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Occupational risk factors for cardiovascular and musculoskeletal disorders in German automotive workers

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Abbreviations

BMI - Body mass index

CVD - Cardiovascular diseases

MSD - Musculoskeletal disorders

ULFL - Upper limb functional limitations

Publication list

Shift work and hypertension: prevalence and disease pathways in a German car manufacturing company. 2015. Am J Ind Med **58**(5):549–60.

Snap-fits and upper limb functional limitations in German automotive workers. 2016. Occup Med (Lond) **66**(6):471–477.

Zusammenfassung

Hintergrund: Arbeiternehmer in der Automobilindustrie sind vielen beruflichen Belastungsfaktoren ausgesetzt. Sie arbeiten häufig in Schichtsystemen, die möglicherweise den zirkadianen Rhythmus stören und damit potentiell negative Auswirkungen auf das Herz-Kreislauf-System verursachen können. Dennoch sind Studien über den Zusammenhang von Schichtarbeit und Bluthochdruck noch nicht schlüssig. Darüber hinaus ist in der Montage der Anteil repetitiver manueller Arbeit durch Clipverbindungen in den letzten Jahren stark angestiegen. Durch manuelle Belastung werden die Autoteile durch Clipverbindungen zusammengedrückt, was potentiell zu muskuloskelettalen Beschwerden im Hand-Arm-Bereich führen kann. In einem großen deutschen Automobilunternehmen haben wir das Risiko für Bluthochdruck bei Schichtarbeitern sowie mögliche muskuloskelettale Beschwerden im Hand-Arm-Bereich bei Montagearbeitern mit Clipsarbeit untersucht.

Methode: Querschnittsdaten eines freiwilligen Gesundheits-Check-ups und Daten des Betriebsregisters lieferten uns Informationen über die Demographie, den kardiovaskulären Status, den funktionalen Status des Hand-Arm-Bereichs, der Exposition mit Schicht- und Clipsarbeit, sowie Daten potentieller Störfaktoren aller Arbeiter. Die Zusammenhänge zwischen Schichtarbeit und Bluthochdruck sowie zwischen Clipsarbeit und der Funktionalität des Hand-Arm-Bereichs wurden mittels logistischer Regressionsmodelle analysiert und für potentielle Störfaktoren adjustiert. Darüber hinaus haben wir Mediationseffekte zwischen Schichtarbeit und Bluthochdruck durch psychosoziale, verhaltensbedingte und physiologische Faktoren sowie die Dosis-Wirkungs-Beziehung zwischen Clipsarbeit und der Funktionalität der oberen Extremitäten analysiert.

Ergebnisse: Bei 25353 Arbeitnehmern hing Schichtarbeit ohne Nachtschicht statistisch signifikant mit Bluthochdruck zusammen (OR 1,15; 95% CI 1,02-1,30). Als potentielle Mediationsfaktoren wurden Schlafstörungen, erhöhter BMI und physische Inaktivität beobachtet. Bei 10722 Mitarbeitern in der Produktion waren mindestens 25 Monate Exposition von Clipsarbeit mit Einschränkungen im Hand-Arm-Bereich statistisch signifikant assoziiert (OR=2,44; 95% CI 1,52-3,92). Es wurde keine Dosis-Wirkung-Beziehung zwischen Clipsarbeit und Einschränkungen im Hand-Arm-Bereich gefunden.

Diskussion/Fazit: Schichtarbeit ohne Nachtschicht führt möglicherweise zu Bluthockdruck, potentiell vermittelt durch Schlafstörungen, erhöhtem BMI und

körperliche Inaktivität. Darüber hinaus könnten die zunehmend in der Produktion eingesetzten Clipsmontagen ein neuer Risikofaktor für muskuloskelettale Beschwerden im Hand-Arm-Bereich sein. Obwohl weitere longitudinale Studien erforderlich sind, um die Kausalität der untersuchten Zusammenhänge zu bestärken, sollten Betriebsärzte die potentiell negativen Auswirkungen von Schichtarbeit und Clipsarbeit rechtzeitig erkennen.

Abstract

Background: Automotive workers are subjected to various occupational exposures. Workers mostly operate in shifts, potentially implying a disturbed circadian rhythm and negative effects on the cardiovascular system. Studies on shift work and hypertension are however inconclusive. Moreover, repetitive manual work through assembling of car parts using snap-fits has during the last decade increased. Snap-fits enable the parts to be pushed together by applying manual force, potentially with a negative effect on workers upper limb function. In a large German automotive company, we investigated shift workers on their hypertension risk, and the upper limb function of assembly workers subjected to a large-scale expansion of the use of snap-fits.

Methods: Cross-sectional data from voluntary company check-ups and company registers provided workers' demographics, cardiovascular status, upper limb functional status, shift work and snap-fit assembly exposure, and data on potential confounders. Associations between shift work and hypertension as well as between snap-fit assembly and upper limb functional limitations (ULFL) were analyzed by logistic regression adjusted for confounders. We additionally investigated mediation effects between shift work and hypertension by psychosocial, behavioral and physiological factors, and the potential of a dose-response relationship between snap-fit assembly and ULFL.

Results: In 25,353 workers, shift work without nights was statistically significantly associated with hypertension (OR=1.15 95% CI 1.02-1.30), potentially mediated by sleep disorders, high BMI and physical inactivity. In 10,722 blue-collar production workers, exposure to snap-fit assembly at least 25 months showed increased odds of ULFL (OR=2.44 95% CI 1.52-3.92). No dose-response relationship between snap-fit duration and odds of ULFL was found.

Discussion/Conclusion: Shift work without nights may lead to hypertension, potentially via sleeping problems, higher BMI and physical inactivity. Further, the continuously increasing use of snap-fits in car assembling might constitute a novel occupational risk factor for ULFL. Despite the need for longitudinal studies, enabling causal inference regarding investigated associations, company physicians should recognize the potential negative effects from shift work and snap-fit assembly.

Introduction

Automotive workers are exposed to various occupational risk factors. For instance, as automotive production largely is a 24-hours operative industry, work is often organized into shifts, which has seemingly unforeseen consequences on workers' health.

To date, shift work has for example been associated with weight gain (Puttonen, Harma et al. 2010, Esquirol, Perret et al. 2011), increased risks of developing the metabolic syndrome (Puttonen, Harma et al. 2010, Esquirol, Perret et al. 2011) and cardiovascular disease (CVD) (Vyas, Garg et al. 2012). CVD in shift workers is possibly triggered by a disrupted circadian rhythm (Hale, Williams et al. 1971, Vyas, Garg et al. 2012). Subsequently, CVD is likely mediated through interdependent stress pathways: behavioral changes such as increased smoking, weight gain and sleeping problems, psychosocial stressors like work-life imbalance and work stress, and physiological stressors such as activation of the autonomic nervous system, and a changed lipid and glucose metabolism (Puttonen, Harma et al. 2010).

Another physiological reaction is increased blood pressure; shift work changes the diurnal variation in blood pressure, flattening the normal nocturnal blood pressure dip (Kitamura, Onishi et al. 2002, Wolk, Gami et al. 2005, Mosendane and Raal 2008). Persistently high blood pressure – hypertension – is closely related to CVD, sharing many risk factors and potentially a similar pathophysiology (Halperin, Sesso et al. 2006). However, despite synthesized evidence of shift workers' excess risk of CVD (Vyas, Garg et al. 2012), studies on shift work and hypertension are inconclusive (Morikawa, Nakagawa et al. 1999, Karlsson, Knutsson et al. 2001, Sakata, Suwazono et al. 2003, Oishi, Suwazono et al. 2005, Nazri, Tengku et al. 2008, Hublin, Partinen et al. 2010, Sfreddo, Fuchs et al. 2010).

Another frequent occupational risk factor in automotive production is repetitive manual work, typically performed in the assembly line. The last decade, assembling of car parts is increasingly realized using so-called snap-fit fasteners (Salmanzadeh, Meyer et al. 2010). Snap-fits lock together from manual insertion force; through pushing the elastic snap-fit parts together they deform, enabling the attachment of the car parts. Locked together, the parts recover their original shape, accompanied by an audible or tactile feedback (Genc, Robert et al. 1998, Bonenberger 2005).

Repetitive assembly work in automotive workers has in general been linked to upper limbs musculoskeletal disorders (Spallek, Kuhn et al. 2010). However, despite being associated with strain in the thenar and triceps musculature (Salmanzadeh, Meyer et al. 2010), snap-fit assembly is not well studied in relation to workers' musculoskeletal function.

Aims

As shift work and snap-fit assembly potentially constitute risk factors for car manufacturing workers' health, this doctoral thesis aimed at investigating the association between:

1. shift work and hypertension
2. snap-fit assembly and upper limb functional limitations (ULFL)

Methods

Study population

The study population consisted of workers at a German car manufacturing company who recurrently since mid July 2006 participate in the company's standardized health check-ups. The exams comprise a voluntary add-on examination (response 93%) made in conjunction with the company's standard compulsory preventive health control, during which extensive subjective and objective health data are collected from each worker. The check-up data combined with company records yielded data on workers' demographics, cardiovascular status, ULFL, and exposure to shift work and snap-fit assembly. For the analyses presented here, baseline check-up data extracted in July 2012 and February 2015 were used (Table 1).

For the analysis of shift work and hypertension, a population of 38,005 workers was restricted through excluding workers for whom the time of shift status measurement and blood pressure examination deviated more than 1 year (N=8,424), and workers with unknown shift status (N=742 part time workers) or missing blood lipid values (N=3,496). The study population for these first analyses thus included N=25,343 workers with no missing data.

A sample of 41,939 workers for the analysis of snap-fit and ULFL was restricted to only blue-collar production workers (N=16,089). The exposed group comprised workers subjected to a large-scale expansion of the use of snap-fit assembly implemented during a 4-month period. We excluded exposed workers for whom check-up data only was available for a time point before the snap-fit expansion (N=382) or during the transition period (N=219) and workers for whom the time of check-up and exposure measurement deviated >1 year (N=4,766). Thus, in total 10,722 workers were available for the analysis.

The study was ethically approved by the Ethical Committee of the Medical Faculty at Ludwig Maximilians University in Munich and was conducted according to the Helsinki declaration.

Variable definitions

Outcome: Arterial hypertension

Workers' one-arm resting blood pressure was measured by company physicians according to guidelines (Haller 2007). Arterial hypertension was defined as a systolic blood pressure >140 mmHg, a diastolic blood pressure >90 mmHg or known hypertension treatment. Hypertensive workers at first reading were subjected to a second measurement.

Outcome: Upper limb functional limitations

ULFLs analyzed concerned workers' arms, hand/wrist and fingers. A worker was designated a ULFL given the presence of an upper limb musculoskeletal disorder (MSD) diagnosis provided by a general practitioner, and a company physician's examination confirming the worker's inability to perform work tasks involving upper-limb strain.

We analyzed all three types of ULFL designations registered in the company's medical documentation system:

- ULFL of the hand/wrist (e.g. due to carpal tunnel syndrome or hand/wrist arthritis)
- ULFL of the arm (e.g. due to epicondylitis or omarthrosis)
- ULFL of the fingers (e.g. due to carpometacarpal osteoarthritis or trigger finger)

Exposure: Shift work

Shift work was defined as 'work at changing hours of the day or work at constant but unusual hours of the day' (Puttonen, Harma et al. 2010). Company registers provided workers' shift status at 6 fixed points in time between July 2006 and July 2012. A worker's shift status was considered valid if the time between shift status measurement and check-up did not exceed 1 year.

Exposure: Snap-fit assembly

Workers were considered exposed to snap-fit assembly if they fulfilled the following two exposure criteria:

1. Worked in any of the 49 departments in which snap-fit was expanded
2. Had their check-up made after the full snap-fit expansion (excluding the 4-months transition period)

For diseased workers, the exposure status was obtained for the time of ULFL designation using the company's medical documentation system. For non-diseased workers, the exposure status was obtained from company records, providing non-diseased workers' department information at 7 fixed time points between July 2006 and February 2015. A non-diseased worker's exposure was considered valid if the time between department information measurement and check-up was ≤1 year.

Statistical analyses

Shift-work and hypertension

We created 4 different exposure categories: day shifts, shift work without nights, rotating shift work with nights and night shifts. The association between shift work and hypertension was analyzed by logistic regression, adjusted for potential confounders (age, gender, occupational status as a proxy for socioeconomic status, heat work and noise exposure). Through sequential adjustments in Model 2 to Model 4 we analyzed whether the following variables were potential confounders, potential mediators or potential moderators: [behavioral] smoking (yes [daily and occasional smokers] vs. no [non and ex-smokers]), body mass index (BMI) (kg/m^2), physical activity (no, occasionally, ≥3 times/week), sleep disorders (never, monthly, weekly, daily), alcohol consumption (no, occasionally, daily), [psychosocial] social disruption (never, rarely, sometimes, mostly, always), [physiological] HDL-C (mg/dL), LDL-C (mg/dL), and triglycerides (mg/dL):

- Model 1: hypertension ~ shift work + potential confounders
- Model 2: hypertension ~ shift work + potential confounders + behavioral factors
- Model 3: hypertension ~ shift work + potential confounders + behavioral factors + psychosocial factors
- Model 4: hypertension ~ shift work + potential confounders + behavioral factors + psychosocial factors + physiological factors

Factors, which through adjustments in Models II-IV reduced the potentially positive statistically significant total effect to a non-significant level, were further subjected to mediation and moderation analyses.

Snap-fits and upper limb functional limitations

Logistic regression was used to predict the odds of workers' ULFL according to duration of snap-fit exposure: 0, 1-12, 13-24 or ≥25 months. Adjustments were made for the potential confounders age, gender, BMI and employment duration before snap-fit expansion; the latter to control for ULFL related exposure workers obtained before the snap-fit expansion.

The potential dose-response relationship between snap-fit exposure and the odds of ULFL was analyzed by comparing incremental effects: ≥25 months vs. 13-24 months, 13-24 months vs. 1-12 months and 1-12 months vs. 0 months.

Results

Total working population

Compared to workers in the smaller sample of N=38,005 used for the shift work study, workers in the larger sample of N=41,939 used for the snap-fit study were less frequently male (86.2% vs. 87.5%), and had a lower mean age (years) (M=37.6 SD=10.2 vs. M=38.9 SD=10.2) and BMI (kg/m^2) (M=25.7 SD=4.3 vs. M=26.8 SD=4.3) (Table 1). Workers in the larger sample were also less frequently in production (59.9% vs. 61.2%), and had a shorter employment duration (years) than worker in the smaller sample (M=13.9 SD=10.6 vs. M=15.3 SD=10.5). Differences were however small.

Table 1. Descriptives of non-restricted samples used for the analysis of shift work and hypertension (extracted in July 2012) and the analysis of snap-fit assembly and upper limb functional limitations (extracted in February 2015). M=mean. SD=standard deviation. BMI=body mass index.

	Shift work sample N=38005	Snap-fit sample N=41939
Age (years), M (SD)	38.9 (10.2)	37.6 (10.2)
Gender male, n (%)	33240 (87.5)	36139 (86.2)
Production: n (%)		
Yes	23274(61.2)	25133 (59.9)
No	14731 (38.8)	16806 (40.1)
BMI (kg/m^2), M (SD)	26.8 (4.3)	25.7 (4.3)
Smokers (ever or current), n (%)	12859 (33.8)	14764 (35.2)
Employment duration (years), M (SD)	15.3 (10.5)	13.9 (10.6)

Shift work and hypertension

Of 25,343 eligible workers, 37.7% worked shift work without nights, 0.8% rotating shift work with nights, 14.1% night shifts and 47.4% worked day shifts. Hypertension was most prevalent among shift workers not working nights (11.5%), followed by nightshift workers (11.0%), and least prevalent among dayshift workers (7.8%) (p<0.001).

Following adjustments, Model 1 showed a statistically significant association between shift work without nights and hypertension, when referencing day shifts (OR=1.15 95% CI 1.02-1.30) (table 2). Having adjusted for behavioral factors (Model 2), no shift work category was statistically significantly associated with hypertension, and further adjustments for psychosocial and physiological factors (Model 3 and Model 4) did not change this association, indicating that behavioral factors might mediate or moderate the effect of shift work without nights on hypertension.

Table 2. Multiple regression models of associations between shift work and hypertension adjusted for a priori confounders (Model 1), behavioral (Model 2), psychosocial (Model 3) and physiological factors (Model 4). Odds ratios (OR) with 95% confidence intervals (95% CI). N=25343.

	Model 1[1]		Model 2[2]		Model 3[3]		Model 4[4]	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Day shifts	1		1		1		1	
Shift work without nights	1.15	1.02-1.30	1.01	0.88-1.16	1.01	0.83-1.16	1.00	0.88-1.15
Rotating shift work with nights	0.89	0.54-1.46	0.86	0.49-1.50	0.86	0.49-1.50	0.85	0.48-1.48
Night shifts	0.91	0.78-1.06	0.85	0.72-1.01	0.85	0.72-1.01	0.82	0.70-0.98

[1] Adjusted for confounders: age, gender, occupational status, noise exposure and heat work.
[2] Adjusted for confounders and behavioral factors: smoking, alcohol consumption, physical exercise, sleep disorders and body mass index.
[3] Adjusted for confounders, behavioral factors and psychosocial factors: social disruption.
[4] Adjusted for confounders, behavioral factors, psychosocial factors and physiological factors: HDL-C, LDL-C and triglycerides.

Further mediation analysis of all behavioral factors showed statistically significant mediation from sleep disorders (OR=1.01), BMI (OR=1.06) and physical inactivity (OR=1.01). No moderation by behavioral factors was found.

Snap-fits and upper limb functional limitations

Of 10,722 eligible workers, 8.4%, 6.9% and 10.3% were exposed to snap-fit assembly for 1-12 months, 13-24 months and ≥25 months, respectively. The prevalence of ULFL in the population was 1.1%, and was positively associated with duration of snap-fit exposure (p<0.01).

The confounder-adjusted model showed that workers exposed to ≥25 months of snap-fit assembly had more than 2-fold odds of having ULFL (OR=2.44 95% CI 1.52-3.92), compared to unexposed workers (table 3). No dose-response relationship between snap-fit exposure and the odds of ULFL was found. Additional adjustment for smoking did not change any of the associations in the models.

Table 3. Odds of upper limb functional limitations (hand/wrist or arm or finger) according to duration of snap-fit exposure and increments of snap-fit exposure based on multiple logistic regression adjusted for potential confounders age, gender and employment duration before snap-fit expansion. N=10693. OR=odds ratio. CI=confidence interval.

	Adjusted OR	95 % CI	
Snap-fit exposure (months):			
Unexposed group	1		
1-12	1.59	0.88	2.88
13-24	1.48	0.76	2.88
≥25	2.44	1.52	3.92
Incremental snap-fit exposure (months):			
1-12 vs. unexposed	1.59	0.88	2.88
13-24 vs. 1-12	0.93	0.40	2.13
≥25 vs. 13-24	1.65	0.78	3.48

Discussion

Shift work and hypertension

Shift workers not working nights were in our population at increased odds of having hypertension compared with their day working colleagues; the effect was potentially mediated via sleep disorders, higher BMI, and physical inactivity.

Similar negative behavioral changes have previously been found regarding smoking and physical inactivity (Nabe-Nielsen, Quist et al. 2011), albeit resulting from night shift work. These results seem plausible, as shift work might lead to BMI via altered levels of leptin, ghrelin and insulin due to sleep disruptions (Morris, Aeschbach et al. 2012, Marqueze, Ulhoa et al. 2014), and through a higher intake of high-fat snacks than day workers (Antunes, Levandovski et al. 2010) often ingested during later hours when the body's energy expenditure is decreased (Romon, Edme et al. 1993, Kim, Son et al. 2013, McHill, Melanson et al. 2014). Reduced sleep also activates the sympathetic nervous system, causing blood pressure increases (Puttonen, Harma et al. 2010), and the constant rotation between shifts or night work (Atkinson, Fullick et al. 2008, Marqueze, Ulhoa et al. 2014) might prevent workers from maintaining an active lifestyle (Atkinson, Fullick et al. 2008).

Snap-fits and upper limb functional limitations

The expansion of snap-fit assembly has potentially had a long-term negative impact on assembly workers' upper limb function, with effects showing after approximately 25 months. In another working population, wrist bending was the main physical risk factor for functional impairment due to upper extremity symptoms (Gardner, Dale et al. 2008). No effect was however documented from forceful gripping, lifting >2lbs, or vibrating tools. As snap-fit assembly characteristically imply wrist bending, however not vibration, heavy lifting or forceful gripping, the results by Gardner et al. potentially support those reported here. The majority of diseased workers had carpal tunnel syndrome or epicondylitis, suggesting that the motion of pushing the snap-fit parts together is what predominantly accounts for reported ULFLs.

Strengths

Both analyses comprised large samples, partly resulting from a high check-up participation (93%), and included extensive, standardized measurements, all of which contribute to a higher generalizability of our findings.

Our shift work study should not have been significantly biased by a healthy worker survivor effect, as only 0.2% of 2-shift workers had left shift work due to health-related reasons, and approximately only 1% of workers applying for the constant night shift at the enterprise under study do not fulfill health criteria. Moreover, the extensive data on psychosocial, behavioral and physiological factors enabled detailed mediation analyses of potential effect pathways between shift work and hypertension.

In the snap-fit analysis, we successfully prevented a healthy worker survivor bias through obtaining cases' exposure information before being transferred to non-exposed departments. Moreover, by analyzing ULFLs instead of upper limb MSDs we obtained a higher specificity of our outcome.

Limitations

Our reported cross-sectional associations do not provide information on causality.

Thereto, workers' exposure to shift work and snap-fit (regarding non-diseased workers), respectively, were measured only at fixed points in time. Nevertheless, a longitudinal comparison of the different exposure measurements showed a relatively stable shift status among all workers, and small movements between departments in blue-collar production workers without ULFL (5.3%). Hence, the limited number of exposure measures should neither have yielded substantial non-differential exposure misclassification regarding our shift work study, nor differential exposure misclassification regarding our snap-fit study.

Further, our shift work analysis lacked data on some psychosocial factors such as work stress, a potential mediator of the effect from shift work on hypertension (Peter, Alfredsson et al. 1999), workers' chronotype, and the timing of blood pressure measurements. Regarding the latter, the highest blood pressure span normally occurs during working hours (Chau, Mallion et al. 1989), thus coinciding with workers' examinations.

Finally, unexposed workers did perform some degree of snap-fit assembly, albeit approximately 20% of that of the exposed group. Still, the advantage of the control group being similar to the exposed group in all other aspects outweighs the potential small underestimation of effect.

Conclusion

Our cross-sectional analyses provide further knowledge about occupational risk factors for cardiovascular and musculoskeletal ill health in automotive workers.

Apart from adding to existing body of research proposing a negative impact of shift work on workers' hypertension status, we brought further clarity to the interplay between shift work, associated behavioral changes, and workers' development of hypertension through showing that hypertension in our population predominantly is affected by sleeping problems, higher BMI and physical inactivity.

Further, to our knowledge unprecedented, our analyses pointed out snap-fit assembly as a potential novel occupational risk factor negatively affecting assembly workers' upper limb musculoskeletal function.

Despite the need for further longitudinal studies enabling causal inference, company physicians should recognize the potential negative effects from shift work and snap-fit assembly, respectively, and if possible monitor affected workers through regular check-ups. As snap-fit assembly work is predominantly organized into shifts, assembly workers might constitute a particularly vulnerable group, thus calling for extra attention from company physicians.

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