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An analysis on neck and upper limb musculoskeletal symptoms in Portuguese automotive assembly line workers

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Abstract

Assembly lines are related to health risks and work-related musculoskeletal disorders (WMSD), particularly of the neck and upper limbs (WULMSD). The assessment of perceived musculoskeletal symptoms is essential to WULMSD prevention, but studies in this field are lacking. A cross sectional survey on assembly line workers (n=270) was performed. The objective of this study was to analyze the frequency and distribution of upper limb musculoskeletal symptoms in assembly line workers. Participants were predominantly men, with ages between 30 and 40 years. Neck and upper limbs pain/discomfort were the most reported symptoms (35.9%), with intensity predominantly moderate or severe. General Health Status and past musculoskeletal injury were the variables more related to the existence of musculoskeletal symptoms; longer working life in the same company, as under 5 years, were related to higher intensity of symptoms. An early identification of musculoskeletal symptoms and health surveillance over time is of most importance to develop WRULMSD prevention measures.

1. INTRODUCTION

Although the introduction of new processes and automation decreased considerably some physical demands for the worker, assembly lines are associated to dynamic and high physical work tasks, as to repetitive movements and awkward postures, particularly in extreme joint positions with force application, as to poor recovery time (Buckley, 2016; Edimansyah et al., 2008; Graham, Agnew, & Stevenson, 2009; Holtermann et al., 2010; Landau et al., 2008; Sancini et al., 2013; Serranheira, Uva, & Lopes, 2008; Sluiter, 2006; Sundstrup et al., 2013a, 2016). Assembly lines are related to occupational health risks, work-related musculoskeletal disorders (WMSD), particularly of the neck and upper limbs (WULMSD) and absenteeism (Eatough, Way, & Chang, 2012; Gold, d'Errico, Katz, Gore, & Punnett, 2009; Hagberg et al., 2012; Kitis, Celik, Aslan, & Zencir, 2009; Pullopdissakul, Ekpanyaskul, Taptagaporn, Bundhukul, & Thepchatrri, 2013; Sadi, MacDermid, Chesworth, & Birmingham, 2007; Sancini et al., 2013; Spallek, Kuhn, Uibel, van Mark, & Quarcoo, 2010; Wang et al., 2009; Zebis et al., 2011).

Pain, disability, reduced quality of life, and loss of mental wellbeing are some of the main WULMSD consequences, with impact either in workers as in organizations (Andersen et al., 2010; Kee & Karwowski, 2007). These are prevalent and costly health conditions (Eerd et al.,

2016) and it is estimated that over 3 million of new workers have WULMSD (Pullopissakul et al., 2013). Recent studies report an average of 14.1 lost days in the period 2015-16 in European countries (Buckley, 2016).

To really understand the burden of upper limbs musculoskeletal disorders and develop prevention measures, it is essential to clearly identify the consequences, as musculoskeletal pain, disability, absenteeism, and its relation to the causes (Woolf, Vos, & March, 2010). Despite workers in assembly lines are exposed to work risk factors of most importance to WULMSD development, the contribution of psychosocial/organizational and individual risk factors should also be addressed, as their interaction, that changes accordingly to the worker (gender, age), workplace and organization (Eatough et al., 2012; Ellis et al., 2010; Johnston, Jimmieson, Jull, & Souvlis, 2009; Madan I, 2015; Oakman & Chan, 2015).

This highlights an early identification of workers at risk to develop WULMSD or at risk of worsening their symptoms in high demanding jobs. The assessment of perceived musculoskeletal symptoms may help distinguishing between the "physiological effects" from the "adverse effects" (Hagberg et al., 2012) and that is for the most importance. Pain and discomfort should be the musculoskeletal symptoms to assess, once they are the first ones reported by workers and the main causes to search clinical help (Buckle & Devereux, 1999; Buckle & Devereux, 2002; Werner, Franzblau, Gell, Ulin, & Armstrong, 2005; Zebis et al., 2011). Additionally, studies have been relating pain and discomfort to higher prevalence of musculoskeletal disorders (Bosch, de Looze, & van Dieën, 2007; Buckle & Devereux, 2002; Hansen, Edlund, & Bränholm, 2005; Schneider, Irastorza, & Copsey, 2010). Discomfort is a perception phenomenon related to pain, fatigue and perceived effort (Hagberg et al., 2012; Madeleine, 2010) and has been used as a subjective outcome for short term effects (Hamberg-van Reenen et al., 2008). It can be defined as the threshold level below where a worker can continue performing the task (Corlett & Bishop, 1976). Its evolution to chronic musculoskeletal pain suggests discomfort as a WMSD predictor (Hamberg-van Reenen et al., 2008).

Nevertheless, incidence rates and prevalence of upper limb musculoskeletal symptoms and disorders are difficult to find and compare, probably because there is not an universal standard for classification and diagnosis (da Costa & Vieira, 2008; Huisstede, Bierma-Zeinstra, Koes, & Verhaar, 2006; Shanahan & Sladek, 2011). In Portugal, the PROUD Study identified WMSD complaints in 2010 and reported, for 11% of the working population, WULMSD as more common in the Automotive Industry and Electronic and Electrical Assembly Lines (Miranda, Carnide, & Lopes, 2010). At the present, studies analyzing the distribution and frequency of upper limb musculoskeletal symptoms overtime are still missing (Kennedy et al., 2010; Zoer, Frings-Dresen, & Sluiter, 2014).

The objective of this study is to analyze the frequency and distribution of upper limb musculoskeletal symptoms in assembly line workers, according to individual factors (as age, work experience, gender...), symptoms existence (body area affected, intensity) and work perceived risk factors (manual handling, force application, posture, vibration, repetitive movements).

2. MATERIALS AND METHODS

2.1. Study Design and Population

A cross-sectional survey with 270 assembly workers was performed between the 17th September 2014 and 1st October 2014 in an automotive industry of Portugal.

A presentation of the study was made to Human Resources and Production. After the authorization of the company and ethics considerations (CNPD – Portuguese Data Protection Authority), a 20 minutes briefing to invite to participation was prepared and done in both shifts (n=1100). A flyer with a sum of the information was distributed. The workers that wanted to participate signed an informed consent (n=400) and filled a form with their email address and number of employee, for posterior codification.

Later an email with a link to the survey was sent to the participants. The online questionnaire was available during 15 days; 270 workers completed the questionnaire.

2.2. Online Questionnaire (WORK4HEALTH® PLATFORM)

The *Work4Health*® platform is an online questionnaire that collected information using SurveyMonkey.inc. Data was organized in 5 groups: demographic information, health data, health status perception, work-related symptoms and work-related information. Its construction had as basis the Nordic Musculoskeletal Questionnaire (Kuorinka et al., 1987), the SALTSA criteria document for WULMSD (Sluiter, Rest, & HW Frings-Dresen, 2001) and a baseline survey conducted by Bohr (Bohr, 2000).

To address the musculoskeletal symptoms, the SALTSA temporal criteria allowed to identify current cases (at the moment, do you have any pain or discomfort?) and a second moment was added (last month, did you have any pain or discomfort?) so that the baseline could be followed in time in other study. To determine the intensity of musculoskeletal symptoms, it was used the numeric pain scale (NPS), validated to measure both pain and discomfort (Johnson, 2005) and a body-chart to mark the body area affected. Regarding the health status, the first question of the Portuguese version of the 12-item short form Health Survey (Sf-12:v2) was used (Cunha-Miranda, Vaz-Patto, Micaelo, Teixeira, Silva, Saraiva-Ribeiro, 2010). Work-related information gathered the subjective information concerning work characteristics (Serranheira et al., 2008), musculoskeletal symptoms existence and its association to work. Other information, like service time or worker's age, was extracted from the company.

2.3 Data analysis

First, a description of the baseline and the analysis of the musculoskeletal symptoms distribution were made. Associations between the symptoms existence and intensity with gender, age, work experience, health past history, general health status and work-related data, were done using Chi-Square (χ^2) tests of independence and correlations tests. The analysis was carried out with SPSS software (IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp.).

3. RESULTS AND DISCUSSION

3.1. Baseline Characteristics

From the 400 workers that returned the informed consent, 272 answered the questionnaire and 270 completed it (24.5% of the 1100 assembly line workers).

3.1.1. Demographic Variables

Participants were mainly men (87%), right-handed (88%), with an average age of 36 years, working at the company in the last 15 years and the majority (65.2%) had secondary school education (Table 1).

3.1.2. Health Data

Health data shows that 46.7% had a normal body mass index (BMI) and 44.8% were overweight - World Health Organization (WHO) criteria.

Perceived general health status (GHS) was signed as "good" by 56.7% of the workers; from these, 13.7% had diseases and took medication. The majority (56.7%) referred a musculoskeletal injury in the past and 2.6% reported having a medical restriction at work for upper limbs conditions (Table 1).

3.1.3. Work-related Musculoskeletal Symptoms

Regarding discomfort or pain, 68.1% answered positively in the last month and 68.5% at the moment. The most reported locations for both periods were neck/cervical (7.4 last month and at the moment), lumbar spine (15.9 and 13%), shoulder (9.2 and 9.3%), wrist (5.9 and 5.5%) and the hands (5.5 and 5.6%) – Table 2. In sum, upper limbs were the body areas most reported in both periods.

The average intensity of musculoskeletal pain/discomfort was 4.02 and 3.66 for the last month and in that moment, respectively (SD=3.23 and 3.06).

Table 1. Demographic, individual and health characteristics.

Variable	N (%)	Mean	SD
Age (years)	-----	36.2	5.03
Gender		-----	-----
<i>Female</i>	33 (12.2)		
<i>Male</i>	237 (87.8)		
Admission (years)	-----	15.07	6.25
BMI		-----	-----
<i>Underweight</i>	1 (0.4)		
<i>Normal</i>	126 (46.7)		
<i>Overweight</i>	121 (44.8)		
<i>Obese</i>	22 (8.1)		
Education		-----	-----
<i>Lower school</i>	4 (1.5)		
<i>Middle School</i>	73 (27)		
<i>Secondary School</i>	176 (65.2)		
<i>Higher education</i>	17 (6.3)		
Diseases		-----	-----
<i>Yes</i>	57 (21.1)		
<i>No</i>	213 (78.9)		
Medication		-----	-----
<i>Yes</i>	67 (24.8)		
<i>No</i>	203 (75.2)		
Musculoskeletal injury (past)		-----	-----
<i>Yes</i>	153 (56.7)		
<i>No</i>	117 (43.3)		
General Health Status		-----	-----
<i>Excellent</i>	18 (6.7)		
<i>Very good</i>	47 (17.4)		
<i>Good</i>	153 (56.7)		
<i>Fair</i>	49 (18.1)		
<i>Poor</i>	3 (1.1)		

Table 2. Musculoskeletal Symptoms distribution.

	last month - n (%)	at the moment - n (%)
Discomfort/Pain		
<i>Yes</i>	184 (68.1)	185 (68.5)
<i>No</i>	84 (31.9)	85 (31.5)
Body area		
<i>Cervical/neck</i>	20 (7.4)	20 (7.4)
<i>Dorsal spine</i>	6 (2.2)	8 (3)
<i>Lumbar spine</i>	43 (15.9)	35 (13)
<i>Lower limbs</i>	43 (15.9)	46 (17)
<i>Upper limbs:</i>	72 (26.6)	76 (28.1)
<i>Shoulder</i>	25 (9.2)	25 (9.3)
<i>Arm</i>	6 (2.3)	7 (2.6)
<i>Elbow</i>	3 (1.1)	7 (2.6)
<i>Forearm</i>	7 (2.6)	7 (2.6)
<i>Wrist</i>	16 (5.9)	15 (5.5)
<i>Hand</i>	15 (5.5)	15 (5.6)

3.1.4. Work-related data

Workers were mainly line operators (46.7%), although inspectors and break-down mechanics also participated (14.4 and 12.6%, respectively).

Considering the perceived work risk factors, manual material handling (MMH) was present in 59.3% of a workday (46.88% of these participants reported it as being present in 25% of the day), repetitive movements in 91.9% of the day (100% of a working day for the majority of participants), tasks with force application were reported by 83.3% of the workers (62.22% referred 25 to 50% of a working day), static positions in 76.3% of a working day (in 25% of the day for 41.26% of the participants reporting static positions) and power tools vibration was mentioned by 52.6% of the participants (for 33% of the participants was present in 25% of their working day).

More than half of the participants (54.4%) answered positively when questioned about the musculoskeletal complaints and its perceived association to work demands.

3.2. Neck and upper limb musculoskeletal symptoms

Concerning the population with neck and upper limb symptoms (n=96), 16 women (48%) reported neck/cervical, shoulder and hand discomfort/pain; 80 men (33.75%) reported symptoms in neck/cervical, shoulder and wrist.

Regarding work experience, classes were created to determine the distribution of neck and upper limbs symptoms existence (0-5y; 6-10y; 11-15y; 16-20y; +20y). The most representative periods of work experience were 0 to 5 years (15.6%) and 16 to 20 years (62.5%).

Applying the same analysis to age's classes, 32.3% of the workers with discomfort/pain had 31 to 35 years and 35.4% had 36-40 years (67.7% of the population with neck and upper limbs symptoms).

From the 96 workers, 59 reported a musculoskeletal injury in the past (61.46%).

At the survey moment the majority of workers with neck and upper limbs musculoskeletal symptoms reported pain/discomfort intensity above 4 in NPS (Table 3). Analyzing the intensity categories and the GHS, 51% of the "good" responses were classified in the "moderate intensity", against 28.6% in the "severe". The "fair" responses were mainly in the "severe" category – 61.54%.

Table 3. Intensity by category.

Discomfort and Pain Intensity	n (%)
Mild discomfort/pain (1-3)	18 (18.8)
Moderate discomfort/pain (4-6)	39 (40.6)
Severe discomfort/pain (7-10)	39 (40.6)

3.3. Associations between variables

The "at the moment" data was chosen to analyze the possible associations between variables.

Associations between having/not having musculoskeletal symptoms with all the groups of variables were determined. No relations were found with age ($\chi^2 = -0.020$; $p=0.794$; $n=270$), work experience ($\chi^2 = -0.016$; $p=0.791$; $n=270$) or professional designation ($\chi^2 = 0.714$; $p=0.023$; $n=270$). Injury in the past had significant correlation to symptoms existence ($r=0.212$; $p=0.01$), as GHS ($r=-0.308$; $p=0.01$).

Other analysis was made concerning the workers only with neck and upper limbs musculoskeletal symptoms (n=96). Intensity of discomfort/pain was only significant associated to GHS ($\chi^2 = 0.24$; $p=0.018$; $n=96$). For age or work experience no associations were found ($\chi^2 = 0.059$; $p=0.571$; $n=96$) ($\chi^2 = 0.066$; $p=0.523$; $n=96$).

3.4. Discussion

Being men, with ages between 30 and 40 years, with an average of 15 years working in the same company, were the most common characteristics in this survey, in agreement with other studies (Ferguson, Marras, Allread, Knapik, & Splittstoesser, 2012; Gold et al., 2009; Kitis et al., 2009; Menegon & Fischer, 2012; Ohlander, Keskin, Weiler, Stork, & Radon, 2016; Pullopdissakul et al., 2013). Regarding musculoskeletal symptoms, despite the different methods and criteria used, neck and upper limbs were also the most reported body areas, as in other studies (Colombini & Occhipinti, 2006; Eatough et al., 2012; Eerd et al., 2016; Gold et al., 2009; Kitis et al., 2009; Sundstrup et al., 2013b). Referring the intensity of musculoskeletal symptoms, in work context the majority of complaints intensity appear to be mild; our study points out higher values, being musculoskeletal pain over 4 in NPS considered as significant (Werner et al., 2005).

Despite the small number of associations between variables, GHS and musculoskeletal injury in the past appear to be the most important variables related to musculoskeletal symptoms existence and intensity. As reported, participants with lower GHS, as those having a past musculoskeletal injury, rated discomfort/pain intensity with higher values. When people have been working for years in assembly lines, chronic conditions are expected; physically demanding jobs have 80 to 150% higher risk to develop chronic health conditions (Shanahan & Sladek, 2011). Along with this, the relation of perceived health status with chronicity (Koolhaas, van der Klink, de Boer, Groothoff, & Brouwer, 2013), could suggest the presence of chronic health conditions in this population.

Although GHS and past musculoskeletal injury were the variables more related to the existence of musculoskeletal symptoms of the neck and upper limbs, longer working life in the same company (over 15 years) had associations to higher intensity symptoms as smaller periods (under 5 years). These results could suggest that chronic conditions prevention should start with younger workers (Macdonald, Driscoll, Stuckey, & Oakman, 2012). These data, along with the fact that our results showed no associations to age, goes on with other study, that reports that even though age and length of service at the same company could be expected to correlate with musculoskeletal symptoms, not existing associations could mean that the allocation of workers in certain tasks can influence musculoskeletal symptoms (Landau et al., 2008). A hypothesis for the authors is that the younger workers could be allocated to "unfavourable" tasks, as the older ones could go to more "favourable". Other studies report lower work experience and its relation to musculoskeletal symptoms (MacDonald, Cairns, Angus, & Stead, 2012). Additionally, our results suggests that having neck and upper limb musculoskeletal symptoms is independent also of gender and education (Loeppke, Edington, Bender, & Reynolds, 2013; Santos & Moreira, 2013; Werner et al., 2005). Gender appears to be not important to determine job allocation in this population. Criteria and health recommendations for job allocation could be an important step.

There are some limitations to point out on this survey. Firstly, the low rate of participation and therefore is limited to compare with other automotive assembly lines. On the other hand, WULMSD have a multifactorial etiology and psychosocial/organizational and work risk factors were not fully addressed in this survey. Perceived work-related information should be analyzed together with an assessment of work risk factors, work ability and clinical examination. Further analysis should determine if our findings could be related to low levels of work ability and quality of life (Sjøgaard, Justesen, Murray, Dalager, & Sjøgaard, 2014).

Despite a consensus concerning predictive factors for musculoskeletal pain and discomfort does not exist (Stewart et al., 2014), our study points out the age under 40, working life over 15 years and GHS as the variables more related to those complaints. More studies on predictive models are important, as monitoring those workers during a period at least of 6 months (Nelson et al., 2006).

4 CONCLUSIONS

This survey identified the frequencies and distribution of musculoskeletal symptoms, individual characteristics, health and work-related perceived information. Age and gender have no

explanatory values for musculoskeletal symptoms. GHS and past musculoskeletal injury were the variables with association to the existence of musculoskeletal symptoms of the neck and upper limbs.

An early identification of musculoskeletal symptoms and continuous health surveillance is of most importance to develop WULMSD prevention measures. Future studies should focus on surveillance methods and following these workers for a broader period.

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REFERENCES

- Andersen, L. L., Zebis, M. K., Pedersen, M. T., Roessler, K. K., Andersen, C. H., Pedersen, M. M., ... Sjøgaard, G. (2010). Protocol for work place adjusted intelligent physical exercise reducing musculoskeletal pain in shoulder and neck (VIMS): a cluster randomized controlled trial. *BMC Musculoskeletal Disorders*, *11*, 173.
- Bohr, P. C. (2000). Efficacy of Office Ergonomics Education. *Journal of Occupational Rehabilitation*, *10*(4), 243–255.
- Bosch, T., de Looze, M. P., & van Dieën, J. H. (2007). Development of fatigue and discomfort in the upper trapezius muscle during light manual work. *Ergonomics*, *50*(2), 161–77.
- Buckle, P., & Devereux, J. (1999). Work-related neck and upper limb musculoskeletal disorders. Luxembourg.
- Buckle, P. W., & Devereux, J. J. (2002). The nature of work-related neck and upper limb musculoskeletal disorders. *Applied Ergonomics*, *33*(3), 207–17.
- Buckley, P. (2016). Work-related Musculoskeletal Disorder (WRMSDs) Statistics, Great Britain 2016. Health and Safety Executive (HSE).
- Colombini, D., & Occhipinti, E. (2006). Preventing upper limb work-related musculoskeletal disorders (UL-WMSDs): new approaches in job (re)design and current trends in standardization. *Applied Ergonomics*, *37*(4), 441–50.
- Corlett, E. N., & Bishop, R. P. (1976). A technique for measuring postural discomfort. *Ergonomics*, *9*, 175–182.
- Cunha-Miranda L., Vaz-Patto J, Micaelo M., Teixeira A, Silva C, Saraiva-Ribeiro J, F. S. G. (2010). The 12-Item Short Form Health Survey (SF-12:v2) – Validação da escala para uso em Portugal Resultados do FRAIL Study. *Acta Reumatologia Port.*
- da Costa, B. R., & Vieira, E. R. (2008). Stretching to reduce work-related musculoskeletal disorders: a systematic review. *Journal of Rehabilitation Medicine: Official Journal of the UEMS European Board of Physical and Rehabilitation Medicine*, *40*(5), 321–8.
- Eatough, E. M., Way, J. D., & Chang, C.-H. (2012). Understanding the link between psychosocial work stressors and work-related musculoskeletal complaints. *Applied Ergonomics*, *43*(3), 554–63.
- Edimansyah, B. A., Rusli, B. N., Naing, L., Mohamed Rusli, B. A., Winn, T., & Tengku Mohamed Ariff, B. R. H. (2008). Self-perceived depression, anxiety, stress and their relationships with psychosocial job factors in male automotive assembly workers. *Industrial Health*, *46*(1), 90–100. DOI: [10.2486/indhealth.46.90](https://doi.org/10.2486/indhealth.46.90).
- Eerd, D. Van, Munhall, C., Irvin, E., Rempel, D., Brewer, S., Van Der Beek, A. J., ... Amick, B. (2016). Effectiveness of workplace interventions in the prevention of upper extremity musculoskeletal disorders and symptoms: an update of the evidence. *Occup Environ Med*, *73*, 62–70.

- Ellis, N., Johnston, V., Gargett, S., MacKenzie, A., Strong, J., Battersby, M., ... Jull, G. (2010). Does self-management for return to work increase the effectiveness of vocational rehabilitation for chronic compensated musculoskeletal disorders? Protocol for a randomised controlled trial. *BMC Musculoskeletal Disorders*, 11, 115.
- Ferguson, S. a, Marras, W. S., Allread, W. G., Knapik, G. G., & Splittstoesser, R. E. (2012). Musculoskeletal disorder risk during automotive assembly: current vs. seated. *Applied Ergonomics*, 43(4), 671–8.
- Gold, J. E., d'Errico, A., Katz, J. N., Gore, R., & Punnett, L. (2009). Specific and non-specific upper extremity musculoskeletal disorder syndromes in automobile manufacturing workers. *American Journal of Industrial Medicine*, 52(2), 124–32.
- Graham, R. B., Agnew, M. J., & Stevenson, J. M. (2009). Effectiveness of an on-body lifting aid at reducing low back physical demands during an automotive assembly task: assessment of EMG response and user acceptability. *Applied Ergonomics*, 40(5), 936–42.
- Hagberg, M., Violante, F. S., Bonfiglioli, R., Descatha, A., Gold, J., Evanoff, B., & Sluiter, J. K. (2012). Prevention of musculoskeletal disorders in workers: classification and health surveillance - statements of the Scientific Committee on Musculoskeletal Disorders of the International Commission on Occupational Health. *BMC Musculoskeletal Disorders*, 13(1), 109.
- Hamberg-van Reenen, H. H., van der Beek, A. J., Blatter, B. M., van der Grinten, M. P., van Mechelen, W., & Bongers, P. M. (2008). Does musculoskeletal discomfort at work predict future musculoskeletal pain? *Ergonomics*, 51(5), 637–48.
- Hansen, A., Edlund, C., & Bränholm, I.-B. (2005). Significant resources needed for return to work after sick leave. *Work (Reading, Mass.)*, 25(3), 231–40.
- Holtermann, A., Jørgensen, M. B., Gram, B., Christensen, J. R., Faber, A., Overgaard, K., ... Søgaard, K. (2010). Worksite interventions for preventing physical deterioration among employees in job-groups with high physical work demands: background, design and conceptual model of FINALE. *BMC Public Health*, 10, 120.
- Huisstede, B. M. a, Bierma-Zeinstra, S. M. a, Koes, B. W., & Verhaar, J. a N. (2006). Incidence and prevalence of upper-extremity musculoskeletal disorders. A systematic appraisal of the literature. *BMC Musculoskeletal Disorders*, 7, 7.
- Johnson, C. (2005). Measuring Pain. Visual Analog Scale Versus Numeric Pain Scale: What is the Difference? *Journal of Chiropractic Medicine*, 4(1), 43–4.
- Johnston, V., Jimmieson, N. L., Jull, G., & Souvlis, T. (2009). Contribution of individual, workplace, psychosocial and physiological factors to neck pain in female office workers. *European Journal of Pain (London, England)*, 13(9), 985–91.
- Kee, D., & Karwowski, W. (2007). A comparison of three observational techniques for assessing postural loads in industry. *International Journal of Occupational Safety and Ergonomics: JOSE*, 13(1), 3–14.
- Kennedy, C. a, Amick, B. C., Dennerlein, J. T., Brewer, S., Catli, S., Williams, R., ... Rempel, D. (2010). Systematic review of the role of occupational health and safety interventions in the prevention of upper extremity musculoskeletal symptoms, signs, disorders, injuries, claims and lost time. *Journal of Occupational Rehabilitation*, 20(2), 127–62.
- Kitis, A., Celik, E., Aslan, U. B., & Zencir, M. (2009). DASH questionnaire for the analysis of musculoskeletal symptoms in industry workers: a validity and reliability study. *Applied Ergonomics*, 40(2), 251–5.
- Koolhaas, W., van der Klink, J. J. L., de Boer, M. R., Groothoff, J. W., & Brouwer, S. (2013). Chronic health conditions and work ability in the ageing workforce: the impact of work conditions, psychosocial factors and perceived health. *International Archives of Occupational and Environmental Health*.

- Kuorinka, I., Jonsson, B., Kilbom, a, Vinterberg, H., Biering-Sørensen, F., Andersson, G., & Jørgensen, K. (1987). Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms. *Applied Ergonomics*, 18(3), 233–7.
- Landau, K., Rademacher, H., Meschke, H., Winter, G., Schaub, K., Grasmueck, M., ... Schulze, J. (2008). Musculoskeletal disorders in assembly jobs in the automotive industry with special reference to age management aspects. *International Journal of Industrial Ergonomics*, 38(7–8), 561–576.
- Loeppke, R., Edington, D., Bender, J., & Reynolds, A. (2013). The association of technology in a workplace wellness program with health risk factor reduction. *Journal of Occupational and Environmental Medicine / American College of Occupational and Environmental Medicine*, 55(3), 259–64.
- MacDonald, L., Cairns, G., Angus, K., & Stead, M. (2012). Evidence review: social marketing for the prevention and control of communicable disease. Stockholm.
- Macdonald, W., Driscoll, T., Stuckey, R., & Oakman, J. (2012). Occupational health and safety in Australia. *Industrial Health*, 50(3), 172–9.
- Madan I, G. P. (2015). The management of musculoskeletal disorders in the workplace. *Best Practice & Research Clinical Rheumatology*, 29(3), 345–355.
- Madeleine, P. (2010). On functional motor adaptations: from the quantification of motor strategies to the prevention of musculoskeletal disorders in the neck-shoulder region. *Acta Physiologica (Oxford, England)*, 199 Suppl, 1–46.
- Menegon, F. A., & Fischer, F. M. (2012). Musculoskeletal reported symptoms among aircraft assembly workers: A multifactorial approach. *Work*, 41(SUPPL.1), 3738–3745.
- Miranda, L. C., Carnide, F., & Lopes, F. (2010). Prevalence of rheumatic occupational diseases – PROUD STUDY. *Acta Reumatológica Portuguesa*, 35(2), 215–226.
- Nelson, A., Matz, M., Chen, F., Siddharthan, K., Lloyd, J., & Fragala, G. (2006). Development and evaluation of a multifaceted ergonomics program to prevent injuries associated with patient handling tasks. *International Journal of Nursing Studies*, 43(6), 717–33.
- Oakman, J., & Chan, S. (2015). Risk management: Where should we target strategies to reduce work-related musculoskeletal disorders? *Safety Science*, 73, 99–105.
- Ohlander, J., Keskin, M.-C., Weiler, S., Stork, J., & Radon, K. (2016). Snap-fits and upper limb functional limitations in German automotive workers. *Occupational Medicine (Oxford, England)*, kqw050.
- Pullopdisakul, S., Ekpanyaskul, C., Taptagaporn, S., Bundhukul, A., & Thepchatri, A. (2013). Upper extremities musculoskeletal disorders: prevalence and associated ergonomic factors in an electronic assembly factory. *International Journal of Occupational Medicine and Environmental Health*, 26(5), 751–761.
- Sadi, J., MacDermid, J. C., Chesworth, B., & Birmingham, T. (2007). A 13-year cohort study of musculoskeletal disorders treated in an autoplant, on-site physiotherapy clinic. *Journal of Occupational Rehabilitation*, 17(4), 610–622.
- Salaffi, F., Ciapetti, a, & Carotti, M. (2012). Pain assessment strategies in patients with musculoskeletal conditions. *Reumatismo*, 64(4), 216–29.
- Sancini, A., Capozzella, A., Caciari, T., Tomei, F., Nardone, N., Scala, B., ... Ciarrocca, M. (2013). Risk of upper extremity biomechanical overload in automotive facility. *Biomedical and Environmental Sciences: BES*, 26(1), 70–5.
- Santos, C. S., & Moreira, S. (2013). *PNSOC - PROGRAMA NACIONAL DE SAÚDE OCUPACIONAL: 2º ciclo - 2013/2017*. Lisboa. Retrieved from <https://www.dgs.pt>.
- Schneider, E., Irastorza, X., & Copey, S. (2010). OSH in figures: Work-related musculoskeletal disorders in the EU — Facts and figures. LUXEMBOURG.

- Serranheira, F., Uva, A. S., & Lopes, F. (2008). *Cadernos/Avulso #05 Lesões Músculo-Esqueléticas e Trabalho: alguns métodos de avaliação do risco*. Lisboa: Sociedade Portuguesa de Medicina do Trabalho.
- Shanahan, E. M., & Sladek, R. (2011). Shoulder pain at the workplace. *Best Practice & Research. Clinical Rheumatology*, 25(1), 59–68.
- Sjøgaard, G., Justesen, J. B., Murray, M., Dalager, T., & Sjøgaard, K. (2014). A conceptual model for worksite intelligent physical exercise training--IPET--intervention for decreasing life style health risk indicators among employees: a randomized controlled trial. *BMC Public Health*, 14(1), 652.
- Sluiter, J. K. (2006). High-demand jobs: age-related diversity in work ability? *Applied Ergonomics*, 37(4), 429–40.
- Sluiter, J. K., Rest, K. M., & HW Frings-Dresen, M. H. (2001). Criteria document for evaluating the work-relatedness of upper extremity musculoskeletal disorders. *Scandinavian Journal of Work, Environment & Health*, 27(c), 1–102.
- Spallek, M., Kuhn, W., Uibel, S., van Mark, A., & Quarcoo, D. (2010). Work-related musculoskeletal disorders in the automotive industry due to repetitive work - implications for rehabilitation. *Journal of Occupational Medicine and Toxicology (London, England)*, 5, 6.
- Stewart, S. K., Rothmore, P. R., Doda, D. V. D., Hiller, J. E., Mahmood, M. A., & Pisaniello, D. L. (2014). Musculoskeletal pain and discomfort and associated worker and organizational factors: a cross-sectional study. *Work (Reading, Mass.)*, 48(2), 261–71.
- Sundstrup, E., Jakobsen, M. D., Andersen, C. H., Jay, K., Persson, R., Aagaard, P., & Andersen, L. L. (2013a). Participatory ergonomic intervention versus strength training on chronic pain and work disability in slaughterhouse workers: study protocol for a single-blind, randomized controlled trial. *BMC Musculoskeletal Disorders*, 14(1), 67.
- Sundstrup, E., Jakobsen, M. D., Andersen, C. H., Jay, K., Persson, R., Aagaard, P., & Andersen, L. L. (2013b). Participatory ergonomic intervention versus strength training on chronic pain and work disability in slaughterhouse workers: study protocol for a single-blind, randomized controlled trial. *BMC Musculoskeletal Disorders*, 14(1), 67.
- Sundstrup, E., Jakobsen, M. D., Brandt, M., Jay, K., Aagaard, P., & Andersen, L. L. (2016). Associations between biopsychosocial factors and chronic upper limb pain among slaughterhouse workers: cross sectional study. *BMC Musculoskeletal Disorders*, 17(1), 104.
- Wang, P.-C., Rempel, D. M., Hurwitz, E. L., Harrison, R. J., Janowitz, I., & Ritz, B. R. (2009). Self-reported pain and physical signs for musculoskeletal disorders in the upper body region among Los Angeles garment workers. *Work (Reading, Mass.)*, 34(1), 79–87.
- Werner, R. A., Franzblau, A., Gell, N., Ulin, S. S., & Armstrong, T. J. (2005). A longitudinal study of industrial and clerical workers: predictors of upper extremity tendonitis. *Journal of Occupational Rehabilitation*, 15(1), 37–46.
- Woolf, A. D., Vos, T., & March, L. (2010). How to measure the impact of musculoskeletal conditions. *Best Practice & Research. Clinical Rheumatology*, 24(6), 723–32.
- Zebis, M. K., Andersen, L. L., Pedersen, M. T., Mortensen, P., Andersen, C. H., Pedersen, M. M., ... Sjøgaard, G. (2011). Implementation of neck/shoulder exercises for pain relief among industrial workers: a randomized controlled trial. *BMC Musculoskeletal Disorders*, 12(1), 205.
- Zoer, I., Frings-Dresen, M. H. W., & Sluiter, J. K. (2014). Are musculoskeletal complaints, related work impairment and desirable adjustments in work age-specific? *International Archives of Occupational and Environmental Health*, 87(6), 647–654.