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Complete List of Authors:	Wirth, Tanja; University Medical Center Hamburg-Eppendorf, Institute for Occupational and Maritime Medicine (ZfAM) Kräft, Jessica; University Medical Center Hamburg-Eppendorf, Institute for Occupational and Maritime Medicine (ZfAM) Marquardt, Berit; University Medical Center Hamburg-Eppendorf, Institute for Occupational and Maritime Medicine (ZfAM) Harth, Volker; University Medical Center Hamburg-Eppendorf, Institute for Occupational and Maritime Medicine (ZfAM) Mache, Stefanie; University Medical Center Hamburg-Eppendorf, Institute for Occupational and Maritime Medicine (ZfAM)
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Indicators of technostress, their association with burnout and the moderating role of support offers among nurses in German hospitals: a cross-sectional study

Tanja Wirth*, Jessica Kräft, Berit Marquardt, Volker Harth, Stefanie Mache

Institute for Occupational and Maritime Medicine (ZfAM), University Medical Center Hamburg-Eppendorf (UKE), 20459 Hamburg, Germany

*Correspondence: t.wirth.ext@uke.de; +49 40 42837 4343

ABSTRACT

Objectives To examine the level of indicators of technostress among nurses with and without a leadership position, the relationship between indicators of technostress and burnout and the moderating role of support offered by employers. The availability of support offers and further needs of nurses were also explored.

Design Cross-sectional online survey using validated scales and open-ended questions.

Setting Acute care hospitals in Germany.

Participants 303 nurses (73.3% female) who have worked at the hospital for at least one year and a minimum of ten hours per week.

Primary and secondary outcome measures Indicators of technostress (complexity, overload, usefulness, lack of technical support and unreliability) served as predictors in multiple linear regression analyses to examine their association with the primary outcome burnout. Support of employers was included as a moderator variable.

Results There were no differences in the level of indicators of technostress found between nurses with and without a leadership position. Techno-overload ($\beta = 0.259$, $p = 0.004$) and techno-complexity ($\beta = 0.161$, $p = 0.043$) were significantly associated with burnout. Support by the employer moderated the relationship between lack of technical support and burnout significantly (R^2 change = 0.026, $F(1,292) = 7.41$, $p = 0.007$). Support offers such as training, IT service and contact persons on the ward helped nurses to be more confident in the use of information and communication technologies (ICT). However, they expressed further needs with regard to these and new offers.

Conclusions There was an association between two indicators of technostress and burnout. Therefore, particular attention should be paid to supporting nurses in terms of techno-overload and techno-complexity. Furthermore, there is still a need for customised support and further offers from employers in the use of digital technologies.

Keywords: Information and communication technology, digital stress, emotional exhaustion, occupational health

STRENGTHS AND LIMITATIONS OF THIS STUDY

- The study comprised a priori hypotheses that were based on theoretical models and current research.
- Validated scales were used to measure indicators of technostress and burnout.
- The cross-sectional design did not allow any conclusions to be drawn about causal relationships.
- The study population was not representative of German nurses, with nurses from single federal states, with German as their mother tongue and with a leadership position being overrepresented in the sample.
- Due to the use of an online survey, it was not possible to calculate the response rate for the study.

INTRODUCTION

Digital transformation in the form of digital work processes and technical aids is increasingly finding its way into the healthcare sector in Germany and is having a growing influence on nursing activities.[1] [2] So far, information and communication technologies (ICT) are most frequently used in nursing practice.[3-5] In an online survey of 1,335 nurses from care facilities and hospitals in Germany, 91.4% of the participants reported having experience in the use of ICT. Among ICT use, experiences in the use of electronic health/nursing records (74.8%) and electronic planning of care processes (71.5%) were mentioned most frequently.[5]

The use of digital technologies in the healthcare system pursues goals such as reducing bureaucracy and improving the exchange of data across different sectors, which in turn can lead to time savings and improved communication. Overall, it is assumed that the workload of nursing staff will be reduced and the quality of nursing care can be improved.[6] Nurses already confirmed some positive effects such as increased efficiency, saved time and improved quality of care.[5] On the other hand, more than half of the participants of a sample of 495 care workers in Germany also feared an increase in time pressure, staff savings and more (performance) control with the use of digital technologies.[4] This is supported by a study that described a persistently high work intensity in nursing care and a lack of resources to learn and use digital technologies. Further, it pointed to challenges such as the inaccuracy of technology fit, susceptibility to errors and failures and the increasing possibility of monitoring and performance control.[7] Overall, care-, work- and health-related effects of the use of digital technologies in nursing care in Germany have so far been barely studied.[2] Therefore, the aim of the study was to examine ICT use, factors that create stress from ICT use as well as their associations with burnout among nurses working in acute care at German hospitals. Furthermore, the study aimed to explore the role of support offered by employers in the use of digital technologies.

Theoretical background

Job Demands-Resources (JD-R) model

The present study uses the JD-R model from Demerouti et al. as a basis.[8] It is as flexible model that depicts both negative and positive indicators of employee well-being and can be applied to various occupational settings. Correspondingly, the model distinguishes between job demands and job resources. While job demands may require constant physical, cognitive and/or emotional effort and are, therefore, associated with job strain, job resources have a functional and motivational potential, can stimulate personal development and lead to high work engagement. Job resources may result from the organisation itself, social relations, the organisation of work and work tasks. The JD-R model assumes that job resources may buffer the effect of job demands on job strain.[9]

Technostress

In the context of increasing digitalisation in the workplace, Brod described the phenomenon of technostress.[10] He defined technostress as a 'modern disease of adaptation caused by an inability to cope with the new computer technologies in a healthy manner' (Brod, p. 16).[10] On the basis of this definition, a conceptual model for understanding technostress was developed by Ragu-Nathan et al.[11] They identified five factors that create stress from the use of ICT (technostress creators or indicators of technostress) and decrease job satisfaction, leading to decreased organizational and continuance commitment. The five indicators are techno-overload, techno-insecurity, techno-invasion, techno-uncertainty and techno-complexity. Techno-overload refers to an overload of information and communication due to digital technologies requiring employees to work faster. Techno-insecurity describes the fear of employees of losing their jobs due to ICT. Techno-invasion

means that boundaries between work and private life are blurring because of ICT. Techno-uncertainty refers to difficulties and feelings of uncertainty in the use of ICT as these are rapidly changing, while techno-complexity describes the efforts of employees in learning and understanding ICT due to their complex nature. On the contrary, three organizational and managerial mechanisms potentially reduce stress from the use of ICT (technostress inhibitors) and increase job satisfaction and organizational and continuance commitment. These are named literacy facilitation, technical support provision and involvement facilitation. Literacy facilitation involves knowledge sharing within the organisation. Technical support provision describes the availability of help and support for technical problems with ICT. Involvement facilitation refers to transparency regarding the introduction and effects of ICT.[11] In the meantime, further technostress categories have been described and investigated,[12 13] the most noteworthy of which is the factor "unreliability". It refers to the usability of technology and describes situations where systems are slow or breakdown, causing stress for users.[12 13]

Burnout

Burnout is a well-known concept in psychosocial research and a widespread phenomenon in the occupational context, especially among human service professionals.[14] It can be defined as 'a state of physical, emotional and mental exhaustion that results from long-term involvement in work situations that are emotionally demanding' (Schaufeli & Greenglass, p. 501).[14] In this respect, Kristensen et al. emphasise the attribution of fatigue and exhaustion to the work context as the key characteristic of the concept.[15]

State of research

Digitisation in organisations (e.g. the use of ICT) is associated with the occurrence of technostress. Research has shown that the degree of digitisation has a statistically significant impact on indicators of technostress. Technostress occurs especially when the degree of digitisation of the workplace does not match the skills of the employees.[16] This can also be applied to the healthcare context. A systematic review referring to the usage of health information systems and medical technology concluded that digitisation causes increased technostress of health personnel.[17] Among health personnel from different health organisations, those working in acute care and rehabilitation hospitals had significant higher levels of technostress in comparison to those working in home care organizations and nursing homes. This was explained by the authors in terms of a more advanced digitisation[18] and underlines the relevance of the setting investigated in the present study.

In terms of profession, working as a physician or a nurse was significantly associated with increased technostress in comparison to medical-therapeutic and medical-technical professions,[18 19] while working in a profession with no professional qualification (e.g. trainees, civilian service, volunteers) was significantly associated with a decrease in technostress.[18] This is in line with cross-sectoral results showing that higher qualified workers experienced higher levels of technostress.[16] Similarly, it could be assumed that experiences of technostress also differ according to the professional position. Nursing staff in leadership positions in hospitals, e.g. ward managers, take on tasks in addition to direct nursing care, such as organisation of work processes and personnel deployment as well as employee and team development. As a result, they may be assigned additional administrative tasks.[20] This in turn could lead to greater use of digital work tools. A study in outpatient care in Germany indicated that technology readiness, which is supposed to predict the successful use of new technologies, was higher among supervisors than among employees in direct care.[21] However, it is still unclear how these differences affect the experience of technostress. The following hypothesis is therefore proposed and will be analysed:

H1: Indicators of technostress (H1a complexity, H1b overload, H1c usefulness, H1d lack of technical support and H1e unreliability) differ significantly among nurses with and without a leadership position.

Indicators of technostress can act as job demands.[22] Several studies suggest a link between technostress at work or its indicators and adverse health outcomes[23-25] as well as burnout symptoms.[16 19 26-30] In a study sample representative of employees in Germany in terms of the distribution across the federal states and the economic sectors, technostress explained about 22% of the variance in emotional exhaustion.[16] Studies among health professionals from different disciplines also found a positive association between technostress or indicators of technostress and burnout symptoms, although the amount of explained variance was somewhat smaller.[19 26-28] For example, 12% of the variance of burnout symptoms could be explained by the three indicators techno-overload, techno-complexity and techno-uncertainty among physicians working in neurological or vascular surgery clinics.[26] Califf et al. found that nurses from hospitals in the USA who associated high levels of techno-overload, techno-unreliability and techno-insecurity with the use of technology in healthcare showed a negative psychological response in the form of distress.[24] To our knowledge, studies from Germany have so far not focused on the professional group of nurses in the context of technostress and mental strain such as burnout symptoms or have only considered them as a small group among health professionals.[19 25 28] Based on the above, the following hypothesis is proposed:

H2: Indicators of technostress (H2a complexity, H2b overload, H2c usefulness, H2d lack of technical support and H2e unreliability) are significantly positively related to nurses' burnout.

Personal resources, such as self-efficacy, were already found to moderate the relationship between technostress and strain. Healthcare workers with higher technology self-efficacy reported lower levels of strain.[25] A systematic review on the effects of technostress on employees' well-being and productivity described that ICT-related organisational resources (technical support, ICT usefulness for the job task, involvement facilitation) lead to positive psychological responses, which in turn create job satisfaction. The authors further stated that these organisational resources may buffer the effects of indicators of technostress on personal outcomes and that social and organisational support are successful coping mechanisms against technostress.[22] Similarly, Tell et al. found significant different levels of technostress according to the degree of implementation of preventive measures by the employer with higher levels of technostress for the group of physicians with a low degree of implementation of preventive measures compared to those with a high degree of implementation.[26] Therefore, it can be assumed that support offered by the employer may serve as a job resource and, in accordance with the JD-R model, also has the potential to buffer the impact of indicators of technostress on burnout symptoms. Therefore, it is proposed that:

H3: Support offered by the employer is significantly related to nurses' burnout.

H4: Support offered by the employer moderates the relationship between indicators of technostress (H4a complexity, H4b overload, H4c usefulness, H4d lack of technical support and H4e unreliability) and nurses' burnout.

Facilitation strategies in healthcare institutions to reduce the impact of technostress and increase job satisfaction and organisational commitment could focus on an active involvement with regard to the implementation of new technologies, training and technical support.[31] However, research on strategies to prevent or reduce technostress, including organisational resources, is sparse.[31-33] Therefore, the following research questions should be explored:

RQ: What types of support offers for technology use are available to, used by, and considered helpful by nurses? What further needs do they have?

Online supplemental figure A takes up the theoretical models of technostress and job demands-resources and summarises the association hypotheses.

METHODS

Study design and data collection

A quantitative cross-sectional study was conducted. Data were collected through an online questionnaire from the middle of April to the beginning of November 2023 via the German online survey platform LamaPoll. A register of hospitals in Germany was prepared for data collection purposes. The register was based on the webpage *www.kliniken.de* and included the contact details of acute care hospitals. Outpatient and rehabilitation clinics were excluded. The final list with all federal states comprised 1.198 hospitals. Whenever possible, the head of nursing was contacted by email and asked to distribute the study information material and the link to the questionnaire to the nursing personnel of the hospital.

Nurses working in inpatient acute care at a German hospital were eligible for taking part in the study. Participants were further required to have been at the hospital for at least one year, to work a minimum of ten hours per week and to use ICT in everyday nursing care. According to the German Federal Statistical Office, there are currently 486,100 registered nurses working in the inpatient sector in Germany.[34] Taking this population, a confidence level of 90%, a margin of error of e = 0.05 and a standard deviation of p = 0.5 as a basis, a sample size of N = 273 was required to represent the population.

Measures

The online questionnaire included self-developed items on sociodemographic information and technology use, validated scales concerning technostress and burnout as well as open-ended questions on support offers. Other parameters from the questionnaire were not included in this analysis. These will be published elsewhere.

Sociodemographic variables

Questions on sociodemographic information of the participants were self-developed and comprised age, sex, mother tongue, professional qualification, working hours, shift work, work experience, leadership position as well as ownership, number of beds and federal state of the hospital.

Use of ICT

The study examined the time of use of eight types of typical ICT in the hospital. These included the hospital information system, electronic care documentation, electronic health/nursing records, electronic planning of care processes, smartphone apps (e.g. pocket guidelines), digital medication management, digital standard operating procedures (SOPs) and decision support systems. Participants were asked to indicate their average time of use of these technologies on a typical working day. The time was recorded in half-hour intervals from a minimum of zero hours to a maximum of ten hours per day. The question was used in a similar way before.[27]

Technostress

The German version of the Digital Stressors Scale (DSS) was used in the study to evaluate indicators of technostress among nurses. The DSS was developed by Fischer et al. to measure the perception of digital stressors in the workplace.[13] Overall, it consists of 50 items and covers ten categories of stressors. Each category can be applied on its own and is measured on a seven-point Likert scale ranging from 1 = strongly disagree to 7 = strongly agree. Higher values indicate higher levels of stress.

The average of the values of the five items of a scale formed the scale value. In this study, five stressor categories were used: complexity, overload, usefulness, lack of technical support and unreliability. All of them were validated and showed acceptable reliability values (Cronbach's alpha > 0.70) in the German validation study.[35]

Burnout

Burnout was measured using the personal burnout subscale of the Copenhagen Burnout Inventory (CBI).[15] The German version was extracted from the Copenhagen Psychosocial Questionnaire (COPSOQ) and had shown high reliability (Cronbach's alpha = 0.91).[36] It comprised six items measured on a five-point Likert scale ranging from 1 = never/almost never to 5 = always. To calculate the scale value, the values were transformed to 0, 25, 50, 75 and 100. The average of the values of the six items formed the scale value.

Support offers

Five self-developed items covered support in the use of technology. An initial question was: "Is there any support offered by your employer in the use of digital technologies" ("yes", "yes, but I don't use these support offers" and "no"). For analysis purposes, these were dichotomised to "yes" and "no". Participants who answered this question in the affirmative were asked to specify these offers and to reflect their usefulness in free-text formats. Those who stated before that they did not use any support offers were asked in an open-ended question for their reasons. The fifth item was also in free-text format and asked all participants about (further) support offers they would like to receive.

Data analysis

First, the data was cleaned and checked for completeness and plausibility. Participants who did not fulfil the inclusion criteria as well as participants with incomplete data were removed from the dataset. Descriptive statistics (frequencies) were used for analysing sociodemographic data and data on ICT use. Means, standard deviations, Cronbach's alpha and intercorrelations were calculated for all indicators of technostress and the burnout scale.

Normality was tested for all metric variables looking at histograms, Q-Q plots, skewness and kurtosis and data was proven for outliers using boxplots and z-scores. No outliers could be detected. As the assumption of normal distribution was violated, the non-parametric Mann-Whitney U test was used for comparing the groups of nurses with and without a leadership position (H1a-H1e). The Holm-Bonferroni procedure was applied to adjust alpha levels for multiple comparisons.

For hypotheses H2a-e and H3, a hierarchical multiple linear regression model was calculated with burnout as the dependent variable. Prerequisites for the regression analysis were tested beforehand using visual inspection of scatterplots for linear relationships and homoscedasticity, Durbin-Watson statistic for independence of residuals, correlation matrix and variance inflation factors (VIF) for multicollinearity as well as standardised residuals and Cook's distance for outliers. Bootstrapping based on 1,000 bootstrap samples was used to generate robust confidence intervals (CI) and standard errors (SE). Model 1 included all indicators of technostress as predictors. Model 2 additionally included the variable of support offered by employer. The variables sex and age were considered as control variables. However, as there was no substantial change in standardised beta coefficients of the predictors with the control variables, a final model without the control variables was calculated and reported in accordance with the suggestions of Becker et al.[37]

For hypothesis H4a-e, separate moderation analyses were carried out to examine the role of support offered by the employer (moderator) on the relationship between indicators of technostress (predictors) and burnout. The predictor variables were mean centred for an easier interpretation of

moderation effects. Whenever there was a moderation effect (significant interaction term), follow-up examinations were carried out in the form of simple slope analyses.

All statistical analyses were conducted using IBM SPSS Statistics (version 26). Moderation analyses were undertaken with the PROCESS macro v4.2.[38] The significance level was set at alpha = 5%. Effect sizes were calculated and interpreted according to Cohen and Hair et al.[39 40]

Responses of participants to the four open-ended questions on support offers were examined using qualitative content analysis. On the basis of the four questions, categories were formed deductively for the category system. These were supplemented by inductively build categories based on the data material. All responses were coded and assigned to the categories using MAXQDA 2020. Quotes from the responses were translated into English.

Patient and public involvement

Patients or the public were not involved in the design, conduct, reporting or dissemination plans of this research.

RESULTS

A total of 1.234 visitors opened the survey link, 557 started the questionnaire and 316 participants completed the survey. Of them, 13 participants were excluded, because they did not meet the inclusion criteria. Therefore, the final study population comprised 303 participants.

Sociodemographic data

Of the participants, 73.3% were female and the majority was between 40-49 and 50-59 years of age (30% and 27.4%, respectively). Most of the participants held a professional qualification in general nursing (89.4%) and worked 35 hours/week or more (78.2%). Overall, 55.8% had a leadership position. **Table 1** provides further information on the study population. The majority of participants worked at hospitals located in the federal states of Bavaria (37.6%) and North Rhine-Westphalia (21.8%) **(online supplemental table A)**.

Table 1 Description of the study population (n=303)

Variables	n	%
Sex		
Female	222	73.3
Male	80	26.4
Diverse	1	0.3
Age group		
20-29 years	40	13.2
30-39 years	69	22.8
40-49 years	91	30.0
50-59 years	83	27.4
≥ 60 years	20	6.6
German as mother tongue		
Yes	286	94.4
No	17	5.6
Professional qualification		
General nurse	271	89.4
Paediatric nurse	23	7.6
Geriatric nurse	7	2.3
Nursing assistant	2	0.7

Working time		
Full-time (≥ 35 hours)	237	78.2
Part-time (15-34 hours)	62	20.5
Part-time (< 15 hours)	4	1.3
Work experience (including formal qualification in nursing)[1]		
1-5 years	10	3.3
6-10 years	38	12.5
11-15 ears	47	15.5
> 15 years	208	68.6
Leadership position		
Yes	169	55.8
No	134	44.2
Support of employer in the use of digital technologies[1]		
Yes	139	45.9
Yes, but no usage of support offers	62	20.5
No	95	31.4
Missing values	7	2.3

[1] Percentages do not add up to 100% due to rounding.

Use of ICT

Overall, 89.4% of participants used hospital information systems during their work with 44.2% of them using it for an average of 0.5-2.5 hours per day. This was followed by the electronic care documentation and health/nursing records, which were used by 78.2% and 72.3% of participants, respectively. About half of the participants applied electronic planning of care processes and digital medication management. Digital SOPs, decision support systems as well as smartphone apps such as pocket guidelines were only used by a minority of participating nurses (11.6%-24.8%). **Online supplemental table B** shows the results on the use of ICT.

Indicators of technostress and burnout

Among the five included indicators of technostress, lack of technical support and techno-unreliability had the highest mean values (4.10 ±1.90 and 4.26 ±1.83, respectively). The participants had an average burnout score of 49.86 ±19.90. All scales showed good reliability with values of Cronbach's α > 0.8. An overview of the descriptive statistics of the technostress and burnout scales can be found in **online supplemental table C**.

Indicators of technostress among nurses with and without a leadership position

Nurses without a leadership position reported higher technostress due to techno-complexity (Mdn = 3.60) and techno-usefulness (Mdn = 4.00) than nurses with a leadership position (Mdn = 3.20 and 3.60, respectively). However, the differences were not statistically significant considering the Holm-Bonferroni corrected alpha. Levels of techno-overload, lack of technical support and techno-unreliability also did not differ significantly between the two groups. Therefore, hypotheses H1a-H1e had to be rejected **(Table 2)**.

Table 2 Comparison of indicators of technostress of nurses with and without a leadership position

Variable	n	Mdn	U	z	Adjusted α[1]	p	Effect size (r)
Techno-complexity							
With leadership position	169	3.20	13184.00	2.459	0.01	0.014	0.14
Without leadership position	134	3.60					

Techno-overload							
With leadership position	169	3.20	11379.50	0.075	0.05	0.940	0.00
Without leadership position	134	3.20					
Techno-usefulness							
With leadership position	169	3.60	12936.50	2.132	0.0125	0.033	0.12
Without leadership position	134	4.00					
Lack of technical support							
With leadership position	169	4.40	10589.00	-0.970	0.0167	0.332	-0.06
Without leadership position	134	4.20					
Techno-unreliability							
With leadership position	169	4.60	11114.00	-0.276	0.025	0.782	-0.02
Without leadership position	134	4.40					

[1] Holm-Bonferroni corrected alpha level

Association of indicators of technostress and support offers with burnout

All indicators of technostress were significantly and positively correlated with burnout (r = 0.187 to 0.329, all p <0.01). Support by the employer in the use of digital technologies was significantly negatively correlated with burnout (r = -0.125, p <0.05) **(online supplemental table D)**.

Model 1 of the hierarchical linear regression, which contained all indicators of technostress, explained about 13% of the variance in burnout (adjusted R^2 = 0.130). When support by the employer was included within model 2, the amount of explained variance increased significantly (p = 0.036) to 14% (adjusted R^2 = 0.140). Both models indicate a medium effect.[39] In the final model, both techno-overload (β = 0.259, p = 0.004) and techno-complexity (β = 0.161, p = 0.043) were statistically significantly positively related to burnout. Hypotheses H2a and H2b were thus confirmed. The other three indicators of technostress showed no significant relationship with burnout. Hence, hypotheses H2c-H2e had to be rejected. With regard to hypothesis H3, support by the employer in the use of digital technologies was not significantly related to burnout (β = -0.116, p = 0.055) and H3 had to be rejected **(Table 3)**.

Table 3 Hierarchical linear regression model of predictors of burnout

	Model 1				**Model 2**			
Variable	**B (95%-CI)**	**SE**	**β**	**p**	**B (95%-CI)**	**SE**	**β**	**p**
Constant	29.793 (22.073 to 37.129)	3.729		0.001	33.866 (24.815 to 42.742)	4.341		0.001
Techno-overload	3.834 (1.550 to 6.127)	1.147	0.263	**0.003**	3.776 (1.612 to 5.959)	1.162	0.259	**0.004**
Techno-complexity	1.992 (-0.108 to 4.012)	1.092	0.142	0.070	2.258 (0.088 to 4.309)	1.093	0.161	**0.043**
Techno-unreliability	1.352 (-1.003 to 3.606)	1.071	0.125	0.211	1.485 (-0.808 to 3.682)	1.071	0.137	0.161
Techno-usefulness	-1.423 (-3.835 to 1.184)	1.201	-0.101	0.235	-1.750 (-4.184 to 0.835)	1.220	-0.125	0.148
Lack of technical support	0.019 (-1.787 to 1.748)	0.952	0.002	0.989	-0.174 (-1.977 to 1.649)	0.955	-0.017	0.878
Support of employer[1]					-4.891 (-9.779 to -0.500)	2.495	-0.116	0.055

R^2	0.145				0.158			
adj. R^2	0.130				0.140			
f^2	0.15				0.16			

n = 296; Displayed are robust CIs and SEs based on 1,000 bootstrap samples. Model 1: F(5, 290) = 9.812, p <0.001; Model 2: F(6, 289) = 9.010, p <0.001, Durbin-Watson statistic = 2.091; [1] No support as reference category

Moderating role of support offers

Support offered by the employer in the use of digital technologies did not significantly moderate the relationship between techno-complexity and burnout (R^2 change = 0.013, F(1,292) = 3.84, p = 0.051), techno-overload and burnout (R^2 change = 0.000, F(1,292) = 0.08, p = 0.772), techno-usefulness and burnout (R^2 change = 0.010, F(1,292) = 2.57, p = 0.110) and techno-unreliability and burnout (R^2 change = 0.005, F(1,292) = 1.27, p = 0.260). Therefore, hypotheses H4a-c and H4e had to be rejected.

Support by the employer moderated the relationship between lack of technical support and burnout significantly (R^2 change = 0.026, F(1,292) = 7.41, p = 0.007), with f^2 = 0.03 indicating a large effect.[40] Thus, hypothesis H4d could be confirmed. When employees stated that they received no support offers in the use of digital technology by their employer there was a non-significant negative relationship between the technostress indicator lack of technical support and burnout (b = -0.70, 95% CI -2.82 to 1.42, p = 0.516). When employees stated that they had support offers in the use of digital technology by their employer there was a significant positive relationship between lack of technical support and burnout (b = 2.88, 95% CI 1.39 to 4.36, p <0.001) **(Figure 1)**.

Known support offers, their benefits and problems as well as further needs of participants

As shown in **Table 1**, 201 (66.3%) participants reported that their employers offered support in the use of digital technologies. Answers of participants to the four open-ended questions on these support offers were coded into four main categories: 'known support offers', 'benefits of offers', 'problems and hindering factors in the use of offers' and 'further needs'. These are described below and supported by quotes from the responses.

Overall, 138 participants specified which support offers they were aware of. Training and further education was named most frequently. These were offered, for example, on specific programmes or innovations. One participant stated:

"We have an extensive training programme, including user training courses, and individual training sessions can also be scheduled, for example, to go into more detail on specific topics. […] Furthermore, when new digital applications are introduced, colleagues from the IT department also offer to accompany the initial implementation phase [...]." (ID 341)

In addition to accompanying such implementation phases, IT departments/services assisted with technical problems and faults, sometimes on site, via a telephone hotline or digital tickets. Several participants described specially trained employees/contact persons (e.g. key users) who also provided support with problems and questions, passed these on to the IT service and informed them about innovations.

"There is a small team (four nurses) who have been released for 8 hours a week to train the nursing staff in the hospital information system and to help with questions or suggestions and, if necessary, to pass these on to the IT." (ID 464)

Offers described were perceived as beneficial by participants because they provided helpful explanations, solutions to problems, exchange opportunities and clarification of questions.

Furthermore, they lead to a more confident usage of the systems. The latter was associated with time savings, reduced anxiety, a lower error rate and personal development by participants.

"They provide confidence in handling and therefore also save time." (ID 195)

Several problems were described in connection with the support offers and reasons why participants did not use them. Most often mentioned was a lack of time resources to participate, for example in training and further education, due to a high workload, low staffing and excessive overtime. As a consequence, some stated that they felt too tired and lacked motivation to take part in these activities.

"Fixed dates - training courses - are sometimes difficult to realise due to poor staffing." (ID 222)

As another hindering factor participants named unfavourable conditions of the offers. This included, for example, that times and dates of training courses were not suitable, offers were not flexible enough or were only directed at certain target groups. Participants further described an insufficient availability of support. For example, contact persons were not available at the weekend, they did not receive a timely support and offers came too late or were cancelled. In this regard, a participant wrote:

"Digital tickets can be created directly in the event of faults, but these are not always dealt with immediately. The IT department has too few resources for our large clinic." (ID 293)

Correspondingly, participants expressed further needs and suggestions for improvements concerning the organisational offers. Many participants wished for an expansion or adaption of the training programme, including a more specific focus on programmes/technologies used as well as training on new features of programmes. Concerning the organisation of training courses participants requested regular repetitions of courses, inclusion of all employees, mandatory courses, courses on site (on the ward) and during working hours, a compatibility with shift work, integration of courses into the familiarisation phase, more capacities, digital training and shorter courses.

"When introducing a new digital application, give short training sessions (10-20 minutes) on the individual wards (preferably between shift changes from early to late shift)." (ID 414)

Several participants also called for better accessibility and availability of the IT department/services. One participant suggested the following:

"Perhaps offer an IT consultation hour for urgent questions...". (ID 293)

In addition, there was a need for more time resources to familiarise with (new) programmes and participate in support offers such as training courses. **Figure 2** summarises all aspects outlined by participants concerning the support offers.

DISCUSSION

This study examined the level of indicators of technostress according to leadership, their relationships with burnout, the moderating role of support offered by the employer and the experiences of nurses with support offers. Hospital information systems and electronic care documentation were the most widely used ICT among nurses in this study. No differences in technostress indicators were found between nurses with and without a leadership position. Of the indicators, techno-overload and techno-complexity were significantly associated with burnout. When there were support offers of the employer in the use of digital technologies, lack of technical support was significantly associated with burnout. Support offers such as training, IT service and contact persons on the ward helped nurses to be more confident in the use of ICT. However, a high

workload, unfavourable conditions of the offers and insufficient availability were seen as hindering factors to benefit from such offers.

In line with former studies, techno-unreliability was one of the highest techno-stressors among participants.[16 24 29] Furthermore, nurses in this study experienced higher techno-unreliability (4.26 vs. 3.30) and lack of technical support (4.10 vs. 3.30) in comparison to participants of a large cross-sectoral survey in the regions of Germany, Switzerland and Austria.[41] A reason could be that digitalisation in German hospitals is still in its infancy. In fact, the user-friendliness of the IT systems used is often criticised because, for example, it takes a long time to retrieve information or the systems frequently crash.[42] Furthermore, expectations of nurses with the use of digital technologies are high. German nurses described in focus groups desired effects of technology. Amongst others these were a decrease in their physical and psychological burden and an increase in saved time that they can apply to direct care activities.[5] Technical problems and a lack of support when such problems occur contradict these wishes and can therefore be perceived as particularly stressful.

Contrary to our hypothesis, the indicators of technostress did not differ significantly between nurses with and without a leadership position. It is possible that the group of nurses with leadership position was too heterogeneous to find differences to nurses without a leadership position. For example, we did not differentiate between those in the hospital management (head of nursing) and those leading a team of nurses on the ward. It seems plausible that ward managers may work with ICT to a similar extent as nurses without a leadership position and are therefore confronted with techno-stressors in a similar way.

The burnout score of nurses in this study was 49.86 ±19.90. This score is higher than the baseline burnout score of employees in the Gutenberg health study of 37.7 ±17.4 (N = 4,278).[43] However, it is comparable to burnout scores of nurses in other European studies.[44 45] Only two of the hypotheses regarding the relationship between indicators of technostress and burnout were confirmed in this study. A point of criticism of previous studies that investigated techno-stressors and their associations with health and work outcomes was that they did not consider the individual indicators of technostress, but rather used composite scores of technostress.[23] In contrary, this study examined five indicators separately, which made it possible to assess their individual role. It was shown, that techno-overload and techno-complexity were significantly positively related to burnout. The result for techno-overload is in line with several studies in the healthcare context.[24-26] In a recent study of hospital employees, both techno-overload and techno-complexity were also significantly positively related to core and secondary symptoms of burnout, conforming our results.[28] One reason why these two factors showed an association with burnout while the other indicators (techno-unreliability, techno-usefulness and lack of technical support) were not significantly related to burnout could be that techno-overload and techno-complexity are more directly connected to efforts for employees, namely in working longer and faster as well as in learning and understanding ICT.[11]

The moderation analyses showed that support by the employer in the use of digital technologies significantly moderated the relationship between lack of technical support and burnout. However, support by the employer did not act as a buffer, as one might have expected with regard to the J-DR model.[9] Instead, it strengthened a positive association between lack of technical support and burnout. One explanation could be that nurses who had general support offers at their disposal were particularly disappointed and frustrated about receiving only limited help and support for technical problems with ICT. Therefore, the results could also indicate that support by the employer did not help them with technical problems, which was associated with higher burnout than if there was no support at all. In this respect, the open-ended questions on support offers also revealed difficulties.

Several participants reported problems related to IT support, e.g. limited availability and lack of timely support from IT service.

Strengths and limitations

According to current knowledge, this was the first study that examined different indicators of technostress, burnout and employer support among German hospital nurses. The tested hypotheses were proposed a priori and were based on theoretical models and recent research. However, the study used a cross-sectional design which did not allow any conclusions to be drawn about causal relationships between the variables. Through the applied recruitment strategy, it was possible to reach a sufficiently large study population. A limitation was that the study population was not representative of German nurses, indicating a non-response bias. Nurses from single federal states especially from Bavaria were overrepresented in the sample.[46] The same is true for nurses with German as their mother tongue.[47] A reason could be that the questionnaire was only available in German. Moreover, nurses with a leadership position seemed to be overrepresented in the sample, which could have been caused by the recruitment via the head of nursing. A further strength of the study was the use of validated scales to measure indicators of technostress and burnout. Though, the technostress scales were not particularly developed or adapted for the context of healthcare, so specific technostress creators could have been missed.[23] Data collection was carried out using an online survey and questions were set as mandatory information, except for questions on support offers. Therefore, there were no limitations regarding missing data. However, it was not possible to calculate the response rate for the study, as it could not be traced whether and to how many nurses the link to the online survey was forwarded.

Implications for practice

This study showed that techno-overload with regard to ICT use was significantly associated with burnout among nurses in acute care at German hospitals. This result underlines the importance of time resources that need to be allocated to nurses to get familiar with ICT such as new software. Furthermore, hospital managers should ensure that ICT use does not lead to additional tasks and an information overload for nursing personnel. In terms of techno-complexity, time resources need to be provided for participation in training and education. To allow nurses to use ICT confidently and efficiently, such training offers should be repeated regularly and designed flexibly. In addition, IT support of hospitals could be expanded so that IT contact persons are also available at weekends, for example, in the event of technical problems. If digital technologies are to contribute to time savings, better communication and quality of care in hospitals, it is generally important that users are actively involved in the development, implementation and evaluation of software.[18 31]

Implications for future research

The results on the association between the five indicators of technostress and burnout indicate that these should also be analysed individually in future studies.[23] Furthermore, a context-specific questionnaire for the healthcare sector could be developed for future research which considers even more specifically, for example through preliminary qualitative interviews, which techno-stressors could be of importance in this field. With regard to technostress and the professional position, future studies could differentiate more precisely between nursing staff with different leadership positions at the hospital to find out more about their levels of technostress. Overall, there is still a lack of longitudinal studies that examine the relationship between different techno-stressors and health outcomes among healthcare professionals in Germany as well as of intervention-based studies.

CONCLUSION

In view of the increasing digitalisation of the healthcare sector, the results of this study provide useful information on the experience of technostress in the use of ICT among hospital nurses in Germany. This study showed an association between some indicators of technostress and burnout. According to the results, particular attention should be paid to supporting nurses in terms of techno-overload and techno-complexity in the future. Furthermore, there is still a need for customised support and further offers from employers in the use of digital technologies among nurses. In this regard, further research should evaluate intervention strategies for such support offers. Longitudinal studies should further verify the association between indicators of technostress and burnout as well as the role of support offers.

DECLARATIONS

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Ethics approval All study participants were informed about the aim of the study and data protection concerns before filling out the online questionnaire and gave their informed consent to participate in the study. Ethical approval for the study was obtained from the Local Ethics Committee of Psychologists at the University Medical Center Hamburg-Eppendorf (UKE), Germany (LPEK-0590).

Data availability statement The dataset analysed during the current study is not publicly available due to German national data protection regulations. It is available from the corresponding author on reasonable request.

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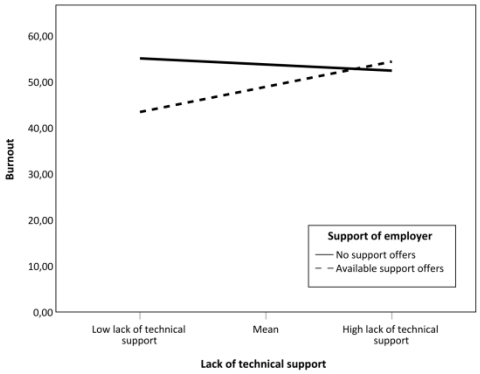
FIGURE LEGENDS

Figure 1 Moderation effect of support offered by the employer

Figure 2 Overview of participants' answers to open-ended questions on support offers



Page 1

Figure 1 Moderation effect of support offered by the employer

209x296mm (300 x 300 DPI)

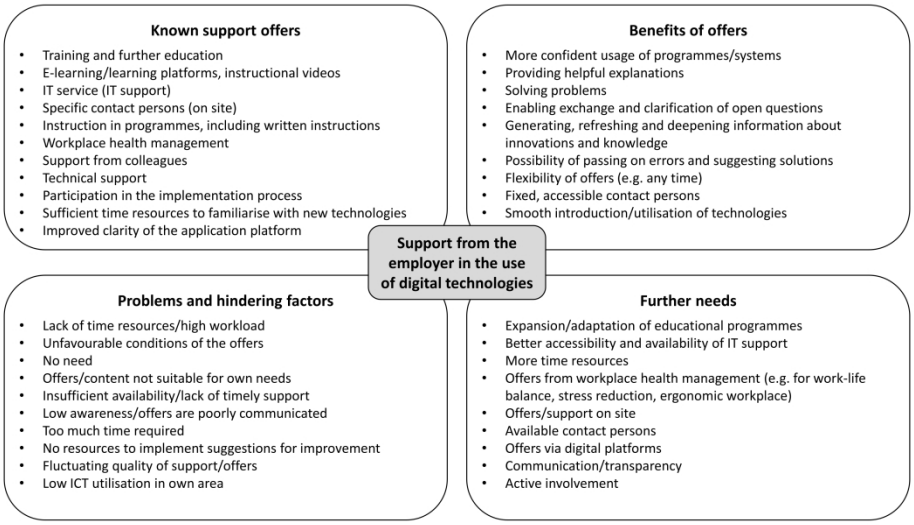


Figure 2 Overview of participants' answers to open-ended questions on support offers

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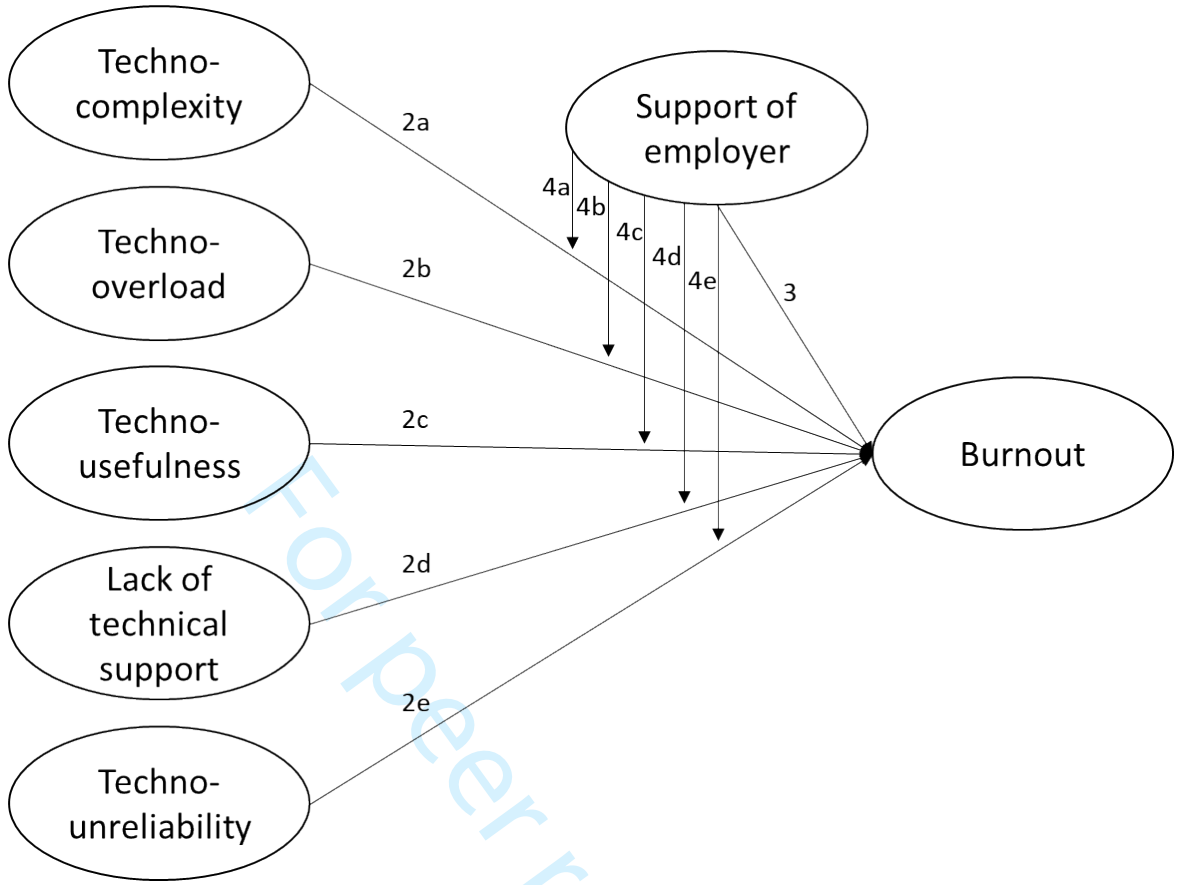

Supplementary Figure A. Conceptual model with hypotheses 2-4 on the relationship between indicators of technostress, support offered by the employer and burnout

Supplementary Table A. Description of the hospitals in which the study participants were employed (n=303)

Variables	n	%
Type of hospital ownership		
Public	190	62.7
Non-profit	75	24.8
Private	28	9.2
Unknown	10	3.3
Number of hospital beds		
≤ 299 beds	99	32.7
300-599 beds	86	28.4
≥ 600 beds	107	35.3
Unknown	11	3.6
Federal state of the hospital		
Bavaria	114	37.6
North Rhine-Westphalia	66	21.8
Lower Saxony	22	7.3
Hesse	21	6.9
Saarland	15	5.0
Hamburg	12	4.0
Brandenburg	8	2.6
Baden-Württemberg	7	2.3
Bremen	7	2.3
Rhineland-Palatinate	7	2.3
Saxony-Anhalt	6	2.0
Schleswig-Holstein	6	2.0
Berlin	4	1.3
Saxony	4	1.3
Thuringia	4	1.3

Supplementary Table B. Average duration of use of different types of ICT in everyday nursing care (hours per day, n=303)

		n (%)				
Type of ICT	**Range**	**No utilisation**	**0.5-2.5 h/day**	**3-5 h/day**	**5.5-7.5 h/day**	**8-10 h/day**
Hospital information system[1]	0-10	32 (10.6)	134 (44.2)	83 (27.4)	39 (12.9)	15 (5.0)
Electronic care documentation	0-10	66 (21.8)	131 (43.2)	53 (17.5)	31 (10.2)	22 (7.3)
Electronic health/ nursing records[1]	0-10	84 (27.7)	125 (41.3)	45 (14.9)	27 (8.9)	22 (7.3)
Electronic planning of care processes	0-10	143 (47.2)	101 (33.3)	33 (10.9)	15 (5.0)	11 (3.6)
Digital medication management	0-10	171 (56.4)	92 (30.4)	20 (6.6)	10 (3.3)	10 (3.3)
Digital SOPs	0-10	228 (75.2)	60 (19.8)	9 (3.0)	1 (0.3)	5 (1.7)
Decision support systems[1]	0-10	260 (85.8)	33 (10.9)	6 (2.0)	2 (0.7)	2 (0.7)
Smartphone apps[1]	0-8	268 (88.4)	28 (9.2)	4 (1.3)	2 (0.7)	1 (0.3)

[1] Percentages do not add up to 100% due to rounding.

Supplementary Table C. Descriptive statistics of the main study variables

Variable	Range	Mean	SD	α
Techno-complexity	1-7	3.44	1.40	0.84
Techno-overload	1-6.6	3.39	1.35	0.84
Techno-usefulness	1-7	3.80	1.41	0.83
Lack of technical support	1-7	4.10	1.90	0.95
Techno-unreliability	1-7	4.26	1.83	0.94
Burnout	0-100	49.86	19.90	0.91

α = Cronbach's alpha, n = 303

Supplementary Table D. Correlation matrix of the main study variables

Variable	1	2	3	4	5	6	7
1. Techno-complexity	303						
2. Techno-overload	0.618**	303					
3. Techno-usefulness	0.696**	0.571**	303				
4. Lack of technical support	0.391**	0.286**	0.470**	303			
5. Techno-unreliability	0.463**	0.416**	0.513**	0.752**	303		
6. Personal burnout	0.291**	0.329**	0.224**	0.187**	0.245**	303	
7. Support by employer[1]	-0.002	-0.044	-0.134*	-0.123*	-0.064	-0.125*	296

Spearman's correlation coefficient; n is shown on the diagonal; [1] No support as reference category; * p <0.05 ** p <0.01 (2-tailed)

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	1
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3-5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6-7
Bias	9	Describe any efforts to address potential sources of bias	6-7
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7-8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7-8
		(*b*) Describe any methods used to examine subgroups and interactions	7-8
		(*c*) Explain how missing data were addressed	7
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	Not applicable
		(*e*) Describe any sensitivity analyses	Not applicable
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	8
		(b) Give reasons for non-participation at each stage	Not applicable
		(c) Consider use of a flow diagram	Not applicable
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8-9
		(b) Indicate number of participants with missing data for each variable of interest	8-9
Outcome data	15*	Report numbers of outcome events or summary measures	9-10
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	7, 10, 11
		(*b*) Report category boundaries when continuous variables were categorized	Not applicable
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	Not applicable
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	11
Discussion			
Key results	18	Summarise key results with reference to study objectives	13
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	14
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	13-15
Generalisability	21	Discuss the generalisability (external validity) of the study results	14
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	15

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Indicators of technostress, their association with burnout and the moderating role of support offers among nurses in German hospitals: a cross-sectional study

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Indicators of technostress, their association with burnout and the moderating role of support offers among nurses in German hospitals: a cross-sectional study

Tanja Wirth*, Jessica Kräft, Berit Marquardt, Volker Harth, Stefanie Mache

Institute for Occupational and Maritime Medicine (ZfAM), University Medical Center Hamburg-Eppendorf (UKE), 20459 Hamburg, Germany

*Correspondence: t.wirth.ext@uke.de; +49 40 42837 4343

ABSTRACT

Objectives To examine the level of indicators of technostress among nurses with and without a leadership position, the relationship between indicators of technostress and burnout and the moderating role of support offered by employers. The availability of support offers and further needs of nurses were also explored.

Design Cross-sectional online survey.

Setting Acute care hospitals in Germany.

Participants 303 nurses (73.3% female) who have worked at the hospital for at least one year and a minimum of ten hours per week.

Primary and secondary outcome measures Indicators of technostress (complexity, overload, usefulness, lack of technical support and unreliability) served as predictors in multiple linear regression analyses to examine their association with the primary outcome burnout. Support of employers was included as a moderator variable. Validated subscales from the Digital Stressors Scale and Copenhagen Burnout Inventory as well as open-ended questions were applied.

Results There were no differences in the level of indicators of technostress found between nurses with and without a leadership position. Techno-overload ($\beta = 0.259$, $p = 0.004$) and techno-complexity ($\beta = 0.161$, $p = 0.043$) were significantly associated with burnout. Support by the employer moderated the relationship between lack of technical support and burnout significantly (R^2 change = 0.026, $F(1,292) = 7.41$, $p = 0.007$). Support offers such as training, IT service and contact persons on the ward helped nurses to be more confident in the use of information and communication technologies (ICT). However, they expressed further needs with regard to these and new offers.

Conclusions There was an association between two indicators of technostress and burnout. Therefore, particular attention should be paid to supporting nurses in terms of techno-overload and techno-complexity. Furthermore, there is still a need for customised support and further offers from employers in the use of digital technologies.

Keywords: Information and communication technology, digital stress, emotional exhaustion, occupational health

STRENGTHS AND LIMITATIONS OF THIS STUDY

- The study comprised a priori hypotheses that were based on theoretical models and current research.
- Validated scales were used to measure indicators of technostress and burnout.
- The cross-sectional design did not allow any conclusions to be drawn about causal relationships.
- The study population was not representative of German nurses, with nurses from single federal states, with German as their mother tongue and with a leadership position being overrepresented in the sample.
- Due to the use of an online survey, it was not possible to calculate the response rate for the study.

INTRODUCTION

Digital transformation in the form of digital work processes and technical aids is increasingly finding its way into the healthcare sector in Germany and is having a growing influence on nursing activities [1, 2]. So far, information and communication technologies (ICT) are most frequently used in nursing practice [3-5]. In an online survey of 1,335 nurses from care facilities and hospitals in Germany, 91.4% of the participants reported having experience in the use of ICT. Among ICT use, experiences in the use of electronic health/nursing records (74.8%) and electronic planning of care processes (71.5%) were mentioned most frequently [5].

The use of digital technologies in the healthcare system pursues goals such as reducing bureaucracy and improving the exchange of data across different sectors, which in turn can lead to time savings and improved communication. Overall, it is assumed that the workload of nursing staff will be reduced and the quality of nursing care can be improved [6]. Nurses already confirmed some positive effects such as increased efficiency, saved time and improved quality of care [5]. On the other hand, more than half of the participants of a sample of 495 care workers in Germany also feared an increase in time pressure, staff savings and more (performance) control with the use of digital technologies [4]. This is supported by a study that described a persistently high work intensity in nursing care and a lack of resources to learn and use digital technologies. Further, it pointed to challenges such as the inaccuracy of technology fit, susceptibility to errors and failures and the increasing possibility of monitoring and performance control [7]. Overall, care-, work- and health-related effects of the use of digital technologies in nursing care in Germany have so far been barely studied [2]. Therefore, the aim of the study was to examine ICT use, factors that create stress from ICT use as well as their associations with burnout among nurses working in acute care at German hospitals. Furthermore, the study aimed to explore the role of support offered by employers in the use of digital technologies.

Theoretical background

Job Demands-Resources (JD-R) model

The present study uses the JD-R model from Demerouti et al. as a basis [8]. It is as flexible model that depicts both negative and positive indicators of employee well-being and can be applied to various occupational settings. Correspondingly, the model distinguishes between job demands and job resources. While job demands may require constant physical, cognitive and/or emotional effort and are, therefore, associated with job strain, job resources have a functional and motivational potential, can stimulate personal development and lead to high work engagement. Job resources may result from the organisation itself, social relations, the organisation of work and work tasks. The JD-R model assumes that job resources may buffer the effect of job demands on job strain [9].

Technostress

In the context of increasing digitalisation in the workplace, Brod described the phenomenon of technostress [10]. He defined technostress as a 'modern disease of adaptation caused by an inability to cope with the new computer technologies in a healthy manner' [10, p. 16]. On the basis of this definition, a conceptual model for understanding technostress was developed by Ragu-Nathan et al. [11]. They identified five factors that create stress from the use of ICT (technostress creators or indicators of technostress) and decrease job satisfaction, leading to decreased organizational and continuance commitment. The five indicators are techno-overload, techno-insecurity, techno-invasion, techno-uncertainty and techno-complexity. Techno-overload refers to an overload of information and communication due to digital technologies requiring employees to work faster. Techno-insecurity describes the fear of employees of losing their jobs due to ICT. Techno-invasion

means that boundaries between work and private life are blurring because of ICT. Techno-uncertainty refers to difficulties and feelings of uncertainty in the use of ICT as these are rapidly changing, while techno-complexity describes the efforts of employees in learning and understanding ICT due to their complex nature. On the contrary, three organizational and managerial mechanisms potentially reduce stress from the use of ICT (technostress inhibitors) and increase job satisfaction and organizational and continuance commitment. These are named literacy facilitation, technical support provision and involvement facilitation. Literacy facilitation involves knowledge sharing within the organisation. Technical support provision describes the availability of help and support for technical problems with ICT. Involvement facilitation refers to transparency regarding the introduction and effects of ICT [11]. In the meantime, further technostress categories have been described and investigated [12, 13], the most noteworthy of which is the factor "unreliability". It refers to the usability of technology and describes situations where systems are slow or breakdown, causing stress for users [12, 13].

Burnout

Burnout is a well-known concept in psychosocial research and a widespread phenomenon in the occupational context, especially among human service professionals [14]. It can be defined as 'a state of physical, emotional and mental exhaustion that results from long-term involvement in work situations that are emotionally demanding' [14, p. 501]. In this respect, Kristensen et al. emphasised the attribution of fatigue and exhaustion to the work context as the key characteristic of the concept [15].

Support offers

Support offered by employers relates to support of nurses in the use of ICT in the work context. Shachak et al. provided a holistic definition of end-user support for health information technology (HIT) including technical support as well as support from colleagues and training. They described it as 'any information or activity that is intended to help users solve problems with, and better use, the system' [16, p. 170]. Beyond that, support offers in the present study include health-related activities of employers, i.e. measures for workplace health promotion, to prevent technostress from the use of ICT [17].

State of research

Digitisation in organisations (e.g. the use of ICT) is associated with the occurrence of technostress. Research has shown that the degree of digitisation has a statistically significant impact on indicators of technostress. Technostress occurs especially when the degree of digitisation of the workplace does not match the skills of the employees [18]. This can also be applied to the healthcare context. A systematic review referring to the usage of health information systems and medical technology concluded that digitisation causes increased technostress of health personnel [19]. Among health personnel from different health organisations, those working in acute care and rehabilitation hospitals had significant higher levels of technostress in comparison to those working in home care organizations and nursing homes. This was explained by the authors in terms of a more advanced digitisation [20] and underlines the relevance of the setting investigated in the present study.

In terms of profession, working as a physician or a nurse was significantly associated with increased technostress in comparison to medical-therapeutic and medical-technical professions [20, 21], while working in a profession with no professional qualification (e.g. trainees, civilian service, volunteers) was significantly associated with a decrease in technostress [20]. This is in line with cross-sectoral results showing that higher qualified workers experienced higher levels of technostress [18]. Similarly, it could be assumed that experiences of technostress also differ according to the

professional position. Nursing staff in leadership positions in hospitals, e.g. ward managers, take on tasks in addition to direct nursing care, such as organisation of work processes and personnel deployment as well as employee and team development. As a result, they may be assigned additional administrative tasks [22]. This in turn could lead to greater use of digital work tools. A study in outpatient care in Germany indicated that technology readiness, which is supposed to predict the successful use of new technologies, was higher among supervisors than among employees in direct care [23]. However, it is still unclear how these differences affect the experience of technostress. The following hypothesis is therefore proposed and will be analysed:

H1: Indicators of technostress (H1a complexity, H1b overload, H1c usefulness, H1d lack of technical support and H1e unreliability) differ significantly among nurses with and without a leadership position.

Indicators of technostress can act as job demands [24]. Several studies suggest a link between technostress at work or its indicators and adverse health outcomes [25-27] as well as burnout symptoms [18, 21, 28-32]. Burnout symptoms are widespread among nurses. The prevalence of emotional exhaustion as the main aspect of the burnout syndrome [33] was found in meta-analyses to be around 30% among nurses from different disciplines [34-36]. Burnout symptoms can have an impact not only on the health of nursing staff, but also on patients, organisations and society [37]. For example, they are associated with sleep disorders [38] and lower organizational commitment and productivity among nurses as well as decreased patient safety, patient satisfaction and quality of care [37]. Some work-related factors that affect burnout symptoms are a high workload, emotional demands [39], lengthy work schedules and rotating shifts [35, 39]. In a study sample representative of employees in Germany in terms of the distribution across the federal states and the economic sectors, technostress explained about 22% of the variance in emotional exhaustion [18]. Studies among health professionals from different disciplines also found a positive association between technostress or indicators of technostress and burnout symptoms, although the amount of explained variance was somewhat smaller [21, 28-30]. For example, 12% of the variance of burnout symptoms could be explained by the three indicators techno-overload, techno-complexity and techno-uncertainty among physicians working in neurological or vascular surgery clinics [28]. Califf et al. found that nurses from hospitals in the USA who associated high levels of techno-overload, techno-unreliability and techno-insecurity with the use of technology in healthcare showed a negative psychological response in the form of distress [26]. To our knowledge, studies from Germany have so far not focused on the professional group of nurses in the context of technostress and mental strain such as burnout symptoms or have only considered them as a small group among health professionals [21, 27, 30]. Based on the above, the following hypothesis is proposed:

H2: Indicators of technostress (H2a complexity, H2b overload, H2c usefulness, H2d lack of technical support and H2e unreliability) are significantly positively related to nurses' burnout.

Personal resources, such as self-efficacy, were already found to moderate the relationship between technostress and strain. Healthcare workers with higher technology self-efficacy reported lower levels of strain [27]. A systematic review on the effects of technostress on employees' well-being and productivity described that ICT-related organisational resources (technical support, ICT usefulness for the job task, involvement facilitation) lead to positive psychological responses, which in turn create job satisfaction. The authors further stated that these organisational resources may buffer the effects of indicators of technostress on personal outcomes and that social and organisational support are successful coping mechanisms against technostress [24]. Similarly, Tell et al. found significant different levels of technostress according to the degree of implementation of preventive measures by the employer with higher levels of technostress for the group of physicians with a low degree of

implementation of preventive measures compared to those with a high degree of implementation [28]. Therefore, it can be assumed that support offered by the employer may serve as a job resource and, in accordance with the JD-R model, also has the potential to buffer the impact of indicators of technostress on burnout symptoms. Therefore, it is proposed that:

H3: Support offered by the employer is significantly related to nurses' burnout.

H4: Support offered by the employer moderates the relationship between indicators of technostress (H4a complexity, H4b overload, H4c usefulness, H4d lack of technical support and H4e unreliability) and nurses' burnout.

Facilitation strategies in healthcare institutions to reduce the impact of technostress and increase job satisfaction and organisational commitment could focus on an active involvement with regard to the implementation of new technologies, training and technical support [40]. However, research on strategies to prevent or reduce technostress, including organisational resources, is sparse [40-42]. Therefore, the following research questions should be explored:

RQ: What types of support offers for technology use are available to, used by, and considered helpful by nurses? What further needs do they have?

Online supplemental figure A takes up the theoretical models of technostress and job demands-resources and summarises the association hypotheses.

METHODS

Study design and data collection

A quantitative cross-sectional study was conducted. Data were collected through an online questionnaire from the middle of April to the beginning of November 2023 via the German online survey platform LamaPoll. A register of hospitals in Germany was prepared for data collection purposes. The register was based on the webpage *www.kliniken.de* and included the contact details of acute care hospitals. Outpatient and rehabilitation clinics were excluded. The final list with all federal states comprised 1.198 hospitals. Whenever possible, the head of nursing was contacted by email and asked to distribute the study information material and the link to the questionnaire to the nursing personnel of the hospital.

Nurses working in inpatient acute care at a German hospital were eligible for taking part in the study. Participants were further required to have been at the hospital for at least one year, to work a minimum of ten hours per week and to use ICT in everyday nursing care. According to the German Federal Statistical Office, there are currently 486,100 registered nurses working in the inpatient sector in Germany [43]. Taking this population, a confidence level of 90%, a margin of error of e = 0.05 and a standard deviation of p = 0.5 as a basis, a sample size of N = 273 was required to represent the population.

Measures

The online questionnaire included self-developed items on sociodemographic information and technology use, validated scales concerning technostress and burnout as well as open-ended questions on support offers **(online supplemental table A)**. Other parameters from the questionnaire were not included in this analysis. These will be published elsewhere.

Sociodemographic variables

Questions on sociodemographic information of the participants were self-developed and comprised age, sex, mother tongue, professional qualification, working hours, shift work, work experience, leadership position as well as ownership, number of beds and federal state of the hospital.

Use of ICT

The study examined the time of use of eight types of typical ICT in the hospital. These included the hospital information system, electronic care documentation, electronic health/nursing records, electronic planning of care processes, smartphone apps (e.g. pocket guidelines), digital medication management, digital standard operating procedures (SOPs) and decision support systems. Participants were asked to indicate their average time of use of these technologies on a typical working day. The time was recorded in half-hour intervals from a minimum of zero hours to a maximum of ten hours per day. The question was used in a similar way before [29].

Technostress

The German version of the Digital Stressors Scale (DSS) was used in the study to evaluate indicators of technostress among nurses. The DSS was developed by Fischer et al. to measure the perception of digital stressors in the workplace [13]. Overall, it consists of 50 items and covers ten categories of stressors. Each category can be applied on its own and is measured on a seven-point Likert scale ranging from 1 = strongly disagree to 7 = strongly agree. Higher values indicate higher levels of stress. The average of the values of the five items of a scale formed the scale value. In this study, five stressor categories were used: complexity, overload, usefulness, lack of technical support and unreliability. All of them were validated and showed acceptable reliability values (Cronbach's alpha > 0.70) in the German validation study [44].

Burnout

Burnout was measured using the subscale on personal burnout of the Copenhagen Burnout Inventory (CBI) [15]. The German version of this subscale was extracted from the Copenhagen Psychosocial Questionnaire (COPSOQ) and had shown high reliability (Cronbach's alpha = 0.91) [45]. It comprises six items measured on a five-point Likert scale ranging from 1 = never/almost never to 5 = always. To calculate the scale value, the values were transformed to 0, 25, 50, 75 and 100. The average of the values of the six items formed the scale value. Higher scale values indicate a higher burnout level (possible range: 0-100).

Support offers

Five self-developed items covered support in the use of technology. An initial question was: "Is there any support offered by your employer in the use of digital technologies" ("yes", "yes, but I don't use these support offers" and "no"). For analysis purposes, these were dichotomised to "yes" and "no". Participants who answered this question in the affirmative were asked to specify these offers and to reflect their usefulness in free-text formats. Those who stated before that they did not use any support offers were asked in an open-ended question for their reasons. The fifth item was also in free-text format and asked all participants about (further) support offers they would like to receive.

Data analysis

First, the data was cleaned and checked for completeness and plausibility. Participants who did not fulfil the inclusion criteria as well as participants with incomplete data were removed from the dataset. Descriptive statistics (frequencies) were used for analysing sociodemographic data and data on ICT use. Means, standard deviations, Cronbach's alpha and intercorrelations were calculated for all indicators of technostress and the burnout scale.

Normality was tested for all metric variables looking at histograms, Q-Q plots, skewness and kurtosis and data was proven for outliers using boxplots and z-scores. No outliers could be detected. As the assumption of normal distribution was violated, the non-parametric Mann-Whitney U test was used for comparing the groups of nurses with and without a leadership position (H1a-H1e). The Holm-Bonferroni procedure was applied to adjust alpha levels for multiple comparisons.

For hypotheses H2a-e and H3, a hierarchical multiple linear regression model was calculated with burnout as the dependent variable. Prerequisites for the regression analysis were tested beforehand using visual inspection of scatterplots for linear relationships and homoscedasticity, Durbin-Watson statistic for independence of residuals, correlation matrix and variance inflation factors (VIF) for multicollinearity as well as standardised residuals and Cook's distance for outliers. Bootstrapping based on 1,000 bootstrap samples was used to generate robust confidence intervals (CI) and standard errors (SE). Model 1 included all indicators of technostress as predictors. Model 2 additionally included the variable of support offered by employer. The variables sex and age were considered as control variables. However, as there was no substantial change in standardised beta coefficients of the predictors with the control variables, a final model without the control variables was calculated and reported in accordance with the suggestions of Becker et al. [46].

For hypothesis H4a-e, separate moderation analyses were carried out to examine the role of support offered by the employer (moderator) on the relationship between indicators of technostress (predictors) and burnout. The predictor variables were mean centred for an easier interpretation of moderation effects. Whenever there was a moderation effect (significant interaction term), follow-up examinations were carried out in the form of simple slope analyses.

All statistical analyses were conducted using IBM SPSS Statistics (version 26). Moderation analyses were undertaken with the PROCESS macro v4.2. [47]. The significance level was set at alpha = 5%. Effect sizes were calculated and interpreted according to Cohen [48] and Hair et al. [49].

Responses of participants to the four open-ended questions on support offers were examined using qualitative content analysis. On the basis of the four questions, categories were formed deductively for the category system. These were supplemented by inductively build categories based on the data material. All responses were coded and assigned to the categories using MAXQDA 2020. Quotes from the responses were translated into English.

Patient and public involvement

Patients or the public were not involved in the design, conduct, reporting or dissemination plans of this research.

RESULTS

A total of 1.234 visitors opened the survey link, 557 started the questionnaire and 316 participants completed the survey. Of them, 13 participants were excluded, because they did not meet the inclusion criteria. Therefore, the final study population comprised 303 participants.

Sociodemographic data

Of the participants, 73.3% were female and the majority was between 40-49 and 50-59 years of age (30% and 27.4%, respectively). Most of the participants held a professional qualification in general nursing (89.4%) and worked 35 hours/week or more (78.2%). Overall, 55.8% had a leadership position. **Table 1** provides further information on the study population. The majority of participants worked at hospitals located in the federal states of Bavaria (37.6%) and North Rhine-Westphalia (21.8%) **(online supplemental table B)**.

Table 1 Description of the study population (n=303)

Variables	n	%
Sex		
Female	222	73.3
Male	80	26.4
Diverse	1	0.3
Age group		
20-29 years	40	13.2
30-39 years	69	22.8
40-49 years	91	30.0
50-59 years	83	27.4
≥ 60 years	20	6.6
German as mother tongue		
Yes	286	94.4
No	17	5.6
Professional qualification		
General nurse	271	89.4
Paediatric nurse	23	7.6
Geriatric nurse	7	2.3
Nursing assistant	2	0.7
Working time		
Full-time (≥ 35 hours/week)	237	78.2
Part-time (15-34 hours/week)	62	20.5
Part-time (< 15 hours/week)	4	1.3
Work experience (including formal qualification in nursing)[1]		
1-5 years	10	3.3
6-10 years	38	12.5
11-15 ears	47	15.5
> 15 years	208	68.6
Leadership position		
Yes	169	55.8
No	134	44.2
Support of employer in the use of digital technologies[1]		
Yes	139	45.9
Yes, but no usage of support offers	62	20.5
No	95	31.4
Missing values	7	2.3

[1] Percentages do not add up to 100% due to rounding.

Use of ICT

Overall, 89.4% of participants used hospital information systems during their work with 44.2% of them using it for an average of 0.5-2.5 hours per day. This was followed by the electronic care documentation and health/nursing records, which were used by 78.2% and 72.3% of participants, respectively. About half of the participants applied electronic planning of care processes and digital medication management. Digital SOPs, decision support systems as well as smartphone apps such as pocket guidelines were only used by a minority of participating nurses (11.6%-24.8%). **Online supplemental table C** shows the results on the use of ICT.

Indicators of technostress and burnout

Among the five included indicators of technostress, lack of technical support and techno-unreliability had the highest mean values (4.10 ±1.90 and 4.26 ±1.83, respectively). The participants had an average burnout score of 49.86 ±19.90. All scales showed good reliability with values of Cronbach's α > 0.8. An overview of the descriptive statistics of the technostress and burnout scales can be found in **online supplemental table D**.

Indicators of technostress among nurses with and without a leadership position

Nurses without a leadership position reported higher technostress due to techno-complexity (Mdn = 3.60) and techno-usefulness (Mdn = 4.00) than nurses with a leadership position (Mdn = 3.20 and 3.60, respectively). However, the differences were not statistically significant considering the Holm-Bonferroni corrected alpha. Levels of techno-overload, lack of technical support and techno-unreliability also did not differ significantly between the two groups. Therefore, hypotheses H1a-H1e had to be rejected **(Table 2)**.

Table 2 Comparison of indicators of technostress of nurses with and without a leadership position

Variable	n	Mdn	U	z	Adjusted α[1]	p	Effect size (r)
Techno-complexity							
With leadership position	169	3.20	13184.00	2.459	0.01	0.014	0.14
Without leadership position	134	3.60					
Techno-overload							
With leadership position	169	3.20	11379.50	0.075	0.05	0.940	0.00
Without leadership position	134	3.20					
Techno-usefulness							
With leadership position	169	3.60	12936.50	2.132	0.0125	0.033	0.12
Without leadership position	134	4.00					
Lack of technical support							
With leadership position	169	4.40	10589.00	-0.970	0.0167	0.332	-0.06
Without leadership position	134	4.20					
Techno-unreliability							
With leadership position	169	4.60	11114.00	-0.276	0.025	0.782	-0.02
Without leadership position	134	4.40					

[1] Holm-Bonferroni corrected alpha level

Association of indicators of technostress and support offers with burnout

All indicators of technostress were significantly and positively correlated with burnout (r = 0.187 to 0.329, all p <0.01). Support by the employer in the use of digital technologies was significantly negatively correlated with burnout (r = -0.125, p <0.05) **(online supplemental table E)**.

Model 1 of the hierarchical linear regression, which contained all indicators of technostress, explained about 13% of the variance in burnout (adjusted R^2 = 0.130). When support by the employer was included within model 2, the amount of explained variance increased significantly (p = 0.036) to 14% (adjusted R^2 = 0.140). Both models indicate a medium effect [48]. In the final model, both techno-overload (β = 0.259, p = 0.004) and techno-complexity (β = 0.161, p = 0.043) were statistically significantly positively related to burnout. Hypotheses H2a and H2b were thus supported. The other three indicators of technostress showed no significant relationship with burnout. Hence, hypotheses H2c-H2e had to be rejected. With regard to hypothesis H3, support by the employer in the use of digital technologies was not significantly related to burnout (β = -0.116, p = 0.055) and H3 had to be rejected **(Table 3)**.

Table 3 Hierarchical linear regression model of predictors of burnout

	Model 1				Model 2			
Variable	**B (95%-CI)**	**SE**	**β**	**p**	**B (95%-CI)**	**SE**	**β**	**p**
Constant	29.793 (22.073 to 37.129)	3.729		0.001	33.866 (24.815 to 42.742)	4.341		0.001
Techno-overload	3.834 (1.550 to 6.127)	1.147	0.263	**0.003**	3.776 (1.612 to 5.959)	1.162	0.259	**0.004**
Techno-complexity	1.992 (-0.108 to 4.012)	1.092	0.142	0.070	2.258 (0.088 to 4.309)	1.093	0.161	**0.043**
Techno-unreliability	1.352 (-1.003 to 3.606)	1.071	0.125	0.211	1.485 (-0.808 to 3.682)	1.071	0.137	0.161
Techno-usefulness	-1.423 (-3.835 to 1.184)	1.201	-0.101	0.235	-1.750 (-4.184 to 0.835)	1.220	-0.125	0.148
Lack of technical support	0.019 (-1.787 to 1.748)	0.952	0.002	0.989	-0.174 (-1.977 to 1.649)	0.955	-0.017	0.878
Support of employer[1]					-4.891 (-9.779 to -0.500)	2.495	-0.116	0.055
R^2	0.145				0.158			
adj. R^2	0.130				0.140			
f^2	0.15				0.16			

n = 296; Displayed are robust CIs and SEs based on 1,000 bootstrap samples. Model 1: F(5, 290) = 9.812, p <0.001; Model 2: F(6, 289) = 9.010, p <0.001, Durbin-Watson statistic = 2.091; [1] No support as reference category

Moderating role of support offers

Support offered by the employer in the use of digital technologies did not significantly moderate the relationship between techno-complexity and burnout (R^2 change = 0.013, F(1,292) = 3.84, p = 0.051), techno-overload and burnout (R^2 change = 0.000, F(1,292) = 0.08, p = 0.772), techno-usefulness and burnout (R^2 change = 0.010, F(1,292) = 2.57, p = 0.110) and techno-unreliability and burnout (R^2 change = 0.005, F(1,292) = 1.27, p = 0.260). Therefore, hypotheses H4a-c and H4e had to be rejected.

Support by the employer moderated the relationship between lack of technical support and burnout significantly (R^2 change = 0.026, F(1,292) = 7.41, p = 0.007), with f^2 = 0.03 indicating a large effect [49]. Thus, hypothesis H4d could be supported. When employees stated that they received no support offers in the use of digital technology by their employer there was a non-significant negative relationship between the technostress indicator lack of technical support and burnout (b = -0.70, 95% CI -2.82 to 1.42, p = 0.516). When employees stated that they had support offers in the use of digital technology by their employer there was a significant positive relationship between lack of technical support and burnout (b = 2.88, 95% CI 1.39 to 4.36, p <0.001) **(Figure 1)**.

Known support offers, their benefits and problems as well as further needs of participants

As shown in **Table 1**, 201 (66.3%) participants reported that their employers offered support in the use of digital technologies. Answers of participants to the four open-ended questions on these support offers were coded into four main categories: 'known support offers', 'benefits of offers', 'problems and hindering factors in the use of offers' and 'further needs'. These are described below and supported by quotes from the responses.

Overall, 138 participants specified which support offers they were aware of. Training and further education was named most frequently. These were offered, for example, on specific programmes or innovations. One participant stated:

"We have an extensive training programme, including user training courses, and individual training sessions can also be scheduled, for example, to go into more detail on specific topics. […] Furthermore, when new digital applications are introduced, colleagues from the IT department also offer to accompany the initial implementation phase [...]." (ID 341)

In addition to accompanying such implementation phases, IT departments/services assisted with technical problems and faults, sometimes on site, via a telephone hotline or digital tickets. Several participants described specially trained employees/contact persons (e.g. key users) who also provided support with problems and questions, passed these on to the IT service and informed them about innovations.

"There is a small team (four nurses) who have been released for 8 hours a week to train the nursing staff in the hospital information system and to help with questions or suggestions and, if necessary, to pass these on to the IT." (ID 464)

Offers described were perceived as beneficial by participants because they provided helpful explanations, solutions to problems, exchange opportunities and clarification of questions. Furthermore, they lead to a more confident usage of the systems. The latter was associated with time savings, reduced anxiety, a lower error rate and personal development by participants.

"They provide confidence in handling and therefore also save time." (ID 195)

Several problems were described in connection with the support offers and reasons why participants did not use them. Most often mentioned was a lack of time resources to participate, for example in training and further education, due to a high workload, low staffing and excessive overtime. As a consequence, some stated that they felt too tired and lacked motivation to take part in these activities.

"Fixed dates - training courses - are sometimes difficult to realise due to poor staffing." (ID 222)

As another hindering factor participants named unfavourable conditions of the offers. This included, for example, that times and dates of training courses were not suitable, offers were not flexible enough or were only directed at certain target groups. Participants further described an insufficient availability of support. For example, contact persons were not available at the weekend, they did not receive a timely support and offers came too late or were cancelled. In this regard, a participant wrote:

"Digital tickets can be created directly in the event of faults, but these are not always dealt with immediately. The IT department has too few resources for our large clinic." (ID 293)

Correspondingly, participants expressed further needs and suggestions for improvements concerning the organisational offers. Many participants wished for an expansion or adaption of the training programme, including a more specific focus on programmes/technologies used as well as training on new features of programmes. Concerning the organisation of training courses participants requested regular repetitions of courses, inclusion of all employees, mandatory courses, courses on site (on the ward) and during working hours, a compatibility with shift work, integration of courses into the familiarisation phase, more capacities, digital training and shorter courses.

"When introducing a new digital application, give short training sessions (10-20 minutes) on the individual wards (preferably between shift changes from early to late shift)." (ID 414)

Several participants also called for better accessibility and availability of the IT department/services. One participant suggested the following:

"Perhaps offer an IT consultation hour for urgent questions...". (ID 293)

In addition, there was a need for more time resources to familiarise with (new) programmes and participate in support offers such as training courses. **Figure 2** summarises all aspects outlined by participants concerning the support offers.

DISCUSSION

This study examined the level of indicators of technostress according to leadership, their relationships with burnout, the moderating role of support offered by the employer and the experiences of nurses with support offers. Hospital information systems and electronic care documentation were the most widely used ICT among nurses in this study. No differences in technostress indicators were found between nurses with and without a leadership position. Of the indicators, techno-overload and techno-complexity were significantly associated with burnout. When there were support offers of the employer in the use of digital technologies, lack of technical support was significantly associated with burnout. Support offers such as training, IT service and contact persons on the ward helped nurses to be more confident in the use of ICT. However, a high workload, unfavourable conditions of the offers and insufficient availability were seen as hindering factors to benefit from such offers.

In line with former studies, techno-unreliability was one of the highest techno-stressors among participants [18, 26, 31]. Furthermore, nurses in this study experienced higher techno-unreliability (4.26 vs. 3.30) and lack of technical support (4.10 vs. 3.30) in comparison to participants of a large cross-sectoral survey in the regions of Germany, Switzerland and Austria [50]. A reason could be that digitalisation in German hospitals is still in its infancy. In fact, the user-friendliness of the IT systems used is often criticised because, for example, it takes a long time to retrieve information or the systems frequently crash [51]. Furthermore, expectations of nurses with the use of digital technologies are high. German nurses described in focus groups desired effects of technology. Amongst others these were a decrease in their physical and psychological burden and an increase in saved time that they can apply to direct care activities [5]. Technical problems and a lack of support when such problems occur contradict these wishes and can therefore be perceived as particularly stressful.

Contrary to our hypothesis, the indicators of technostress did not differ significantly between nurses with and without a leadership position. It is possible that the group of nurses with leadership position was too heterogeneous to find differences to nurses without a leadership position. For example, we did not differentiate between those in the hospital management (head of nursing) and those leading a team of nurses on the ward. It seems plausible that ward managers may work with ICT to a similar extent as nurses without a leadership position and are therefore confronted with techno-stressors in a similar way.

The burnout score of nurses in this study was 49.86 ±19.90. This score is higher than the baseline burnout score of employees in the Gutenberg health study of 37.7 ±17.4 (N = 4,278) [52]. However, it is comparable to burnout scores of nurses in other European studies [53, 54]. Only two of the hypotheses regarding the relationship between indicators of technostress and burnout were supported in this study. A point of criticism of previous studies that investigated techno-stressors and

their associations with health and work outcomes was that they did not consider the individual indicators of technostress, but rather used composite scores of technostress [25]. In contrary, this study examined five indicators separately, which made it possible to assess their individual role. It was shown, that techno-overload (β = 0.259) and techno-complexity (β = 0.161) were significantly positively related to burnout. The result for techno-overload is in line with several studies in the healthcare context [26-28]. Califf et al. found a comparable effect size for the association between techno-overload and negative psychological response (β = 0.25) among nurses employed in the United States [26], while other German studies reported higher coefficients for the association of techno-overload with strain (β = 0.54) [27] and with burnout (B = 0.44, own calculation: β = 0.39) [28]. In a recent study of German hospital employees, both techno-overload and techno-complexity were also significantly positively related to core symptoms of burnout. The effect size was similar to our study and higher for techno-overload (B = 0.19, own calculation: β = 0.23) than for techno-complexity (B = 0.13, own calculation: β = 0.13), which is consistent with our results [30]. One reason why these two factors showed an association with burnout while the other indicators (techno-unreliability, techno-usefulness and lack of technical support) were not significantly related to burnout could be that techno-overload and techno-complexity are more directly connected to efforts for employees, namely in working longer and faster as well as in learning and understanding ICT [11].

The moderation analyses showed that support by the employer in the use of digital technologies significantly moderated the relationship between lack of technical support and burnout. However, support by the employer did not act as a buffer, as one might have expected with regard to the J-DR model [9]. Instead, it strengthened a positive association between lack of technical support and burnout. One explanation could be that nurses who had general support offers at their disposal were particularly disappointed and frustrated about receiving only limited help and support for technical problems with ICT. Therefore, the results could also indicate that support by the employer did not help them with technical problems, which was associated with higher burnout than if there was no support at all. In this respect, the open-ended questions on support offers also revealed difficulties. Several participants reported problems related to IT support, e.g. limited availability and lack of timely support from IT service.

Strengths and limitations

According to current knowledge, this was the first study that examined different indicators of technostress, burnout and employer support among German hospital nurses. The tested hypotheses were proposed a priori and were based on theoretical models and recent research. However, the study used a cross-sectional design which did not allow any conclusions to be drawn about causal relationships between the variables. Through the recruitment strategy applied, it was possible to achieve the required sample size of N = 273 that had been calculated for the study beforehand. A limitation was that the study population was not representative of German nurses, indicating a non-response bias. Nurses from single federal states especially from Bavaria were overrepresented in the sample [55]. The same is true for nurses with German as their mother tongue [56]. A reason could be that the questionnaire was only available in German. Moreover, nurses with a leadership position seemed to be overrepresented in the sample, which could have been caused by the recruitment via the head of nursing. Therefore, the external validity of the study results must be regarded as limited and a generalisation to the overall population of German hospital nurses is not possible. A further strength of the study was the use of validated scales to measure indicators of technostress and burnout. Though, the technostress scales were not particularly developed or adapted for the context of healthcare, so specific technostress creators could have been missed [25]. In addition, the data is based on self-reports of participants, which may have introduced a response bias. Data collection was carried out using an online survey and questions were set as mandatory information, except for

questions on support offers. Therefore, there were no limitations regarding missing data. However, it was not possible to calculate the response rate for the study, as it could not be traced whether and to how many nurses the link to the online survey was forwarded.

Implications for practice

With regard to the cross-sectional nature of this study, only preliminary implications can be derived, which are to be understood as initial suggestions for practice. This study showed that techno-overload with regard to ICT use was significantly associated with burnout among nurses in acute care at German hospitals. This result underlines the importance of time resources that need to be allocated to nurses to get familiar with ICT such as new software. Furthermore, hospital managers should ensure that ICT use does not lead to additional tasks and an information overload for nursing personnel. In terms of techno-complexity, time resources need to be provided for participation in training and education. To allow nurses to use ICT confidently and efficiently, such training offers should be repeated regularly and designed flexibly. In addition, IT support of hospitals could be expanded so that IT contact persons are also available at weekends, for example, in the event of technical problems. If digital technologies are to contribute to time savings, better communication and quality of care in hospitals, it is generally important that users are actively involved in the development, implementation and evaluation of software [20, 40].

Implications for future research

The results on the association between the five indicators of technostress and burnout indicate that these should also be analysed individually in future studies [25]. Furthermore, a context-specific questionnaire for the healthcare sector could be developed for future research which considers even more specifically, for example through preliminary qualitative interviews, which techno-stressors could be of importance in this field. With regard to technostress and the professional position, future studies could differentiate more precisely between nursing staff with different leadership positions at the hospital to find out more about their levels of technostress. Overall, there is still a lack of longitudinal studies that examine the relationship between different techno-stressors and health outcomes among healthcare professionals in Germany as well as of intervention-based studies. However, such studies would be needed to verify the cross-sectional results of this study and to develop concrete policy implications.

CONCLUSION

In view of the increasing digitalisation of the healthcare sector, the results of this study provide useful information on the experience of technostress in the use of ICT among hospital nurses in Germany. This study showed an association between some indicators of technostress and burnout. According to the results, particular attention should be paid to supporting nurses in terms of techno-overload and techno-complexity in the future. Furthermore, there is still a need for customised support and further offers from employers in the use of digital technologies among nurses. In this regard, further research should evaluate intervention strategies for such support offers. Longitudinal studies should further verify the association between indicators of technostress and burnout as well as the role of support offers.

DECLARATIONS

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S.M.; Writing – original draft: T.W.; Writing – Review and editing: J.K., B.M., V.H., S.M. All authors read and approved the final version of the manuscript. T.W. acts as the guarantor for the final manuscript.

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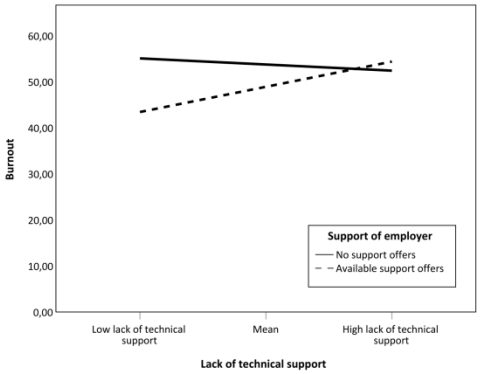
FIGURE LEGENDS

Figure 1 Moderation effect of support offered by the employer

Figure 2 Overview of participants' answers to open-ended questions on support offers



Page 1

Figure 1 Moderation effect of support offered by the employer

209x296mm (300 x 300 DPI)

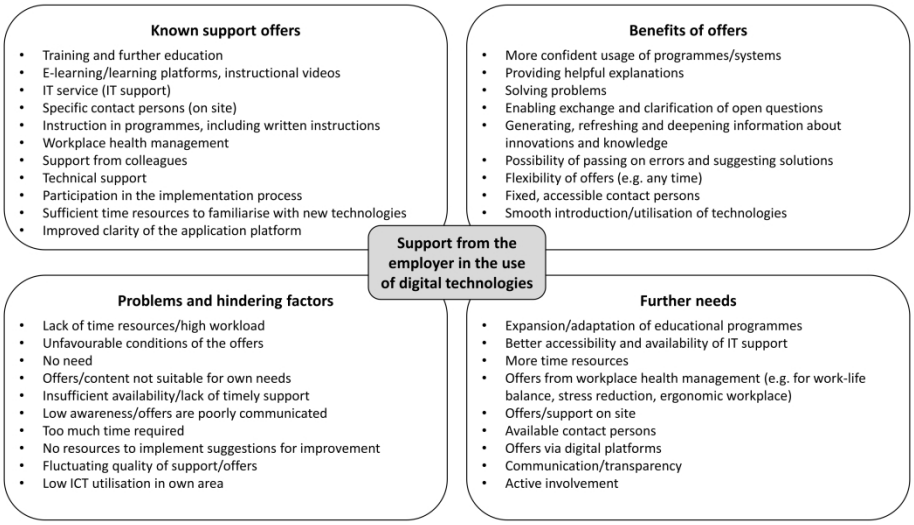
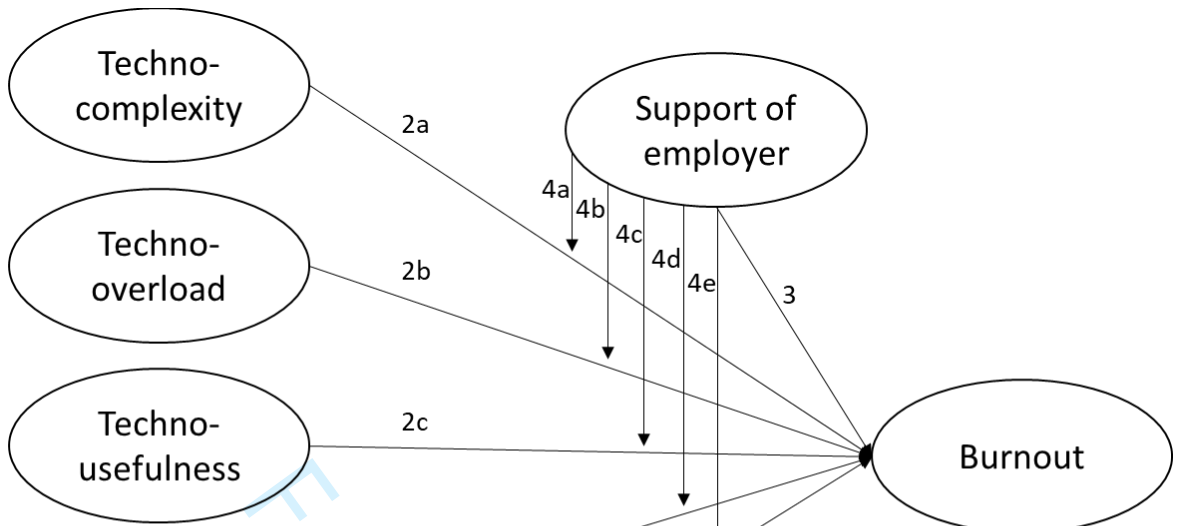


Figure 2 Overview of participants' answers to open-ended questions on support offers

338x190mm (300 x 300 DPI)



Supplementary Figure A. Conceptual model with hypotheses 2-4 on the relationship between indicators of technostress, support offered by the employer and burnout

Supplementary Table A. Overview of the reported scales and items of the online questionnaire

Section	Scales/items	Number of items	Response categories	Reference
Sociodemographic data: Personal details and workplace information	Age	1	Up to 19 years, 20-29, 30-39, 40-49, 50-59, 60 years or older	Self-developed
	Sex	1	Male, female, diverse	
	German as mother tongue	1	Yes, no	
	Professional qualification	1	General nurse, paediatric nurse, geriatric nurse, nursing assistant (old and new professional training)	
	Working time	1	Full-time with 35 hours/week or more, part-time with 15-34 hours/week, part-time or hourly employed with less than 15 hours/week	
	Work experience in the current hospital, overall work experience	2	1-5 years, 6-10 years, 11-15 years, more than 15 years	
	Leadership position	1	Yes, no	
	Ownership of the hospital	1	Private, public, non-profit, I don't know	
	Number of beds of the hospital	1	Up to 299 beds, 300-599, 600 beds or more, I don't know	
	Federal state of the hospital	1	Baden-Württemberg, Bavaria, Berlin, Brandenburg, Bremen, Hamburg, Hesse, Lower Saxony, Mecklenburg-Western Pomerania, North Rhine-Westphalia, Rhineland-Palatinate, Saarland, Saxony, Saxony-Anhalt, Schleswig-Holstein, Thuringia	
Use of information and communication technologies (ICT)	Average time of use of ICT on a typical working day in the last month	8	0, 0.5, 1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5, 5.5, 6, 6.5, 7, 7.5, 8, 8.5, 9, 9.5, 10 hours/day	Adapted from Bail et al. 2023[29]
Information on technostress	Techno-complexity, techno-overload, techno-usefulness, lack of technical support and techno-unreliability of the Digital Stressors Scale (DSS)	25	1 = strongly disagree, 2, 3, 4, 5, 6, 7 = strongly agree	Fischer et al. 2021[13] (German version: Riedl et al. 2022[44])

Information on work and health	Personal burnout of the Copenhagen Burnout Inventory (CBI)	6	Never/almost never, seldom, sometimes, often, always	Kristensen et al. 2005[15] (German version: Nübling et al. 2005[45])
Support offers	Availability of support offers	1	a) Yes, b) yes, but I don't use these support offers, c) no	Self-developed
	a) Specification of support offers, usefulness of support offers	2	Free-text format	
	b) Specification of support offers, reasons for not using support offers	2	Free-text format	
	c) Requests for further support offers	1	Free-text format	

Supplementary Table B. Description of the hospitals in which the study participants were employed (n=303)

Variables	n	%
Type of hospital ownership		
Public	190	62.7
Non-profit	75	24.8
Private	28	9.2
Unknown	10	3.3
Number of hospital beds		
≤ 299 beds	99	32.7
300-599 beds	86	28.4
≥ 600 beds	107	35.3
Unknown	11	3.6
Federal state of the hospital		
Bavaria	114	37.6
North Rhine-Westphalia	66	21.8
Lower Saxony	22	7.3
Hesse	21	6.9
Saarland	15	5.0
Hamburg	12	4.0
Brandenburg	8	2.6
Baden-Württemberg	7	2.3
Bremen	7	2.3
Rhineland-Palatinate	7	2.3
Saxony-Anhalt	6	2.0
Schleswig-Holstein	6	2.0
Berlin	4	1.3
Saxony	4	1.3
Thuringia	4	1.3

Supplementary Table C. Average duration of use of different types of ICT in everyday nursing care (hours per day, n=303)

		n (%)				
Type of ICT	**Range**	**No utilisation**	**0.5-2.5 h/day**	**3-5 h/day**	**5.5-7.5 h/day**	**8-10 h/day**
Hospital information system[1]	0-10	32 (10.6)	134 (44.2)	83 (27.4)	39 (12.9)	15 (5.0)
Electronic care documentation	0-10	66 (21.8)	131 (43.2)	53 (17.5)	31 (10.2)	22 (7.3)
Electronic health/ nursing records[1]	0-10	84 (27.7)	125 (41.3)	45 (14.9)	27 (8.9)	22 (7.3)
Electronic planning of care processes	0-10	143 (47.2)	101 (33.3)	33 (10.9)	15 (5.0)	11 (3.6)
Digital medication management	0-10	171 (56.4)	92 (30.4)	20 (6.6)	10 (3.3)	10 (3.3)
Digital SOPs	0-10	228 (75.2)	60 (19.8)	9 (3.0)	1 (0.3)	5 (1.7)
Decision support systems[1]	0-10	260 (85.8)	33 (10.9)	6 (2.0)	2 (0.7)	2 (0.7)
Smartphone apps[1]	0-8	268 (88.4)	28 (9.2)	4 (1.3)	2 (0.7)	1 (0.3)

[1] Percentages do not add up to 100% due to rounding.

Supplementary Table D. Descriptive statistics of the main study variables

Variable	Range	Mean	SD	α
Techno-complexity	1-7	3.44	1.40	0.84
Techno-overload	1-6.6	3.39	1.35	0.84
Techno-usefulness	1-7	3.80	1.41	0.83
Lack of technical support	1-7	4.10	1.90	0.95
Techno-unreliability	1-7	4.26	1.83	0.94
Burnout	0-100	49.86	19.90	0.91

α = Cronbach's alpha, n = 303

Supplementary Table E. Correlation matrix of the main study variables

Variable	1	2	3	4	5	6	7
1. Techno-complexity	303						
2. Techno-overload	0.618**	303					
3. Techno-usefulness	0.696**	0.571**	303				
4. Lack of technical support	0.391**	0.286**	0.470**	303			
5. Techno-unreliability	0.463**	0.416**	0.513**	0.752**	303		
6. Personal burnout	0.291**	0.329**	0.224**	0.187**	0.245**	303	
7. Support by employer[1]	-0.002	-0.044	-0.134*	-0.123*	-0.064	-0.125*	296

Spearman's correlation coefficient; n is shown on the diagonal; [1] No support as reference category; * p <0.05 ** p <0.01 (2-tailed)

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	1
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3-6
Objectives	3	State specific objectives, including any prespecified hypotheses	5-6
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6-7
Bias	9	Describe any efforts to address potential sources of bias	6-7
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7-8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7-8
		(*b*) Describe any methods used to examine subgroups and interactions	7-8
		(*c*) Explain how missing data were addressed	7
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	Not applicable
		(*e*) Describe any sensitivity analyses	Not applicable
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	8
		(b) Give reasons for non-participation at each stage	Not applicable
		(c) Consider use of a flow diagram	Not applicable
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8-9
		(b) Indicate number of participants with missing data for each variable of interest	8-9
Outcome data	15*	Report numbers of outcome events or summary measures	9-10
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	7, 10, 11
		(*b*) Report category boundaries when continuous variables were categorized	Not applicable
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	Not applicable
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	11
Discussion			
Key results	18	Summarise key results with reference to study objectives	13
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	14
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	13-15
Generalisability	21	Discuss the generalisability (external validity) of the study results	14
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	16

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.