© OCT 2022 | IRE Journals | Volume 6 Issue 4 | ISSN: 2456-8880
DOI: https://doi.org/10.64388/IREV6I4-1720146

Chronic Occupational Stress, Sedentary Work, and Cardiovascular Risk: Evidence Relevant to the U.S. Workforce and the Moderating Role of Physical Activity

ADEDAYO ADEKOLA
Department of Public Health, University of New Haven, Connecticut, USA

Abstract- ***Cardiovascular disease (CVD) is the number one killer of U.S. adults and most exposure that people get to modifiable risk factors occurs during the workday. Two occupational stressors present in the modern American workplace chronic psychosocial stress at work and prolonged occupationally-derived sitting have been associated with increased cardiovascular disease risk individually, however, few studies have examined both exposures, and what effect regular exercise may have to mitigate those risk markers is unknown. This narrative review is meant to bring together theoretical, epidemiological and mechanistic evidence to study the impact of occupational stress (job strain and effort-reward imbalance) as well as sedentary work on cardiovascular outcomes among U.S. workers and assess the evidence, to date, for physical activity as a potential moderator. A narrative synthesis was undertaken of 20 different peer-reviewed sources ranging from foundational models of stress to prospective cohort studies, systematic reviews or meta-analyses. High levels of job strain (characterized by high psychological demands and low decision latitude) have been consistently linked to greater risks of myocardial infarction and coronary heart disease in U.S. and similar, industrialized populations, with some theorized mechanisms being dysregulations in the autonomic nervous system and hypotalamo pituitary adrenal axis and adverse health behaviors. In large-scale meta-analyses, higher levels of occupational sedentary behavior predicted higher risk of all-cause mortality and cardiovascular disease mortality independently of leisure-time physical activity, although this association was much weaker among people who had higher levels of physical activity on their leisure time. The reviewed evidence indicates that occupational stress and physical activity exposure has overlapping, but different physiological exposures and pathways, and that physical activity exposure has a meaningful interaction in mitigating the increased risk from either exposure. Replacing work related risk factors, promoting structured movement, and promoting physical activity existence studies indicate that workplace strategies that include combining the job redesign and physical activity promotion may provide a more holistic pathway to cardiovascular risk reduction for the U.S. workforce than changes which target a single work risk factor alone.***

Keywords: Occupational Stress, Cardiovascular Disease, Job Strain, Sedentary Behavior, Physical Activity, Workplace Health, U.S. Workers.

I. INTRODUCTION

A. The modern American workplace and cardiovascular disease

Despite the fact that cardiovascular disease remains the leading cause of death for adults in the United States, a large proportion of modifiable risk that contributes to these deaths are influenced by conditions to which one is exposed at work. Physical and psychological characteristics of working life job demand, worker control, time spent sitting that affect physical activity levels (PAL) and cardiovascular disease risk, are now well known for being important targets for cardiovascular epidemiology, not just a secondary aspect of work.

B. Two Long Term Tendencies of the U.S. Labor Market Are of Particular Interest

The first is the rise of psychologically demanding work situations with limited autonomy in job tasks and acing, like in call centers, in health care support careers or jobs related to logistics and in many other service careers. The second is that physically strenuous jobs have gone, and desk jobs using a computer often have replaced them, requiring many to sit for long periods. There has been little interaction between the two developments in research literature, despite their often being present in the same occupations, and, presumably, in the same workers.

C. The Theoretical Frameworks for Occupational Psychosocial Stress

The prevailing theories in this literature are those of Karasek (1979) which rely on the dual factors of decision latitude and job demands, proposing that it is combination of high job demands and low decision latitude, or 'liking' jobs, which causes psychological strain. Occupations with this occupational profile are called 'high strain' jobs, and these jobs not only demand person have been most consistently associated with poor cardiovascular health. Sometime later, Kristensen (1995) added a third dimension to the model: social support, noting that social support at work is one resource that can buffer some of the strain of high-demand low control work.

Another view is Siegrist's (1996) effort-reward imbalance theory, where it is the balance of efforts to the rewards of the job that is the determining factor strain occurs when a person's continuing efforts are not rewarded adequately, whether in terms of monetary compensation, esteem, promotion or job security. The former (the demand-control model) heeds more to control over the work process, while the latter (the effort-reward model) heeds to fairness in the worker-employer exchange and both models have generally been viewed as complementary rather than competing models of how the psychosocial work environment translates into physiological strain. Both have been operationalized and tested in large occupational cohorts including on U.S. survey data from the Health Examination Survey and the Health and Nutrition Examination Survey (Karasek et al., 1988), as well as in occupational cohorts like the Whitehall II civil service study whose results on organizational justice and the coronary risks have provided guidance for occupational health across the U.K. (Kivimäki et al., 2005).

D. The Authors of The Institute of Medicine Report On The Impact of Sedentary Work Argue

Another strand of research, though one increasingly united with others, has focused on the impact of watching a person's occupation and the amount of time they spend sitting, rather than the more popular looking at whether they manage to have enough (leisure) exercise. This separation is important because a worker can comply with the public health guidelines for other activities whilst exceedingly sedentary during their working hours; and there is growing evidence into the metabolic and vascular health effects of being sedentary for many (>8) continuous hours (Carter et al., 2017) often referred to as the 'sitting disease' hypothesis. Several large prospective cohort studies as well as pooled analyses (including a harmonized meta-analysis of over a million people, Ekelund et al., 2016) and a national study in Australia (van der Ploeg et al., 2012) and an occupational cohort of Japanese workers (Kikuchi et al., 2015) have all returned a consistent dose-responsive association of increased total sitting time with all-cause and cardiovascular mortality. In 2016 the American Heart Association finally published its evidence-based science advisory on sedentary behavior as a valid risk factor in cardiovascular disease for which a clinical and/or public health focus is warranted (Young et al., 2016).

As detailed in the introduction and the background of this project, physical activity is a possible moderating variable.

A natural question that arises is whether sedentary time and physical activity are actually opposites and thus sit on a single spectrum, and if not then, can there be a beneficial effect from increasing physical activity to mitigate the cardiovascular risk associated with a higher level of sedentary behavior or with high strain work? The influential response to the meta-analysis of sedentary behavior specifically from Ekelund et al. (2016) argued that the mortality risk of high sitting time was confined to the least physically active and those in the most physically active groups had little associated excess risk even with high duration of sitting time. What remains largely unstudied by direct empirical work are questions about whether there is a buffering effect for the psychosocial pathway between physically active workers and work strain (or vice versa) that is, do physically active workers working in high strain jobs have the same protection.

E. In What Ways Will You Define the Central Concepts

The operational definitions of the terms used throughout this review are important to briefly define first to consider the findings of this review. Karasek's

(1979) model does not view any job high in demands but also high in control as a straining job and these jobs (often termed "active" jobs) have not been consistently associated with cardiovascular risk. Effort-reward imbalance (Siegrist, 1996) is the perception that the effort a worker puts in is not rewarded through the means of wages, esteem and career security and/or development. Sedentary behavior is defined in the literature as any waking behavior outside of sleep that involves low level energy expenditure and is distinct from volume of physical activity (measured as amount of moderate-to-vigorous exercise) which is referred to as physical inactivity, e.g. an individual may be sedentary for the majority of the day and physically active during specific intense exercise periods. In the studies synthesized for this review, physical activity typically has been defined as leisure-time (or overall) moderate to vigorous activity, based either on self-report or, more recently, on accelerometer-measurements.

F. Review's Purpose and Scope

This review summarizes the evidence with respect to three related questions regarding the relationship of psychosocial stress operationalized via the job strain and effort-reward imbalance models with cardiovascular disease (CVD) risk and sedentary occupational behavior with CVD risk among the U.S. working population.

(1) magnitude of the extent to which physical activity is associated with the risk for cardiovascular or all-cause mortality and (2) degree to which an interaction between physical activity and cardiovascular or all-cause mortality exists; (3) to assess the moderation by physical activity of the relationship between the different risks and cardiovascular or all-cause mortality. Where international cohort evidence and meta-analytic evidence has directly influenced U.S. guidelines on occupational health, high-quality evidence was used to convey the review, while recognizing that there are constructs for which primary data are sparser from the U.S. evidence base, and the generalizability of the international evidence is discussed in the Discussion.

II. METHOD

A. Literature Search Strategy

This is a narrative, integrative rather than systematic review inspired by the embracing of an interdisciplinary field as a context for considering the three types of literature on occupational psychosocial stress, sedentary behavior and physical activity, which are not typically combined. Including combinations of job strain, effort-reward balance, psychosocial working environment, sedentary behavior, sitting time, occupational sitting, physical activity, cardiovascular disease, coronary heart disease, myocardial infarction and mortality in bibliographic searches, relevant peer-reviewed sources (PubMed/MEDLINE and Scopus) in English were identified. Hand-searching of reference lists of retrieved review articles and meta-analysis studies was used to identify any other foundational theoretical or empirical references and the American Heart Association's formal science advisory on sedentary behavior was included as a benchmark policy source.

B. Accessibility Requirements and Sources Selection

Potential sources were prospective cohort studies that evaluated either psychosocial stress at work or physical activity exposure at work or total sedentary behaviors, as well as papers that presented a fundamental theoretical statement or model for occupational psychosocial stress, occupational sedentary behaviors, or physical activity exposure for cardiovascular or all-cause mortality outcomes and were peer-reviewed. Studies were prioritized according to the following criteria: there was direct generalizability to U.S. working populations, or research was conducted in U.S. working populations. First, where primary data for the U.S. population were inadequate which is the status of much of the literature on effort-reward imbalance methodologically rigorous comparative international cohort studies were selected because of their seminal impact on current thinking and practice in the U.S. on occupational health, and their regular use as a source of data in recent reviews that were centered on the U.S. Twenty sources were found that met these criteria and were included in the synthesis of findings, as shown in Table 1 and Figure 1.

C. Data Synthesis Approach

Because of the methodological diversity of the studies (prospective cohort studies, pooled meta analyses, cross-sectional surveys and theoretical papers), the risk of bias scoring and meta analyses approach were not applied. Rather, the results were narratively presented in three sections related to the three research questions addressed by the review: (a) Job strain and cardiovascular risk, (b) Sedentary work behavior and cardiovascular and mortality risk and (c) Physical activity as a moderator. Synopsis of studies within each domain was accomplished by examining studies for the consistency of the direction, proposed mechanism, and population characteristics of the study, and tabulated to support the narrative synopsis found in the Results section.

Table 1: Overview of the Literature Search and Selection Strategy

Element	Description
Databases searched	PubMed/MEDLINE, Scopus; supplemented by hand-search of reference lists and one formal science advisory
Search terms	job strain; effort-reward imbalance; occupational stress; psychosocial work environment; sedentary behavior; sitting time; physical activity; cardiovascular disease; coronary heart disease; myocardial infarction; mortality
Publication window	1979–2019 (foundational model papers through recent meta-analyses)
Language	English-language, peer-reviewed sources only
Population priority	U.S. working-age adults prioritized; comparable industrialized-country cohorts retained where U.S.-specific data were limited
Source types included	Prospective cohort studies; meta-analyses and systematic reviews; theoretical/model-defining papers; one national science advisory
Total sources synthesized	N = 20

III. RESULTS

A. The following is a brief overview of the literature reviewed in this study

These 20 sources were retained because they addressed general overviews of models of occupational stress, evidence on job strain or effort-reward imbalance (ERI) and cardiovascular outcomes, evidence on sedentary occupational behaviors and cardiovascular outcomes or mortality, and mechanistic investigations of psychological stress and metabolic dysfunction. The biggest literature relating to job strain and effort reward imbalance to cardiovascular disease was shown in Figure 1 (55%), reflecting the longer research tradition in this field, and since the initial formulation of Karasek (1979). A smaller, but still extensive body of work specifically focused on sedentary occupational behaviors (25%) appeared, given the increased availability of accelerometric data, and large linked cohorts of working people and mortality outcomes over the last decade. The remaining ones included basic theoretical frameworks (15%) or mechanistic evidence about stress-metabolism (5%). Importantly, none of the aforementioned sources summarized in the reviewed literature evaluated job strain, sedentary behavior, and physical activity simultaneously in the same cohort in the U.S. which is why a synthesis of this review was developed.

© OCT 2022 | IRE Journals | Volume 6 Issue 4 | ISSN: 2456-8880
DOI: https://doi.org/10.64388/IREV6I4-1720146

Figure 1: Distribution of Reviewed Literature by Thematic Domain

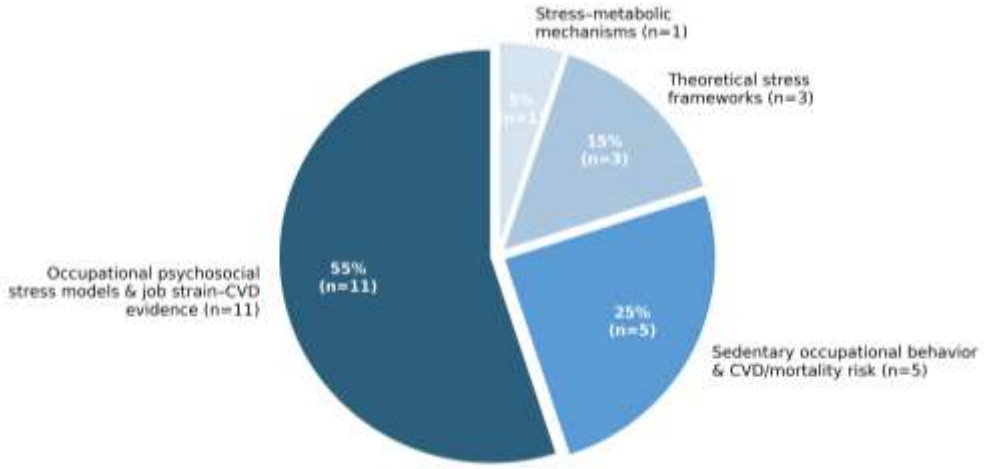

Figure 1. Distribution of the 20 reviewed sources across four thematic domains of the occupational stress sedentary behavior cardiovascular disease literature.

B. Job Strain, Effort Reward Imbalance and Cardiovascular Risk in the United States of America

Links between job strain and cardiovascular outcomes in U.S. populations go back to analyses of the national Health Examination Survey and Health and Nutrition Examination Survey, where high job strain (high demands and low decision latitude) was linked to an increase in the prevalence of myocardial infarction, over and above the usual cardiovascular risk factors (Karasek et al., 1988). In subsequent studies, autonomic indices were used to measure cardiovascular reactivity of U.S. working samples, where there was physiological support for the prevalence data reported above, with patterns of increased cardiovascular reactivity showing a physiological association with high-strain job classifications (Collins et al., 2005). The large body of evidence that had accumulated by then led Belkic and colleagues (2004) to state that job strain posed a major, and then underrecognized, risk factor for cardiovascular disease and should be treated as a risk factor along with well-documented behavioral and biomedical risk factors.

This evidence has been corroborated by prospective cohort studies conducted in countries outside of the United States, which have influenced U.S. occupational health practitioners' concepts of the psychosocial work environment. In a large follow-up Finnish study, this self-reported work stress was an independent risk factor for cardiovascular mortality over a number of years, even after adjusting for common risk factors (Kivimäki et al., 2002). In the Whitehall II civil service cohort, moreover, low organizational justice (a measure of perceived decision-making and interpersonal justice in the workplace, and closely related to the effort-reward imbalance model) was a risk factor for coronary heart disease (CHD) when organizational justice was low, but not when it was high, suggestive of a protective effect across the favorable end of the psychosocial spectrum (Kivimäki et al., 2005). Similar job strain–adverse cardiovascular risk-factor profile associations have also been found in occupational groups other than those in North America and Europe: in a study of petrochemical workers (Poorabdian et al., 2013) and in a study of government workers (Taheri et al., 2014).

This body of evidence was summarised for a clinical and occupational health audience via two narrative reviews. One of the first comprehensive reviews of the literature, by Schnall, Landsbergis and Baker's (1994), suggested that the relationship between the perception of job strain and cardiovascular disease was robust enough between study designs to warrant

public health action. Twenty years later, Kivimäki and Kawachi (2015) performed a very similar analysis, and concluded that by then, evidence supporting the link between work stress and cardiovascular disease was as consistent as several known behavioral risk factors, and that a life-course approach to exposure (where accumulated exposures to occupational stress act synergistically in increasing cardiovascular risk over the working lifetime) (Li et al., 2016.) was as applicable.

Table 2: Selected Studies on Job Strain, Effort-Reward Imbalance, and Cardiovascular Risk

Study	Population / Design	Key Finding
Karasek et al. (1988)	U.S. national survey cohorts (HES/HANES)	High-strain job classification associated with greater prevalence of myocardial infarction, independent of standard risk factors
Collins et al. (2005)	U.S. working adults; autonomic indices	High job strain linked to cardiac autonomic patterns consistent with elevated cardiovascular risk
Kivimäki et al. (2002)	Finnish industrial cohort; prospective	Work stress predicted higher cardiovascular mortality over follow-up, independent of conventional risk factors
Kivimäki et al. (2005)	UK Whitehall II civil service cohort	Higher organizational justice associated with reduced coronary heart disease risk; a graded, dose-like pattern
Poorabdian et al. (2013)	Iranian petrochemical workers	High-demand, low-control jobs associated with adverse cardiovascular risk-factor profiles
Taheri et al. (2014)	Government officials and office workers (Iran)	Occupational stress associated with elevated cardiovascular risk-factor burden in white-collar employees
Belkic et al. (2004)	Comprehensive literature review	Concluded job strain constitutes a major, independent source of cardiovascular disease risk
Schnall et al. (1994)	Narrative review	Early synthesis identifying job strain as a consistent, clinically relevant cardiovascular risk factor
Kivimäki & Kawachi (2015)	Narrative review	Work stress evidence judged comparable in consistency to established behavioral cardiovascular risk factors
Li et al. (2016)	Life-course review	Cumulative occupational stress exposure across a working career compounds cardiovascular risk

C. Sedentary Occupational Behavior and Cardio-Vascular Or Mortality Risk

The evidence base for association between sedentary behaviour and cardiovascular and all-cause mortality is comparatively new but methodologically solid and based on large, representative, prospective and pooling studies. In fact, a harmonized meta-analysis by Ekelund et al. (2016) of over one million men and women showed an increase in all-cause mortality with higher daily time spent sitting, and the magnitude of the association was greatest in the group that reported the lowest level of leisure-time physical activity. In a large Australian cohort of 220,000 adults, an association between greater daily sitting time and higher risk of all-cause mortality was observed even after accounting for physical activity

and other variables, suggesting that it is not just due to a lack of movement (van der Ploeg et al., 2012). A Japanese work-specific occupational cohort confirmed this, with each additional hour of occupational sitting time associated with an increased risk of all-cause mortality among working adults and not sitting for leisure time (Kikuchi et al., 2015).

It has been proposed that there is a mechanistic basis for why sitting seems to be associated with a cardiovascular risk beyond being the result of inadequate levels of physical activity. Carter and colleagues (2017) reviewed the various physiological mediators thought to cause the association, which include lowered contracts in the skeletal muscle, lowered vascular endothelial function, and detrimental changes in lipid and glucose metabolism during extended periods of continuous sitting, with some but not complete relief from the adverse effects of sitting through structured exercise performed elsewhere. To acknowledge this growing evidence, in 2016 the American Heart Association presented its official "Science Advisory Statement that Sedentary Behavior is a distinct risk factor for cardiovascular disease morbidity and mortality and that clinical and public health guidelines should reflect this distinction" (Young et al., 2016).

Table 3: Selected Studies on Sedentary Occupational Behavior and Cardiovascular Risk

Study	Population / Design	Key Finding
Ekelund et al. (2016)	Harmonized meta-analysis; >1,000,000 adults	Higher sitting time associated with greater all-cause mortality; risk concentrated among the least physically active
van der Ploeg et al. (2012)	Australian cohort; N ≈ 222,497	Longer daily sitting time predicted higher all-cause mortality independent of physical activity level
Kikuchi et al. (2015)	Japanese occupational cohort	Longer occupational sitting time associated with higher all-cause mortality among employed adults
Carter et al. (2017)	Mechanistic review	Identifies vascular and metabolic pathways (endothelial dysfunction, dyslipidemia) linking sitting to cardiovascular risk
Young et al. (2016)	AHA science advisory	Formally classifies sedentary behavior as an independent cardiovascular risk domain, distinct from inactivity

D. Physical Activity as a Moderator

The most salient proof of a moderating effect of PA is provided by the results of the Ekelund et al. (2016) harmonised meta-analysis which has investigated the risk of mortality simultaneously for classes of sitting time and PA, instead of seeing these two as separate exposures. The trend appeared to be the same across cohorts: When compared with low sitting time, sitting time in the least active group was associated with a significant up trend in mortality risk, while sitting time in the most active group was almost flat (only marginally higher than low sitting time) and, in a number of analyses, indistinguishable from no difference at all. This trend suggests that physical activity not only acts as an additional protective factor but also seems to significantly reduce the sitting-associated hazard as well, especially at higher doses of physical activity.

However, it is less directly supported by literature reviewed and thus the hypothesis is plausible that an analogous buffering pattern occurs within the psychosocial stress pathway. Kivimäki and Steptoe's (2018) review of the association of stress and cardiovascular other diseases progression discusses both a direct pathway between work stress and other diseases progression, via activation of the sympathetic nervous system, or the hypothalamic/pituitary adrenal axis, and an indirect pathway, where prolonged work stress negatively affects workers' participation in protective health-related behaviors, such as regular workout activity.

Although none of the studies reviewed directly examined the interaction between physical activity and sedentary behavior within the same cohort of Americans, there are biological mechanisms why this would be expected to occur; physical activity has been shown to have opposite effects on several of the same physiologic pathways associated with the impact of sedentary behavior and stress: sympathetic hyperactivity, systemic inflammation, and adverse metabolic profiles (Kuo et al., 2019). Table 4 provides a qualitative risk pattern rising out of this double reading of the literatures on sedentary behavior and job strain, while Figure 2 shows a conceptual gradient of cardiovascular risk for exposure profiles as a function of the two exposures.

Table 4: Illustrative Risk Pattern Across Joint Sedentary Behavior and Physical Activity Categories

Sitting Time	Physical Activity Level	Pattern of Mortality Risk
Low	High	Reference (lowest risk) group
High	High	Minimal to no excess risk relative to reference
Low	Low	Modestly elevated risk relative to reference
High	Low	Substantially elevated risk relative to reference; steepest gradient observed in this group

E. Convergence of Psychosocial Stress and Sedentary Behaviour

While no reviewed study included both sedentary behavior and occupational stress as independent risk factors for cardiovascular disease in a single U.S. population, there are some studies that suggest potential downstream pathways that could support an interactive or additive effect between the two risk factors. Kuo and colleagues (2019) conducted a systematic review and meta-analysis that revealed a consistent relationship between all psychological stresses and the metabolic syndrome, a group of cardiometabolic abnormalities (abdominal adiposity, insulin resistance and hypertension) that are very similar to those that Carter et al. (2017) described as the metabolic effects of prolonged sitting. Kivimäki and Steptoe (2018) also point out that such a relationship is likely not to be fully independent, in true working populations those who experience high strain at work may be more likely to have sedentary coping patterns and they may be less likely to do physical activity, which might otherwise help them cope with the strain. This overlap could indicate that U.S. workplaces have a more significant cardiovascular impact than studies focusing on the impact of occupational stress or a sedentary lifestyle alone may have estimated.

Another place of overlap is with regard to timing and duration of exposure. A life-course recently introduced by Li et al. (2016) has the advantage that it takes into consideration that exposure to occupational psychosocial stress may continue for many years or decades during the working life span and that each increased exposure increments the cardiovascular risk. The dose-response gradients in the sitting-time literature also seem to be quite similar; that shown by Ekelund et al. (2016) and van der Ploeg et al. (2012) appear to be sitting time measured as a cumulative behavior over a number of years rather than as isolated periods. This common time structure will mean that the two exposures also will be associated with disproportionate compounding effects on workers who are in the same high-strain, high-sedentary work task long term, and that an exposure that starts early in a working career potentially has a disproportionate long-term effect over a late exposure.

F. Synthesis: A Working Model for U.S. Occupational Cardiovascular Risk

Integrating the three domains, reviewed evidence suggests a working model whereby U.S. workers' cardiovascular risk is partly influenced by at least three levels of occupational factors that act along partially independent, but mechanistically interacting, pathways: psychosocial strain stemming from the imbalance of job demands, job control, and job outcomes or rewards; time spent sedentary arising from physical characteristics of the job; and physical activity mainly acquired outside work, which seems

to be able to strongly, if not entirely, reduce the hazard attributable to the other two. In this model, a descriptive profile consisting of high psychological strain, a large amount of sedentary time, and low physical activity, which is common in the desk-based service and administrative occupations of the U.S. economy, ranks as the highest-risk occupation, and a profile consisting of the low-risk components of the highest-risk profile ranks as the lowest-risk. From the literature we reviewed, it seems that the intermediate categories, in which only one adverse exposure is available, are meaningfully more risky, but not nearly so risky as the combined-exposure profile. This working model is not intended to be a validated, predictive model of cardiovascular risk in the workplace; rather, it should be seen as a synthesis of clues from various directions rather than as a validated solution to a workplace cardiovascular risk reduction problem that is satisfied by a single workplace intervention.

IV. DISCUSSION

A. Use the Main Findings In The Document To Write A Summary

This review aggregated evidence from twenty sources, and included three interrelated questions related to cardiovascular risk with the U.S. working population. First, findings from the U.S. national surveys of job strain and effort-reward imbalance were consistently shown to be linked to increased cardiovascular risk in both autonomic physiology studies and in similar international cohorts, independent of conventional risk factors, and regardless of the type of job. Third is there's a dose-response association between sedentary work and cardiovascular and all-cause mortality, evident in large pooled analyses and recognized as an independent risk factor for both cardiovascular and all-cause death independent of physical inactivity. Third, levels of physical activity were again shown to significantly mitigate the hazard of sedentary time, and there was the strongest evidence that high levels of activity would buffer the hazard of large amounts of sedentary time, although there remain limitations in direct evidence of this effect; and there was only indirect evidence based on mechanisms from low and moderate activity levels.

Consequently, it appears that exposures to occupational stress and to sedentary behavior may not be mutually exclusive and may act multiplicatively when both are present, as is the case for many jobs particularly those with long hours in which workers sit for large portions of their daytime that are linked to cardiovascular disease.

B. Implications for the U.S. Occupational Health Policy and Workplace Practice

The results have a number of implications for U.S. employers and occupational health practitioners. It may also be important to recognize that interventions intended to reduce one exposure (such as standing desks to decrease sitting time) may be limited in reducing risk because of the apparent overlap of mechanisms underlying the exposures (for example, introduction of wellness programmers to increase physical activity that don't address workload and decision latitude). To this a more comprehensive approach would include job redesign strategies to increase workers control and ensure that increased effort also equates increased reward (Karasek, 1979; Siegrist, 1996), with some measures to ensure reduced prolonged uninterrupted sitting (such as having one or two physical breaks during the day), sit-stand workstations and including walking meetings, and providing organizational support for more regular physical activity outside of work. The components surrounding job strain and effort-reward imbalance in the workplace have also received some attention to guide job redesign and job management efforts, respectively, in a complementary approach to addressing the amount of movement workers engage in, and the 2016 American Heart Association advisory (Young et al., 2016) provides a nice evidence-based anchor around the sedentary-behavior part of such programs.

C. Limitations and Strengths of the Existing Evidence-Based Knowledge

The conclusions should be tempered by some of the underlying limitations of the evidence. The literature on effort-reward imbalance and organizational justice is mainly developed in Europe with occupational cohorts and although some literature in the United States is supportive of a link between these variables in the broader “job strain” model, replication of

findings on effort-reward imbalance is still quite limited, leaving some question regarding the magnitude of these associations in the United States. Many of the international reports cited for their contribution in some aspect to mechanisms or theory, including that of some of the petrochemical and governmental/working groups outside North America, are not necessarily fully applicable to the structure or the regulatory environment of U.S. jobs. Measurement heterogeneity also concerns the different instruments used to operationalize job strain, effort-reward imbalance and sitting time at work in specific studies as well as the possibility of recall bias when using self-report instruments for sitting time and causal inference limitations in the cross-sectional study designs of some of the studies that were reviewed. Finally, and most importantly to the goal of the present review, no study reviewed directly examined the three-way interaction of occupational stress, sedentary behavior, and physical activity within one group of people. The statistical interaction proposed in the present review to apply to the stress pathway, therefore, was indirect and thus based on mechanistic plausibility.

D. Expertise and Skills in Equity Issues Across the U.S. Workforce

It is important to note that the presence of both occupational stress and sedentary work is not the same across the U.S. workforce, which has an impact on examining interpretations of the findings synthesized here. High-strain jobs specifically those defined by the demand-control model are mainly found in lower and middle-wage occupations that tend to be demanding with respect to performance and in which workers have little discretion over the method, pace, or schedule of performances for example, in customer service, in the warehouses and logistic sectors, and in many healthcare support occupations. In parallel, the trend of desk-based and computer mediated working has mainly affected white and blue collar/professional occupations, so that even though exposures to desk based work and psychosocial strain, may be associated with comparable cardiovascular outcomes, they are not necessarily found simultaneously in the same subset of workers. Job-strain risk for workers in physically demanding, low-control jobs could be disproportionately high without necessarily being significantly higher in sedentary exposure; sedentary exposure risk for workers in low-strain, highly sedentary jobs, could be the inverse profile; and the highest joint risk could be most likely in jobs that subjected workers to both exposures (e.g., many administrative, data-entry, or call-center occupations). Access to wellness resources, flexible schedules and paid time to exercise is also positively associated with occupational status, so even workplace-based interventions that are only modeled after professional workplace may not work as well for the lower wage, high-strain occupations where there might be more of a need for interventions that can reduce cardiovascular risk, a factor that must be kept in mind for designing and targeting future workplace interventions.

E. Future Research Directions

To address this gap, large-scale prospective cohort studies in the U.S. that collectively, objectively (and accurately) assess both occupational psychosocial exposure (using a validated demand-control instrument or effort-reward imbalance instrument) and sedentary time (ideally through accelerometry or otherwise) and physical activity during extended follow-up periods to capture incident cardiovascular events would be required. Finally, there is mixed evidence from the observational literature that a combined job redesign and structured movement and physical activity will result in greater reduction of cardiovascular risk than single exposure job redesign and physical activity intervention, which can only be answered through the conduct of randomized or quasi-experimental workplace intervention trials that incorporate both job redesign and physical activity.

V. CONCLUSION

Chronic occupational stress and sitting time are two factors that have independent, well-documented links to cardiovascular risk among working populations and the U.S. evidence base, developed to a greater extent for the job strain construct than for effort-reward imbalance, is generally similar to the literature reviewed here. The effect of physical activity seems to help meaningfully buffer the cardiovascular risk associated with long bouts of

sitting, and mechanistic evidence suggests a similar buffering effect may occur for the stress pathway, although there is not direct evidence for such an interaction in a U.S. cohort. The take-home message for employers, occupational health practitioners, and policy makers is that, if they are going to reduce cardiovascular risk exposure, they should consider an approach to these exposures that targets job design, sedentary time, and physical activity collectively rather than any one exposure alone. Future research on cardiovascular health in the workplace should focus on closing the research gap on their combined and interactive effects, as U.S. employment trends continue to shift to work that is cognitively demanding, low in physical exertion and mostly done sitting at a desk.

REFERENCES

[1] Belkic, K. L., Landsbergis, P. A., Schnall, P. L., & Baker, D. (2004). Is job strain a major source of cardiovascular disease risk? Scandinavian Journal of Work, Environment & Health, 30(2), 85–128. https://doi.org/10.5271/sjweh.769

[2] Carter, S., Hartman, Y., Holder, S., Thijssen, D. H., & Hopkins, N. D. (2017). Sedentary behavior and cardiovascular disease risk: Mediating mechanisms. Exercise and Sport Sciences Reviews, 45(2), 80–86. https://doi.org/10.1249/JES.0000000000000106

[3] Collins, S. M., Karasek, R. A., & Costas, K. (2005). Job strain and autonomic indices of cardiovascular disease risk. American Journal of Industrial Medicine, 48(3), 182–193. https://doi.org/10.1002/ajim.20204

[4] Ekelund, U., Steene-Johannessen, J., Brown, W. J., Fagerland, M. W., Owen, N., Powell, K. E., Bauman, A., & Lee, I.-M. (2016). Does physical activity attenuate, or even eliminate, the detrimental association of sitting time with mortality? A harmonised meta-analysis of data from more than 1 million men and women. The Lancet, 388(10051), 1302–1310. https://doi.org/10.1016/S0140-6736(16)30370-1

[5] Karasek, R. A. (1979). Job demands, job decision latitude, and mental strain: Implications for job redesign. Administrative Science Quarterly, 24(2), 285–308. https://doi.org/10.2307/2392498

[6] Karasek, R. A., Theorell, T., Schwartz, J. E., Schnall, P. L., Pieper, C. F., & Michela, J. L. (1988). 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). American Journal of Public Health, 78(8), 910–918. https://doi.org/10.2105/AJPH.78.8.910

[7] Kikuchi, H., Inoue, S., Odagiri, Y., Inoue, M., Sawada, N., & Tsugane, S. (2015). Occupational sitting time and risk of all-cause mortality among Japanese workers. Scandinavian Journal of Work, Environment & Health, 41(6), 519–528. https://doi.org/10.5271/sjweh.3526

[8] Kivimäki, M., Ferrie, J. E., Brunner, E., Head, J., Shipley, M. J., Vahtera, J., & Marmot, M. G. (2005). Justice at work and reduced risk of coronary heart disease among employees: The Whitehall II Study. Archives of Internal Medicine, 165(19), 2245–2251. https://doi.org/10.1001/archinte.165.19.2245

[9] Kivimäki, M., & Kawachi, I. (2015). Work stress as a risk factor for cardiovascular disease. Current Cardiology Reports, 17(9), 630. https://doi.org/10.1007/s11886-015-0630-8

[10] Kivimäki, M., Leino-Arjas, P., Luukkonen, R., Riihimäki, H., Vahtera, J., & Kirjonen, J. (2002). Work stress and risk of cardiovascular mortality: Prospective cohort study of industrial employees. BMJ, 325(7369), 857. https://doi.org/10.1136/bmj.325.7369.857

[11] Kivimäki, M., & Steptoe, A. (2018). Effects of stress on the development and progression of cardiovascular disease. Nature Reviews Cardiology, 15(4), 215–229. https://doi.org/10.1038/nrcardio.2017.189

[12] Kristensen, T. S. (1995). The demand-control-support model: Methodological challenges for

future research. Stress Medicine, 11(1), 17–26. https://doi.org/10.1002/smi.2460110104

[13] Kuo, W. C., Bratzke, L. C., Oakley, L. D., Kuo, F., Wang, H., & Brown, R. L. (2019). The association between psychological stress and metabolic syndrome: A systematic review and meta-analysis. Obesity Reviews, 20(11), 1651–1664. https://doi.org/10.1111/obr.12915

[14] Li, J., Loerbroks, A., Bosma, H., & Angerer, P. (2016). Work stress and cardiovascular disease: A life course perspective. Journal of Occupational Health, 58(2), 216–219. https://doi.org/10.1539/joh.15-0326-OP

[15] Poorabdian, S., Mirlohi, A. H., Habibi, E., & Shakerian, M. (2013). Association between job strain (high demand-low control) and cardiovascular disease risk factors among petrochemical industry workers. International Journal of Occupational Medicine and Environmental Health, 26(4), 555–562.

[16] Schnall, P. L., Landsbergis, P. A., & Baker, D. (1994). Job strain and cardiovascular disease. Annual Review of Public Health, 15, 381–411.

[17] Siegrist, J. (1996). Adverse health effects of high-effort/low-reward conditions. Journal of Occupational Health Psychology, 1(1), 27–41. https://doi.org/10.1037/1076-8998.1.1.27

[18] Taheri, M., Mirlohi, A. H., Habibi, E., & Shakerian, M. (2014). Occupational stress and cardiovascular risk factors in high-ranking government officials and office workers. Iranian Red Crescent Medical Journal, 16(8), e11747. https://doi.org/10.5812/ircmj.11747

[19] van der Ploeg, H. P., Chey, T., Korda, R. J., Banks, E., & Bauman, A. (2012). Sitting time and all-cause mortality risk in 222,497 Australian adults. Archives of Internal Medicine, 172(6), 494–500. https://doi.org/10.1001/archinternmed.2011.2174

[20] Young, D. R., Hivert, M.-F., Alhassan, S., Camhi, S. M., Ferguson, J. F., Katzmarzyk, P. T., Lewis, C. E., Owen, N., Perry, C. K., Siddique, J., & Yong, C. M. (2016). Sedentary behavior and cardiovascular morbidity and mortality: A science advisory from the American Heart Association. Circulation, 134(13), e262–e279. https://doi.org/10.1161/CIR.0000000000000440