Characteristics of workplace psychosocial resources and risk of diabetes: a prospective cohort study

Short running title: Workplace resources and risk of diabetes

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Word count: 3927 (including main text, table, and figure legends)

Number of figures: 4

Number of tables: 1

Number of references: 38

Abstract

Objective

To examine whether characteristics of workplace psychosocial resources are associated with the risk of type 2 diabetes among employees.

Research Design and Methods

Participants were 49,835 employees (77% women, aged 40-65 and diabetes-free at baseline) from the Finnish Public Sector cohort study. Characteristics of horizontal (culture of collaboration and support from colleagues) and vertical (leadership quality and organizational procedural justice) psychosocial resources were self-reported. Incident type 2 diabetes (n=2148) was ascertained via linkage to electronic health records from national registers. We used latent-class modeling to assess the clustering of resource characteristics. Cox proportional hazard models were used to examine the association between the identified clusters and risk of type 2 diabetes during 10.9 years of follow-up, adjusting for age, sex, marital status, educational level, type of employment contract, comorbidity and diagnosed mental disorders.

Results

We identified four patterns of workplace psychosocial resources: ‘unfavorable’; ‘favorable vertical’; ‘favorable horizontal’; and ‘favorable vertical and horizontal.’ Compared with the ‘unfavorable’, ‘favorable vertical’ (HR=0.87 95%CI 0.78;0.97), ‘favorable horizontal’ (HR=0.77 95%CI 0.67;0.88), and ‘favorable vertical and horizontal’ (HR=0.77 95%CI 0.68;0.86)

resources were associated with a lower risk of type 2 diabetes, with the strongest associations seen in employees at age 55 or older ($P_{interaction}$=0.03). These associations were robust to multivariable adjustments and were not explained by reverse causation.

Conclusions

Employees working in a favorable level of culture of collaboration, support from colleagues, leadership quality, and organizational procedural justice have a lower risk of developing type 2 diabetes than those without such favorable workplace psychosocial resources.

Keywords: Workplace psychosocial resources, organizational procedural justice, leadership quality, social support, collaboration, type 2 diabetes

Introduction

Chronic stress is suggested to increase the risk of type 2 diabetes through changes in health-related behaviors and via triggering of the immune system response and a cortisol-induced increase in glucose production in the liver combined with inhibition of insulin production in the pancreas.(1-4) Several studies and meta-analyses support this hypothesis, showing that people under work stress have a 10 to 60% higher risk of developing type 2 diabetes.(5-9)

Previous research has proposed behavioral, mental and physiological pathways linking psychosocial working environment to the development of type 2 diabetes.(5-9) However, from a prevention perspective, it is important to identify resources at work that can protect the health of the employees and counteract the potential health effects of stressful work factors.(10) The workplace provides a foundation for social and professional networks. It has been shown that people in the labor market have better physical and mental health than those outside of the labor market, although this observation may be partly attributed to health selection mechanisms.(11) Specifically, favorable characteristics of psychosocial resources such as high leadership quality, procedural justice, and social support at work are related to a lower risk of mental health problems among the employees.(12)

Empirical evidence of the effects of workplace psychosocial resources on long-term physical health outcomes, including diabetes, is sparse and conflicting.(3; 13; 14) The few prospective studies are based on relatively few diabetes cases (13; 14) or with a focus on only a single workplace psychosocial resource.(3; 13; 14) This limited focus on specific psychosocial resources may be problematic, as resources tend to cluster in some work teams. Also, workplace psychosocial resources in different hierarchical domains, e.g., organizational,

leadership, and group levels, may commonly coexist at work, potentially affecting each other and having synergistic influences on employee health.(10) Thus, large prospective studies that examine the co-existence of various workplace psychosocial resources and their association with type 2 diabetes are needed.

The current study aims at 1) identifying clusters of workplace psychosocial resources from four well-established hierachical domains including both horizontal and vertical dimensions and 2) in a prospective design examining whether these clusters are associated with the risk of developing type 2 diabetes. Horizontal dimensions include the culture of collaboration and social support from colleagues. Vertical dimensions refer to leadership quality and organizational procedural justice.

Methods

Study population

We used data from the Finnish Public Sector Study (FPS), an on-going dynamic cohort study with repeated questionnaire follow-ups every two to four years. FPS was established in 1997-1998, consisting of employees in the municipal services of 10 Finnish towns and 21 public hospitals, who had a job contract for a minimum of six months, aged between 18 and 65 at the time of participation.(15) We included all participants aged between 40 and 65 at their first eligible participation from 2000 to 2014 (flowchart, Figure 1). To ascertain incident type 2 diabetes during the follow-up, all prevalent type 1 or type 2 diabetes cases were excluded at baseline (Figure 1). Ethical approval was obtained from the Ethics Committee of the Hospital District of Helsinki and Uusimaa.(15)

Workplace psychosocial resources

To cover different hierarchical domains of workplace psychosocial resources, we included: i) culture of collaboration, ii) support from colleagues, iii) leadership quality, and iv) organizational procedural justice. All measurements were based on validated items with a 5-point Likert scale. Cut-offs were chosen based on previous research practice for categorizing into two or four groups.(Supplementary Text S1)

Culture of collaboration (items from workplace social capital scale) was measured by mean value of two items (Cronbach's alpha=0.77): ‘Do members of the work unit build on each other’s ideas to achieve the best possible outcome?’ and ‘People in the work unit cooperate to help develop and apply new ideas.’(16) The population mean value was used as a cut-off of defining a ‘good’ or ‘poor’ culture of collaboration. Participants were included if they had responded to at least one of the two items.

Support from colleagues (item from Statistics Finland’s measurement on working climate(17)) was measured by one question: ‘Open solidarity prevails at our workplace, demonstrated by mutual willingness to help.’ Those who answered 'somewhat agree' or 'completely agree’ were identified as having support from colleagues.

Leadership quality included four aspects of leadership (three items from The Stress Profile and one item from the relational justice scale),(18; 19) following a previous multi-cohort study by Madsen et al.,(20) measuring whether a supervisor (i) cares about the feelings of employees (caring), (ii) listens to the subordinates’ opinions on important cases (listens), (iii) rewards good work effort (appreciative) and (iv) informs in good time on decisions taken and

their consequences (informative). Collapsing these four items resulted in a scale with high internal consistency (Cronbach's alpha=0.88). Quartile of the variable was used to indicate the exposure to ‘low’, ‘intermediately low’, ‘intermediately high’, and ‘high’ level of leadership quality. The leadership variable was coded as missing if responses to at least two of the four individual items were missing.

Organizational procedural justice was identified using a modified version of Moorman’s scales (Cronbach's alpha=0.90),(21) defined as fairness for resolving disputes and allocating resources,(22) with asking whether procedures in the workplace are designed to (i) collect accurate information necessary for making decisions, (ii) provide opportunities to appeal or challenge the decision, (iii) hear the concerns of all those affected by the decision, and (iv) generate standards so that decisions can be made with consistency. We divided the distribution of responses into quartiles to indicate the exposure to ‘low’, ‘intermediately low’, ‘intermediately high’, and ‘high’ levels of procedural justice. The variable was coded as missing if responses to at least two of four items were missing.

Ascertainment of type 2 diabetes

All participants were linked to nationwide health and population registers using the unique personal identification numbers in Finland. We used all available information at different historical time points to capture incident diabetes. Type 2 diabetes was identified with codes ICD-8/9 250 and ICD-10 E11 as a primary or secondary diagnosis in electronic records from health and death registers with information on inpatient, and death. The participants were also linked to records of filled prescriptions (medication register) with information on Anatomical

Therapeutic Chemical codes. We used A10A (insulins and analogs), A10B (blood glucose-lowering drugs, excluding insulins), and A10X (other drugs used in diabetes) to identify patients with type 2 diabetes. Insulin treatment can indicate both type 1 and type 2 diabetes. However, because all participants were free from diabetes at baseline at the age of 40 or older, we assumed that the vast majority of individuals starting insulin treatment were type 2 diabetes cases. All prevalent type 1 diabetes events (e.g., ICD-8/9 249 and ICD-10 E10) were excluded at the baseline when insulin treatment (A10A) was applied as a criterion.

Covariates

Confounders were identified using directed acyclic graphs (a formalized diagram outlining assumptions about how variables are interconnected) informed by previous literature (Supplementary Figure S1).(23) Main confounders included age, sex (‘men’/’women’), marital status (‘married or cohabiting,’ ‘single,’ ‘separated or divorced’, ‘windowed’), educational level (‘≤9 years’, ‘10–12 years’, ‘≥13 years’), type of employment contract (‘permanent’/‘non-permanent’), pre-existing comorbidities and pre-existing diagnosed mental disorders. Information on these variables (except self-reported marital status) was extracted from the national register in Finland. Pre-existing comorbidities (calculated from Charlson Comorbidity Index) and pre-existing diagnosed mental disorders were detected using ICD codes from the national patient register when the diseases were recorded before the baseline (Supplementary Table S1).

We also considered health-related behaviors including smoking (‘current smoker’/’non-smoker’), risky alcohol consumption (‘yes’/’no’) and physical inactivity (‘yes’/’no’), other clinical

factors, i.e. body mass index and symptoms of mental health problems and other work-related factors, i.e. job demands (‘high’/’low’) and occupational grade (‘high’, ‘medium’, ‘low’) (Supplementary Text S2). However, due to the unclear temporality between these factors and our baseline measurement of psychosocial resources, these factors were considered more as mediators than confounders, and were adjusted for in a supplementary analysis but not in the main analysis.

Statistical analysis

We first conducted a latent class analysis to identify clustering of psychosocial resources among the baseline participants (i.e. the first eligible participation).(24) The classes observed at the first eligible participation were robust over time and could be extrapolated regardless of the participation year (Supplementary Figure S2). We decided on a four-class model by combining the criteria of a smaller Bayesian Information Criterion (BIC) value (i.e., the model fit), distribution of class membership probabilities, class sizes, and interpretability of the identified patterns (Supplementary Figure S3).(25) A previous study suggested a categorization of vertical (relations with employers and supervisors) and horizontal (relations with co-workers) social capital, providing theoretical support for our interpretation of the latent classes.(26)

Hazard ratios (HR) were estimated using the Cox proportional hazard model with follow-up length as the underlying time scale to examine the association between clusters of resources and type 2 diabetes. Participants were censored if they developed type 2 diabetes; died; or at the end of the follow-up (31 December 2016), whichever came first. The proportional hazard

assumption was checked both graphically using log-log plot and statistically by including interaction terms between time and covariates. No obvious violation was detected. The model was first minimally adjusted for sex and age, and then additionally adjusted for country of birth, marital status, educational level, type of employment contract, comorbidity score, and diagnosed mental disorders. In a supplementary analysis, the association between each individual type of resources and type 2 diabetes was assessed. To calculate the absolute effects of public health relevance, we estimated the corresponding incidence rate difference (IRD) using the Aalen additive hazards model.(27) We calculated the prevented fraction for the population (PFP) using the following formula: P_d (1-HR) / [1-(1-HR)(1- P_d)] where P_d is the prevalence of the resource clusters among diabetes cases.(28) PFP estimates the proportion of a disease outcome that has been prevented due to the presence of a protective factor, assuming that it is a causal relation.

In sensitivity analyses, we i) applied a one-year washout period to address the possibility of reverse causation; ii) restricted the follow-up length to the first four years of follow-up to identify possible immediate effects; iii) additionally adjusted for body mass index, alcohol consumption, smoking, physical activity, and symptoms of mental health problems; (iv) additionally adjusted for occupational grade and job demands.

We explored the potential effect modification of age group, sex, educational level and occupational grade on the association between psychosocial resources and type 2 diabetes.(29) Multiplicative interactions and additive interactions were tested using the Cox proportional regression and additive hazards model, respectively.

We used R package ‘poLCA’ version 1.4.1 for latent class analysis, SAS 9.4, ‘Proc phreg’ for the Cox proportional hazard model, and R package ‘timereg’ version 1.9.3 for Aalen additive model. Risk estimates were expressed as HR and IRD per 10,000 person-years and their 95% confidence intervals.

Results

Patterns of workplace psychosocial resources

We identified four latent classes of workplace resources (Figure 2 and Supplementary Table S2). Among the 49,835 baseline participants, 24% were grouped into the ‘unfavorable’ resource class, experiencing unsupportive psychosocial resources for all four resources. The ‘favorable vertical’ class (29%) was characterized by intermediate to high levels of procedural justice and leadership quality and low levels of co-worker support and culture of collaboration. The ‘favorable horizontal’ class (18%) was characterized by high levels of coworker support and culture of collaboration and low to intermediate levels of procedural justice and leadership quality. The individuals in the ‘favorable vertical and horizontal’ class (29%) reported relatively high workplace psychosocial resources across all dimensions.

Characteristics of the participants in each latent workplace resource class are presented in Table 1 and Supplementary Table S3. Resource clusters seemed to differ in terms of age, sex, educational level, marital status, holding a permanent job contract, occupational grade, and perceiving high job demands. The level of self-reported mental health and body mass index and proportion of diagnosed mental disorders, being physically active, drinking alcohol excessively and smoking also varied across the resource classes.

Workplace psychosocial resources and type 2 diabetes

During a mean follow-up time of 10.9 years, we identified 2148 incident type 2 diabetes cases recorded among 49,835 initially diabetes-free participants in FPS (Incidence: 39 per 10,000 person-years).

Figure 3 shows the relationship between baseline workplace psychosocial resources and type 2 diabetes. After adjusting main confounders, ‘favorable vertical’ (HR: 0.87 95% CI: 0.78;0.97, IRD: -6 per 10,000 person-years, PFP=4.3%), ‘favorable horizontal’ (HR: 0.77 95% CI: 0.67;0.88, IRD: -10 per 10,000 person-years, PFP=4.3%) and ‘favorable vertical and horizontal’ (HR: 0.77 95% CI: 0.68;0.86, IRD: -11 per 10,000 person-years, PFP=7.0%) resource classes were associated with a lower risk of developing type 2 diabetes compared to ‘unfavorable’ resource class.

When analyzing each of the four types of resources individually, we found some associations between individual resources and type 2 diabetes, but they almost disappeared when adding all individual resources into the same model (Figure 3 and Supplementary Figure S4).

To address reverse causality arising from an underlying disease process affecting the perception of the work situation already at baseline, we excluded diabetes cases within the first year of follow-up. The results remained almost unchanged (Supplementary Figure S5). Restricting the follow-up to the first four years also showed similar effect estimates (Supplementary Figure S5). Adjustments of lifestyle or work-related factors did not materially affect the magnitude of the effect, but the adjustment of self-reported mental health slightly attenuated the association (Supplementary Figure S6). There was an additive interaction

between age groups and resource ($P_{interaction}$=0.03), showing stronger associations among employees aged 55 or older (Supplementary Figure S7B). No interactions were found for sex, educational level and occupational grade on neither a multiplicative nor an additive scale (Supplementary Figure S7C).

Conclusions

In a large longitudinal study, we identified a clear pattern of clustering of workplace psychosocial resources. While 29% of the participants experienced favorable psychosocial resources across all domains, one in four employees worked in a low-resource psychosocial working environment characterized by low levels of both horizontal and vertical psychosocial resources. The first group had a lower risk of developing type 2 diabetes, especially among older employees. The latter group of employees were at higher risk of diabetes and also more likely to suffer from e.g. poorer self-reported mental health at baseline. The patterns of workplace psychosocial resources were stable across study waves, and the findings appeared not to be biased by reverse causation or confounding by other factors.

Comparisons with previous studies

To our knowledge, this is the first study investigating the association between clustering of workplace resources and type 2 diabetes. Our findings are in line with a previous study using data from 10,308 English civil servants, showing that workplace low social support was associated with a higher risk of type 2 diabetes.(3) However, among 6784 Danish healthcare workers with 253 incident diabetes cases, the intermediate level of leadership quality was more protective of incident type 2 diabetes than low and high levels of leadership quality.(13)

Another study of 3752 Canadian female employees with 259 incident diabetes, found that a low level of workplace social support was more protective regarding the development of type 2 diabetes compared with high workplace social support.(14) The previous Danish and Canadian studies included far fewer incident diabetes cases, did not consider the censoring due to death or migrations, and might have overadjusted for mediators, e.g., self-reported depression, compared with our study.

Possible pathways

In light of previous studies on diabetes etiology, an effect of workplace psychosocial resources on type 2 diabetes seems plausible. Among English civil servants, relational occupational justice was associated with a 25% lower risk of developing the metabolic syndrome in men.(30) Using the same dataset, circulating inflammatory markers interleukin-6 was found to mediate 10% of the longitudinal association between workplace social support and onset of diabetes.(3) Additionally, a Japanese study showed an association between lower levels of supervisor support and a higher risk of developing insulin resistance.(4) Social support has further been found to lead to a smoother blood pressure reaction, higher oxytocin levels, and lower level of cortisol and inflammation in response to an acute psychological stressor.(31) These physiological mechanisms support the hypothesis that workplace psychosocial resources may be important in preventing type 2 diabetes.

Our descriptive results showed favorable psychosocial resources at work had better self-reported mental health. The additional adjustment of self-reported mental health slightly attenuated the association, implying a potential pathway through poor mental health.

However, the association between mental health and type 2 diabetes was not confirmed in a previous multi-cohort study,(32) leaving the pathway through mental health somewhat equivocal.

Another plausible pathway is via changes in health-related behaviors. Our study showed that health-related lifestyle tended to differ according to resource classes. Stronger leadership at work could make work-related lifestyle interventions more successful.(33) A longitudinal association has been found between a high level of social capital and an increased probability of smoking cessation.(34) Cross-sectional evidence showed favorable psychosocial working conditions correlated with lower alcohol consumption and higher physical activity.(35; 36)

Public health implications

Our study adds to the existing literature by looking into the combination of workplace psychosocial resources across vertical and horizontal dimensions. It is interesting that there were no obvious associations between individual resources and type 2 diabetes when addressed individually, while a clear association was found when patterns of psychosocial resources and diabetes were considered together. Future research may be required to disentangle potential interactions among these resource elements.

Given the annual diabetes incidence of 39 per 10,000 persons among Finnish public sector employees, the observed associations, if causal, suggest a yearly reduction of up to 10 per 10,000 persons for ‘favorable horizontal’ and a yearly reduction of 11 per 10,000 persons for ‘favorable vertical and horizontal’ resources, comparing with the ‘unfavorable.’ The importance of ‘favorable vertical and horizontal’ resource was further supported by a PFP of

7%, indicating that if our finding is causal and the ‘favorable vertical and horizontal’ resource were to be replaced by the ‘unfavorable,’ the incidence of type 2 diabetes would be 7% higher. Nevertheless, the calculation of PFP based on the prevalence of resources and should be interpreted with caution.

Moreover, we found an interaction between age and resources on the additive (P=0.03) but not multiplicative scale (P=0.25), suggesting that the absolute effect of resources on diabetes was larger among those older than 55 than younger. This difference between interaction measures is not surprising. When both age and resources are associated with diabetes development, absence of multiplicative interaction implies the presence of additive interaction.(37) Additive interaction may be of better public health relevance, as it estimates the number of additional diabetes cases prevented in one group compared to another. For older employees, workplace psychosocial resources may contribute to the selection, optimization, and compensation strategies, aiming at reducing age-related losses while keeping age-related gains.(38) Previous literature suggests health benefits as a consequence of intervening on any resources.(10) The additive interaction implied such benefits may be most pronounced for organizations with a large number of older workers.

Strengths and limitations

The items on colleague support, culture of collaboration, leadership, and procedural justice were measured by standard scales or questionnaire items at the individual level, with applying a flexible data-driven approach for categorizing the workplace resources, allowing us to account for measurement error while not relying on predefined characterizations.(25) The

latent class approach also provided class membership probabilities, which indicates estimates' certainty. The categorization of latent classes in our study were based on the highest-class membership probability for each person. This procedure could have resulted in some degree of misclassification of the workplace resources, which may have attenuated the results slightly. Further, resources were only measured at the baseline. Without considering timing, duration and changes of the exposure, the association may be underestimated. While this study included a broad range of commonly studied group, leader and organizational level resources, several important workplace resources were not covered. These include at least control, rewards, ethical culture, predictability, autonomy and job security. Although a high correlation might exist between resources, future studies mapping a wider range of workplace resources in relation to diabetes risks are warranted.

Type 2 diabetes cases were ascertained using register-based data with the best available information from Finland's certified health reimbursement. These data were independent of the exposure measurement and allowed for a virtually full follow-up. People below 40 years of age were excluded to reduce the possibility that taking metformin was due to polycystic ovarian syndrome and the possibility of being treated by insulin due to type 1 diabetes. Therefore, in our study, we believe to have captured the vast majority of the individuals diagnosed with type 2 diabetes. However, as type 2 diabetes is more likely to be treated in primary care and appear in the health register later than the first time of the diagnosis, we may have slightly underestimated the association between resources and type 2 diabetes. Nevertheless, as we included any health reimbursement due to type 2 diabetes, including medication prescription and hospital admissions, this underestimation is probably minimal.

The detailed assessment of the baseline workplace psychosocial resources is a strength of this study. As these resources tend to coexist in the real-life setting, our study provides evidence on various combinations of resources, which may facilitate the development of complex multi-level workplace interventions. Our study took advantage of the large sample size with long enough follow-up to allow for type 2 diabetes to develop. We also had sufficient power to investigate the existence of reverse causation by excluding people diagnosed as diabetics within one year after the baseline. Further, the study population was representative of Finnish public sector employees. However, caution should be taken when generalizing our results to private-sector employees and cultural settings with different workplace psychosocial resources perceptions.

In conclusion, we identified four distinct patterns of psychosocial resources at work, which tended to cluster in specific groups of individuals. Favorable horizontal and vertical psychosocial resources were associated with the lowest risk of developing type 2 diabetes. These findings suggest that measures aiming at improving workplace psychosocial resources might help preserve the health of the employees. Future studies are needed to understand the effect of the timing of exposure and the mechanistic pathways.

Acknowledgments

TX, NHR, AJC, RR, LLMH, and HW contributed to the conception and design of the study. TX performed the analysis, interpreted data, and drafted the article. JP prepared datasset for analyses, ran the statistical codes and provided suggestions on the revision of codes. JV and MK contributed to access to relevant data. TL contributed to the application of statistical

methods. All authors have contributed to the critical revision and approved submission of the manuscript. NHR is the guarantor of the study.

We want to thank Martin Claeson from the Stress Research Institute to manage the data for analysis.

This project is supported by the Danish Working Environment Research Fund (grant 13-2015-09). TX was supported by a grant from the Swedish Research Council for Health, Working Life and Welfare (#2020-00040). RR was supported by research grands from NordForsk (grant 70521) and the Danish Working Environment Research Fund (grant 10-2016-03). JV was supported by the Academy of Finland (grant 321409 and 329240) and NordForsk (75021). LMH was supported by a grant from the Swedish Research Council for Health, Working Life and Welfare (#2019-01318). MK was supported by research grants from NordForsk (grant 70521, the Nordic Research Programme on Health and Welfare), the Academy of Finland (329202), and Finnish Work Environment Fund (190424) and, outside this work, by research grants from the UK Medical Research Council (grant MRC S011676) and the US National Institute on Aging (NIA) (grant R01AG056477). AJC moved to Novo Nordisk at the end of the project. Her current employer has no role in the study design, analyses and results interpretation.

Duality of Interest:

AJC is an employee at Novo Nordisk A/S. No other potential conflicts of interest relevant to this article were declared.

Reference

1. Pouwer F, Kupper N, Adriaanse MC. Does emotional stress cause type 2 diabetes mellitus? A review from the European Depression in Diabetes (EDID) Research Consortium. Discov Med 2010;9:112-118
2. Kelly SJ, Ismail M. Stress and type 2 diabetes: a review of how stress contributes to the development of type 2 diabetes. Annual review of public health 2015;36:441-462
3. Magnusson Hanson LL, Virtanen M, Rod NH, Steptoe A, Head J, Batty GD, Kivimäki M, Westerlund H. Does inflammation provide a link between psychosocial work characteristics and diabetes? Analysis of the role of interleukin-6 and C-reactive protein in the Whitehall II cohort study. Brain, behavior, and immunity 2019;78:153-160
4. Hino A, Inoue A, Mafune K, Nakagawa T, Hayashi T, Hiro H. Changes in the psychosocial work characteristics and insulin resistance among Japanese male workers: a three-year follow-up study. Journal of occupational health 2016;58:543-562
5. Nyberg ST, Fransson EI, Heikkilä K, Ahola K, Alfredsson L, Bjorner JB, Borritz M, Burr H, Dragano N, Goldberg M. Job strain as a risk factor for type 2 diabetes: a pooled analysis of 124,808 men and women. Diabetes Care 2014;37:2268-2275
6. Ferrie JE, Virtanen M, Jokela M, Madsen IE, Heikkila K, Alfredsson L, Batty GD, Bjorner JB, Borritz M, Burr H, Dragano N, Elovainio M, Fransson EI, Knutsson A, Koskenvuo M, Koskinen A, Kouvonen A, Kumari M, Nielsen ML, Nordin M, Oksanen T, Pahkin K, Pejtersen JH, Pentti J, Salo P, Shipley MJ, Suominen SB, Tabak A, Theorell T, Vaananen A, Vahtera J, Westerholm PJ, Westerlund H, Rugulies R, Nyberg ST, Kivimaki M. Job insecurity and risk of diabetes: a meta-analysis of individual participant data. Cmaj 2016;188:E447-e455
7. Xu T, Magnusson Hanson LL, Lange T, Starkopf L, Westerlund H, Madsen IEH, Rugulies R, Pentti J, Stenholm S, Vahtera J, Hansen ÅM, Kivimäki M, Rod NH. Workplace bullying and violence as risk factors for type 2 diabetes: a multicohort study and meta-analysis. Diabetologia 2018;61:75-83
8. Nordentoft M, Rod N, Bonde J, Bjorner J, Madsen IEH, Pedersen L, Cleal B, Magnusson Hanson L, Nexø M, Pentti J, Stenholm S, Sterud T, Vahtera J, Rugulies R. Effort-reward imbalance at work and risk of type 2 diabetes in a national sample of 50,552 workers in Denmark: A prospective study linking survey and register data. Journal of psychosomatic research 2019;128:109867
9. Li W, Yi G, Chen Z, Dai X, Wu J, Peng Y, Ruan W, Lu Z, Wang D. Is job strain associated with a higher risk of type 2 diabetes mellitus? A systematic review and meta-analysis of prospective cohort studies. Scandinavian journal of work, environment & health 2021;47:249-257
10. Nielsen K, Nielsen MB, Ogbonnaya C, Känsälä M, Saari E, Isaksson K. Workplace resources to improve both employee well-being and performance: A systematic review and meta-analysis. Work & Stress 2017;31:101-120
11. Tapia Granados JA, House JS, Ionides EL, Burgard S, Schoeni RS. Individual joblessness, contextual unemployment, and mortality risk. American journal of epidemiology 2014;180:280-287
12. Finne LB, Christensen JO, Knardahl S. Psychological and social work factors as predictors of mental distress: a prospective study. PloS one 2014;9
13. Poulsen K, Cleal B, Clausen T, Andersen LL. Work, diabetes and obesity: a seven year follow-up study among Danish health care workers. PloS one 2014;9:e103425-e103425
14. Smith PM, Glazier RH, Lu H, Mustard CA. The psychosocial work environment and incident diabetes in Ontario, Canada. Occupational Medicine 2012;62:413-419
15. Joensuu M, Kivimäki M, Pentti J, Virtanen M, Väänänen A, Vahtera J. Components of job control and mortality: the Finnish Public Sector Study. Occupational and environmental medicine 2014:536-542
16. Kouvonen A, Kivimäki M, Vahtera J, Oksanen T, Elovainio M, Cox T, Virtanen M, Pentti J, Cox SJ, Wilkinson RG. Psychometric evaluation of a short measure of social capital at work. BMC public health 2006;6:251

17. Lehto A-M. Quality of working life and equity. Helsinki, Finland: Statistics Finland 1991;
18. Setterlind S, Larsson G. The stress profile: A psychosocial approach to measuring stress. Stress Medicine 1995;11:85-92
19. Elovainio M, Kivimäki M, Vahtera J. Organizational justice: evidence of a new psychosocial predictor of health. American journal of public health 2002;92:105-108
20. Madsen IEH, Hanson LLM, Rugulies R, Theorell T, Burr H, Diderichsen F, Westerlund H. Does good leadership buffer effects of high emotional demands at work on risk of antidepressant treatment? A prospective study from two Nordic countries. Social psychiatry and psychiatric epidemiology 2014;49:1209-1218
21. Lallukka T, Halonen JI, Sivertsen B, Pentti J, Stenholm S, Virtanen M, Salo P, Oksanen T, Elovainio M, Vahtera J, Kivimäki M. Change in organizational justice as a predictor of insomnia symptoms: longitudinal study analysing observational data as a non-randomized pseudo-trial. International journal of epidemiology 2017;46:1277-1284
22. Gluschkoff K, Elovainio M, Hintsa T, Pentti J, Salo P, Kivimäki M, Vahtera J. Organisational justice protects against the negative effect of workplace violence on teachers' sleep: a longitudinal cohort study. Occupational and environmental medicine 2017;74:511
23. Greenland S, Pearl J, Robins JM. Causal diagrams for epidemiologic research. Epidemiology 1999:37-48
24. Hagenaars JA, McCutcheon AL. *Applied latent class analysis*. Cambridge University Press, 2002
25. Hulman A, Witte DR, Vistisen D, Balkau B, Dekker JM, Herder C, Hatunic M, Konrad T, Færch K, Manco M. Pathophysiological characteristics underlying different glucose response curves: a latent class trajectory analysis from the prospective EGIR-RISC study. Diabetes Care 2018;41:1740-1748
26. Oksanen T, Kouvonen A, Vahtera J, Virtanen M, Kivimaki M. Prospective study of workplace social capital and depression: are vertical and horizontal components equally important? Journal of epidemiology and community health 2010;64:684-689
27. Rod NH, Lange T, Andersen I, Marott JL, Diderichsen F. Additive Interaction in Survival Analysis: Use of the Additive Hazards Model. Epidemiology 2012;23:733-737
28. Strain T, Brage S, Sharp SJ, Richards J, Tainio M, Ding D, Benichou J, Kelly P. Use of the prevented fraction for the population to determine deaths averted by existing prevalence of physical activity: a descriptive study. The Lancet Global Health 2020;8:e920-e930
29. Hackett RA, Steptoe A. Type 2 diabetes mellitus and psychological stress—a modifiable risk factor. Nature Reviews Endocrinology 2017;13:547
30. Gimeno D, Tabak AG, Ferrie JE, Shipley MJ, De Vogli R, Elovainio M, Vahtera J, Marmot MG, Kivimaki M. Justice at work and metabolic syndrome: the Whitehall II study. Occupational and environmental medicine 2010;67:256-262
31. Uchino BN. Social support and health: a review of physiological processes potentially underlying links to disease outcomes. Journal of behavioral medicine 2006;29:377-387
32. Magnusson Hanson LL, Rod NH, Vahtera J, Peristera P, Pentti J, Rugulies R, Madsen IEH, LaMontagne AD, Milner A, Lange T, Suominen S, Stenholm S, Xu T, Kivimäki M, Westerlund H. Multicohort study of change in job strain, poor mental health and incident cardiometabolic disease. Occupational and environmental medicine 2019;76:785
33. Mattke S, Liu H, Caloyeras J, Huang CY, Van Busum KR, Khodyakov D, Shier V. Workplace Wellness Programs Study: Final Report. Rand Health Q 2013;3:7-7
34. Kouvonen A, Oksanen T, Vahtera J, Väänänen A, De Vogli R, Elovainio M, Pentti J, Leka S, Cox T, Kivimäki M. Work-place social capital and smoking cessation: the Finnish Public Sector Study. Addiction (Abingdon, England) 2008;103:1857-1865

35. Colell E, Sánchez-Niubò A, Benavides FG, Delclos GL, Domingo-Salvany A. Work-related stress factors associated with problem drinking: A study of the Spanish working population. American journal of industrial medicine 2014;57:837-846
36. Griep RH, Nobre AA, Alves MGDM, Da Fonseca MDJM, Cardoso LDO, Giatti L, Melo ECP, Toivanen S, Chor D. Job strain and unhealthy lifestyle: Results from the baseline cohort study, Brazilian Longitudinal Study of Adult Health (ELSA-Brasil). BMC public health 2015;15
37. VanderWeele TJ, Knol MJ. A tutorial on interaction. Epidemiologic Methods 2014;3:33-72
38. Truxillo DM, Cadiz DM, Hammer LB. Supporting the aging workforce: A review and recommendations for workplace intervention research. 2015;

Table 1. Baseline characteristics of participants in the Finnish Public Sector Study, by workplace psychosocial resources (N=49,835).

	Total sample N=49,835	Unfavorable n=11,932 24%	Favorable vertical n=14,215 29%	Favorable horizontal n=9218 18%	Favorable vertical and horizontal n=14,470 29%	p-value *
Social demographic characteristics						
Age, mean	48	48	48	47	48	<0.001
Female sex, %	77	73	76	81	80	<0.001
Educational level, %						<0.001
Low	11	12	12	9	11	
Medium	36	38	37	36	35	
High	52	50	50	56	54	
Marital status, %						<0.001
Married or cohabiting	76	74	76	77	78	
Single	9	10	9	8	8	
Divorced or separated	13	14	13	13	13	
Windowed	2	1	2	2	2	
Clinical characteristics						
Charlson Comorbidity Index ≥ 1, %	9	9	9	8	8	0.60
Diagnosed mental disorders, %	2	2	1	1	2	0.04
Work-related characteristics						
Non-permanent job contract, %	10	7	11	9	13	<0.001

* p-values for testing the hypothesis that at least one group is different from the others; ANOVA tests performed for continuous characteristics and chi-square tests performed for categorical characteristics.

Figure legends:

Figure 1. Flow chart of the study population.

Figure 2. Workplace psychosocial resource pattern in each latent class estimated among people's first participation in wave 2000-2014 (N=49,835), including 'unfavorable' (24%), 'favorable vertical' (29%), 'favorable horizontal' (18%) and 'favorable vertical and horizontal' (29%) classes.

Figure 3. Associations of workplace psychosocial resources with incident type 2 diabetes according to latent workplace resource clusters and individual type of workplace resources (N=49,835).