



Associations of understaffing and cardiovascular health of hospital care providers: A multi-source study

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ABSTRACT

Background: Understaffing in hospitals is a serious problem in healthcare work since it jeopardizes efficiency, reliability and quality of care as well as the work life of the healthcare professionals. However, estimates on the associations of understaffing and cardiovascular health in healthcare professionals are lacking. Further shortcomings refer to the problem, that determinant and outcome measures are often assessed via self-reports what increases the risk of spurious estimates due to common source bias.

Objective: We sought to reliably identify associations between understaffing and cardiovascular health in hospital nurses.

Methods: Multi-source and cross-sectional study. N = 273 nurses of a large academic hospital were surveyed. All filled out a standardized questionnaire to report psychosocial work conditions and underwent a standardized medical examination. Cardiovascular health outcomes were blood pressure and blood cholesterol (total cholesterol level, LDL-cholesterol) as well as the SCORE classification. Logistic regression analyses were applied to calculate risk estimates for the understaffing and cardiovascular health relationship, adjusted for individual and life-style factors (e.g., sex, age, BMI, alcohol consumption, smoking) and work related characteristics (i.e., shift work, leadership position, work load, autonomy, social support at work).

Results: Multivariate associations revealed significant relationships of perceived understaffing with increased blood pressure [OR = 1.60, 95% CI: 1.05, 2.43] and increased total cholesterol [OR = 1.42, 95% CI: 1.04, 1.95]. LDL cholesterol level was associated with understaffing. We furthermore observed associations of high autonomy and high cholesterol levels.

Conclusions: Nurses in hospital units with lower staffing ratios had an increased risk for adverse cardiovascular health, irrespective of workload and social support. We discuss implications for future research on potential mechanisms of understaffing and nurses' health outcomes. The associated risks of poor nurse-patient-ratios for provider health need to be addressed through work and organizational design efforts.

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What is already known about the topic?

- Understaffing is a pervasive state in many healthcare organizations with consequences for patient care outcomes.
- In terms of provider outcomes, previous research reported associations between understaffing and nurses' mental well-being.

- Reliable estimates for associations between understaffing and care providers' cardiovascular health yet are missing.

What this paper adds

- Using a sample of acute care nurses in Germany, our multi-source study of physical examinations and nurses' self-report shows that understaffing is associated with increased blood pressure and blood cholesterol levels.
- We further report that understaffing has genuine influences on nurses' cardiovascular health, beyond the effects of work overload and insufficient social support.

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- Perceived understaffing has harmful influences for provider cardiovascular health.

1. Background

Understaffing is an endemic problem in many healthcare institutions. It is defined as that there are too few employees to complete the work expected (Hudson and Shen, 2015). Specifically in healthcare settings, understaffing occurs when there are too few professionals (below the core staffing levels) to fulfill essential patient care tasks and to maintain functions of the hospital unit. This results in an imbalance of resources, i.e., manpower, and exceeding demands, i.e., patient load (Hudson and Shen, 2015).

A growing research base suggests that understaffing compromises quality of clinical practice (Aiken et al., 2002, 2014; Brooks Carthon et al., 2019; Butler et al., 2011). Delivery of healthcare in settings with low nurse to patient ratios was associated with higher risks of adverse patient outcomes, e.g., mortality and failure to rescue rates after surgical care in hospitals (Aiken et al., 2002) or infection rates (Mitchell et al., 2018; Rogowski et al., 2013). Particularly the problem of missed care (defined as omission of required care procedures in the course of healthcare delivery) has been attributed to low staffing levels (Ball et al., 2018). Moreover, it has been consistently shown across different healthcare systems that the ratio of qualified nurses being in charge of inpatient care is associated with favorable patient outcomes, i.e., a higher nurse/patient ratio is associated with increased levels of safe, high-quality care (Aiken et al., 2014; Cho et al., 2015).

Compared to this large literature base on effects of understaffing on patient outcomes, there is little research on effects of understaffing on provider outcomes such as nurses well-being and health. Predominantly, self-reported mental well-being outcomes have been surveyed with particular focus on burnout, dissatisfaction, and intention to leave (Aiken et al., 2014; Nantsupawat et al., 2015; Shin et al., 2018). From our perspective, particularly three shortcomings remain in the current literature base:

First, to the best of our knowledge, effects of understaffing on nurses' health are limited, particularly with regard to cardiovascular health outcomes. Psychosocial risk factors such as exposure to adverse working conditions and chronic job stress contribute to cardiovascular health (Backe et al., 2012; Gilbert-Ouimet et al., 2014; Kivimaki and Steptoe, 2018; Li et al., 2015). Cardiovascular diseases are highly prevalent in the workforce and job strain is a well-established risk factor for coronary heart disease (Kivimaki and Steptoe, 2018; Li et al., 2015). Yet, employee's cardiovascular health is influenced through an interplay of different demands in the occupational and private environment as well as personal predispositions (Kivimaki et al., 2012; Kivimaki and Steptoe, 2018; Li et al., 2015). Nonetheless, previous studies that specifically investigated nurses reported inconsistent findings concerning the associations of adverse working conditions, job stress, and cardiovascular health outcomes (Allesoe et al., 2010; Lamy et al., 2014; Lee et al., 2002). Concerning the effects of understaffing on cardiovascular health, one study among French hospital nurses found no associations between perceived inadequate staffing and blood pressure (de Gaudemaris et al., 2011).

Secondly, we sought to determine the specific and isolated effects of perceived understaffing on nurses' health, irrespective of two further psychosocial job stressors: work overload and lack of social support. Previous research mostly considered understaffing as job-related risk factor with no control for further sources of work stress in the workplace (de Gaudemaris et al., 2011). We attempt to adjust for work overload as well as (lack of) social support to reliably estimate the individual and shared associations of perceived understaffing with nurses' cardiovascular health. Previous research showed that feelings of isolation or loneliness trigger acute psychological stress

that increases risks for coronary heart diseases (Steptoe and Kivimaki, 2012). Effective social relationships with functional support in the work environment mitigate risks whereas social isolation and loneliness increase risks to cardiovascular health (Valtorta et al., 2016). It has been moreover argued that understaffing and unit workload are not the same construct: Quantitative and qualitative workload demands may exert very different influences on unit members' efforts to complete the work with strong dependence on group's capabilities to manage workload (Hudson and Shen, 2015). Therefore it is of utmost interest, to identify genuine associations of understaffing on nurses' health, irrespective of the influence of social support at work and overall work load.

Our third objective was to reliably estimate the association between understaffing and cardiovascular health. It has been repeatedly argued that single source measures of determinant work factors and employee outcomes increase risks of spurious results due to common method bias (Kasl, 1998). We therefore set out a multi-source study that used different sources of information. Expert-assessed cardiovascular health parameters ensure objective and independent measures of nurses' health status and mitigate subjective bias.

1.1. Our research model

Altogether, our motivation was to determine reliable estimates for associations between unit understaffing and nurses' cardiovascular health. As explained above, we propose that understaffing is a genuine stressor that does not equate with increased workload or insufficient colleague support. Specifically, we hypothesized that understaffing is an independent source of job strain with unique effects for nurses' cardiovascular health, irrespective of increased workload or lack of social support. Fig. 1 depicts our research model of our key study variables and outcomes of interests:

1.2. Study objectives

Drawing upon a multi-source study, we sought to determine individual and shared associations between understaffing and psychosocial work characteristics and cardiovascular health outcomes in hospital nurses. Specifically, we

- (1) sought to explore bivariate associations between perceived understaffing, psychosocial work characteristics, and provider characteristics and three cardiovascular health outcomes (i.e., blood pressure, total cholesterol, LDL cholesterol); and,
- (2) to determine adjusted associations of perceived understaffing levels with nurses' cardiovascular health-outcomes, respectively.

2. Methods

2.1. Study design and approval

We established a multi-source and cross-sectional study that combined self-report methods with medical examinations that were conducted by a physician. This investigation was part of a larger work environment project in this hospital (Heiden et al., 2013).

Ethical approval was provided by the Ethics Committee of the Medical Faculty of Munich University (358-11) and was obtained prior to the study. Agreement was gathered from hospital workers' council, local, and nursing department heads. Pseudonymisation was established through numeric study codes on questionnaires and examination protocols, to allow matching of survey and examination data. Nurses' informed consent was obtained before data collection as well as examinations.

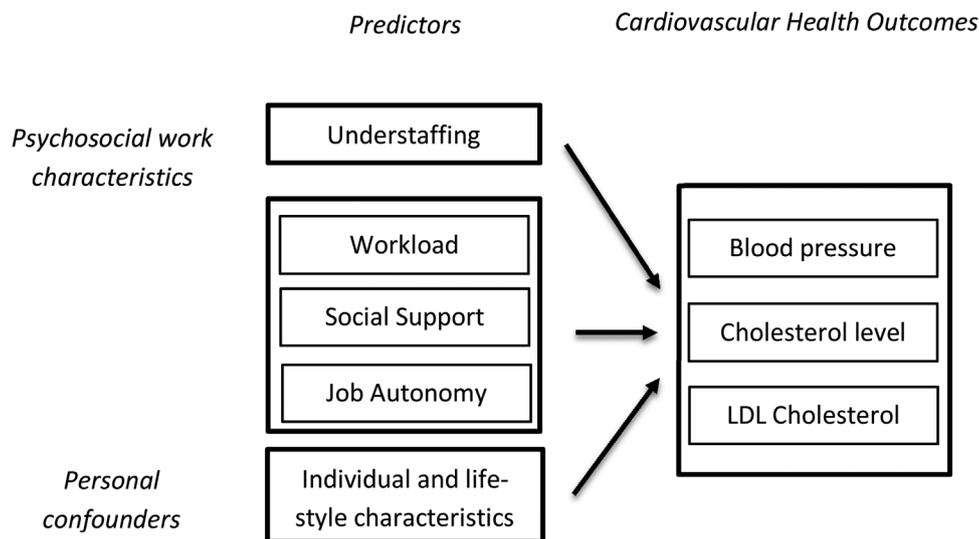


Fig. 1. Our research model of understaffing, psychosocial work characteristics, individual and life-style risk factors, and nurses' cardiovascular health outcomes.

2.2. Setting

Setting was a large University Hospital in South Germany. It houses around 2000 beds, is one of largest academic hospitals in Germany, serves an urban area, and provides all types of medical services and acute care. Included were all 953 nursing professionals of hospital's intensive care units (ICUs), all operating rooms (ORs), all anesthesia units, three inpatient wards (1 general surgery, 1 trauma, 1 obstetrical care), and staff of the intra-hospital patient transportation services (mainly employed in pre- and post-surgical patient transfers).

2.3. Variables and procedure

First, surveys were sent out to all eligible professionals. The survey included questions concerning individual and psychosocial work conditions (all described below). All questionnaires were equipped with sealed return envelopes. Attached was an invitation for a physical examination (during the working time). Respondents of the survey needed to indicate separately their interest in the physical examination.

Secondly, screenings for cardiovascular health outcomes were conducted consistent to European Guidelines on Cardiovascular Disease Prevention (2018) with all nurses who indicated their explicit consent. Two appointments were scheduled with the study team: First, our study nurse measured blood pressure, fasting blood lipids, glucose and BMI. This appointment was arranged at a convenient day time for participants during our study's periods. It was then followed by a separate medical examination and a structured interview by a qualified physician (with background in occupational medicine) including a second reading of blood pressure. Examinations were only performed during daytime and took place in separate rooms of the respective hospital units.

2.4. Participants

Eligible nursing professionals were informed through internal mailings. Data collection followed a stepwise procedure. 438 nurses completed the survey. 275 provided consent for physical examination and received an invitation. 273 nurses underwent the

examination. We thus finally obtained combined data for $n = 273$ nurses, i.e., matches of survey and examination data.

2.5. Measures and data sources

2.5.1. Predictor variables

Our survey used scales on psychosocial work characteristics that originate of a well-established tool for work analysis in hospital work (named TAA-KH-S). It is frequently used in Germany and has been tested for reliability and factorial validity (Büssing and Glaser, 2002; Glaser et al., 2015; Schneider et al., 2017). We deployed the following three scales:

2.5.2. Understaffing

This one-item scale measures perceived staffing level on the ward or hospital unit, respectively: "Staffing level is sufficient in this unit/ward". Likert-scale range: 1="no, not at all", 5="yes, to a very great extent". Item responses were coded reversely such that high values indicate high levels of understaffing.

2.5.3. Work overload

This three-items scale measures when job duties exceed the available for their completion, resulting in overburdening work pressures and unsustainable work pace (e.g., "Even in a constant hurry, the workload is often too high to complete"). Likert-scale range: 1="no, not at all", 5="yes, to a very great extent". Cronbach's Alpha = .81.

2.5.4. Job autonomy

This scale consists of eight items and refers to autonomous decision-making and individual discretion in planning as well as carrying out work; example items are "I can make own decision on task goals" or "I determine for myself how I accomplish my work". Likert-scale range: 1="no, not at all", 5="yes, to a very great extent". Cronbach's Alpha = .94.

2.5.5. Social support

This scale consists of six items that indicate social support through coworkers at work (Frese, 1999). It consists of two subscale of three questions each that ask for perceived support through supervisors and colleagues, respectively (e.g., "how much

can you rely on the following persons when things get tough at work" or "how much is each of the following people willing to listen to your work-related problems"). It is a commonly used scale for social support at work, tested for reliability and validity, and has been repeatedly applied in occupational health research (e.g., Dormann and Zapf, 1999; Frese, 1999). A four-point Likert scale was used (1="not at all", 4="completely"). Cronbach's Alpha for the overall (6-items) scale was .79 (for the three-items subscale support through supervisors: CA = .87; for the three-items subscale support through coworkers: CA = .78).

Employees' *sociodemographic and life-style information* were gathered to control for potential confounders. The following characteristics were included: Gender (0=male, 1=female); Age (in years); Body Mass Index (Employee's BMI Score); Alcohol consumption: Occasional or regular intake of alcohol (0=no, 1=yes); Smoking/Nicotine use (0=Non-Smoker, 1=Smoker). We further obtained information on shift work [Wording: Are you working shifts? (Shift work is regular work outside normal working hours); answer options: 0=no, 1=yes] and leadership position (having supervisory or leadership duties, 0=yes, 1=no).

Further information was collected on working time (1=full time contract, i.e., 38.5 h/week; 2=part-time contract) and professional level (1=examined nurse with leadership responsibilities; 2=examined nurses; 3=nursing assistant; 4=currently in training; 5=other).

2.5.6. Cardiovascular health outcomes

Three cardiovascular health parameters, obtained during standardized medical examinations, were used as study outcomes. For each cardiovascular health-outcome, participants were respectively classified into two categories, i.e., normal vs. elevated risk. This dichotomization was based on the European Guidelines on cardiovascular disease prevention (2018) and official classification of the European Society of Cardiology (Williams et al., 2018):

Blood pressure was measured twice. Mean scores of both measures (for systolic and diastolic parameters, respectively) were computed and classified into: (1) normal blood pressure (below 140/90 mmHg); (2) high blood pressure (above 140/90 mmHg).

Total cholesterol level was the second outcome: Hereby, professionals were classified according to their overall cholesterol level into two groups: (1) normal with <5 mmol/L (<190 mg/dL), and (2) group with increased risk (\geq 190 mg/dl).

Low Density Lipoprotein (LDL) Cholesterol was used to classify two groups. Participants with measures of <3 mmol/L (<115 mg/dl) was grouped as normal, whereas nurses with LDL \geq 115 mg/dl were considered as risk group.

Additionally, all participants were asked for previous events of cardiovascular diseases, current medications, and previous physician-based diagnoses of cardiovascular diseases. A specialist in cardiology reviewed all medications. Nurses were allocated to respective risk groups, if medications were reported that suggested employee's elevated risks of cardiovascular health, i.e., current intake of medication against high blood pressure.

To obtain the relative risks compared to the general population, we furthermore classified each nurse concerning their individual SCORE value (Systemic Coronary Risk Estimation). This epidemiological risk value indicates the 10 year risk of fatal cardiovascular diseases. It is based on a large epidemiological database and accounts for gender, age, systolic blood pressure, total cholesterol, and smoking status (Perk et al., 2012). We used the low risk charts applicable for Germany with seven different risk classes; from lowest risk group (below <1% of fatal disease in the next 10 years) up to up to highest risk group (15% and over) (Perk et al., 2012).

2.6. Statistical methods

Prior to testing our research objectives, we computed prevalence data of our study variables. We then employed comparisons between the group of survey respondents who took part in the medical examination (i.e., our actual study group) and those who only completed the questionnaire (but did not undergo the examination). Our analyses for attrition bias used ANOVA and Chi-Square-Tests. Listwise deletion of missing data was applied. To answer our study objectives, we computed for the group with full data, bi- and multivariate analyses to determine the associations between risk factors and our three cardiovascular health-parameters. We applied logistic regression analyses to obtain risk estimates. We first obtained crude regression estimates for all bivariate associations, respectively. In line with our research model (cf., Fig. 1), our multivariate regression model consistently included the following predictor variables for all three cardiovascular health-outcomes: Perceived understaffing as well as further psychosocial work characteristics (i.e., shift work, leadership position, workload, autonomy, social support) as well as individual and life-style factors (i.e., sex, age, BMI, alcohol consumption, smoking). Our three cardiovascular health-outcome variables were blood pressure, overall blood cholesterol level, and LDL cholesterol level. We obtained multivariate associations with adjusted estimates, respectively for each of the three cardiovascular health-outcomes. Additional analyses were conducted to test the robustness of our findings: First, we repeated our multivariate analyses with each of the social support subscales both subscales, i.e., support from supervisors or support from coworkers. Secondly, we included further potential confounders information on nurses' weekly work time (number of contracted work hours per week) as well as shift work (yes/no). For further sensitivity analyses we excluded nurses who assumed leadership positions since they may have different perceptions while they staff their units themselves or their work overload may include different processes. Finally, to explore for potential moderation effects, we included additional predictors of understaffing-work overload and understaffing-social support interactions into our multivariate analyses. Prior to all analyses, continuous predictor variables were standardized (through mean-centering) to limit multi collinearity. All analyses were computed with SPSS 24.0 (IBM Inc., Chicago).

3. Results

We first analyzed for group differences between our actual study group (i.e., nurses with survey and medical examination data) and compared to those who only completed the survey. We did not observe a difference concerning most individual characteristics. Yet, nurses who did not indicate interest in medical examinations were significantly younger and experienced higher levels of understaffing. All other psychosocial work characteristics were not different between the groups (cf., Supplementary Table A-1).

3.1. Sample characterization and prevalence of cardiovascular health outcomes

Our final sample consisted of 41 male (15%) and 232 female nurses (85%). Mean BMI was 24.88 (SD = 4.6, Range 16–46). 204 (74.4%) were evaluated as non-smokers and 78 participants (28.6%) reported no consumption of alcohol. 227 (83.2%) worked in a shift work schedule and 47 (17.2%) were holding a leadership position.

Overall, we identified 61 participants with elevated blood pressure (22.3%), 117 (42.9%) with elevated overall cholesterol, and 95 (34.8%) with increased levels of LDL-cholesterol. Further

information on mean levels of our psychosocial work characteristics can be found in Table 1.

3.2. Multivariate associations of work stressors and cardiovascular outcomes

In the next step, we sought to determine the crude and multivariate associations of the individual and psychosocial work characteristics with our three cardiovascular health parameters, i.e., blood pressure, total cholesterol, and LDL-cholesterol. Concerning blood pressure, we observed that older participants and nurses with higher BMI showed consistently higher likelihoods of increased blood pressure (cf., Table 2). The multivariate analyses revealed that perceived understaffing was significantly related to higher risks of increased blood pressure [OR 1.60 (95% CI 1.05; 2.43), $p = .03$].

Concerning total cholesterol level, age was again significantly associated with higher likelihood of increased risks of cholesterol above the cut-off value (cf., Table 2). For the psychosocial work characteristics we identified a significant association of understaffing and cholesterol levels [OR 1.42 (95% CI 1.04; 1.95), $p = .03$]. We additionally observed a significant relationship between job autonomy and cholesterol, such that high autonomy was related to significantly higher likelihood of high cholesterol [OR 1.60 (95% CI 1.17; 2.19), $p < .01$].

For LDL-cholesterol parameters, understaffing was not significantly associated with this outcome, this adjusted association however almost attained levels significance [OR 1.45 (95% CI .98; 2.14), $p = .062$]. We also identified a significant relationship between job autonomy and LDL-cholesterol such that nurses with high autonomy had a higher likelihood of increased LDL-cholesterol measures [OR 1.74 (95% CI 1.19; 2.54), $p < .01$].

Our additional analyses did not change the observed findings (all below reported results can be obtained in detail from the corresponding author). Our observed results did not change with neither of the two social support subscales (i.e., through supervisors or coworkers) as predictors. Secondly, inclusion of nurses' weekly work time did not influence the results for blood pressure (outcome I) and overall blood cholesterol level (outcome II). For our third outcome, we observed a strong relationship between understaffing and nurses' LDL cholesterol level that was close to significance: higher levels of understaffing were associated with increased LDL cholesterol [OR = 1.45 (95% CI .98, 2.14); $p = .06$]. We tested for group differences between nurse leaders and nurses without leadership obligations: we did not identify significant group differences in reports of understaffing, work overload, and social support. Furthermore, we repeated the multivariate analyses only with the subgroup of nurses who assumed no leadership position ($n = 212$). We observed again a relationship of understaffing and elevated blood pressure [OR = 1.98 (95% CI 1.19, 3.30);

Table 1
Prevalence of individual and psychosocial work characteristics and cardiovascular health outcomes.

		Prevalence n/%; Mean (SD)	n/%; Mean (SD)	
		Outcome I: Blood Pressure		
		normal (n = 211, 77.3%)	high (n = 61, 22.3%)	
Predictors	Individual characteristics	Gender (male / female)	27 (12.8%) / 184 (87.2%)	
		Age	37.50 (10.9)	
		BMI	24.00 (3.96)	
		Alcohol intake (no/yes)	53 (25.1%) / 158 (74.9%)	
		Smoking (no/yes)	157 (74.4%) / 54 (25.6%)	
		Shift work (no/yes)	27 (13.3%) / 176 (86.7%)	
		Leadership position (yes/no)	33 (16.1%) / 172 (83.9%)	
		Psychosocial work characteristics	Understaffing	3.16 (1.23)
			Work overload	3.11 (.82)
			Social support at work	3.12 (.47)
Job autonomy	3.16 (.83)			
		Outcome II: Total Cholesterol Level		
		normal (n = 153, 56%)	high (n = 117, 42.9%)	
Individual characteristics	Individual characteristics	Gender (male / female)	23 (15.0%) / 130 (85%)	
		Age	36.55 (10.29)	
		BMI	24.72 (4.84)	
		Alcohol intake (no/yes)	43 (28.1%) / 110 (71.9%)	
		Smoking (no/yes)	116 (75.8%) / 37 (24.2%)	
		Shift work (no/yes)	19 (12.8%) / 130 (87.2%)	
		Leadership position (yes/no)	21 (14.1%) / 128 (85.9%)	
		Psychosocial work characteristics	Understaffing	3.10 (1.23)
			Work overload	3.02 (.80)
			Social support at work	3.14 (.45)
Job autonomy	3.09 (.86)			
		Outcome III: LDL Cholesterol Level		
		Normal (n = 127, 46.5%)	High risk (n = 95, 34.8%)	
Individual characteristics	Individual characteristics	Gender (male / female)	18 (14.2%) / 109 (85.5%)	
		Age	35.34 (10.28)	
		BMI	24.37 (4.51)	
		Alcohol intake (no/yes)	35 (27.6%) / 92 (72.4%)	
		Smoking (no/yes)	98 (77.2%) / 29 (22.8%)	
		Shift work (no/yes)	13 (10.6%) / 110 (89.4%)	
		Leadership position (yes/no)	12 (9.8%) / 110 (90.2%)	
		Psychosocial work characteristics	Understaffing	3.20 (1.25)
			Work overload	3.10 (.76)
			Social support at work	3.12 (.44)
Job autonomy	3.06 (.84)			

Notes: M Mean, SD Standard deviation; Psychosocial work characteristics: Scale 1=no, not at all to 5=yes, very much.

Table 2

Crude and multivariate associations of individual and psychosocial work characteristics and cardiovascular health outcomes.

		Associations with cardiovascular health outcomes		
		Outcome I: Blood Pressure		
		OR [95% CI]	OR [95% CI]	
Predictors		Crude associations	Adjusted, multivariate associations	
Individual characteristics	Gender (male / female)	.49 [.24; 1.01]	.36 [.14; .90]	
	Age	1.07 [1.04; 1.10]	1.07 [1.04; 1.11]	
	BMI	1.20 [1.12; 1.28]	1.20 [1.11; 1.29]	
	Alcohol intake (no/yes)	.52 [.28; .94]	.72 [.34; 1.57]	
	Smoking (no/yes)	.87 [.44; 1.70]	1.13 [.48; 2.66]	
	Shift work (no/yes)	.98 [.42; 2.28]	1.45 [.52; 3.99]	
	Leadership position (yes/no)	.62 [.30; 1.25]	.78 [.33; 1.83]	
	Psychosocial work characteristics	Understaffing	1.20 [.89; 1.61]	1.60 [1.05; 2.43]
		Work overload	.84 [.63; 1.13]	.68 [.46; 1.03]
		Social support at work	.89 [.67; 1.19]	.99 [.69; 1.44]
Job autonomy		1.01 [.75; 1.34]	1.28 [.87; 1.89]	
		Outcome II: Total Cholesterol Level		
		Crude associations	Adjusted, multivariate associations	
Individual characteristics	Gender (male / female)	.97 [.50; 1.90]	1.04 [.48; 2.24]	
	Age	1.06 [1.03; 1.08]	1.06 [1.03; 1.08]	
	BMI	1.01 [.96; 1.07]	.99 [.93; 1.06]	
	Alcohol intake (no/yes)	1.00 [.58; 1.70]	.87 [.47; 1.63]	
	Smoking (no/yes)	1.13 [.65; 1.96]	1.50 [.79; 2.83]	
	Shift work (no/yes)	.87 [.42; 1.78]	1.13 [.49; 2.61]	
	Leadership position (yes/no)	.55 [.29; 1.04]	.76 [.38; 1.54]	
	Psychosocial work characteristics	Understaffing	1.23 [.96; 1.58]	1.42 [1.04; 1.95]
		Work overload	1.21 [.94; 1.54]	1.18 [.88; 1.60]
		Social support at work	.86 [.67; 1.10]	.83 [.62; 1.12]
Job autonomy		1.22 [.95; 1.56]	1.60 [1.17; 2.19]	
		Outcome III: LDL Cholesterol Level		
		Crude associations	Adjusted, multivariate associations	
Individual characteristics	Gender (male / female)	.66 [.33; 1.34]	.50 [.21; 1.17]	
	Age	1.08 [1.05; 1.11]	1.08 [1.05; 1.11]	
	BMI	1.09 [1.02; 1.16]	1.09 [1.01; 1.17]	
	Alcohol intake (no/yes)	.79 [.44; 1.40]	.84 [.40; 1.75]	
	Smoking (no/yes)	1.56 [.86; 2.84]	2.60 [1.23; 5.53]	
	Shift work (no/yes)	.51 [.24; 1.12]	.67 [.26; 1.73]	
	Leadership position (yes/no)	.32 [.15; .68]	.59 [.24; 1.44]	
	Psychosocial work characteristics	Understaffing	1.11 [.85; 1.45]	1.45 [.98; 2.14]
		Work overload	1.06 [.81; 1.38]	.96 [.67; 1.39]
		Social support at work	.98 [.75; 1.29]	1.01 [.72; 1.43]
Job autonomy		1.33 [1.01; 1.76]	1.74 [1.19; 2.54]	

Notes: OR Odd ratio for likelihood for high-risk group (for outcome I: blood pressure above 140/90 mmHg; for outcome II: total cholesterol \geq 190 mg/dl; for outcome III: LDL cholesterol \geq 115 mg/dl). bold if significance level $p < .05$.

$p = .008$], yet no association with overall [OR = 1.30 (95% CI .92, 1.84); $p = .14$] and LDL cholesterol [OR = 1.35 (95% CI .88, 2.08); $p = .17$]. Our tests for potential moderation effects did not reveal changes in the above reported results: we did not observe significant associations for predictors that accounted for interactions of workload and understaffing as well as social support and understaffing.

Finally, we analyzed nurses' SCORE values that indicate their 10 year risk of fatal cardiovascular diseases. We obtained the following distribution: < 1% risk group: $n = 214$ (80.1%), 1% risk group: $n = 37$ (13.9%), 2–4% risk group: $n = 12$ (4.5%), 5–9% risk group: $n = 1$ (0.4%), >15% group: $n = 3$ (1.1%). We compiled to groups comparing non-critical and critical SCORE results. The non-critical group of 1% risk and below consisted of 251 nurses (94%) compared to the group with elevated risks ($n = 16$, 6%). We repeated our multivariate analyses with this bivariate SCORE outcome. The correlational analyses revealed no significant associations and are reported in Appendix (cf., Table A-2).

4. Discussion

We sought to determine individual and shared associations between understaffing and psychosocial work characteristics and cardiovascular health outcomes in hospital nurses. Drawing upon a

sample of 273 hospital nurses in Germany, our multi-source study of physical examinations and nurses' self-report revealed that perceived understaffing was associated with increased blood pressure and blood cholesterol levels. It further demonstrates that understaffing shows genuine influences for nurses' cardiovascular health, beyond the effects of work overload and insufficient social support. Our study's contributions are several-fold:

First, nurses who worked in hospital units with lower levels of perceived staffing had an increased risk for adverse cardiovascular health in terms of high blood pressure and increased blood cholesterol. Adequate unit staffing ensure effective matches between nurse's competencies and patient's needs with safe and reliable care system outcomes - for providers as well as their patients. Our findings suggest that perceived lack of personnel resources and manpower in the hospital is a risk for nurses' health in terms of cardiovascular functioning. Previous research predominantly surveyed effects of understaffing for mental well-being outcomes in care providers like burnout, dissatisfaction, and intention to leave (Aiken et al., 2014; Nantsupawat et al., 2015; Shin et al., 2018). However, our results advocate that perceived understaffing contributes to adverse physiological health outcomes. Our outcome measure of elevated blood pressure levels do though not represent chronic hypertension. Notwithstanding, high blood pressure values may indicate the onset of sustained

hypertension (Backe et al., 2012; Gilbert-Ouimet et al., 2014). Yet, we acknowledge that for our third cardiovascular health outcome (LDL cholesterol), we did not establish multivariate associations with perceived understaffing. Previous reviews on relationships between work stress and the etiology of serum lipids reported inconsistent findings, particularly if homogenous professional samples are surveyed with limited likelihoods of exposure contrasts (Eddy et al., 2017; Hansen et al., 2009; Sara et al., 2018). Few studies reported small to moderate associations between work stress and lipoprotein levels (e.g., Kivimaki et al., 2002; Magnusson Hanson et al., 2017; Shirrom et al., 2009). Altogether, our findings are consistent to previous findings on the profound influences of adverse psychosocial work conditions and stress on cardiovascular morbidity (Allesoe et al., 2010; Backe et al., 2012; Lamy et al., 2014; Sara et al., 2018). Our additional analyses concerning nurses' SCORE classifications suggest that future studies should expand their scope into the long-term effects of acute job stressors, i.e., current staffing ratios. Our results draw upon on a cross-sectional design within a comparatively healthy and young group of nursing professionals. Inferences concerning the long-term consequences of job stressors on cardiovascular health are thus limited.

Understaffing can be characterized as a multidimensional problem of lack of manpower as well as unavailability of knowledge, skills, and abilities. If understaffing persists over time, this stressor has hazardous effects on employee health and functioning (Hudson and Shen, 2018, 2015). Our operationalization in this study addressed nurses' evaluation of manpower understaffing. Future investigations should address particularly understaffing in terms of missing knowledge and expertise. It has been argued that manpower understaffing might be perceived as a challenge that can be successfully mastered, whereas expertise understaffing poses hindrances and is associated with negative well-being and health outcomes (Hudson and Shen, 2018). Nonetheless, it has been proposed that manpower understaffing is a more potent predictor of work outcomes (Hudson and Shen, 2018). We acknowledge that our preliminary tests for sample attrition suggested potential self-selection bias such that nurses with lower age and higher perceptions of understaffing refrained from the medical examination (cf., Table A-1). We assume post-hoc that nurses from units with low manpower resources had no temporal availabilities for participation in examinations.

Secondly, the associations between understaffing and nurses' blood pressure and LDL cholesterol remained significant after controlling for the influence of work overload and social support. Our observations expand previous findings that solely analyzed for bivariate associations and blood pressure (de Gaudemaris et al., 2011). Yet, our multivariate findings suggest that perceived understaffing in hospital units has genuine effects on nurses' health, irrespective of the levels of workload and social support, i.e., effects were significant after controlling for the statistical influences of overload and availability of social support at work. This corroborates the notion that the effects of understaffing unfold differently and do not equate with high work overload nor insufficient social support (Hudson and Shen, 2018, 2015). However, our results do not provide necessary insights into the bio-behavioral mechanisms through which understaffing exerts its negative, stressful influences on nursing professionals' cardiovascular health. Post-hoc, we infer that persistent manpower and expertise absence may be particularly pronounced in interdependent care work with profound effects for physiological stress responses. Shortcomings in operations of the nursing care delivery systems and specifically low staffing ratios jeopardize achievement of patient-specific and task-specific goals as well as well compromise collaboration and team work (Welton, 2016). Nurses may seek to compensate performance deficits with higher efforts,

but at the costs of well-being on the job. Future investigations should therefore test, how qualitative as well as quantitative workload and role ambiguity aggravate or limit the hazardous health effects of understaffing over time (Hudson and Shen, 2018; Welton, 2016). Our observations may also contribute to further research into contextual characteristics of the hospital units and if health effects of understaffing are more pronounced in certain clinical areas. Our sensitivity analyses included only nurses who assumed no leadership position. Consistently, we observed an association of understaffing and blood pressure yet no association with both cholesterol measures. This observation calls for further considerations in future studies: although we did not identify a significant difference between nurse leaders and their subordinates concerning their evaluation of all three psychosocial work characteristics, nurse leaders may have greater influence on staffing decisions and different processes of workload may occur within this particular group.

Thirdly, our observations challenge the role of job autonomy and control for nurses job-related health outcomes. Contrary to our assumptions, we observed that high levels of autonomy were associated with poor cardiovascular outcomes in terms of overall cholesterol levels (outcome II) and LDL cholesterol level (outcome III). Traditionally, job autonomy has been considered a fundamental resource for effective task regulation and beneficial for workers health and mental well-being (de Lange et al., 2003; Karasek, 1979; Theorell et al., 2015). Yet, high levels of job autonomy can also be associated with poor health, cardiovascular, and well-being outcomes (Juvanhol et al., 2018; O'Donnell et al., 2015). This has also been shown for care providers, e.g., eldercare workers (Kubicek et al., 2014). One explanation for such detrimental effects is, that high job autonomy might be linked to increased self-regulatory efforts due to planning requirements and decreased predictability of work tasks (Juvanhol et al., 2018). Yet, investigations into inverse as well as curvilinear relationships between job autonomy and well-being or health outcomes are limited (De Jonge and Schaufeli, 1998). Notwithstanding, that empirical evidence on the influence of job autonomy or influence on cardiovascular health outcomes is mixed (Allesoe et al., 2010; Lee et al., 2002). Our findings suggest further investigations into the boundary conditions of job autonomy in the work environments with high levels of demands and complexity (Juvanhol et al., 2018; Riese et al., 2004). It has been suggested that physiological dysregulation with sympathetic activation and parasympathetic withdrawal occurs when high autonomy is perceived as an additional stressor (O'Donnell et al., 2015). Hence, future investigations should scrutinize this assumption with inclusion of provider outcomes that indicate cardiovascular sympathetic and parasympathetic regulation.

4.1. Limitations

Although this study has a number of significant strengths, including combination of nurses' self-reports and physician evaluation of nurses' cardiovascular health, several limitations of this study have to be considered. Since this is a cross sectional study, no causal inferences can be drawn from our observations. Yet, other prospective studies showed that chronic exposure to stressful psychosocial work conditions in the hospital adversely contribute to cardiovascular health in nurses (Allesoe et al., 2010). Various sources of bias may have occurred such as that we did not control for personality factors and stressors outside of work. However, we controlled for the influence of shift work and specific personal characteristics (such as gender, age, and BMI) that are well-established risk factors for cardiovascular health (Kivimaki et al., 2012; Puttonen et al., 2010). We acknowledge that our proxy measure for shift work does not capture the variety of work time

schedules in hospitals and countries. Future studies should therefore incorporate more nuanced measures of shift work schedules with particular focus on night shift exposure. Blood pressure readings and lipid screenings were performed only during day times and were guideline based. Yet, future studies on understaffing and cardiovascular health outcomes in nurses should also expand their scope of potential cardiac-health measures beyond the major yet few indicators used in the present study. External validity of the results need to be carefully considered since the findings are based on an Academic hospital setting in Germany what may limit generalization to other contexts where different regulations concerning staffing levels and policies are in place. The sample consisted of a majority of acute care nurses. Potential selection bias in terms of healthy workers bias needs to be acknowledged such that nurses with severe symptoms (e.g., ischaemic heart diseases, angina pectoris) may have been already dropped out before the investigation; our SCORE classifications revealed that our sample consisted of comparatively healthy nurses compared to the overall population in Germany (with 94% considered of comparatively low risk of 1% and below). Our measures of workload did not account of patient acuity as well as complexity what is fundamental to determining staffing needs. Contextual influences of the workplace such as task interdependencies, needs for coordination of care, and intra-unit task communication as well as concerning routine or novel, highly demanding tasks need to be taken into account in future studies. Although our measures of psychosocial risk factors at work were based upon reliable and valid measures, subjective bias cannot be ruled out. Yet, a previous study showed that understaffing perceptions are shared to some degree among work group members (Hudson and Shen, 2018). Our single-item question assessed perceived understaffing and referred to adequate levels of nurse-patient ratios. Yet, it is not the same as actual staffing ratios in the unit or more fine grained measures of perceived adequacy of staffing (Kramer and Schmalenberg, 2005). Therefore, further investigations into associations between nurses' subjective perceptions of understaffing and actual staffing ratios are necessary. It has been previously proposed that potential associations are not isomorphic or perfectly correlated, since perceptions of understaffing can be influenced by other factors other than actual staffing conditions in the units (Hudson and Shen, 2015). Likewise, we cannot infer about short term, temporary or acute states of understaffing what might be compensated differently, e.g., one ICU night shift with fewer nurses in which new patient admissions are delayed to the morning for the next, completely staffed shift.

4.2. Implications

Concerning implications for nursing practice: our results are in line with previous investigations demonstrating the harmful health effects of adverse work conditions in the hospital (Allesoe et al., 2010). This study adds to the growing body of evidence that staff shortage is a major problem in care not only for patient safety and care outcomes but as well as for health provider outcomes and, specifically, for nurses' cardiovascular health. Our observations should be taken into account in primary prevention in terms of organizational and work design in hospitals and mitigating adverse factors and work conditions that contribute to cardiovascular risks in nurses.

Concerning implication for future research, our findings call for investigations into the health-related consequences of understaffing and potential buffering or mitigating conditions. In-depth studies need to be undertaken that identify mechanisms how perceptions and chronic conditions of understaffing contribute to nurses health. We assume that behavioral strategies and task routines are changed under chronic care pressures such that nurses

prioritize for case complexity or take instances for missed care into account. However, this might come in line with higher job strain and perceptions of chronic exhaustion and depersonalization with potentially long-term consequences for nurses' health. Additionally, future research should consider different facets of understaffing in terms of manpower understaffing as well as expertise or skill understaffing with applying more fine-grained definitions and conceptualizations (Hudson and Shen, 2015; Welton, 2016). It has been argued that mere quantitative appraisals (i.e., too few employees) is incomplete since understaffing unfolds as a multidimensional construct of different facets, i.e., severity (i.e., degree of staffing shortage), type of personnel shortage, and time (Hudson and Shen, 2015). Since we did not obtain any data on nurses' skill mix within and across units, we recommend further studies to take account of this.

5. Conclusions

Understaffing is a pervasive state in many healthcare organizations. This present multi-source study serves as an important first step, to understand the individual costs for nurses' health. It suggests that perceptions of understaffing are associated with adverse nurses' cardiovascular health outcomes in terms of elevated blood pressure and cholesterol levels. Future studies should further investigate the complex effects of chronic understaffing in hospital units for nurses health outcomes over time. In times of growing economic pressures and ongoing efforts to stretch human resources in hospitals, further scholarly attention needs to be paid on associated provider health outcomes.

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Ethics approval

The Ethics Committee of the Medical Faculty of Ludwig-Maximilians-University approved this study (Nr 358-11).

Declaration of Competing Interest

The authors declare that they have no conflict of interest.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:<https://doi.org/10.1016/j.ijnurstu.2019.103390>.

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