Review Article

Developing a Job Exposure Matrix of Work Organization Hazards in the United States: A Review on Methodological Issues and Research Protocol

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ABSTRACT

Background: Most job exposure matrices (JEMs) have been developed for chemical and physical hazards in the United States (US). In addition, the overall validity of most JEMs of work organization hazards using self-reported data in the literature remains to be further tested due to several methodological weaknesses.
Methods: This paper aims to review important methodological issues with regard to a JEM of work organization hazards using self-report data and to present a research protocol for developing a four-axis (job titles, hazards, sex, and time) JEM of major work organization hazards using the US General Social Survey-Quality of Work-Life (GSS-QWL) data (2002—2018; N = 7,100 workers).
Results: Five methodological weaknesses in existing JEMs of work organization hazards using self-report data were identified: having only two axes (hazard and occupation), using psychometrically weak items and scales, including scales having little interoccupational variability, unresolved optimal minimum numbers of subjects per occupation, and low accessibility. The methodological weaknesses were successfully addressed in the proposed research protocol.
Conclusion: The work organization JEM to be developed will significantly facilitate and strengthen occupational epidemiological studies on work organization hazards and major health outcomes, improve national and occupational surveillance of work organization hazards, and promote interventions for a healthy work environment in the US.

1. Introduction

A job exposure matrix (JEM), a cross-tabulation between workplace hazards and occupation title, has been used as an essential exposure assessment tool for epidemiological studies, hazard surveillance, prevention of hazards, and risk quantification in occupational safety and health research [1—7]. However, in the United States (US), most job exposure matrices have been developed for chemical and physical hazards [8—14], not for work organization hazards [15] (e.g., job control, job demands, social support at work, low rewards, long work hours, safety climate, and work and family conflicts). Work organization hazards increase the risk of cardiovascular disease (CVD) [16—18], common mental disorders [19—22], dementia [23—25], musculoskeletal disorders [26—

29], injuries [30,31], absenteeism [32,33], and presenteeism [34,35]. In addition, in contrast to chemical and physical workplace hazards restricted to some occupational groups, work organization hazards exist in all occupations [5].

However, there is no JEM of work organization hazards based on recent, nationally representative data of US working populations. There has been a JEM of job control and job demands based on Karasek's demand-control model [36] that were developed using the Quality of Employment Survey (QES) data (1969–1977) [37], but its contemporary applicability and utility for epidemiological research, hazard surveillance, and hazard control are limited [7] because of the substantial changes in the working life of US workers over the past 40 years: for example, changes in organizational practices (e.g., lean production systems), work arrangements (e.g.,

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increasing non-standard work), technology (e.g., automation), the structure of occupation, industry, and demographics (e.g., service-driven economy, increased women's labor force participation, and aging workforce), and labor relations (e.g., decreased union density) [15,38]. In addition, the overall validity of most JEMs of work organization hazards using self-reported data in the literature remains to be further tested due to several methodological issues [6,39]. The important methodological issues should be clearly analyzed and resolved prior to creating a high-quality JEM of work organization hazards using self-reported data.

The main purposes of this paper are to discuss important methodological issues with regard to a JEM of work organization hazards based on an extensive review of the literature and to present a research protocol for creating a four-axis (job titles, hazards, sex, and time) JEM of major work organization hazards using the 2002—2018 US General Social Survey-Quality of Work-Life (GSS-QWL) data.

1.1. Utilities of a JEM of work organization hazards

1.1.1. For epidemiological research

Work organization hazards (mainly based on the two influential work stress models, the Karasek's model [36] and Siegrist's effort-reward imbalance model [40]), have been intensively studied with CVD [16—18], common mental disorders [19—22], and musculoskeletal disorders [26—29]. However, most epidemiological studies have been conducted with individual self-reports of exposures. Thus, there has been ongoing uncertainty about the reported associations between work organization hazards and health outcomes [7,19,41—44], although there is some evidence of the validity for individual self-reports of job control and job demands against expert observations and administrative records [45—47].

Compared with individual self-reports, a JEM of work organization hazards provides more economical and reliable exposure information on work organization hazards by averaging out individual self-report bias on a group (occupation) level and/or removing the chance of recall bias for exposure. In addition, information on work organization hazards, except for detailed job titles, is missing in most US national data like the National Health and Nutrition Examination Survey [37,48]. If JEM-based work organization hazards are linked to the national clinical and registry data via detailed occupational codes [23—25,48—55], it will substantially facilitate epidemiological studies on a wide range of work organization hazards (see Table 1) and several major national health problems (opioid-related death, obesity, suicide, cancer, as well as CVD) [56—63].

Furthermore, a JEM of work organization hazards, if additionally incorporated into other JEMs of chemical, physical, microbiological, and ergonomic hazards, as in the comprehensive Finnish JEM [5,6], will significantly promote epidemiological studies which can elucidate the independent and combined contributions of multiple worksite hazards in the etiology of chronic diseases (e.g., CVD and cancer) in working populations, which have rarely been explored [63].

1.1.2. For national surveillance and other purposes

In addition to epidemiological research, the JEM-based approach has also served other purposes such as national hazard surveillance (e.g., occupational distributions of chemical hazard exposures by specific chemical agent and exposure level over time) [6], data source of national and occupational estimates of hazard exposures in health risk assessment [6,64] or decision-making for workers' compensation [6,65], and evaluation of the impact and cost of changing occupational exposure limits of chemical hazards [6]. A JEM of work organization hazards also serves the aforementioned purposes. For example, Niedhammer et al. [66] used a JEM approach to monitor occupation-level changes in job control, job demands, and social support at work during 2003—2010 in a French working population. Karasek et al. [37] used a JEM approach to identify high-risk occupations for job strain (a combination of low job control and high psychological job demands) [36] in the US Quality of Employment Survey data, which may function as a strong stimulus for interventions to improve psychosocial working conditions in high-risk occupations. In addition, a JEM of work organization hazards if it is analyzed or further specified by socioeconomic status, gender, or race/ethnicity has great potential to be used as a useful tool for monitoring and promoting social equity in psychosocial working conditions. Some investigators demonstrated differential distributions of job strain by socioeconomic status [19] and gender [45] using a JEM approach and graphic analysis. Furthermore, a JEM of work organization hazards can also be used by workplace stakeholders (individual workers, unions, and management) and practitioners for estimating workers' current and cumulative exposure to work organization hazards based on their job title, gender, and employment period, which may be essential information for decision-making of workers' compensation or interventions to improve psychosocial working conditions.

2. Materials and methods, and Results

2.1. Five methodological issues in creating a high-quality JEM of work organization hazards

Despite the aforementioned utilities, due attention should be given to critical methodological issues in creating a high-quality JEM of work organization hazards particularly using self-reported data. Many JEMs of work organization hazards in the literature have been developed based on large national survey data sets in the US [7], Sweden [67], Finland [5,6,41], Denmark [68], Norway [69], France [20,70], Spain [2,3], and Australia [71]. Most existing JEMs of work organization hazards share some of the following methodological weaknesses:

First, most existing work organization JEMs have only two axes (hazard and occupation) and do not have sex-specific or time period-specific information [2,3,5,6,20,68,70]. A JEM approach can ignore real differences in work organization hazards among workers within the same occupation [1,7,66,67,71,72]. In addition, work organization profiles may significantly differ by sex and time period even in the same occupation. Furthermore, due to because of possible nondifferential exposure misclassification, a JEM approach is likely to underestimate the real association between work organization hazards and health outcomes in epidemiological studies. Nonetheless, the aforementioned issues of a JEM approach can be mitigated to some extent by creating a JEM with detailed rather than simplified occupation codes [66,73] and with other additional stratification variables [67].

Second, a JEM of work organization hazards should be constructed with valid questionnaire items and scales. However, some JEMs include conceptually or psychometrically weak scales and items. For instance, the Australian JEM [71] includes one scale labeled "job demands and complexity." But the scale includes conceptually different items (e.g., "My job is more stressful …" and "use many of my skills and abilities"). In addition, some items of standard work stressor scales (e.g., psychological job demands of the Job Content Questionnaire [74]) can be differently understood by workers depending on their occupations (physically vs. mentally demanding jobs) [75—77] or survey times (before and after the Great Recession in 2008) [78]. Thus, the construct-and item-level

Table 1
A preliminary list of 31 items for 16 work organization domains selected from the General Social Survey-Quality of Work-Life (GSS-QWL) Questionnaire for analysis in this project. All 31 items have been used in all five waves (2002, 2006, 2010, 2014, and 2018) of the General Social Surveys

Work organization domain	Item wording
Hours of work	How many hours did you work last week, at all jobs?
Skill Development	My job requires that I keep learning new things I have an opportunity to develop my own special abilities I get to do a number of different things on my job My job lets me use my skills and abilities
Decision Making	In your job, how often do you take part with others in making decisions that affect you? I am given a lot of freedom to decide how to do my own work
Workload	My job requires that I work very fast I have too much work to do everything well I have enough time to get the job done
Role Conflict	I am free from the conflicting demands that other people make of me
Physical Demands	Does your job require you to do repeated lifting, pushing, pulling or bending? Does your job regularly require you to perform repetitive or forceful hand movements or involve awkward postures?
Resource Adequacy	I receive enough help and equipment to get the job done I have enough information to get the job done How often are there not enough people or staff to get all the work done?
Supervisor Support	My supervisor is concerned with the welfare of those under him or her My supervisor is helpful to me in getting the job done
Coworker Support	The people I work with can be relied on when I need help The people I work with take a personal interest in me
Recognition	When you do your job well, are you likely to be praised by your supervisor or employer?
Respect	At the place where I work, I am treated with respect
Promotions	Promotions are handled fairly The chances for promotion are good
Pay Fairness	How fair is what you earn on your job in comparison to others doing the same type of work you do?
Job Security	The job security is good
Safety Climate	The safety of workers is a high priority with management where I work There are no significant compromises or shortcuts taken when worker safety is at stake Where I work, employees and management work together to ensure the safest possible working conditions
Work and Family Conflict	How often do the demands of your job interfere with your family life? How often do the demands of your family interfere with your work on the job?

Job control, psychological job demands, and job strain scales can be additionally created based on Karasek's Demand-Control Model [36]. Job Control = Skill Development + Decision Making. Psychological Job Demands = Workload + Role Conflict. High Job Strain = A combination of low job control and high psychological job demands. Effort, reward, and effort-reward imbalance scales can be additionally created based on Siegrist's Effort-Reward Imbalance Model [40]. Effort = Psychological Job Demands. Reward = Recognition + Respect + Promotions + Pay Fairness + Job Security. Effort-Reward Imbalance = A combination of low reward and high effort.

measurement equivalence [79,80] between occupation, sex, and time period should be first tested and assured.

Third, despite little interoccupational variability (e.g., $R^2 < 1\%$), some hazards are included in JEMs of work organization hazards (e.g., fairness of pay in an Australian JEM [71]). In general, job control, psychological job demands, job strain, emotional demands, work hours, and physical job demands have been reported to vary considerably between detailed occupations [20,67,69,71,81]. On the other hand, supervisor support, coworker support, and job insecurity vary to a lesser extent between occupations. Little is known about the interoccupational variability of emerging work organization hazards, such as safety climate and work–family conflict. Cohidon et al. [70] included only the scales having at least a moderate level of interoccupational variability ($R^2 \geq 10\%$) in their JEM of work organization hazards.

Fourth, there is no strong empirical basis in the literature for an optimal minimum number of subjects in each occupation for creating a JEM of work organization hazards using self-reported data [39]. Without appropriate tests or justifications, several different minimum numbers of subjects per occupation (e.g., 3, 4, or 10) have been applied to work organization JEMs [41,48,67]. Higher minimum numbers of subjects in each occupation for a JEM will result in more precise exposure estimates. However, the occupations with insufficient numbers of subjects can be excluded from a

JEM, which results in a JEM covering a limited proportion of the total job titles available in their source data, for example, 50% in a US QES-based JEM [48] and 37% in a Finish JEM [41]. If the occupations with insufficient numbers of subjects would be included in a JEM after a merge with related occupations into a broader occupation group, their exposure estimates would be less specific. On the other hand, it is also not known yet whether different minimum numbers of subjects per occupation significantly affect the performance of the JEMs in terms of association with health outcomes [39].

Fifth, most existing JEMs of work organization hazards are not available on the Internet [37,67]. For the developed JEM to be widely used among users, the JEM should be available at or downloadable from a user-friendly website, similar to the Spanish JEM website (www.matemesp.org). Such a website will also be an efficient communication channel with users about systematic revisions and updates of the developed JEM [66,82] in the future.

2.2. A research proposal for creating a four-axis JEM of work organization hazards using the GSS-QWL data

Here, I present a research protocol for developing a four-axis (job titles, hazards, gender, and time) JEM of major work organization hazards using the GSS-QWL data (2002 2018; N = 7,100

workers). This research protocol will be informative to those who are interested in detailed information on how to create a high-quality JEM of work organization hazards while addressing the aforementioned JEM-related methodological issues using self-reported data.

The main aims of this project are (1) to develop a four-axis (hazard, occupation, sex, and time) JEM of major work organization hazards using recent national survey data and (2) to create a user-friendly website with the newly validated JEM. To create the four-axis JEM of major work organization hazards, core questionnaire items and scales for major work organization hazards (e.g., 31 items for 16 scales, Table 1) will be selected from GSS-QWL data (2002−2018). The core items and scales will be tested for their measurement equivalence between sex, occupations, and survey times, and inter-occupational variability. Nine two-axis (hazard and occupation) JEMs with different minimum numbers of subjects per occupation will be created with validated scales. The best two-axis JEM will be determined based on tests against individual-based scores for hazard classification and associations with health-related outcomes. The final four-axis JEM will further specify sex and time. The information in the developed JEM will be summarized into Microsoft Excel and Access files that will be easily downloadable and searchable for information by users at a user-friendly website.

2.2.1. NIOSH QWL questionnaire

In 2001, National Institute for Occupational Safety and Health (NIOSH) developed the Quality of Work-Life (QWL) questionnaire (76 items in total; 60 items for working conditions and 16 items for health-related outcomes) to assess the contemporary working life of US workers [83]. The NIOSH QWL questionnaire has been used in nationally representative samples of US workers every four years as part of the General Social Survey (GSS) since 2002. Thus, the GSS-QWL data (2002−2018) are one of the best data sources for creating a general population JEM of work organization hazards in the US. In addition, the data can be continuously updated with not only more data on existing QWL items but also additional new QWL items for emerging work organization hazards from future QWL surveys. However, the psychometric validity of the QWL items and scales remains to be further tested (see the following passages). The US Department of Labor Occupational Information Network, based on expert evaluations or incumbent self-reports, may be another useful occupation-level information source for some work organization hazards (e.g., emotional labor) [84,85]; however, it was not originally designed to measure work organization hazards, and its validity was very weak in nonhealthcare workers [84]. In addition, as mentioned before, many JEMs of work organization hazards have been constructed based on large national survey data.

2.2.2. The GSS-QWL data (2002−2018)

As noted in the earlier passage, the NIOSH QWL questionnaire has been administered as part of the GSS in 2002 (N = 1,725), 2006 (N = 1,669), 2010 (N = 1,133), 2014 (N = 1,207), and 2018 (N = 1,369). In total, 7,103 workers as a full-timer or part-timer filled out the GSS-QWL questionnaire. Among them, 7,071 workers had a valid occupational code (see the following passage). The GSS used the National Opinion Research Center at the University of Chicago National Sampling Frame for an equal probability multistage cluster sample of housing units for the entire United States. The participation rates of the NIOSH QWL surveys have been 69−71% in 2002, 2006, 2010, and 2014 [86]. However, the participation rate of the NIOSH QWL survey was 59% in 2018 [87]. To provide better exposure estimates, a four-axis JEM of major work organization hazards will be created (Fig. 1).

- Axis I: Detailed occupational codes (N = 461): Four-digit codes of the 2010 US Census Occupation Classification (COC) are included in the GSS-QWL survey data. However, in contrast with the 2010 COC system, the 2010 US Standard Occupational Classification (SOC) system has a clear hierarchical coding structure [88,89], which is essential to create a 100% coverage of the JEM for all detailed occupations in the QWL survey data [64,66,73]. There are 23 major groups, 97 minor groups, and 461 broad occupations in the 2010 SOC system. If the hazard information is not available at the most detailed level, the hazard information at the next most detailed level will be used. Thus, the COC codes in GSS-QWL data will be recoded into the hierarchical major (two-digit, e.g., **11**-0000: "Management Occupations"), minor (three-digit, e.g., **11-1**000: "Top Executives"), and broad (six-digit, e.g., **11-1010**: "Chief Executives") 2010 SOC codes using the standard crosswalk between the 2010 US COC and SOC codes available on the website of the US Census Bureau [90].
- Axis II: Work organization hazards (N ≤ 16): The final number of work organization hazards will be determined after the validation procedures of selected NIOSH QWL items and scales (see the following passages "Psychometric analysis" and "Interoccupation variability").
- Axis III: Sex (N ≤ 2): Men and women. The four-axis JEM will provide both general and sex-specific information on work organization hazards. Work organization profiles may significantly differ between men and women even in the same occupation. For instance, job control level was significantly lower in women than in men even though they hold the same occupational title [67]. In addition, the inter-occupational variability of work organization hazards may differ by gender [41,67].
- Axis IV: Time (N ≥ 2). The four-axis JEM will provide both the whole period (2002−2018) and period-specific (e.g., 2002−2006 and 2010−2018) information on work organization hazards. For instance, work organization profiles may significantly differ between the survey periods before and after the Great Recession in 2008. Myers et al. [91] reported that job strain, low job control, and work−family conflict significantly increased in
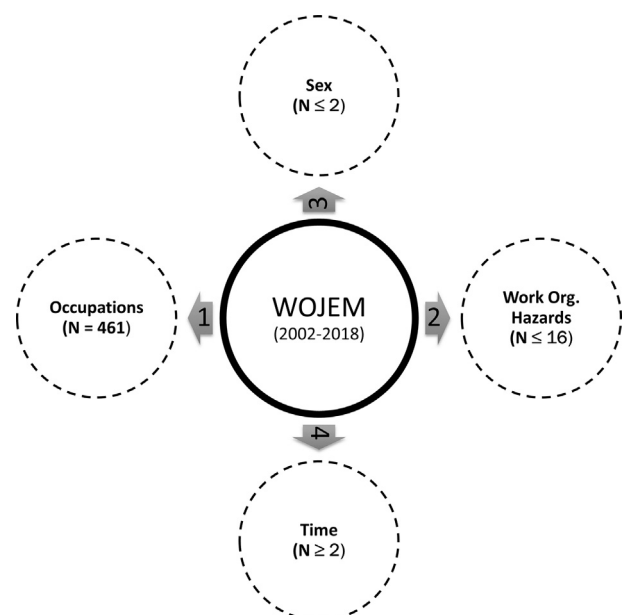

Fig. 1. A four-axis work organization job exposure matrix (WOJEM) using the General Social Survey-Quality of Work Life (GSS-QWL) data (2002−2018).

US working populations over the period 2002–2014, while no significant changes were observed for psychological job demands, social support at work, and rewards.

2.2.3. Psychometric analysis

2.2.3.1. Selection of important NIOSH QWL items

Among the original NIOSH QWL 60 items for working conditions, we will select important NIOSH QWL items for analysis with the following criteria: (1) whether they have been used in all five waves of GSS (2002–2018); (2) whether item wording is clear; (3) whether they are important work stressors from the perspectives of contemporary work stress theories, such as the Demand-Control model [40], the Effort-Reward Imbalance model [61], or organizational justice model [92]; or/and (4) whether their health effects have been documented in the literature. A preliminary list of important NIOSH QWL items and scales is presented in Table 1 (31 items for 16 domains).

2.2.3.2. Measurement equivalence between occupation, sex, and time

One central issue is measurement equivalence (construct-level and item-level) of the selected NIOSH QWL items and scales between comparison groups. In other words, whether an item "elicits the same conceptual frame of reference" in comparison groups should be examined along with "whether respondents calibrate the intervals anchoring the measurement continuum in the same manner" [80, p. 644]. The two issues will be addressed by factor analysis and differential item functioning (DIF) analysis.

Factor structure of selected QWL items will be explored and compared between sex, time periods (2002–2006 vs. 2010–2018), and five high-level occupation groups based on the US SOC major codes [88,89] (Management, Business, Science, and Arts; Service; Sales and Office; Natural Resources, Construction, and Maintenance; and Production, Transportation, and Material Moving). Given a lack of previous factor analyses of the QWL items, exploratory factor analysis will be undertaken. The scree test and the eigenvalue criterion (>1) as well as underlying theoretical concepts will be used to determine the number of factors. The criterion of the significance of the factor coefficient will be set at 0.30, as usual. The items having low factor loadings in factor analyses will not be used for the final JEM.

DIF analysis by sex, occupation group, and time period, as in the aforementioned factor analysis for selected QWL scales including at least two or more items. An item shows DIF if "all respondents at a given level of the attribute measured (at a given index score) do not have equal probability of scoring positively on the item regardless of subgroup membership" [93]. The partial gamma coefficient method [79,94] will be used for DIF statistics. Moderate to large DIF between comparison groups will be defined as items with partial gamma outside the interval (-0.31 to 0.31) and its 95% confidence interval significantly outside the interval (-0.21 to 0.21) [93]. If an item turns out to be a "moderate to large" DIF item, it will not be used for the final JEM.

2.2.4. Interoccupation variability

The proportion of the total variance in each work organization hazard will be examined with R^2 values by the 2010 six-digit SOC codes in the QWL data (2002–2018). This will be done separately for men and women because the interoccupational variability may differ by sex [67,71]. According to the recommendation of Cohidon et al. [70], only the scales having at least a moderate level of interoccupational variability ($R^2 \geq 10\%$) will be included in the final JEM. R^2 values will be greater than 10% at least in job control (skill discretion and decision authority) [36], psychological job demands,

job strain, work hours, and physical effort scales in the QWL data, which will be in line with the literature [20,67,69,71,81].

2.2.5. Determining the best two-axis JEM

Given the unknown optimal minimum number of subjects per occupation for creating a JEM [39], nine two-axis JEMs with varying minimum numbers of subjects per occupation (from 2 to 10) will be created. Preliminary analyses indicated that the number of subjects per SOC broad (six-digit) occupation in the GSS-QWL data (N = 7,071) varied from 1 to 201. Among the total 369 broad occupations available in the GSS-QWL data, 331 broad occupations (N = 7,033) had two or more 2 subjects, whereas 38 broad occupations had only one subject. On the other hand, 159 broad occupations (N = 6,031) have at least 10 or more subjects, whereas 172 broad occupations had 9 or fewer subjects. The hazard scores for a broad occupation having sufficient numbers of subjects will be estimated by averaging the hazard scores of all subjects in the broad occupation. However, the hazard scores for a broad (six-digit) occupation (e.g., "Chief Executives": **11-1010**) having insufficient numbers of subjects will be estimated from the average scores in the upper-level (e.g., three-digit) occupational group (e.g., "Top Executives": **11-1000**) to which the broad occupation belongs in the hierarchical SOC system.

The JEMs will be based on estimates of population means for the scales validated in the aforementioned procedures, weighted based on sampling weights of survey data of GSS-QWL data [87]. As a sensitivity analysis, unweighted estimates will also be obtained. To obtain unbiased estimates of population means for each scale in the presence of missing data ($<30\%$), missing data values will be imputed by the multiple imputation method [95]. The hazard scores for each six-digit occupation will be also dichotomized at the medians of the hazard scores [66,69] in the whole QWL data for classifying each occupation into a low- or high-hazard occupation.

The created nine two-axis JEMs will be compared against the individual self-reports in terms of the agreement level for hazard classification (high/low) and associations with the four standard Healthy Days (HD) measures of the Centers for Disease Control and Prevention (general health, mental health, physical health, and activity limitation) [96,97] available in the GSS-QWL data. The agreement level for low- and high-hazard occupations will be examined with kappa statistics, sensitivity, and specificity. As recommended [97–99], the HD measures will be dichotomized at fair or poor for general health and 14 or more unhealthy days for the other three measures for analyses. In comparison with the individual self-reports, among the eight two-digit JEMs, the best two-axis JEM will be chosen with two criteria of high agreement level and consistent associations with the HD measures. Associations will be examined using multivariate logistic regression analysis after controlling for age and gender. The analysis will be conducted with consideration of the characteristics of complex survey data of the GSS-QWL data.

In my preliminary analysis with the unweighted GSS-QWL data (2002–2018), the performance of the two-axis JEM of job control and physical demands was not affected by varying minimum numbers of subjects per occupation from 2 to 10. For instance, the agreement levels for low job control between individual self-reports and each of nine JEMs with the varying minimum numbers of subjects were similar: kappa values, 0.29–0.31. The association between JEM-based low job control and self-rated general health was consistent across the nine JEMs (prevalence ratios ranged from 1.79 to 1.85), which was also very similar to the association using individual self-reports (1.87). The aforementioned analyses will be repeated with weighted GSS-QWL data and will be done for other work organization hazards (e.g.,

psychological job demands, work hours, job insecurity, rewards, effort—reward imbalance, and work—family conflict).

2.2.6. Creating the final four-axis JEM

The best two-axis JEM will be further specified with sex-specific and time-specific information on work organization hazards. For example, if the best two-axis JEM would be the one having "2" as the minimum number of subjects per occupation, among the 331 broad occupations having ≥2 subjects in the GSS-QWL data (2002—2018), 265 broad occupations for men and 237 occupations for women would have additional sex-specific hazard information. In addition, 271 broad occupations during 2002—2006 and 267 broad occupations during 2010—2018 will have additional time-specific hazard information.

2.2.7. A website with the developed JEM for researchers and practitioners

A user-friendly website with the developed JEM of major work organization hazards will be created. The information in the developed JEM will be summarized into Microsoft Excel and Access files. Excel files of the JEM would be more suitable for researchers who want to use the JEM for epidemiological research and analysis. Access files of the JEM would be better for practitioners and other users to search for the scores of work organization hazards by occupation, sex, and time period. The website will provide the following contents: background, methodology, users' manual, the developed JEM in Access and Excel files, publications with the developed JEM, revisions and updates of the JEM (when additional information is available, for example, the 2022 GSS-QWL survey data to be released in 2023), contact information for Question (Q) & Answer (A) and the following JEM-related websites: the website for successful interventions for specific work organization hazards (https://healthywork.org) and the US websites for the JEMs of chemical and physical hazards (e.g., power-frequency magnetic fields: https://www.cdc.gov/niosh/topics/emf/jem-powerfreq/jempowerfreq.html).

3. Discussion

In this article, I discussed five important methodological issues in creating a JEM of work organization hazards particularly using self-reported data: having only two axes (hazard and occupation), using psychometrically weak items and scales, including scales having little interoccupational variability, unresolved optimal minimum numbers of subjects per occupation, and low accessibility of existing JEMs of work organization hazards. I presented a research protocol for creating a JEM of major work organization hazards using the GSS-QWL data (2002—2018) in which the aforementioned methodological issues were addressed by creating a four-axis (hazard, occupation, sex, and time) JEM, using only psychometrically validated items and scales, including only scales having at least a moderate level of interoccupational variability, empirically determining an optimal minimum numbers of subjects, and creating a user-friendly website with the work organization JEM (WOJEM) to be developed. Given the fact that work organization hazards significantly vary by time and gender, and most of existing JEMs of work organization hazards have only two-axes (hazard and occupation), the proposed four-axis WOJEM will serve as a valuable tool to more accurately estimate workers' current and cumulative exposure to work organization hazards, based on their job title, gender, and employment period. In addition, the validity of the proposed four-axis WOJEM is expected to be high due to the rigorous validation tests for psychometric validity, interoccupational variability, and optimal minimum numbers of subjects. The research protocol will be also a good practical guide to

researchers and practitioners who are interested in developing a high-quality JEM of work organization hazards using self-reported data. The new JEM of work organization hazards based on recent, nationally representative data of US working populations will significantly facilitate and strengthen occupational epidemiological studies on work organization hazards and major health outcomes, improve national and occupational surveillance of work organization hazards, and promote interventions for a healthy work environment in the US.

Conflicts of interest

All authors have no conflicts of interest to declare.

Acknowledgments

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.shaw.2020.05.007.

References

[1] Bouyer J, Hémon D. Retrospective evaluation of occupational exposures in population-based case-control studies: general overview with special attention to job exposure matrices. Int J Epidemiol 1993;22(Suppl. 2):S57—64.

[2] García AM, González-Galarzo MC, Angel-Alba M, Jose Gordo, et al. A job exposure matrix for Spanish workers; 2011. Available from: https://www.mapfre.com/fundacion/html/revistas/seguridad/n123/docs/Articulo2en.pdf.

[3] García AM, González-Galarzo MC, Kauppinen T, Delclos GL, Benavides FG. A job-exposure matrix for research and surveillance of occupational health and safety in Spanish workers: MatEmESp. Am J Ind Med 2013;56(10):1226—38.

[4] Hoar SK, Morrison AS, Cole P, Silverman DT. An occupation and exposure linkage system for the study of occupational carcinogenesis. J Occup Med 1980;22(11):722—6.

[5] Kauppinen T, Toikkanen J, Pukkala E. From cross-tabulations to multipurpose exposure information systems: a new job-exposure matrix. Am J Ind Med 1998;33(4):409—17.

[6] Kauppinen T, Uuksulainen S, Saalo A, Mäkinen I, Pukkala E. Use of the Finnish information system on occupational exposure (FINJEM) in epidemiologic, surveillance, and other applications. Ann Occup Hyg 2014;58(3):380—96.

[7] Schwartz J. Imputation f job characteristics scores. In: Schnall PL, et al., editors. Occupational medicine: state of the art reviews — the workplace and cardiovascular disease, vol. 15(1). Philadelphia: Hanley & Belfus; 2000. p. 172—5.

[8] Bowman JD, Touchstone JA, Yost MG. A population-based job exposure matrix for power-frequency magnetic fields. J Occup Environ Hyg 2007;4(9):715—28.

[9] Cheng W, Roberts B, Mukherjee B, Neitzel RL. Meta-analysis of job-exposure matrix data from multiple sources. J Expo Sci Environ Epidemiol 2018;28(3):259—74.

[10] Cicioni C, London SJ, Garabrant DH, Bernstein L, Phillips K, Peters JM. Occupational asbestos exposure and mesothelioma risk in Los Angeles County: application of an occupational hazard survey job-exposure matrix. Am J Ind Med 1991;20(3):371—9.

[11] Feingold L, Savitz DA, John EM. Use of a job-exposure matrix to evaluate parental occupation and childhood cancer. Cancer Causes Control 1992;3(2):161—9.

[12] Lee DG, Lavoué J, Spinelli JJ, Burstyn I. Statistical modeling of occupational exposure to polycyclic aromatic hydrocarbons using OSHA data. J Occup Environ Hyg 2015;12(10):729—42.

[13] Sieber Jr WK, Sundin DS, Frazier TM, Robinson CF. Development, use, and availability of a job exposure matrix based on national occupational hazard survey data. Am J Ind Med 1991;20(2):163—74.

[14] Stewart PA, Stenzel MR, Ramachandran G, Banerjee S, Huynh TB, Groth CP, Kwok RK, Blair A, Engel LS, Sandler DP. Development of a total hydrocarbon ordinal job-exposure matrix for workers responding to the Deepwater Horizon disaster: the GuLF STUDY. J Expo Sci Environ Epidemiol 2018;28(3):223–30.

[15] National Institute for Occupational Safety and Health (NIOSH). The changing organization of work and the safety and health of working people. DHHS (NIOSH) Publication No. 2002–116. Available from: https://www.cdc.gov/niosh/docs/2002-116/pdfs/2002-116.pdf?id=10.26616/NIOSHPUB2002116.

[16] Dragano N, Siegrist J, Nyberg ST, et al. Effort-reward imbalance at work and incident coronary heart disease: a multicohort study of 90,164 individuals. Epidemiology 2017;28(4):619–26.

[17] Kivimäki M, Nyberg ST, Batty GD, et al. Job strain as a risk factor for coronary heart disease: a collaborative meta-analysis of individual participant data. Lancet 2012;380:1491–7.

[18] Virtanen M, Nyberg ST, Batty GD, et al. Perceived job insecurity as a risk factor for incident coronary heart disease: systematic review and meta-analysis. BMJ 2013;347:f4746.

[19] Choi B, Clays E, de Bacquer D, Karasek R. Socioeconomic status, job strain, and common mental disorders: an ecological (occupational) analysis. Scan J Work Environ Health 2008;6(Suppl. l):22–32.

[20] Cohidon C, Santin G, Chastang JF, Imbernon E, Niedhammer I. Psychosocial exposures at work and mental health: potential utility of a job-exposure matrix. J Occup Environ Med 2012;54(2):184–91.

[21] Stansfeld S, Candy B. Psychosocial work environment and mental health–a meta-analytic review. Scand J Work Environ Health 2006;32(6):443–62.

[22] Theorell T, Hammarström A, Aronsson G, Träskman Bendz L, Grape T, Hogstedt C, Marteinsdottir I, Skoog I, Hall C. A systematic review including meta-analysis of work environment and depressive symptoms. BMC Public Health 2015;15:738.

[23] Andel R, Crowe M, Hahn EA, Mortimer JA, Pedersen NL, Fratiglioni L, Johansson B, Gatz M. Work-related stress may increase the risk of vascular dementia. J Am Geriatr Soc 2012;60(1):60–7.

[24] Seidler A, Nienhaus A, Bernhardt T, Kauppinen T, Elo AL, Frölich L. Psychosocial work factors and dementia. Occup Environ Med 2004;61(12):962–71.

[25] Wang HX, Wahlberg M, Karp A, Winblad B, Fratiglioni L. Psychosocial stress at work is associated with increased dementia risk in late life. Alzheimers Dement 2012;8(2):114–20.

[26] Bongers PM, Kremer AM, ter Laak J. Are psychosocial factors, risk factors for symptoms and signs of the shoulder, elbow, or hand/wrist?: a review of the epidemiological literature. Am J Ind Med 2002;41(5):315–42.

[27] Clays E, De Bacquer D, Leynen F, Kornitzer M, Kittel F, De Backer G. The impact of psychosocial factors on low back pain: longitudinal results from the Belstress study. Spine 2007;32:262–8.

[28] Lundberg U. Psychophysiology of work: stress, gender, endocrine response, and work-related upper extremity disorders. Am J Ind Med 2002;41:383–92.

[29] Ostergren PO, Hanson BS, Balogh I, Ektor-Andersen J, Isacsson A, Orbaek P, Winkel J, Isacsson SO. Malmö Shoulder Neck Study Group. Incidence of shoulder and neck pain in a working population: effect modification between mechanical and psychosocial exposures at work? Results from a one year follow up of the Malmö shoulder and neck study cohort. J Epidemiol Community Health 2005;59(9):721–8.

[30] Useche SA, Ortiz VG, Cendales BE. Stress-related psychosocial factors at work, fatigue, and risky driving behavior in bus rapid transport (BRT) drivers. Accid Anal Prev 2017;104:106–14.

[31] Wei C, Gerberich SG, Ryan AD, Alexander BH, Church TR, Manser M. Risk factors for unintentional occupational injury among urban transit bus drivers: a cohort longitudinal study. Ann Epidemiol 2017;27(12):763–70.

[32] Milner A, Butterworth P, Bentley R, Kavanagh AM, LaMontagne AD. Sickness absence and psychosocial job quality: an analysis from a longitudinal survey of working Australians, 2005-2012. Am J Epidemiol 2015;181(10):781–8.

[33] Svedberg P, Mather L, Bergström G, Lindfors P, Blom V. Work-home interference, perceived total Workload, and the risk of future sickness absence due to stress-related mental diagnoses among women and men: a prospective twin study. Int J Behav Med 2018;25(1):103–11.

[34] Oshio T, Tsutsumi A, Inoue A, Suzuki T, Miyaki K. The reciprocal relationship between sickness presenteeism and psychological distress in response to job stressors: evidence from a three-wave cohort study. J Occup Health 2017;59(6):552–61.

[35] Yang H, Hitchcock E, Haldeman S, Swanson N, Lu M, Choi B, Nakata A, Baker D. Workplace psychosocial and organizational factors for neck pain in workers in the United States. Am J Ind Med 2016;59(7):549–60.

[36] Karasek RA. Job demands, job decision latitude, and mental strain: implications for job redesign. Adm Sci Q 1979;24:285–308.

[37] Karasek RA, Theorell T, Schwartz JE, Schnall PL, Pieper CF, Michela JL. Job characteristics in relation to the prevalence of myocardial infarction in the US health examination survey (HES) and the health and nutrition examination survey (HANES). Am J Public Health 1988;78(8):910–8.

[38] Choi B, Schnall PL, Yang H, Dobson M, Landsbergis P, Israel L, Karasek R, Baker D. Sedentary work, low physical job demand, and obesity in US workers. Am J Ind Med 2010;53(11):1088–101.

[39] Choi B. Determining an optimal minimum number of subjects in each occupation for a job exposure matrix (JEM) using self-reported data: a missing test. Scand J Work Environ Health 2019;45(4):421–2.

[40] Siegrist J. Adverse health effects of high-effort/low-reward conditions. J Occup Health Psychol 1996;1(1):27–41.

[41] Solovieva S, Pensola T, Kausto J, Shiri R, Heliövaara M, Burdorf A, Husgafvel-Pursiainen K, Viikari-Juntura E. Evaluation of the validity of job exposure matrix for psychosocial factors at work. PLoS One 2014;9(9):e108987.

[42] Kolstad HA, Hansen AM, Kærgaard A, Thomsen JF, Kaerlev L, Mikkelsen S, Grynderup MB, Mors O, Rugulies R, Kristensen AS, Andersen JH, Bonde JP. Job strain and the risk of depression: is reporting biased? Am J Epidemiol 2011;173(1):94–102.

[43] Theorell T, Hasselhorn HM. On cross-sectional questionnaire studies of relationships between psychosocial conditions at work and health–are they reliable? Int Arch Occup Environ Health 2005;78(7):517–22.

[44] Waldenström K, Härenstam A. Does the job demand-control model correspond to externally assessed demands and control for both women and men? Scand J Public Health 2008;36(3):242–9.

[45] Karasek RA, Theorell T. Healthy work: stress, productivity, and the reconstruction of working life. New York (NY): Basic Books; 1990.

[46] Frese M, Zapf D. Methodological issues in the study of work stress: objective vs subjective measurement of work stress and the question of longitudinal studies. In: Cooper CL, Payne R, editors. Causes, coping and consequences of stress at work. Chichester, UK: Wiley & Sons; 1988. p. 375–411.

[47] Gimeno D, Benavides FG, Mira M, Martinez JM, Benach J. External validation of psychological job demands in a bus driver sample. J Occup Health 2004;46(1):43–8.

[48] Schwartz JE, Pieper CF, Karasek RA. A procedure for linking psychosocial job characteristics data to health surveys. Am J Public Health 1988;78(8):904–9.

[49] Alfredsson L, Karasek R, Theorell T. Myocardial infarction risk and psychosocial work environment: an analysis of the male Swedish working force. Soc Sci Med 1982;16(4):463–7.

[50] Alterman T, Shekelle RB, Vernon SW, Burau KD. Decision latitude, psychologic demand, job strain, and coronary heart disease in the Western Electric Study. Am J Epidemiol 1994;139(6):620–7.

[51] Amick 3rd BC, McDonough P, Chang H, Rogers WH, Pieper CF, Duncan G. Relationship between all-cause mortality and cumulative working life course psychosocial and physical exposures in the United States labor market from 1968 to 1992. Psychosom Med 2002;64(3):370–81.

[52] Hammar N, Alfredsson L, Johnson JV. Job strain, social support at work, and incidence of myocardial infarction. Occup Environ Med 1998;55(8):548–53.

[53] Johnson JV, Stewart W, Hall EM, Fredlund P, Theorell T. Long-term psychosocial work environment and cardiovascular mortality among Swedish men. Am J Public Health 1996;86(3):324–31.

[54] Toivanen S. Job control and the risk of incident stroke in the working population in Sweden. Scand J Work Environ Health 2008;34(1):40–7.

[55] Torén K, Schiöler L, Söderberg M, Giang KW, Rosengren A. The association between job strain and atrial fibrillation in Swedish men. Occup Environ Med 2015;72(3):177–80.

[56] Harduar Morano L, Steege AL, Luckhaupt SE. Occupational patterns in unintentional and undetermined drug-involved and opioid-involved overdose deaths - United States, 2007-2012. MMWR Morb Mortal Wkly Rep 2018;67(33):925–30.

[57] Centers for Disease Control and Prevention. CDC national health report: leading causes of morbidity and mortality and associated behavioral risk and protective factors- United States, 2005–2013. MMWR 2014;63(4):3–27.

[58] Choi B, Dobson M, Schnall P, Garcia-Rivas J. 24-hour work shifts, sedentary work, and obesity in male firefighters. Am J Ind Med 2016;59(6):486–500.

[59] Choi B, Schnall P, Dobson M. Twenty-four-hour work shifts, increased job demands, and elevated blood pressure in professional firefighters. Int Arch Occup Environ Health 2016;89(7):1111–25.

[60] Kuper H, Yang L, Theorell T, Weiderpass E. Job strain and risk of breast cancer. Epidemiology 2007;18:764–8.

[61] Choi B. Job strain, long work hours, and suicidal ideation in US workers: a longitudinal study. Int Arch Occup Environ Health 2018;91(7):865–75.

[62] Nyberg ST, Fransson EI, Heikkilä K, et al. Job strain as a risk factor for type 2 diabetes: a pooled analysis of 124,808 men and women. Diabetes Care 2014;37(8):2268–75.

[63] National Institute for Occupational Safety and Health (NIOSH). National occupational research agenda for cancer, reproductive, cardiovascular, and other chronic disease prevention. CRC. 2017. Available from: https://www.cdc.gov/nora/crosssectors/crc/pdfs/National_Occupational_Research_Agenda_for_CRC_508.pdf.

[64] Siemiatycki J, Lavoué J. Availability of a new job-exposure matrix (CANJEM) for epidemiologic and occupational medicine purposes. J Occup Environ Med 2018;60(7):e324–8.

[65] Fadel M, Valter R, Quignette A, Descatha A. Usefulness of a job-exposure matrix 'MADE' as a decision tool for compensation of work-related musculoskeletal disorders. Eur J Public Health 2019 Jan 9. https://doi.org/10.1093/eurpub/cky274 [Epub ahead of print].

[66] Niedhammer I, Milner A, LaMontagne AD, Chastang JF. Study of the validity of a job-exposure matrix for the job strain model factors: an update and a study of changes over time. Int Arch Occup Environ Health 2018;91(5):523–36.

[67] Johnson JV, Stewart WF. Measuring work organization exposure over the life course with a job-exposure matrix. Scand J Work Environ Health 1993;19(1):21–8.

[68] Wieclaw J, Agerbo E, Mortensen PB, Burr H, Tuchsen F, Bonde JP. Psychosocial working conditions and the risk of depression and anxiety disorders in the Danish workforce. BMC Public Health 2008;8:280.

[69] Hanvold TN, Sterud T, Kristensen P, Mehlum IS. Mechanical and psychosocial work exposures: the construction and evaluation of a gender-specific job exposure matrix (JEM). Scand J Work Environ Health 2019;45(3):239—47.

[70] Cohidon C, Niedhammer I, Wild P, Guéguen A, Bonenfant S, Chouanière D. Exposure to job-stress factors in a national survey in France. Scand J Work Environ Health 2004;30(5):379—89.

[71] Milner A, Niedhammer I, Chastang JF, Spittal MJ, LaMontagne AD. Validity of a job-exposure matrix for psychosocial job stressors: results from the household income and labour dynamics in Australia survey. PLoS One 2016;11(4): e0152980.

[72] Goldberg M, Hémon D. Occupational epidemiology and assessment of exposure. Int J Epidemiol 1993;22(Suppl. 2):S5—9.

[73] Niedhammer I, Chastang JF, Levy D, David S, Degioanni S, Theorell T. Study of the validity of a job-exposure matrix for psychosocial work factors: results from the national French SUMER survey. Int Arch Occup Environ Health 2008;82(1):87—97.

[74] Karasek RA, Gordon G, Pietrokovsky C, Frese M, Pieper C, Schwartz J, et al. Job content questionnaire and user's guide. Los Angeles (CA), Lowell(MA): University of Southern California/University of Massachusetts; 1985.

[75] Choi B, Kurowski A, Bond M, Baker D, Clays E, De Bacquer D, Punnett L. Occupation-differential construct validity of the Job Content Questionnaire (JCQ) psychological job demands scale with physical job demands items: a mixed methods research. Ergonomics 2012;55(4):425—39.

[76] Bjorner JB, Pejtersen JH. Evaluating construct validity of the second version of the Copenhagen Psychosocial Questionnaire through analysis of differential item functioning and differential item effect. Scand J Public Health 2010;38(3 Suppl. l):90—105.

[77] Kristensen TS, et al. The distinction between work pace and working hours in the measurement of quantitative demands at work. Work & Stress 2004;18: 305—22.

[78] Chungkham HS, Ingre M, Karasek R, Westerlund H, Theorell T. Factor structure and longitudinal measurement invariance of the demand control support model: an evidence from the Swedish Longitudinal Occupational Survey of Health (SLOSH). PLoS One 2013;8(8):e70541.

[79] Choi B, Bjorner JB, Ostergren PO, Clays E, Houtman I, Punnett L, Rosengren A, De Bacquer D, Ferrario M, Bilau M, Karasek R. Cross-language differential item functioning of the job content questionnaire among European countries: the JACE study. Int J Behav Med 2009;16(2):136—47.

[80] Riordan CM, Vandenberg RJ. A central question in cross-cultural research: do employees of different cultures interpret work-related measures in an equivalent manner? J Manage 1994;20(3):643—71.

[81] Karasek R, Brisson C, Kawakami N, Houtman I, Bongers P, Amick B. The Job Content Questionnaire (JCQ): an instrument for internationally comparative assessments of psychosocial job characteristics. J Occup Health Psychol 1998;3(4):322—55.

[82] Le Moual N, Zock JP, Dumas O, Lytras T, Andersson E, Lillienberg L, Schlünssen V, Benke G, Kromhout H. Update of an occupational asthma-specific job exposure matrix to assess exposure to 30 specific agents. Occup Environ Med 2018;75(7):507—14.

[83] Murphy LR. Job stress research at NIOSH: 1972—2002. In: Perrewe Pamela L, Ganster Daniel C, editors. Historical and current perspectives on stress and health (research in occupational stress and well-being, vol. 2. Emerald Group Publishing Limited; 2002. p. 1—55.

[84] Cifuentes M, Boyer J, Gore R, d'Errico A, Tessler J, Scollin P, Lerner D, Kriebel D, Punnett L, Slatin C. PHASE in Healthcare Research Team. Inter-method agreement between O*NET and survey measures of psychosocial exposure among healthcare industry employees. Am J Ind Med 2007;50(7):545—53.

[85] Glomb TM, Kammeyer-Mueller JD, Rotundo M. Emotional labor demands and compensating wage differentials. J Appl Psychol 2004;89(4):700—14.

[86] Smith TW, Hout M, Marsden PV. General social survey, 1972-2016 [cumulative file]. Codebook. ICPSR 36797.

[87] Smith Tom W, Michael Davern, Jeremy Freese, Michael Hout. General social surveys, 1972-2018. [machine-readable data file]. Chicago: NORC; 2019. Principal investigator, Tom W. Smith; Co-Principal investigators, Michael Davern, Jeremy freese and Stephen L. Morgan, NORC ed. 1 data file (64,814 logical records) and 1 codebook (3,758 pp).

[88] US Bureau of Labor Statistics. The 2010 standard occupational classification structure. Available from: https://www.bls.gov/soc/soc_structure_2010.pdf.

[89] Rhode Island Department of Labor and Training. Standard occupational classification system. Available from: http://www.dlt.ri.gov/lmi/pdf/soc.pdf.

[90] US Census Bureau. Census occupation codes with crosswalk; 2010. Available from: https://www.census.gov/topics/employment/industry-occupation/guidance/code-lists.html.

[91] Myers S, Govindarajulu U, Joseph M, Landsbergis P. Changes in work characteristics over 12 years: findings from the 2002-2014 US national NIOSH quality of work life surveys. Am J Ind Med 2019;62(6):511—22.

[92] Greenberg J. Organizational justice: yesterday, today, and tomorrow. J Manage 1990;16(2):399—432.

[93] Ørhede E, Kreiner S. Item bias in indices measuring psychosocial work environment and health. Scand J Work Environ Health 2000;26(3):263—72.

[94] Bjorner JB, Kreiner S, Ware JE, Damsgaard MT, Bech P. Differential item functioning in the Danish translation of the SF-36. J Clin Epidemiol 1998;51(11):1189—202.

[95] Sterne JA, White IR, Carlin JB, Spratt M, Royston P, Kenward MG, Wood AM, Carpenter JR. Multiple imputation for missing data in epidemiological and clinical research: potential and pitfalls. BMJ 2009;338:b2393.

[96] Center for Disease Control and Prevention. Measuring healthy days. Atlanta, Georgia: CDC. November 2000. Available from: https://www.cdc.gov/hrqol/pdfs/mhd.pdf.

[97] Moriarty DG, Zack MM, Kobau R. The Centers for Disease Control and Prevention's Healthy Days Measures - population tracking of perceived physical and mental health over time. Health Qual Life Outcome. 2003;1:37.

[98] Dwyer-Lindgren L, Mackenbach JP, van Lenthe FJ, Mokdad AH. Self-reported general health, physical distress, mental distress, and activity limitation by US county, 1995-2012. Popul Health Metr 2017;15(1):16.

[99] Rijs KJ, van der Pas S, Geuskens GA, Cozijnsen R, Koppes LL, van der Beek AJ, Deeg DJ. Development and validation of a physical and psychosocial job-exposure matrix in older and retired workers. Ann Occup Hyg 2014;58(2):152—70.