between days may occur (Mathiassen *et al.* 2003, Svendsen *et al.* 2005). To obtain reliable exposure estimates, several sampling strategies can be chosen to reduce the measurement time without losing too much accuracy (e.g. sampling over multiple moments within or across days; Mathiassen *et al.* 2003). The choice for a sampling strategy depends on the tasks to be distinguished, variation in exposure within and between days and the reliability of the measurement method chosen (Mathiassen *et al.* 2003). For example, Liv *et al.* (2010) showed that when exposure data are correlated within days, efficiency can be improved by distributing the sample widely across the day or across days. We used four randomly selected observation moments for each worker over the course of a workday as it has been shown that a total of four observations are sufficient for group-based assessment of work exposures (Hoozemans *et al.* 2001). Not taking variability in exposure over days or weeks into account might result in an underestimation of the variability within persons. Nevertheless, as we assigned group-based risk estimates to each individual in a group, this was at least partially compensated by taking variability between subjects into account.

We observed a selection of workers for all task groups, while we assigned median task group values of MSP risk estimates to each individual within a specific task group. This group-based measurement approach is efficient and might lead to more reliable estimates of exposure, since random measurement errors may decrease compared to individual estimates of exposure (Hoozemans *et al.* 2001, Jansen and Burdorf 2003). The choice for a group estimate was made based on a pilot study showing that for postural observations, the largest variation derives from within-worker variation rather than between-worker variation (van der Beek and Frings-Dresen 1998). This proposition was confirmed, after collecting the data, by showing small within-group variability and large between-group variability (Ariëns *et al.* 2001). Therefore, the choice of a group sampling approach in our study seems justified.

In our study, associations have been assessed using ORs. It is generally known (e.g. Twisk 2003) that ORs can lead to overestimations of relative risks when the prevalence of the dependent variable is high. However, the use of ORs in epidemiological studies is widely accepted. Furthermore, in the present dataset, calculation of risk associations instead of ORs resulted in comparable conclusions (non-reported data).

In this study, consistent with earlier work (Hoogendoorn *et al.* 2000, Ariëns *et al.* 2001), MSP was defined when workers reported regular or prolonged pain in the last 12 months in at least one of the three annual follow-up questionnaires. The prevalence of pain according to this definition is relatively high (32, 51 and 22% for neck pain, LBP and shoulder pain, respectively; Table 1). Because of this high prevalence, it is expected that the group of workers reporting prolonged pain in the last 12 months is a heterogeneous group that might attenuate associations with the estimated risk of MSP. It could be that a more strict definition, for example, taking pain severity into account, would have led to stronger associations. Workers with MSP at baseline were included in the current

analysis, in contrast with earlier studies on this study population (Hoogendoorn *et al.* 2000, Ariëns *et al.* 2001). Since it is known that recurrence is a typical characteristic of MSP (Hestbaek *et al.* 2006, van Oostrom *et al.* 2011), excluding workers with pain at baseline seems rather arbitrary, since it cannot be excluded that workers without complaints at baseline had pain in previous years. Moreover, risk estimates cannot be affected by previous MSP, as observers were not aware of these estimates. Excluding workers with MSP in the past might therefore enhance the healthy worker effect while reducing the external validity of the results. Including these workers, therefore, seems reasonable.

Data on MSP risk estimates and on the reported prevalence of MSP during at least one of the three years of follow-up were available for 1338 workers who reported neck pain (75%), LBP (78%) and shoulder pain (63%) (Table 1). This rather substantial loss to follow-up could possibly have led to selection or attribution bias. However, descriptive statistics show that the group of workers who dropped out of the cohort during the three years of follow-up did not differ considerably in terms of gender, age and working hours a week (Table 1), which renders such bias unlikely. At baseline in the group of workers with follow-up data, pain was slightly higher compared to the group of dropouts, suggesting the opposite healthy worker effect.

We did not correct for confounders, such as age and gender in the analysis. It is plausible that observers incorporated the effect of these confounders in their MSP risk estimates. For example, it is possible that observers, in general, rate the risk of a task differently when it is performed by an old lady compared to a young man. As this already results in an implicit correction for these confounders, extra correction for these confounders seems redundant. Furthermore, group estimates were assigned to all members of each task group, which diminishes the effect of these confounders.

Furthermore, the MSP risk estimation was conducted by observers who were trained to make systematic observations of work postures. It has been shown that postural observations are sufficiently reliable in work-site situations (van der Beek *et al.* 1992, Bao *et al.* 2009). However, since regrettably no inter- and intra-observer reliability tests were performed for the risk estimates, differences in estimation between observers might have occurred. Finally, observers had substantial knowledge of ergonomics and human kinesiology; however, they were not specifically trained to make risk estimations. Ergonomic practitioners may be better trained to make such risk estimations. Therefore, the present results refer to judgments made by observers trained for postural observations and these estimates may not necessarily be the same as judgments by ergonomics experts.

5. Conclusion

From the present study, it can be concluded that trained observers are able to estimate the risk of neck and shoulder pain, however, observers have difficulty predicting an increased risk of LBP. Risk estimation of trained observers, therefore, provides a method that is crude but useful for neck and shoulder pain risk assessment in ergonomics practice and in epidemiological studies.

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