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Prediction of violence or threat of violence among employees in social work, healthcare and education: the Finnish Public Sector cohort study

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ABSTRACT

Objectives To develop a risk prediction algorithm for identifying work units with increased risk of violence in the workplace.

Design Prospective cohort study.

Setting Public sector employees in Finland.

Participants 18 540 nurses, social and youth workers, and teachers from 4276 work units who completed a survey on work characteristics, including prevalence and frequency of workplace violence/threat of violence at baseline in 2018–2019 and at follow-up in 2020–2021. Those who reported daily or weekly exposure to violence or threat of violence daily at baseline were excluded.

Exposures Mean scores of responses to 87 survey items at baseline were calculated for each work unit, and those scores were then assigned to each employee within that work unit. The scores measured sociodemographic characteristics and work characteristics of the work unit.

Primary outcome measure Increase in workplace violence between baseline and follow-up (0=no increase, 1=increase).

Results A total of 7% (323/4487) of the registered nurses, 15% (457/3109) of the practical nurses, 5% of the social and youth workers (162/3442) and 5% of the teachers (360/7502) reported more frequent violence/threat of violence at follow-up than at baseline. The area under the curve values estimating the prediction accuracy of the prediction models were 0.72 for social and youth workers, 0.67 for nurses, and 0.63 for teachers. The risk prediction model for registered nurses included five work unit characteristics associated with more frequent violence at follow-up. The model for practical nurses included six characteristics, the model for social and youth workers seven characteristics and the model for teachers included four characteristics statistically significantly associated with higher likelihood of increased violence.

Conclusions The generated risk prediction models identified employees working in work units with high likelihood of future workplace violence with reasonable accuracy. These survey-based algorithms can be used to target interventions to prevent workplace violence.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ We had data on nurses, social and youth workers, and teachers allowing us to create prediction models that that consider the unique work unit characteristics of each occupation.

⇒ Bootstrapped-enhanced least-absolute-shrinkage-and-selection-operator regression allowed us to identify the most robust work unit-level predictors of increased workplace violence.

⇒ Using work unit-level predictors had the upside of being able to identify employees working in units where the risk of workplace violence is likely to rise in the future, but at the same time, these predictors overlook individual characteristics that could contribute to this increased risk.

INTRODUCTION

Workplace violence encompasses a wide range of offensive behaviours. According to the International Labour Organization (ILO), it includes 'any action, incident or behaviour that departs from reasonable conduct, resulting in the assault, threat, harm or injury of a person in the course of, or as a direct consequence of, their work'.[1 2] Violence in the workplace can take the form of physical or mental abuse, which may involve verbal threats, throwing objects, hitting, kicking or the use or threat of a weapon. The ILO emphasises that the perpetrator could be an unrelated criminal, a current or former colleague, supervisor, manager or an individual with a personal relationship to an employee but no workplace affiliation. However, the most prevalent form of workplace violence typically involves individuals associated with the organisation's services, such as customers, clients, patients, students or others.

Exposure to workplace violence is associated with various adverse outcomes, including turnover intentions,[3] sleep problems,[4] mental distress,[5] mental disorders[6–8] and even suicide.[9] In the public sector, violence or threats from patients, pupils, clients or customers have been reported more often

by women, younger employees, nurses and teachers.[10] High job demands in nurses and teachers[11–13] and organisational injustice in teachers[4] have also been linked to an increased likelihood of workplace violence in these occupations. However, to date, no previous studies have employed data-driven approaches to examine the interaction of multiple predictors with likelihood of increased violence.

Our objective was to assess the extent to which work unit characteristics can predict the increase in violence or threat of violence in occupations prone to such incidents, including nurses, social and youth workers, and teachers.[10] Work unit data were obtained by aggregating employee responses from standard workplace surveys. To comprehensively capture multiple predictors, we examined a wide range of potential predictors at the work unit level. These included sociodemographic characteristics such as age and sex distribution, and work characteristics, including psychosocial work environment, and turnover and retirement intentions. Since predictors of workplace violence may vary across occupations, we developed separate predictive models for each occupation.

METHODS
Study design and participants
This observational prospective multiwave cohort study is based on the Finnish Public Sector (FPS) study including personnel of 11 cities and 5 public sector health and social care organisations.[14] We used data from two survey waves of the FPS, the first conducted in 2018–2019 (T1) and the second in 2020–2021 (T2). The response rate was 71% in both T1 and T2. Responding to the survey was voluntary.

The sample selection is described in figure 1. We focused on occupational groups in which violence is common, that is, registered nurses (n=4487), practical nurses working either in healthcare, elderly care or childcare (n=3109), social workers and youth counsellors (n=3442), and teachers (n=7502). We excluded participants who reported frequent exposure (ie, daily or weekly) to workplace violence already at T1 and those with missing data on workplace violence at T2. The included participants were those who responded to a workplace survey at T1, reported encountering violence or threat of violence at workplace monthly, less often or not at all at T1, and responded to questions on frequency of workplace violence (daily, weekly, monthly, less often, not at all) at T1 and T2. The total number of included participants was 18 540 from 4276 work units. We computed mean scores of their responses to workplace survey items at baseline for each work unit and assigned those mean scores to each participant within that respective work unit. We used these aggregated survey responses at T1 to predict the increase in workplace violence at T2.

Measures
Violence/threat of violence at work was measured with self-reports at T1 and T2 using the following question: 'Have any of the following violent or threatening confrontations involving clients happened to you over the past 12 months?' (yes/no): (1) throwing or breaking things; (2) mental abuse (eg, verbal threats); (3) physical violence (eg, hitting, kicking); (4) threatening with a weapon (firearm, edged weapon, striking weapon). 'yes' to any kind of violence was coded as 1, and 'no' to all was coded as 0. If the respondent replies 'yes', we asked how often confrontations had happened using the following response format: 'daily', 'weekly', 'monthly', 'less frequently' and 'no violence/threat of violence'. Our outcome was dichotomous: increase in workplace violence versus no increase in workplace violence. As we only included in study participants who reported
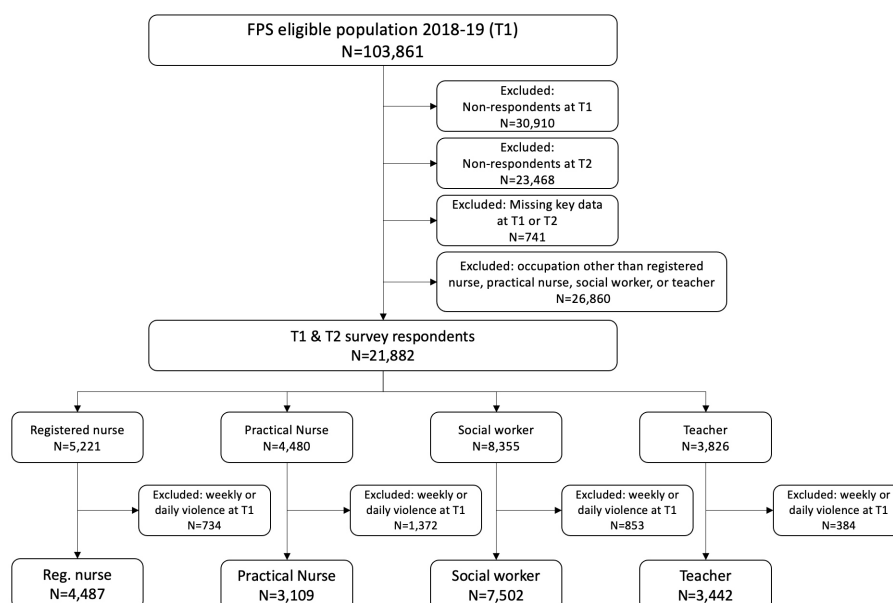

Figure 1 Flow chart of the sample selection. FPS, Finnish Public Sector.

encountering violence or threat of violence at workplace monthly, less often or not at all at T1, increase in workplace violence was indicated if the participant reported violence or threat of violence at workplace on weekly or daily basis at T2. Those participants who reported workplace violence or threat of workplace violence monthly, less often or not at all at T2 belonged to the group of 'no increase in workplace violence'.

The predictor variables were individual survey responses aggregated to work unit level (87 variables). In addition, organisational records on employee turnover and number of employees were aggregated to work unit level resulting in a total of 89 predictor variables on sociodemographic characteristics, work characteristics, psychosocial work environment factors, leadership, turnover and retirement intentions in each work unit. Detailed description is provided in online supplemental appendix 1, but a bullet-point list of the predictors follows:

▶ Sociodemographic characteristics of the work unit
  – Mean age.
  – Proportion of women.
  – Proportion of full-time and part-time employees.
  – Proportion of temporary employees.
  – Proportion of managers and specialists (ie, employees with high occupation-based socioeconomic status).
  – Proportion of manual workers (ie, employees with low occupation-based socioeconomic status).
  – Proportion of day workers.
  – Proportion of shift workers.
  – Mean length of employment.
  – Years in shift work.
  – Turnover.
  – Work unit size.
▶ Work characteristics
  – Five items on job demands.[15 16]
  – Nine items on job control.[15 16]
  – One item on effort at work.[17]
  – Three items on work rewards.[17]
  – Seven items on worktime control.[18 19]
  – Five items on job insecurities.[20 21]
  – Two items on changes at work.
  – Seven items on procedural justice.[22]
  – Six items on relational justice.[22]
  – Four items on supervisor support.
  – Four items on support from the work unit to supervisor.
  – Two items on performance appraisals/career development discussions: having had such a discussion within the last 12 months, and whether the discussion was perceived useful.[23]
  – Fourteen items on team climate on four dimensions: safety, support for innovation, vision and task orientation.[24 25]
  – One item on discrimination at work: Is there discrimination due to age, gender, education, opinion, status, origins, language, religion, believes/convictions, political activity, trade union activity,

health, disability, sexual orientation, or gender identity/gender expression?[26]
  – Five items on job satisfaction.
  – One item on retirement intentions.
  – one item on turnover intentions.

The response format in most of the items in the survey was a five-point scale from 1=strongly agree to 5=strongly disagree. For ease of interpretability, we reverse-coded the items so that more was more, that is, a higher score always indicated a stronger agreement. The survey form, which includes all the items that are based on previous research, is also provided in online supplemental appendix 2.

Statistical analysis

We generated risk prediction models separately for four occupational groups: registered nurses, practical nurses, social and youth workers, and teacher. For each occupational group, we split our data into training and test datasets with a 75/25 split, stratifying for the outcome. The training dataset was used to develop the prediction model and the test dataset was used to test the predictive validity of the model in an independent dataset.[27] These dataset were stratified by the outcome to ensure that the proportion of those reporting violence or threat of violence at T2 was the same in both datasets. We used bootstrap-enhanced least-absolute-shrinkage-and-selection-operator (LASSO) with logistic regression to create our prediction model. In selecting our final predictors, we used 10-fold cross-validation and determined the optimal lambda value.[27] With the optimal lambda value, we can find a sparse model that balances between simplicity, that is a model with a small number of predictors, and precision, a model with good predictive performance.

We standardised all predictors for LASSO, and the final predictors selected by regular LASSO may vary based on the sample and how strongly the predictors are correlated. However, with bootstrap-enhanced lasso, the final predictors are selected based on a set proportion of the bootstrap replications. For our study, we used 100 bootstrap replications and set the threshold for predictor selection to 95%.

We then used the predictors retained from the bootstrap-enhanced LASSO model to fit a model to the training dataset, which was used to predict the outcome in the test data. It is important to note that the variables retained by LASSO are a result of optimising for the number of variables in the model and overfitting, so not all variables may be statistically significant in the final model. To evaluate the performance of our models, we compared our predictions against the observed cases of increased violence, plotted an receiver operating characteristic (ROC) curve, and computed the area under the curve (AUC). We also plotted the predicted probabilities for increased violence cases for ease of risk comparison between those who reported encountering violence more often and those who did not.

As a sensitivity analysis, we recreated prediction models using backward stepwise regression. We set a limit on

Table 1 Characteristics of the study participants at baseline (T1) by occupational group

		Registered nurses (n=4487)	Practical nurses (n=3109)	Social and youth workers (n=3442)	Teachers (n=7502)	P for difference between groups
Work unit size, mean (SD)		27.2 (30.9)	23.4 (24.7)	25.7 (42.0)	33.2 (25.2)	<0.001
Sex, %	Men	8.2	11.8	17.0	25.5	<0.001
	Women	91.8	88.2	83.0	74.5	
Age, mean (SD)		44.3 (3.7)	44.3 (4.0)	45.0 (4.2)	46.0 (3.2)	<0.001
Working time, %	Full time	91.8	91.3	95.9	95.8	<0.001
	Part time	8.2	8.7	6.1	4.2	
Type of work, %	Day work	53.7	28.8	72.4	96.7	<0.001
	Shift work*	46.3	71.2	18.6	3.3	<0.001
Increased violence from T1 to T2, %		7.2	14.7	4.7	4.8	<0.001

*Shift work and other irregular working times.

the number of predictors to match those selected by the LASSO models. We tested the performance of these models using the same methods as the LASSO models. All data analyses were performed using R (V.4.1.2), RStudio (V.2021.09.2), and packages bolasso (V.0.1.0) and glmnet (V.4.1-4). The study was conducted according to the Transparent reporting of a multivariable prediction model for individual prognosis or diagnosis (TRIPOD) guideline.

Patients and public involvement
No patients or members of the public were involved in the design, conduct or reporting of this research.

RESULTS
The descriptive characteristics of the study population (ie, those who had encountered violence monthly, less often or not at all at T1) are shown in table 1. A total of 7% (323/4487) of the registered nurses, 15% (457/3109) of the practical nurses and 5% of the social and youth workers (162/3442) and teachers (360/7502) reported increased workplace violence.

Selection of variables to prediction of increased risk of workplace violence
Variable selection was performed separately for each occupational group. Five variables were statistically significantly associated with increased violence at work among registered nurses. Working in a unit where employees reported that their work required strenuous effort (OR 1.62, 95% CI 1.16 to 2.26) and having influence over shift arrangements (OR 2.53, 95% CI 1.82 to 3.52) were associated with higher odds of increased violence. A higher percentage of temporary employees (OR 1.16, 95% CI 1.04 to 1.30) and higher percentage of manual workers in the work unit (OR 1.13, 95% CI 1.08 to 1.19) were also associated with higher odds of increased violence. Receiving rewards from work through personal satisfaction was associated with lower odds of increased violence

(OR 0.33, 05% CI 0.20 to 0.54) (table 2). The sensitivity analysis using backwards stepwise regression analysis was largely like the main model. 'Threat of redundancy' was the only additional variable statistically significantly associated with increased risk of violence (online supplemental appendix 3, table A).

Eleven variables were selected for practical nurses including eight variables statistically significantly (p<0.05) associated with increased violence at work in a multivariable analysis. Working in a unit where employees actively provide their supervisor with information about work-related matters (OR 2.62, 95% CI 1.66 to 4.14), where work required learning new skills (OR 2.22, 95% CI 1.29 to 3.81) but also included many similar, repetitive tasks (OR 1.77, 05% CI 1.17 to 2.69) were associated with higher odds of increased violence. Protective factors (ie, variables that were associated with lower odds of increased violence) were working in a unit with high task variety (OR 0.37, 95% CI 0.23 to 0.58), where everyone felt understood and accepted (OR 0.53, 95% CI 0.37 to 0.77), having enough time to get work done (OR 0.70, 95% CI 0.56 to 0.87), working in a unit with day work (OR 0.82, 05% CI 0.77 to 0.88) and in units with a higher turnover rate (OR 0.90, 95% CI 0.83 to 0.98) (table 2). The sensitivity analysis produced a set of variables corresponding to the main model but including additionally threat of redundancy, higher decision latitude and higher work-time control associating with increased risk of violence (online supplemental appendix 3, table B)

The predictors selected for social workers included seven variables, all reaching statistical significance (p<0.05). Work units with varying tasks (OR 3.17, 95% CI 1.47 to 6.82), higher percentage of discrimination at the work unit (OR 1.21, 95% CI 1.01 to 1.45) and more years shift work (OR 1.11, 95% CI 1.07 to 1.15) were associated with higher odds of increased violence. Protective factors against increasing violence were working in a unit where there were possibilities to take breaks (OR 0.29, 95% CI

Table 2   Work unit level predictors for increased violence among different occupational groups

Measure	Predictor variable (item)	OR	95% CI
Nurses (N=4487)			
Sociodemographics	%, temporary employees (per 10% increase)	1.16	1.04 to 1.30
Sociodemographics	%, manual workers (per 10% increase)	1.13	1.08 to 1.19
Job demands	Work requires very strenuous effort	1.62	1.16 to 2.26
Rewards from work	Rewards through personal satisfaction	0.33	0.20 to 0.54
Work time control	Influence over shift arrangements	2.53	1.82 to 3.52
Work time control	Influence over timing of vacations	0.92	0.59 to 1.43
Practical nurses (N=3109)			
Sociodemographics	%, manual workers (per 10% increase)	1.00	0.95 to 1.06
Sociodemographics	%, turnover (per 10% increase)	0.90	0.83 to 0.98
Sociodemographics	%, day work (per 10% increase)	0.82	0.77 to 0.88
Job demands	Enough time to get the work done	0.70	0.56 to 0.87
Job control (skill discretion)	Work requires learning new skills	2.22	1.29 to 3.81
Job control (skill discretion)	Work includes many similar, repetitive tasks	1.77	1.17 to 2.69
Job control (skill discretion)	Work includes different tasks (task variety)	0.37	0.23 to 0.58
Work time control	Influence over taking leave	0.87	0.66 to 1.15
Job insecurity	Threat of involuntary transfer to other work tasks	0.87	0.69 to 1.09
Team climate (safety)	Everyone feels understood and accepted in work unit	0.53	0.37 to 0.77
Support to supervisor	Employees actively provide the supervisor with information about work-related matters	2.62	1.66 to 4.14
Social workers (N=3442)			
Sociodemographics	Mean age (per 10-year increase)	0.55	0.36 to 0.86
Sociodemographics	%, manual workers (per 10% increase)	0.86	0.78 to 0.94
Sociodemographics	Years in shift work (per 1-year increase)	1.11	1.07 to 1.15
Job control (skill discretion)	Work requires creativity	0.41	0.23 to 0.74
Job control (skill discretion)	Work includes different tasks (task variety)	3.17	1.47 to 6.82
Work time control	Possibility to take breaks during the workday	0.29	0.21 to 0.40
Team climate (safety)	Discrimination at work unit (per 10% increase)	1.21	1.01 to 1.45
Teachers (N=7502)			
Sociodemographics	%, temporary employees (per 10% increase)	1.01	0.92 to 1.12
Sociodemographics	%, turnover per (10% increase)	1.31	1.13 to 1.51
Job control (decision latitude)	A lot of independent decisions in work	0.34	0.20 to 0.57
Job control (skill discretion)	Work requires creativity	2.74	1.15 to 6.55
Job control (skill discretion)	Work includes different tasks (task variety)	4.41	1.91 to 10.2
Support to supervisor	Work unit supports their supervisor	0.94	0.65 to 1.37
Team climate (goal clarity)	Members of the work unit understand their goals	0.91	0.54 to 1.53

Statistically significant associations are coloured.

0.21 to 0.40), where the work required creativity (OR 0.41, 95% CI 0.23 to 0.74), with higher mean age (OR 0.55, 95% CI 0.36 to 0.86) and more employees in manual occupations (OR 0.86, 95% CI 0.78 to 0.94) (table 2). The sensitivity analysis produced a set of variables corresponding to that in the main model but including contradicting associations of supervisory behaviours with increased risk of violence (online supplemental appendix 3, table C).

The set of predictors for teachers included seven variables, four reaching statistical significance (p<0.05). Variables associated with higher odds of increased violence were working in a school with high task variety (OR 4.41, 95% CI 1.91 to 10.2), high creativity (OR 2.74, 95% CI 1.15 to 6.55) and higher turnover rate (OR 1.31, 95% CI 1.13 to 1.51). In turn, working in a school with higher decision latitude among the teachers (OR 0.34, 95% CI
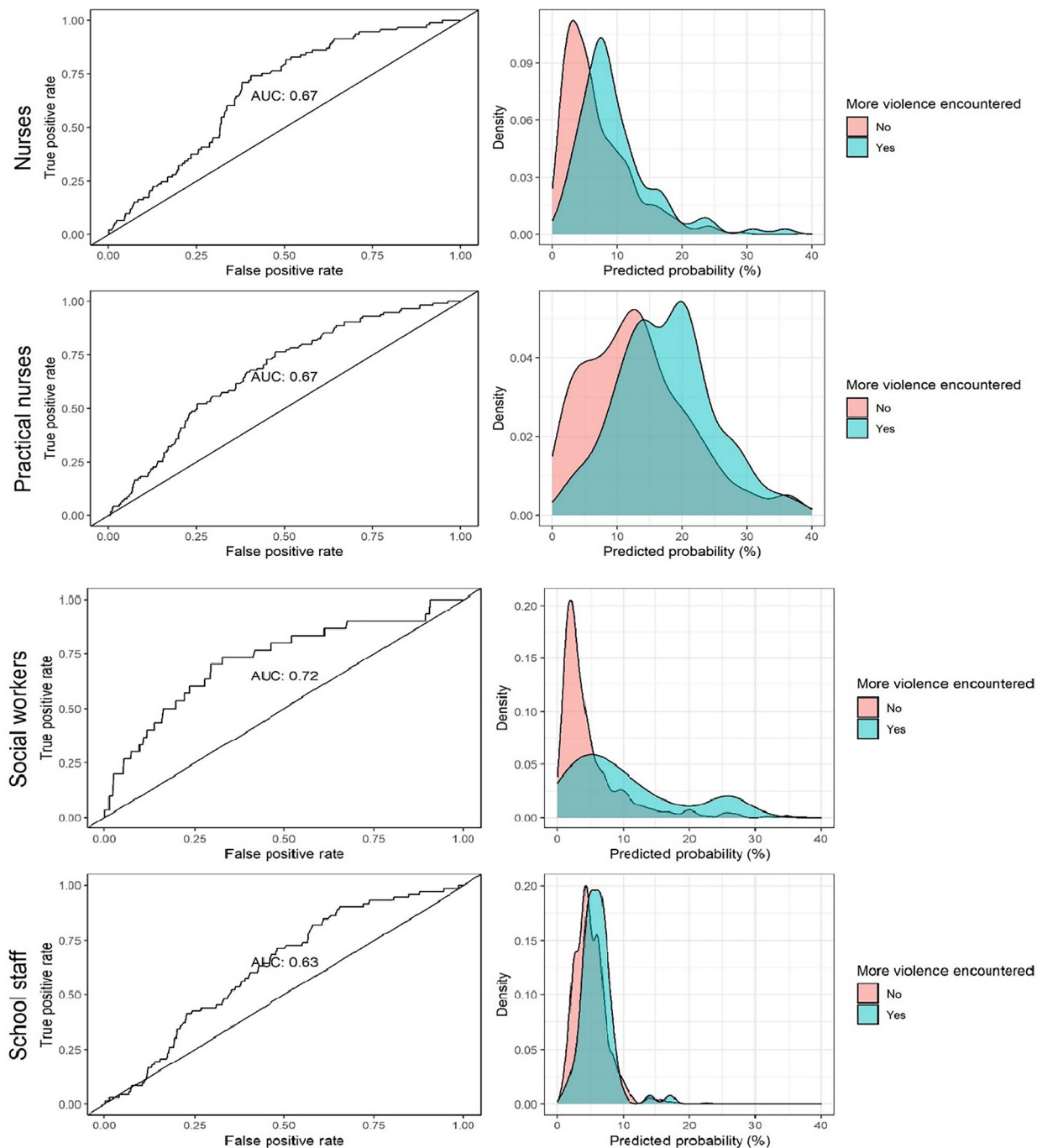
Figure 2 Model performance by occupation. Left side: Receiver operating characteristic curve for work unit-level prediction for encountering more violence (lambda=min+1 standard error). Right side: Density plot for encountering more violence at T2 by predicted probability (logistic regression, work unit-level predictor variables). AUC, area under the curve.

0.20 to 0.57) was associated with lower odds for increased violence (table 2). The sensitivity analysis produced a set of predictors largely corresponding to that in the main model but included unexpected associations of beneficial goals and low threat of discontinuation of assignments with increased risk of violence (online supplemental appendix 3, table D).

Model performance
The ROC curves and density plots for the models constructed using the LASSO-selected variables are shown in figure 2. The curves of those encountering more violence and those not, were largely overlapping. The AUC scores were between 0.63 and 0.72, the best model performance achieved by the model in social and youth workers (AUC=0.72) and the poorest performance in the model on teachers (AUC=0.63). The model performance of sensitivity analysis was like main models and shown in online supplemental appendix 3, figure A.

Table 3 shows detection rate, false positive rate and ratio of true to false positive for the two models using various

Table 3   Detection rate (%), false positive rate (%) and ratio of true to false positive for predictive probability using various risk thresholds

	Predictive probability of increased violence for cut-off of a positive test result						
Nurses	5%	10%	15%	20%	25%	30%	35%
Detection rate	83.9	34.4	15.1	6.5	2.2	2.2	1.1
False positive rate	55.0	21.8	8.4	2.7	0.87	0.10	0.10
Ratio true to false positive	1/7	1/7	1/6	1/5	1/5	½	1/1
Practical nurses							
Detection rate	94.8	85.2	61.7	35.7	18.3	8.7	6.1
False positive rate	82.5	63.5	37.0	19.9	9.7	5.9	3.8
Ratio true to false positive	1/5	1/4	1/4	1/3	1/3	1/4	¼
Social and youth workers							
Detection rate	70.0	40.0	26.7	20.0	20.0	3.3	3.3
False positive rate	29.6	12.8	6.3	3.5	2.5	0.96	0.36
Ratio true to false positive	1/12	1/12	1/9	1/7	1/5	1/4	1/3
Teachers							
Detection rate	64.4	2.7	1.4	–	–	–	–
False positive rate	44.1	3.8	0.89	–	–	–	–
Ratio true to false positive	1/17	1/35	1/16	–	–	–	–

risk thresholds for test positive result. For a 5% cut-off for positive test results (ie, increased violence in follow-up), the detection rate was 64% for teachers, 70% for social and youth workers, 84% for registered and public health nurses, and 95% for practical nurses. The corresponding true to false ratios for positive test result were 1 to 5–17. That is, while many cases were detected, this came at a price of many false positives, that is, cases where violence did not increase despite our prediction. With 15% cut-off as the threshold, detection rate decreased, but false positive rate did not improve markedly. The detection and false positive rates and ratios of true to false positives of the sensitivity analysis are shown in online supplemental appendix 3, table E.

DISCUSSION

This cohort study of 18 540 nurses, social and youth workers, and teachers identified several independent predictors of increased violence including sociodemographic characteristics of the work unit, demands of the job (haste and lack of time) and job control (skill discretion, decision latitude and work time control) and safety of the team climate at the work unit. Occupational group-specific risk prediction algorithms generated using those variables showed reasonable predictive power for social and youth workers and for nurses, but rather low predictive power for teachers.

We are not aware of previous studies on prediction algorithms for workplace violence, but the predictors, including sociodemographic factors, observed in this study agree with pre-existing evidence on correlates of violence at work. High influence over work shifts in registered nurses, low percentage of employees in day work in practical nurses and longer work history in shift work in social and youth workers marked higher likelihood of increased violence. All these items are indicators of working in shifts. Shift work has also previously been linked with risk of violence .[28 29] For other work unit characteristics, the direction of the association varied by occupation. High turnover rate at the work unit was a risk predictor (ie, associated with a higher likelihood of increased violence) among teachers, but it was associated with a slightly lower likelihood of increased violence among practical nurses. A previous study found an association between turnover intentions and workplace violence among nurses.[8] In our study, a higher turnover rate in work units where the practical nurses worked probably co-occurred with other characteristics related to lower violence risk. For example, higher turnover rate could characterise working in a unit in which violence is less common. Other inconsistencies in predictors between occupational groups involved the proportion of manual workers in the work unit. A larger proportion was associated with increased risk of violence in nurses, but reduced risk in social and youth workers. These inconsistencies warrant further investigation.

In addition to work unit-level sociodemographic characteristics, individual items of job demands and job control scales were most strongly associated with risk of increased violence. High job demands, such as high work pace and insufficient time to get the work done at the work unit, were associated with increased risk of violence among nurses. Among social and youth workers, possibilities to take breaks were associated with lower likelihood of increased violence. Supporting these findings, the review

articles have listed workload as one of the risk predictors for workplace violence in physicians,[28] and in nurses.[29] However, the evidence is inconclusive as there are major gaps in previous research: several studies were based on qualitative data, most quantitative studies are limited to cross-sectional data, and in some studies, the design was not reported.[28 29] Longitudinal evidence is largely lacking.

The relationship with items of job control and increased violence was complex. In the job demands-job control, (ie, JDJC model) on work stress,[15 16] job control is divided into skill discretion and decision latitude. Skill discretion includes task variety, and requirements for creativity and learning. High task variety at the work unit was a protective factor among practical nurses, but a risk predictor among teachers and social and youth workers. High creativity at the work unit was a protective factor for social and youth workers, but a risk predictor for teachers. High requirements for learning new things were a risk predictor for practical nurses. High decision latitude at the work unit (school) was a protective factor in teachers. As noted also previously, the associations of the dimensions of the JDJC-model on health and well-being may vary by occupation.[30–32]

The safety of the team climate (non-discrimination and acceptance) was shown to be associated with a lower likelihood of increased violence in practical nurses and social and youth workers. This would imply that horizontal psychosocial resources, as identified in previous research,[33] might be able to buffers against increase in violence. In turn, vertical resources, such and organisational justice or indicators of leadership quality,[33] did not predict increased risk of violence among the selected occupational groups.

Strengths and limitations

The strengths of this study include a large baseline population of public sector employees from which we could select subgroups of occupational groups with a high risk of workplace violence. The survey data included several questions (89 item) from various themes including sociodemographic characteristics, work characteristics, workplace psychosocial stressors and resources, and job satisfaction, including retirement intentions. To test the robustness of our prediction models, we built them twice, first with LASSO and then with backward stepwise regression, both producing roughly similar risk prediction models. To increase the validity and practical useability of our results, we aggregated the predictor variables to represent work unit level situation. Use of work unit-aggregated variables decreases the role of response style and self-reporting bias. Second, identification of work units rather than individuals at high risk of increasing violence, is more useful for subsequent interventions.

This study has several limitations. First, as data only included four high-risk public sector occupational groups, generalising the findings to other groups is not possible. Additionally, relying on a self-reported measure of violence or threat of violence may lead to subjectivity bias, possibly underestimating or overestimating violence prevalence. Furthermore, the predominantly female composition of the occupational groups in our study limits generalisability to other demographics. Using single items instead of full scales in our study may also be considered a limitation. However, we identified individual items with strong predictive ability and, by minimising survey items, increased tool usability. Future research should develop risk prediction models for other high-risk occupations like police and security guards. Exploring violence predictors in low-risk occupations, such as library workers, is also important. Unlike high-risk occupations with preventive tools and training, low-risk workers may lack resources to handle violent situations. Finally, the use of single items instead of full scales on questionnaire measures may be considered as a weakness of our study. However, as we aimed to develop a tool for employers with maximum useability, we needed to identify the individual items within the scales (ie, measures of latent constructs) that would provide the best predictive ability with minimum number of survey items.

CONCLUSIONS

In the current study, we set out to develop risk prediction models at work unit-level for workplace violence using data collected from comprehensive workplace surveys. We achieved a satisfactory level of prediction accuracy, particularly for social and youth workers and nurses. The developed models may offer tools for employers to identify work units that are at higher risk of experiencing increased violence in the workplace. We found some shared factors among nurses and social and youth workers that predicted increased violence, such as shift work and high work demands, including a fast work pace, inadequate time and insufficient breaks. In addition, we observed that a supportive team climate may act as a protective factor against the escalation of violence.

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Web appendices

Web appendix 1. Details on predictor variables.

Work unit sociodemographic characteristics

Work unit level variables were created as average age; percentage of women; percentage of temporary employees; percentage of managers, senior officials, and professionals (ISCO codes 1-2); percentage of manual workers (ISCO codes 5-9); turnover percentage (share of new employees as compared to previous survey); size of the work unit; average job tenure; average years in current job; percentage of part-time workers, percentage in day job; average years in shift work.

Work unit psychosocial stressors

The survey included measures of *job demands and job control*.[1][2] Job demands were measured with 5 items, which considered time pressures and deadlines, lack of time to do what was expected, and work overload. The job control scale combines two concepts, skill discretion (the opportunities of an individual to develop his or her special abilities within the job, 6 items) and decision authority (individual's abilities to be part of the decision-making process within the organization, 3 items).

Worktime control (7 items) was measured using a questionnaire in which the participants were asked to evaluate on a scale from 1 (very much) to 5 (very little) how much they could influence the following aspects of their working time: length, starting and ending times, breaks, and handling of private matters during the workday, scheduling of work shifts, vacations and paid days off, and the taking of unpaid leave.[3][4]

Efforts and rewards at work (4 items): Effort was measured with one question ("How much do you feel you invest in your job in terms of skill and energy?") and reward was assessed with three questions about feelings of getting a return from work in terms of (1) income and job benefits, (2) recognition and prestige, and (3) personal satisfaction. The response format was a five-point scale from 1 = very much to 5 = very little.[5]

Job insecurities were measured with 5 items: 'Does your job involve the following insecurities': threat that some work tasks will be terminated; involuntary transfer into another work tasks; threat

1

of temporary lay-offs; threat of permanent lay-offs; threat of excessive workloads. The scale was from 1=very much to 5= very little.[6 7]

Changes at work were measured with 2 items: 'When you think about all the changes that have happened in your work during the last 12 months, how would you describe those from your own point of view?' with a scale from 1=mostly positive to 7=mostly negative. We also enquired whether the respondent felt she/he could take part when changes were planned with a response scale 1=I have very much influence over the changes; 2=I have some influence over the changes; 3=Most often the changes occur unexpectedly, I don't have influence over them.

Leadership and management at the work unit

Procedural justice (7 items): The scale considers whether the decision-making procedures at the workplace are accurate, correctable, consistently applied, and whether the procedures include opinions from the people involved.[8]

Relational justice (6 items): The scale includes items evaluating whether the supervisors use kindness and consideration, are truthful, and can suppress personal biases.[8]

Supervisor support (4 items): The scale includes items evaluating the extent to which the supervisor supports and encourages, rewards from good performance, trusts, and encourages employees to educate and develop themselves in their work.

In *support from the work unit to supervisor* (4 items), participants were asked to evaluate the extent to which employees perceive employees to have a role in successful leadership, inform their supervisor on work-related matters, value the competence of their supervisor, and support their supervisor.

Performance appraisals/career development discussions were measured with two items: having had such a discussion within the last 12 months (1=No, 2=Yes), and whether the discussion was perceived useful (1=Useful, 2=Not useful, but not totally useless, 3=Useless).

Team climate at the work unit

Team climate (14 items): The work unit cooperation and interaction was measured using the short version [9] of the Team Climate Inventory (TCI).[10] TCI conceptualizes team climate into four

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dimensions: participations safety (4 items), support for innovation (3 items), vision (4 items), and task orientation (3 items).

Discrimination was measured with a single item: Is there discrimination due to age, gender, education, opinion, status, origins, language, religion, believes/convictions, political activity, trade union activity, health, disability, sexual orientation, or gender identity/gender expression? (1=No, 2=Yes).

Satisfaction with job, satisfaction with employer, and intentions to leave

Job satisfaction was measured with 5 items: Employees were asked to evaluate the extent to which they were satisfied with their personal growth and development; the feeling of accomplishing something significant; possibilities to think and act independently at work; challenges provided by the job. The scale was from 1=very unsatisfied to 5=very satisfied. In addition, we asked whether the respondent would recommend the current employer to a friend, with a scale dichotomized into 1=Yes; 2=No.

Retirement intentions were measured with a single item: "Do you see yourself working until your personal retirement age?" with response scale 1=Yes, I see myself working until my retirement age; 2=Yes, I see myself working even after my retirement age; 3=No, I don't see myself working until retirement age.

Turnover intentions were measured with a single item: "Have you considered changing employer?" with response scale 1=No, I want to keep working for my current employer; 2=Yes, I have considered changing employer; 3=I have already recruited to another employer.

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Web appendix 2.

Questionnaire

How well do the following statements apply to your work? To what degree do you agree or disagree with the statement?

	Fully agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Fully disagree
1) I have to be fast in my work	☐	☐	☐	☐	☐
2) My work requires very strenuous effort	☐	☐	☐	☐	☐
3) An unreasonable amount of work is expected of me	☐	☐	☐	☐	☐
4) I have enough time to get my work done	☐	☐	☐	☐	☐
5) My work is very fast-paced	☐	☐	☐	☐	☐
6) I can make a lot of independent decisions in my work	☐	☐	☐	☐	☐
7) My work requires me to be creative	☐	☐	☐	☐	☐
8) My work requires me to learn new things	☐	☐	☐	☐	☐
9) My work involves many similar, repetitive tasks	☐	☐	☐	☐	☐
10) I have a lot of influence related to my work	☐	☐	☐	☐	☐
11) My work requires well developed skills	☐	☐	☐	☐	☐
12) I get to do a wide variety of things in my work	☐	☐	☐	☐	☐
13) I have the opportunity to develop my special skills	☐	☐	☐	☐	☐

The following questions are about how invested you are in your work and how rewarding the work is. How much do you feel:

	To a very great extent	To a considerable extent	Neither a little nor a lot	Not very much	Very little
1) You focus your abilities and resources on your work	☐	☐	☐	☐	☐
2) You are compensated for the work you do in terms income, employee benefits, etc.	☐	☐	☐	☐	☐
3) You receive recognition or respect for the work you do	☐	☐	☐	☐	☐
4) You receive personal satisfaction from the work you do	☐	☐	☐	☐	☐

How much are you able to influence your working hours?

	Very much	Quite a lot	To some extent	Fairly little	Very little
1) The duration of your working day	☐	☐	☐	☐	☐
2) The start and end time of your working day	☐	☐	☐	☐	☐
3) Your ability to take breaks during your working day	☐	☐	☐	☐	☐
4) The handling of personal matters during your working day	☐	☐	☐	☐	☐
5) Shift arrangements	☐	☐	☐	☐	☐
6) The dates and times of holidays and time off	☐	☐	☐	☐	☐
7) Taking unpaid leave and other leave	☐	☐	☐	☐	☐

2) Do you believe you will be able to continue working until retirement age?

☐ Yes, I believe I will be able to continue until retirement
☐ Yes, I believe I will continue to work even when I will be on pension (temporary work, substituting, etc.)
☐ I do not think I will continue

Have you considered changing employers?

☐ No, I wish to continue in the service of my current employer
☐ I have considered changing employers
☐ I am seeking to change employers

Would you recommend your current employer to a friend?

☐ Yes, definitely
☐ Yes, probably
☐ Probably not
☐ No, I would not

Are any of the following uncertainties connected to your work?

	Very much	Quite a lot	To some extent	Fairly little	Very little
1) The possibility of discontinued work assignment(s)	☐	☐	☐	☐	☐
2) Involuntary transfer to other tasks	☐	☐	☐	☐	☐
3) The threat of involuntary, temporary dismissal	☐	☐	☐	☐	☐
4) The threat of redundancy	☐	☐	☐	☐	☐
5) Workload exceeding capacity	☐	☐	☐	☐	☐

6

When you think about the changes that have occurred at your workplace over the past 12 months, how would you characterize your own situation from your point of view?

Two opposite extremes are given after the question. There are seven boxes in between. The closer the response box is to an extreme, the better it corresponds to that alternative. Please tick the alternative that best corresponds to your opinion.

The changes have mostly been positive ☐ ☐ ☐ ☐ ☐ ☐ ☐ The changes have mostly been negative

---

Do you have an opportunity to be involved when changes affecting your work are planned?

☐ I can have a significant influence on the changes
☐ I can have some influence
☐ Changes often take place unexpectedly; I have no opportunity to influence them

---

This section investigates co-operation in your work community/at your workplace (e.g. school, day-care centre, hospital ward). Please tick the most appropriate alternative for each statement.

	Fully agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Fully disagree
1) We keep each other up to date on work-related matters	☐	☐	☐	☐	☐
2) We genuinely try to share things within the work community	☐	☐	☐	☐	☐
3) Our attitude is: "We work together"	☐	☐	☐	☐	☐
4) Everyone feels they are understood and accepted	☐	☐	☐	☐	☐
5) Employees actively provide the supervisor with information about work-related matters	☐	☐	☐	☐	☐
6) It is apparent in our work community that employees and their activities contribute to the success of the management	☐	☐	☐	☐	☐
7) Our work community values supervisor competence	☐	☐	☐	☐	☐
8) Our work community strives to support the supervisors in their work	☐	☐	☐	☐	☐
9) The members of our work community are always looking for new, fresh ways to deal with problems related to our work	☐	☐	☐	☐	☐
10) Our work community spends time developing new ideas	☐	☐	☐	☐	☐
11) The members of our work community work together to implement new ideas	☐	☐	☐	☐	☐

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The next questions deal with the goals of your work community/workplace and work evaluation. Please tick the box that best reflects your opinion.

	Very much	Quite a lot	To some extent	Fairly little	Very little
1) Do you believe that the members of your work community fully understand the goals of the work community?	☐	☐	☐	☐	☐
2) Do you support the goals of your work community?	☐	☐	☐	☐	☐
3) Do you believe that your work community's goals are achievable?	☐	☐	☐	☐	☐
4) Do you believe the goals are beneficial?	☐	☐	☐	☐	☐
5) Do the members of your work community have the readiness to question the grounds for the work your work community does?	☐	☐	☐	☐	☐
6) Do you highlight the weakness of your operations in order to improve your work?	☐	☐	☐	☐	☐
7) Do the member of your work community take into account suggestions for improvement made by others in order achieve the best possible outcome?	☐	☐	☐	☐	☐

Do people at your workplace experience discrimination based on the following reasons: age, sex, education, opinions, position, origin, citizenship, language, religion, ideology, political activities, trade union activities, health, disability, sexual orientation or gender identity/gender expression

☐ No   ☐ Yes

This section deals with your nearest supervisor's actions. Please tick the alternative that best corresponds with your opinion.

	Fully agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Fully disagree
1) My supervisor considers his/her subordinates' opinions in important matters	☐	☐	☐	☐	☐
2) My supervisor's personal biases do not have an negative effect on his/her decisions	☐	☐	☐	☐	☐
3) My supervisor provides his/her subordinates with information about decisions and their impact in due course.	☐	☐	☐	☐	☐
4) My supervisor treats his/her subordinates with kindness and consideration	☐	☐	☐	☐	☐
5) My supervisor respects the rights of employees	☐	☐	☐	☐	☐
6) I can trust my supervisor	☐	☐	☐	☐	☐
7) My supervisor supports and encourages me	☐	☐	☐	☐	☐
8) My supervisor rewards good work performance	☐	☐	☐	☐	☐
9) My supervisor trusts his/her employees	☐	☐	☐	☐	☐
10) My supervisor encourages employees to					

8

The following statements deal with the decision-making process concerning your work community within the organisation (sector, etc.). Please tick the alternative that best corresponds with your current opinion about decision-making.

	Fully agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Fully disagree
1) Decisions are made based on correct information	☐	☐	☐	☐	☐
2) Failed decisions can be withdrawn or changed	☐	☐	☐	☐	☐
3) All concerned parties are represented when decisions are being made	☐	☐	☐	☐	☐
4) Decisions are consistent (the same rules apply to everyone)	☐	☐	☐	☐	☐
5) Everyone has the right to voice their opinions in matters related to themselves	☐	☐	☐	☐	☐
6) The effects of the decisions are monitored and reported on	☐	☐	☐	☐	☐
7) Additional information is provided about the grounds for the decisions upon request	☐	☐	☐	☐	☐

How happy are you about the following factors in your work?
Two opposite extremes are given after the question. There are seven boxes in between. The closer the response box is to an extreme, the better it corresponds to that alternative. Please tick the alternative that best corresponds to your opinion.

	Very unsatisfied						Very satisfied
1) Individual growth and development at work	☐	☐	☐	☐	☐	☐	☐
2) The feeling that I have achieved something meaningful at work	☐	☐	☐	☐	☐	☐	☐
3) My possibilities to think and act independently at work	☐	☐	☐	☐	☐	☐	☐
4) The level of challenges at work	☐	☐	☐	☐	☐	☐	☐

1) Have you had a one-on-one performance appraisal (discussion of goals) at work during the past 12 months?

☐ No
☐ Yes

2) What did you think of the performance appraisal you had with regard to your own work and development at work?

☐ Useful
☐ Not useful, but not useless
☐ Useless

9

1) For how many years have you been employed by your current employer? ⬚⬚ years

2) How long have you been in your current position? ⬚⬚ years

3) Do you work

- ☐ Full time
- ☐ Part time

4) What is your usual working time model?

- ☐ Regular daytime work
- ☐ Shift work, no night shifts (two-shift work)
- ☐ Shift work, incl. night shifts (three-shift work)
- ☐ Regular night work
- ☐ Other form of irregular working hours

5) How many years total have you been doing shift work? ⬚⬚ years

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Web appendix 3. Risk prediction models with stepwise regression.

Table A. Work-unit level predictors for increased violence in follow-up among registered and public health nurses.

Predictor variable	OR	95% CI
%, manual workers (per 10% increase)	1.36	1.20, 1.53
Rewards through personal satisfaction	0.72	0.63, 0.84
Influence over shift arrangements	1.78	1.51, 2.11
Influence over taking leave	0.77	0.67, 0.89
Threat of redundancy	1.22	1.08, 1.38

Table B. Work-unit level predictors for increased violence in follow-up among practical nurses.

Predictor variable	OR	95% CI
%, day work (per 10% increase)	0.58	0.48, 0.70
Enough time to get the work done	0.68	0.59, 0.79
Influence related to work	1.32	1.12, 1.55
Work includes different tasks (task variety)	0.71	0.62, 0.81
Influence over dates and times of holidays and days off	1.34	1.11, 1.62
Influence over taking leave	0.75	0.63, 0.91
Threat of redundancy	1.25	1.11, 1.41
Everyone feels understood and accepted in work unit	0.67	0.56, 0.80
Work unit understands their goals (goal clarity)	1.20	1.01, 1.43
Supervisor support	1.46	1.26, 1.70
The feeling of achieving something meaningful at work	0.85	0.72, 0.99

Table C. Work-unit level predictors for increased violence in follow-up among social and youth workers.

Predictor variable	OR	95% CI
%, manual workers (per 10% increase)	0.74	0.60, 0.92
Work requires creativity	0.69	0.55, 0.87
Work includes different tasks (task variety)	1.40	1.09, 1.81
Possibility to take breaks during the workday	0.51	0.42, 0.61
Supervisor's personal biases do not have a negative effect on his/her decisions	0.66	0.49, 0.91
Supervisor support	1.57	1.14, 2.16
Years in shift work (per 1-year increase)	1.68	1.42, 1.97

Table D. Work-unit level predictors for increased violence in follow-up among teachers.

Predictor variable	OR	95% CI
%, temporary employees (per 10% increase)	1.25	1.10, 1.41
Work is very fast-paced	1.41	1.22, 1.63
Can make a lot of independent decisions in work (decision latitude)	0.73	0.63, 0.84
Threat of discontinued work assignments	0.72	0.60, 0.85
Work unit understands their goals (goal clarity)	0.69	0.56, 0.86
General belief that the goals are beneficial	1.37	1.11, 1.69
The effects of the decisions are monitored and reported on	1.18	0.98, 1.43

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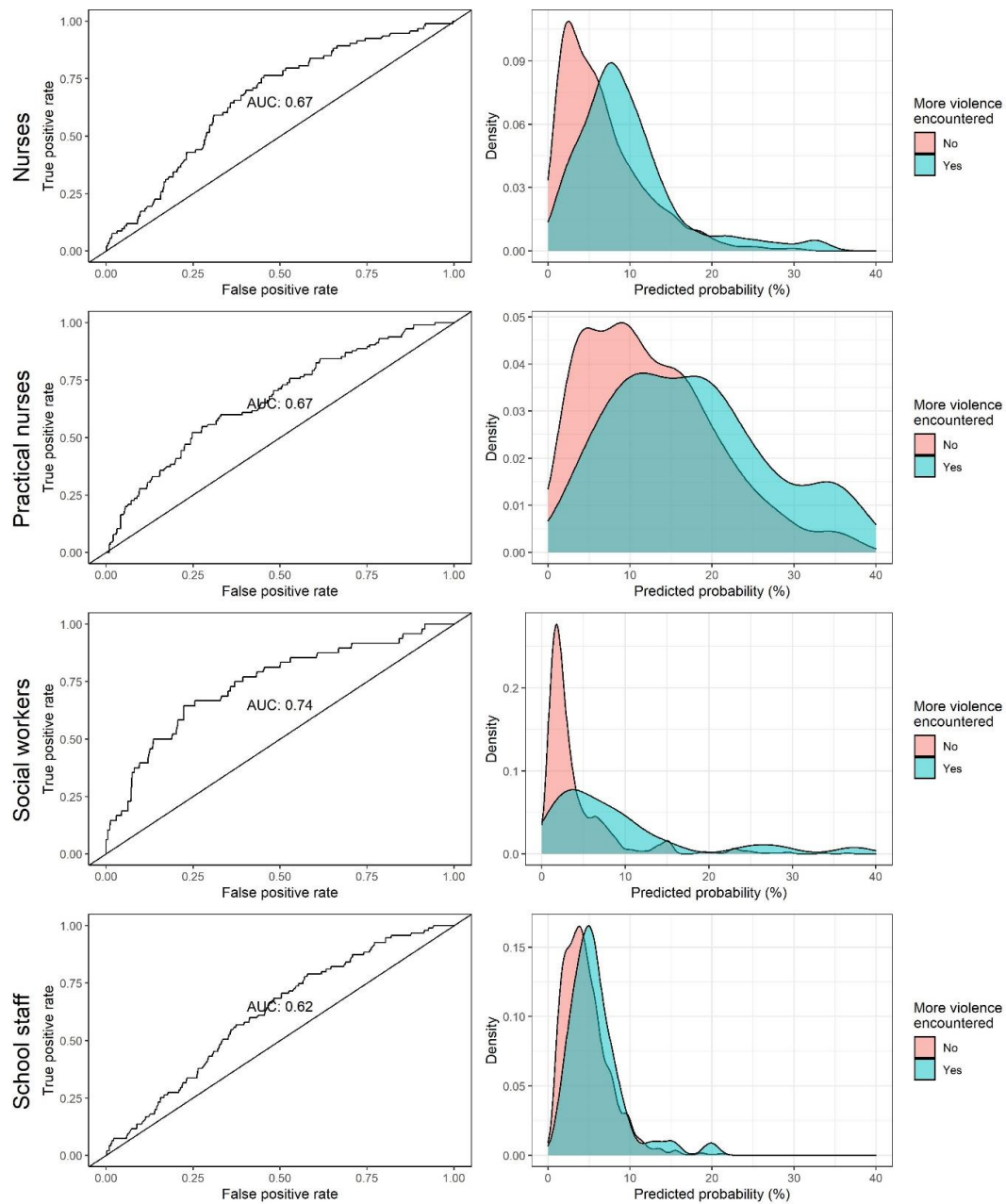
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Figure A. Backward stepwise regression model performance by occupation. Left side: ROC-curve for
work unit -level prediction for encountering more violence (lambda=min). Right side: Density plot for
encountering more violence at T2 by predicted probability (logistic regression, work unit -level
predictor variables).

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Table E. Detection rate (%), false positive rate (%), and ratio of true to false positive for predictive probability using various risk thresholds. (Backward stepwise regression models).

	Predictive probability of bullying violence? for cut off of a positive test result						
Nurses	5%	10 %	15%	20%	25 %	30 %	35 %
Detection rate	79.6	36.56	11.83	7.53	4.30	2.15	0.00
False positive rate	52.8	20.70	8.07	2.43	0.97	0.19	0.10
Ratio true to false positive	1/7.3	1/6.3	1/7.5	1/3.6	1/2.5	1/1.0	1/0.0
Practical nurses							
Detection rate	93.0	76.52	60.00	40.87	27.83	20.87	16.52
False positive rate	79.5	56.71	38.31	20.66	11.31	6.49	4.52
Ratio true to false positive	1/4.9	1/4.3	1/3.7	1/2.9	1/2.3	1/1.8	1/1.6
Social and youth workers							
Detection rate	64.6	29.17	18.75	14.58	10.42	6.25	6.25
False positive rate	23.2	7.38	4.43	2.46	0.98	0.25	0.12
Ratio true to false positive	1/6.1	1/4.3	1/4.0	1/2.9	1/1.6	1/2.0	1/3.0
Teachers							
Detection rate	54.7	7.37	4.21	-	-	-	-
False positive rate	36.3	4.77	0.95	-	-	-	-
Ratio true to false positive	1/12.4	1/12.1	1/4.3	-	-	-	-