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Work-related psychosocial and physical paths to future musculoskeletal disorders (MSDs)

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ABSTRACT

Given the human, industrial and societal costs of Musculoskeletal Disorders (MSDs) we evaluated antecedents to MSDs (assessed as pain, doctor diagnosis, and workplace injury) over a six-year period T1 (2014/2015) and T2 (2020/2021). The purpose of the study was to examine the role of the organisational climate (i.e., psychosocial safety climate, PSC) for employees' psychological health and safety as an antecedent to physical demands, and psychosocial risks (e.g., low control, harassment) that in turn might relate to MSDs using a longitudinal design. We used matched data from follow-up telephone interviews of 432 Australian employees. We found evidence for several psychosocial paths; PSC was related to future workplace injuries through decision authority; PSC was related to MSD pain through depressive symptoms. For future doctor diagnosed MSDs, PSC was directly negatively related. Older age, being male and low income was related to work injury; being female associated with MSD pain; and being older was associated with MSD diagnosis. A novel finding was the linkage between psychosocial risks (low skill discretion and harassment) and future physical demands leading to future MSD pain and work injury highlighting a new pathway linking psychosocial and physical aspects. Overall poor PSC was found as a distal antecedent of all MSDs. Decision authority and skill discretion were most critical psychosocial risks in predicting future pain and injuries. Psychosocial factors predicted future demands. Actions should target improving PSC and autonomy and reducing harassment and physical demands, to decrease the incidence of MSDs.

1. Introduction

Musculoskeletal Disorders (MSDs) are some of the most prevalent types of occupational injuries and diseases worldwide incurring tremendous costs for both employees and their organisations (Bonfiglioli et al., 2022; Caponecchia et al., 2020; Oakman et al., 2018; Safe Work Australia, 2020; Serna Arnau et al., 2023). MSDs refer to 'a range of conditions that affect joints, spinal vertebrae and intervertebral discs, the synovium, muscles, tendons and related tissues, soft tissues, and connective tissues' (Safe Work Australia, 2016; p. 4). In Australia, physical injuries including MSDs accounted for 87% of serious workers' compensation claims for injury or disease during 2019-20. Muscle/tendon injuries and traumatic joint/ligament specifically accounted for 43% of all serious claims (Safe Work Australia, 2019-20). In the European Union, work-related MSDs remain the most typical problem at work, with roughly three out of every five employees in the EU-28 reporting MSD related complaints, the most reported forms including backache and muscular pain in the upper limbs, shoulders, and neck (Jan de Kok et al., 2019). Further, in 2020/2021 an estimated 470,000 workers across Great Britain were affected by work-related musculoskeletal disorders, accounting for 28% of all work-related ill-health, both upper limb, neck or back the most commonly reported work-related MSD (Health & Safety Executive, 2021). With musculoskeletal conditions significantly limiting mobility and dexterity and overall levels of functioning, dramatically impacting a person's ability to work, preventing work-related MSDs requires identifying and controlling relevant physical and psychosocial work-related factors contributing to these injuries (Harris-Adamson et al., 2022; Oakman et al., 2022).

1.1. Aetiology: What we know

Over the past two decades, a substantial body of literature has

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supported the complex and multifactorial aetiology of work-related MSDs. The workplace risk factors that put an individual at increased risk of MSD development are characterized into three broad categories, 1) physical or biomechanical risks related to physical activities or ergonomic characteristics in the workplace (e.g., repetitive movements, improper postures and heavy lifting); 2) psychosocial risks (e.g., high demands, low control and poor social supports); and 3) individual risks (e.g., age, gender, income, education) (Hernandez & Peterson, 2013). Though, researchers have investigated relationships between individual, psychosocial and biomechanical factors in the genesis of MSDs, both separately and through their interactions (Eijckelhof et al., 2013; Hauke et al., 2011; Harris-Adamson et al., 2022), distal determinants preceeding these factors, and the aetiological pathways that follow, require further investigation.

Understanding the pathways by which these factors manifest and then interact in any given work environment has been theorized as a dual process via physical and psychosocial pathways. The physical pathway proposition is that physical demands are a direct antecedent to MSDs. By contrast, the psychosocial pathway proposition is that psychosocial risk factors such as lack of autonomy, excessive work demands, and poor social support are precursors to MSDs. Contemporary efforts towards effective prevention of developing MSDs requires the investigation of dual aetiological pathways involving both psychosocial and physical risks (Eatough et al., 2012; Gerr et al., 2014a, 2014b; McLinton et al., 2019; Robertson et al., 2021). There is substantial evidence linking physical demands to MSD development (Converso et al., 2018; Wahlström, 2005; Welch et al., 2009). While evidence demonstrating how psychosocial factors at work contribute to prevalence of MSDs continues to grow (Robertson et al., 2021; Zare et al., 2021) psychosocial risks leading to MSDs are less widely recognised and researched (Leka et al., 2015; Macdonald & Oakman, 2015).

1.2. What is the gap

Understanding the kinds of work-related psychosocial and physical risk factors that are detrimental to workers' physical health is necessary to prevent MSDs. However, while integrative theoretical frameworks linking the dual pathways (physical and psychosocial) have been proposed (e.g., Bailey et al., 2015; Hämmig, 2020; Mateos-González et al., 2023) an integrative framework with PSC as the source of the pathways is missing. In an effort to establish the cause of the dual-process pathways, the 'cause of the causes' of physical and psychosocial risks, we include PSC. Although aspects such as leadership and organisational climate are implicated (Christensen et al., 2018), these factors are considered mainly as co-occurring proximal factors rather than potential distal determinants of MSDs and physical and psychosocial risk factors at work, leaving a gap in the explanation about more distal causes. Without optimal information about aetiology, efforts to prevent MSDs may be inefficient and misguided.

Given the prevalence and costs of MSDs, this paper aims to understand whether the psychosocial safety climate as the corporate climate for employees' psychological health is a distal cause of MSDs via the dual-process pathways due to its link to work conditions. Moreover, we aim to address the dearth of longitudinal studies in the field and shine more light on the causation of MSDs and the role of PSC, job demands and resources, by using longitudinal two-wave Australian population-based interview data from employees with a six-year lag. We extend the foundational work by Bailey et al. (2015) in the following ways (1) exploration of a time lag beyond one year between measurement points to enable exposure and time for causes to have effects, (2) investigate the role of job resources beyond job demands, and (3) exploration of more severe psychological health effects beyond emotional exhaustion (burnout) to include depressive symptoms. In this paper, we operationalize MSDs in three ways, in terms of (1) pain associated with MSDs, (2) doctor diagnosis of MSDs, and (3) workplace injury.

1.3. Current evidence and pathways leading to MSDs

A two process (physical and psychosocial) pathway (or mechanism) has been theorized to explain how work-related factors manifest and interact to impact physical health.

1.3.1. Physical pathways leading to MSDs

First, the physical pathway posits that biomechanical demands are a proximal antecedent to MSDs. It is well established that heavy lifting, frequent bending and twisting, and whole-body vibration are associated with frequencies for back and neck disorders (Coenen et al., 2014; Parreira et al., 2018). Further, combinations of push and pull activities, which frequently occur in manufacturing and office-based roles, are associated with hand/arm disorders (Gerr et al. 2014b; Hoozemans et al., 2014;). Conditions such as carpal tunnel syndrome, hand-arm vibration syndrome and tendonitis, are linked with exposure to repetitive tasks, forceful tasks, the combination of repetition and force, the combination of repetition and cold, and hand vibration (National Research Council and Institute of Medicine, 2001). Computer-based work involving increased mouse usage and poor seated posture are also known risk factors in MSD development (Wahlström, 2005).

For MSDs in other body regions (i.e., neck, shoulder, and knee) with pain, tenderness and stiffness, there is evidence that these conditions are associated with exposure to repetitive movement, improper static postures, and awkward positions (such as kneeling, squatting). Symptoms of MSDs are exacerbated by limited access to adequate resources such as appropriate ergonomic supports (Wahlström, 2005; Welch et al., 2009). In this study, physical risks are assesed in terms of physical demands, moving/lifting heavy loads, rapid and continuous physical activity, and working for long periods with the head/ body or arms in physically awkward positions. The current study expects physical demands to be positively related to MSDs.

1.3.2. Psychosocial pathways leading to MSDs

In addition to physical risks, research evidence shows the risk of developing MSDs from exposure to a range of psychosocial factors (i.e., Eijckelhof et al., 2013; Hauke et al., 2011; Lang et al., 2012; López-González et al., 2022). High levels of workload, monotonous tasks, low levels of job control, poor supervisor and coworker support are associated with disorders across multiple body regions including back neck and/or shoulder, upper and lower extremities (Hauke et al., 2011; Lang et al., 2012; National Research Council and Institute of Medicine, 2001; Yulita et al., 2014).

A recent systematic literature review focusing on the associations between psychosocial risk factors and the risk of MSDs at work, found that low job control, low job decision authority and low job satisfaction were significantly associated with an increase in the risk of MSDs (James et al., 2021). Psychosocial risk factors like inadequate social support, lack of control at work and high workload were also associated with increased risk of MSDs (Tang et al., 2022). Additionally, exposure to bullying, harassment, and violence is also a potential link to stress responses. Bullying at work has a detrimental impact on employee personal resources leading to an erosion of personal resources and decreased individual energy (Tuckey & Neall, 2014). Further, workers with less social support often express prolonged recovery time after superficial acute musculoskeletal injuries (Bailey et al., 2015).

One line of reasoning concerning why psychosocial factors relate to MSDs is that psychosocial stressors trigger physiological reactions, including biochemical stress responses potentially giving rise to increased muscle tension, co-activation and load on the musculoskeletal system (Bongers et al., 2006), decreased blood supply in the extremities (Visser & van Dieën, 2006), and prohibition of muscle repair (Theorell et al., 2002). There is evidence showing that psychosocial stressors make muscle fibres more susceptible to injuries, likely by permanently activating low-threshold motor units. An accumulation of these psychosocial factors increases the risk of future MSDs due to sustained exposure

and the depletion of resources and/or coping pathways over time (Bailey et al., 2015; Tuckey & Neall, 2014). Work stress is often associated with MSDs (Bongers et al., 1993). Research evidence from a review study on 54 longitudinal studies concluded that psychosocial factors contribute to the development of MSDs and should be regarded as a separate risk factor for MSDs (Hauke et al., 2011). López-González et al. (2022) investigated the interrelationships between physical and psychosocial risks and MSDs. They found that high exposure to both physical and psychosocial risks significantly predicts the likelihood of MSDs. Further, research by Eijckelhof et al. (2013) supports the hypothesis of synergistic effects between psychosocial factors and biomechanical factors that influence the MSDs. In the current study, psychosocial risks are assessed in the broad scope of job demands and resources. We expect psychosocial demands will positively relate and psychosocial resources to negatively relate to MSDs.

Additionally, early tests of elements of the psychosocial pathway (mechanism) showed that work demands related to emotional exhaustion (burnout), a state of psychological weariness, tiredness, or fatigue, but also impact physical health (Yulita et al. 2014). Similarly, research shows that psychosocial factors and depression are significant predictors of MSDs (Ng et al., 2019). Therefore, in the current study, we expect mental health issues (depressive symptoms and burnout) to positively relate to MSDs. In cross sectional research in health professionals (Hämmig, 2020), it was found that MSDs were most often the consequence of physical demands at work, followed by mental health issues (general stress). These propositions are integrated into the mediation hypotheses in Section 1.6.

1.4. Psychosocial safety climate as a common source of MSD causes

Psychosocial Safety Climate (PSC) is potentially a common cause of the dual-process pathways. PSC theory is an innovation in the field of work and organisational psychology (Dollard & Bakker, 2010; Dollard & Karasek, 2010; Law et al., 2011) and reflects the corporate climate to support employees psychological health and safety. PSC refers to 'policies, practices and procedures for the protection of worker psychological health and safety' (Dollard & Bakker, 2010, p. 579). PSC is specifically concerned with managerial values and action and incorporates management commitment, management priority, organisational communication, and organisational participation and involvement in the protection of employee psychological health and safety. PSC theory has promoted interdisciplinarity research through integrating work stress and safety science, bridging the construct of PSC. The construct is empirically distinct from related constructs such as team psychological climate, organisational social support, and safety climate (Idris et al., 2012). Whereas the safety climate construct predicts safety behaviour and injuries (Griffin & Curcuruto, 2016), PSC predicts psychosocial risks in work design and work conditions that in turn affect worker health, particularly psychological health. Previous research provides evidence that PSC is a leading indicator for psychosocial factors that impact psychological health, but also MSDs and physical health outcomes. This research includes evidence by Bailey et al., 2015 who found PSC to be a precursor to psychosocial risks (including workplace bullying, harassment and pressure), that in turn related to MSD's, supporting the psychosocial-physical pathway. However, it should be noted that although Bailey et al. (2015) had the potential to uncover longitudinal effects between psychological health and MSD, only cross-sectional effects of this linkage were found. Additionally, Garrick et al. (2014) also found support of PSC as a predictor of physical health problems mediated through increased job demands.

Other research has also investigated the relationship between PSC and physical health outcomes, including musculoskeletal issues, work-related injuries, and workers' compensation claims (Loh et al., 2020). Evidence found by Zadow et al. (2017) emphasized poor PSC plays a critical role in the psychological health erosion pathway, culminating in greater work-related injuries and underreporting of both physical and psychological injury, highlighting the need for future research to consider the physical-psychosocial safety explanation. PSC is specifically concerned with psychological health but reasonably it could have an expanded role, linking MSDs through psychosocial pathways. If so this provides even stronger science driven argument for better workplace PSC. Given the above we expect PSC to be negatively related to physical and psychosocial demands, and positively related to psychosocial resources. For efficiency these propositions are integrated into mediation hypotheses in Section 1.6.

1.5. PSC as a predictor of 'Causal' pathways

PSC research has supported the psychosocial pathway (Bailey et al., 2015; Garrick et al., 2104; Yulita et al., 2014; Zadow et al., 2017). In light of this research, the psychosocial pathway has been supported in combination with a physical pathway in relation to MSDs, though most findings have been limited to cross-sectional effects even where there has been the potential to uncover longitudinal effects (Bailey et al., 2015). This evidence has substantiated a new proposition that the PSC framework extends the health erosion pathway (Dollard & Bakker, 2010) of the Job Demands Resources Model (Demerouti et al., 2001) as a predictor of psychological health. The evidence also revealed an expanded function of PSC as a potential predictor for physical injuries at work via emotional exhaustion. Exposure to the psychosocial risk factors (i.e., bullying, harassment, and violence) affects the capacity to act safely or feel supported by safety systems at work, thus leading to more employee accidents (Tuckey & Neall, 2014). Therefore, it is necessary to understand workplace factors (psychosocial and physical factors) in the work environment to prevent work-related injuries.

The significance of these contributions was mirrored in later research integrating physical and psychosocial pathways to explain MSD risks in health care settings (Bronkhorst & Vermeeren, 2016). This multilevel cross-sectional study investigated the relationship between organisational safety climate (PSC and physical safety climate) and organisational health performance outcomes (i.e., absenteeism, presenteeism, health care utilisation) mediated by individual worker health (MSDs and emotional exhaustion/burnout). Three pathways were tested: a physical pathway commencing with physical safety climate mediated by MSDs; a psychosocial pathway commencing with PSC mediated by emotional exhaustion, and a pathway commencing with PSC mediated by emotional exhaustion → MSDs effect. Their findings did not support the physical pathway because the physical safety climate was unrelated to MSDs. The psychosocial pathway was supported in relation to health outcomes (absenteeism and presenteeism). The combined physical and psychosocial pathway explained differences in the third outcome: health care utilisation. The findings confirmed a cross-sectional psychosocial process mechanism, PSC → emotional exhaustion → MSDs (Bronkhorst & Vermeeren, 2016), but again these paths were cross-sectional.

1.6. The current study

In this study we focused on MSDs through the lens of psychosocial and physical mechanisms. As shown in Fig. 1, we use a dual-process framework to examine MSDs, with PSC as a lead indicator, and including a (1) physical and (2) psychosocial paths. Four hypothesised process paths are proposed as outlined in Fig. 1:

Path 1 (a + b): *Hypothesis 1* (PSC-physical pathway): PSC relates to physical factors that in turn relate to MSDs.
Path 2 (a + b): *Hypothesis 2* (PSC-psychosocial pathway): PSC relates to psychosocial factors (demands and resources) that in turn relate to MSDs.
Path 3 (a + b + c): *Hypothesis 3* (PSC extended psychosocial pathway predicting MSDs): PSC relates to psychosocial factors that relate to psychological health and in turn MSDs.

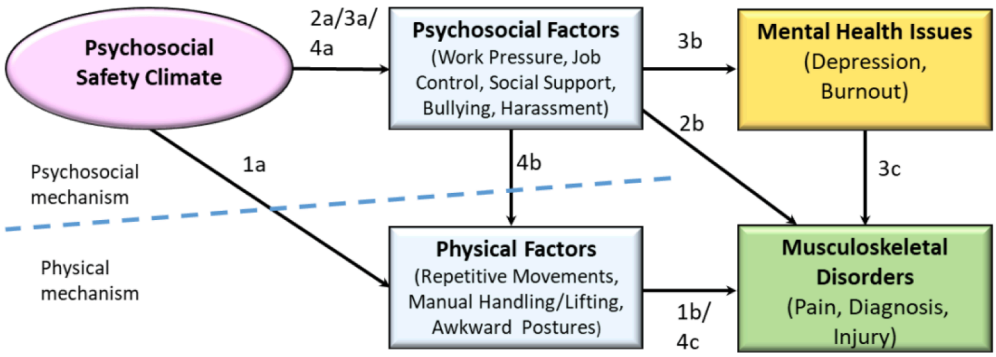

Fig. 1. Proposed Study Framework with Process Paths.

Path 4 (a + b + c): *Hypothesis 4* (PSC psychosocial mechanism predicting physical demands and MSDs): PSC relates to MSDs through psychosocial factors (demands and resources) and physical demands (transition hypothesis).

Note each of these hypotheses pertain to the three MSDs as per: (a) pain, (b) diagnosis, and (c) injury.

Mental ill-health symptoms such as emotional exhaustion are related to MSDs but only cross-sectionally (Bailey et al., 2015). Therefore, we included depressive symptoms as a stronger example of poor mental health to investigate any significant predictive (longitudinal) role in mediating the association of PSC or psychosocial and physical risk factors to MSDs (Zamri et al., 2017). We further extend Bailey et al. (2015) by exploring the role of resources in addition to demands, and explicitly investigating kinds of MSDs, pain, doctor diagnosis, and workplace injury.

We explored the relationships over a six-year period. It is likely that MSDs take time to manifest and short time intervals between antecedents and MSDs may lead to null results. Previously Bailey et al. (2015) found several links over a 12-month period, but not in relation to the impact of poor mental health on MSDs.

2. Research method

2.1. Design and participants

2.1.1. Participants and data collection

The data collection is part of a larger cohort Australian Workplace Barometer (AWB) study (with data collection in 2009, 2014–15 and 2020–21). We used the longitudinal data collected in 2014–15 and 2020–2021, recruited randomly from the Australian Electronic White Pages and a directory of Australian mobile phone numbers. We recontacted people who had previously participated in the AWB since 2009. Prospective participants received letters/SMS informing them of the study's purpose and the interview procedure. In the AWB study, a population-based random sampling approach ensured a representative sample (via post-stratification) of workers (18–65 year) across a range of organisations and industries.

The (name withheld for anonymity) cohort study, evaluated prior psychosocial risks for (i) MSDs and (ii) reported workplace physical risk factors in workers continuously (both T1 and T2) employed in three Australian states (NSW, WA and Vic) since Time 1. The matched sample (n = 432) was collected at Time 1 (2014/2015) and Time 2 (2020/2021) from employed workers over the age of 18 (Mean = 54 years), randomly selected at T1 via the Electronic White Pages from a wide range of occupations and industries (Bailey et al., 2015). The sample was approximately 45 per cent males (n = 193) and 55 per cent females (n = 239), with 65 per cent (n = 280) working full-time with an average income over $80 k. Most of the participants had higher education (bachelor's degree or higher, 51.6 per cent, n = 223; Certificate/Diploma, 27.8 per cent, n = 120) in 2014–2015. A further split of matched data from employees who remained within the same organisation across T1/T2, resulted in n = 269. The University XX's Human Research Ethics Committee approved this longitudinal study through different projects and ethics applications in each research time.

2.1.2. Survey method

Data were gathered using Telephone Interviews at T1 and T2. The interview method allowed for high-quality data due to the comparatively low response bias and good generalisability compared to web- or social media-based surveys and online self-report techniques (Kurniawan, 2018; Szolnoki & Hoffmann, 2013).

2.2. Measures

2.2.1. Potential risk factors for MSDs

The potential risk factors for MSDs were assessed by developing a list of risks and a range of responses in collaboration between the authors and based upon a priori hypotheses and previous research.

2.2.2. Demographics

These included age, gender, income, and education as used previously in the AWB. Age was measured based on year of birth. Gender identification was questioned by 'Do you identify as ….?' ranged as 1 (*Male*), 2 (*Female*), 3 (*Non-binary*), 4 (*Transgender Male*), and 5 (*Transgender Female*). However, only male and female groups were included due to the limited number of other gender groups in this study. Income was probed by 'Before tax is taken out, which of the following best describes your income from your main job in the last 12 months?' ranged from 1 (Up to $12,000) to 11 (More than $200,000). Education was discovered by asking 'What best describes the highest educational qualification you have obtained?' on a range of responses from 1 (Still at school) to 7 (Bachelor's degree or higher).

2.2.3. Psychosocial safety climate (PSC)

Psychosocial safety climate was assessed with the PSC-12 (Hall et al., 2010), which consists of four themes; management commitment, management priority, organisational communication, and organisational participation (see Table D in the supplementary materials). An example item is "Senior management considers employee psychological health to be as important as productivity". Responses were on a Likert scale from 1 (*strongly disagree*) to 5 (*strongly agree*) and summed up to present as PSC total score ($\alpha = 0.95$).

2.2.4. Psychosocial factors (Demands)

2.2.4.1. Work pressure.. *Work pressure* was measured using the five-item job demands scale from the new Job Content Questionnaire (JCQ 2.0; Karasek et al., 1998, https://www.jcqcenter.org). An instance item is "My job requires working very hard". We measured sum of all items on

a Likert scale, varying from 1 (*strongly disagree*) to 4 (*strongly agree*); α = 0.65.

2.2.4.2. Workplace harassment. We used seven items from Richman et al.'s (1996) scale to measure workplace harassment (e.g., "I have been sworn and/or yelled at.") and violence (i.e., "I have experienced being physically assaulted/threatened"). All the responses were on a 5-point Likert scale, varying from 1 (*very rarely/never*) through to 5 (*very often/always*) and summed up to present as workplace harassment (α = 0.70).

2.2.4.3. Workplace Bullying.. We assessed workplace bullying through an amended version of the QPSNordic Bullying Questionnaire (Dallner et al., 2000): Participants were asked, "Have you been subjected to bullying at the workplace during the last six months?" If they said yes, they were asked about length, frequency, and the position of the bully at work (a manager and/or a co-worker).

2.2.5. Psychosocial factors (Resources)

2.2.5.1. Job Control.. Scales from the JCQ 2.0 were used to measure two job control constructs; *skill discretion* (e.g., "I have an opportunity to develop my own special abilities.") α = 0.73; and *decision authority* (e.g., "My job allows me to make a lot of decisions on my own"); α = 0.76. A Likert response format was used for all items summed up for both scales (skill discretion and decision authority), with responses ranging from 1 (*strongly disagree*) to 4 (*strongly agree*).

2.2.5.2. Social Support.. The JCQ 2.0 scales were used to measure *supervisor social support* (e.g., "My supervisor/manager is helpful in getting the job done"); α = 0.85, and *co-worker social support* (e.g., "I am treated with respect by my co-workers"); α = 0.83. Responses ranged from 1 (*strongly disagree*) to 4 (*strongly agree*) summed up on both supervisor social support and co-worker social support scales.

2.2.6. Physical factors (Demands)

2.2.6.1. Physical job risks were measured using three items adapted from the JCQ-2.0 (Karasek et al., 1998). These are assessed as physical demands, moving/lifting heavy loads, rapid and continuous physical activity, and working for long periods with head/ body or arms in physically awkward positions. An example item is "My job requires lots of physical effort". We measured all the responses on a four-point Likert scale, extending from 1 (*strongly disagree*) to 4 (*strongly agree*) and summed up the items to present as physical job demands (α = 0.80).

2.2.7. MSD outcomes

2.2.7.1. MSD Pain.. MSD Pain was assessed with three items from the Nordic Musculoskeletal Questionnaire (NMQ; Kuorinka et al., 1987). This scale includes symptoms of pain in the back, neck, muscles, arms, legs, or joint areas like knee or hips, with an example item "[During the past 7 days] how much were you bothered by back or neck pain?". We evaluated the responses on a four-point Likert scale from 1 (*not at all)*, 2 (*a little*), 3 (*some*) to 4 (*a lot*), α = 0.68. From the four-point scale we constructed three pain levels, "*Not at all*", "*Some or a little*", and "*A lot*". We did this by defining: "*A lot*" as a respondent reporting this across any responses to neck or back, limb or joint or muscle soreness pain; "*Not at all*" by a match across all responses; and "*Some or little*" by any other match.

2.2.7.2. Doctor diagnosed musculoskeletal Disorders.. MSDs diagnosed were assessed with a list of common MSD conditions and asking the participants, "Has a doctor EVER told you that you have a musculoskeletal condition?" If yes: "what was it?". Thirteen common MSDs like "Carpal Tunnel Syndrome", "Tendonitis", "Muscle and or Tendon and/ or Ligament Strain", were provided with "*yes"* (1), "*no"* (0) responses. The number of MSDs diagnosed were added as the total score for this measure.

2.2.7.3. Physical injuries at Work.. Was assessed with a question asking, "Have you had a significant physical injury in the past 12 months?" that has arisen from inside the workplace. Response was 0 = no and 1 = yes.

2.2.8. Mental health issues

2.2.8.1. Depressive symptoms. Depressive symptoms were assessed using all nine items from the Patient Health Questionnaire (PHQ-9; Spitzer et al., 1999). The PHQ-9 is a self-report measure used for making diagnoses based on depressive episodes under DSM-IV criteria for a depressive disorder. The time reference for this study was modified to the last four weeks. Items were measured on a 4-point Likert scale, ranging from 1 (*not at all*) to 4 (*nearly every day*).

2.2.8.2. Burnout. Burnout was assessed with the five items from the Maslach Burnout Inventory (MBI; Schaufeli et al., 1996). Items were measured on a 7-point Likert scale, ranging from 1 *(never)* to 7 *(always)*.

2.3. Statistical analysis

SPSS-28 and AMOS-28 software (IBM Corp, 2021) were used to test hypotheses and perform all statistical analyses.

2.3.1. Analysis strategy 1

Depending on the nature of the outcome measure we used a logistic regression model (doctor diagnosis, injury), ordinal regression (pain) and linear regression (physical demands) to assess the multivariate association between workplace factors (psychosocial and/or physical) with MSDs.

To test Hypothesis 1 to 3 and the process paths depicted in Fig. 1, the effect of each component was tested in a series of nested multivariate regression models. All independent variables were at Time 1 with the dependent MSD measures at Time 2. The models and the Likelihood Ratio Test [LRT, Chi-Square Change] comparison models are:

Model 0: PSC.

Model I: PSC + physical risk. The LRT between Model I and Model 0 tells us whether there is a path between physical risk factors and MSD (path 1b). The amount and direction of change in the PSC estimate between Model 0 (without physical risk factors) and Model I (with physical risk factors) provides information about whether PSC predicts MSD *independently* of physical factors or *via* physical factors.

Model II: PSC + psychosocial risk. The LRT between Model II and Model 0 tells us whether there is a path between psychosocial risk factors and MSD (path 2b). The amount and direction of change in the PSC estimate between Model 0 (without psychosocial risk) and Model II (with psychosocial risk) will tell us whether PSC predicts MSD *independently* of the psychosocial risk or *via* the psychosocial risk factors.

Model III: PSC + psychosocial risk + mental health issues. The LRT between Model III and Model II tells us whether there is a path between mental health issues and MSD (path 3c). The amount and direction of change in the PSC or psychosocial risk estimates between Model II (without mental health issues) and Model III (with mental health issues) tells us whether PSC or psychosocial risk (path 2b) predicts MSD independently of mental health issues or via the mental health issues.

Model IV: PSC + physical risk + psychosocial factors + mental health issues. The LRT between Model IV and Model II tells us whether there is a path between physical risk factors and MSD that is independent of psychosocial factors (path 1b or 4c). The amount and direction of change in the PSC estimate between Model II (without physical risk) and Model IV (with physical risk) informs whether PSC predicts MSD independently of this path.

Model V: PSC + physical risk + psychosocial risk + mental health issues + demographics (gender, age, education, and income). Significant effects are over and above demographic effects.

Model VI: Model with MSD pain only as outcome; Baseline MSD pain + PSC + physical risk + psychosocial risk + mental health issues + demographics. Significance of effects are over and above baseline levels of MSD pain.

In addition, to test Hypothesis 4, we controlled for T1 physical hazards in an attempt to predict future work environments from prior work environments. We selected into this analysis workers from within the same organisation six years later (n = 269). The outcome was on an interval scale (Stevens, 1946), so we used linear regression, and applied the models as noted above (See Fig. 2).

Given the long time-lag between T1 and T2 and the expectation of small effects, and considering all hypothesised effects were directional, we used a liberal p value of 0.1 for bidirectional test significance. Considering half the p-value (i.e., p / 2) for the unidirectional test will still control for Type-I error at p =.05 Also as noted by Thiese et al. (2016) 'consideration of low p values (e.g., $p < 0.10$) as "trending toward statistical significance" may be clinically relevant for improving practice, particularly in smaller studies' (p. 929).

2.3.2. Analysis strategy 2

Next, we integrated all of the results into one SEM model (with the full sample, n = 432) (tests path 2a, 3a, 4a, 3b, 4b and all others). We used structural equation modelling (SEM) and AMOS 28 software to test mediation effects controlling for measurement error (Holmbeck, 1997).

3. Results

Means, standard deviations and correlations between variables at T1 (i.e., cross-sectional) and MSDs at T2 are shown in Table 1.

3.1. Results for analysis strategy 1

3.1.1. Predicting MSD pain at T2 from T1 measures

With MSD pain as the outcome, in the lagged Model 0, PSC was significantly negatively related B = -0.02, SE = 0.01, p =.06 (considering the conservative p =.1 adopted in the study, see Table 2). Physical demands added significantly to the model with PSC, (Model I), Chi-Square = 9.80, df = 2, p =.007. Chi-Square change = 6.37 > Critical value of 5.02, df = 1, p =.02, and positively related to MSD pain in the future, B = 0.13, SE = 0.05, p =.01. Model II added significantly to Model 0 which included PSC, Chi-square change = 13.48 > critical value 12.02 at df = 7, p =.10, with skill discretion negatively related B = -0.07, SE = 0.02, p =.005. A significant negative relationship between decision authority and MSD pain was not consistent with the hypotheses. Likewise, no psychosocial demands were related to MSD pain. Since PSC remained significant in the Model I with physical demands, but not psychosocial factors (Model II) this implies PSC is not mediated by physical demands but is via psychosocial factors.

Model III added burnout and depressive symptoms to Model II, and the fit was significantly improved with Chi-square change = 23.76 > critical value at 10.60, df = 2, p =.005. Depressive symptoms at T1 were significantly and positively associated with MSD pain at T2. Skill discretion remained negatively related to future MSD pain implying an independent path to MSD (not via mental health issues).

Model IV added physical demands to Model II, Chi-square change = 28.81 > Critical value of 16.26, df = 3, p =.001 with physical demands significant, B = 0.11, SE = 0.06, p <.05, reaffirming the strong direct effect of this on MSDs. Note in this model, skill discretion becomes not significant implying a possible path to MSDs through physical demands. Females also reported more future MSD pain than men, B = 0.56, SE = 0.22, p =.01. With physical demands and being female in the model, skill discretion and decision authority were no longer significant.

In Model V, adding depressive symptoms and burnout to the psychosocial + physical model was a significant improvement, Chi-Square change = 22.62, greater than the critical value of 13.82, df = 2, p =.001 with depressive symptoms, being female, and physical demands still significant in this model.

In the final model (Model VI), we added MSD pain T1 to Model V (note we did not have T1 measures for doctor diagnosed or workplace injury measures)with a significant improvement in model fit, Chi-square change = 66.23, greater than the critical value of 7.88, df = 15, p =.001. MSD Pain T1 was significantly positively associated with MSD Pain T2. Physical demands, depressive symptoms, being female were also significant. All together these preliminary tests imply that PSC could relate to future MSDs through psychosocial factors, physical factors, individual factors (gender) or mental health issues.

3.1.2. Predicting diagnosed MSDs at T2 from T1 measures

Model 0 PSC was significantly and negatively related to future MSD diagnosis, B = -0.02, SE = 0.01, p =.05 such that higher levels of PSC were associated with a lower likelihood of MSD diagnosis in the future. Other models were not significant. Aside from PSC, older workers reported more MSDs diagnosed, B = 0.03, SE = 0.01, p =.02 (see Table A in the supplementary materials).

3.1.3. Predicting physical injuries at work at T2 from T1 measures

Model 0 was not significant, PSC T1 was not related to future physical injuries. Model I added significantly to Model 0 with physical demands T1 significantly positively related to future physical injuries at work T2, B = 0.31, SE = 0.11, p <.001. Model II showed significant improvement on Model 0, Chi-square change = 14.01 df = 7, greater than the critical value of 12.02 at p =.05. Decision authority T1 was negatively related to physical injuries T2, B = -0.11, SE = 0.04, p <.01.

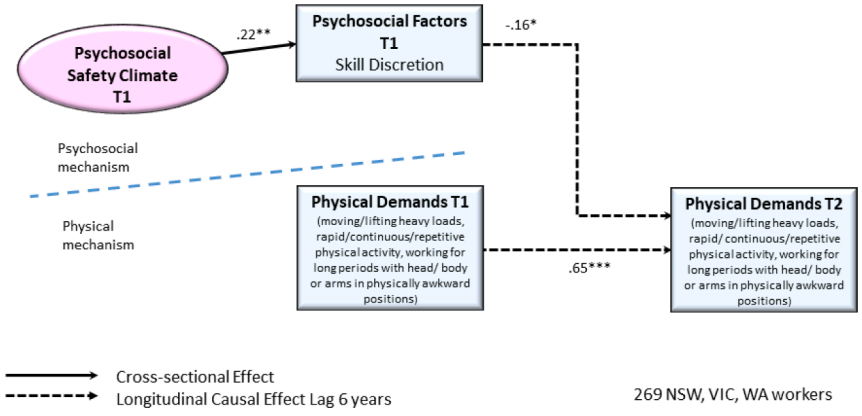

Fig. 2. Predicting Future Physical Demands.

Table 1
Means, Standard Deviations and Correlations.

	M	SD	N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1. Age (T1)	54	10.56	432	-																
2. Gender (T1)	1.55	.50	432	-.10*	-															
3. Income (T1)	6.77	2.39	409	-.12*	-.36**	-														
4. Education (T2)	5.97	1.50	432	.14**	.04	.16**	-													
5. PSC (T1)	40.44	9.70	432	.01	.01	.01	-.09	-												
6. Physical Demands (T1)	5.93	1.9	432	.02	-.01	-.19**	-.16**	-.06	-											
7. Psychological Demands (T1)	31.29	5.13	432	-.07	.07	.15**	.15**	-.36**	.11*	-										
8. Skill Discretion (T1)	35.27	5.19	432	-.05	-.01	.29**	.29**	.22**	-.23**	.03	-									
9. Decision Authority (T1)	35.56	6.15	432	-.13**	.01	.15**	.05	.35**	-.17**	-.10*	.45**	-								
10. Supervisors Support (T1)	9.36	1.69	432	.07	-.01	-.01	.03	.53**	-.09*	-.28**	.25**	.38**	-							
11. Co-workers Support (T1)	9.79	1.39	432	.02	.02	.03	.08	.31**	-.12*	-.12*	.30**	.24**	.47**	-						
12. Workplace Bullying (T1)	0.09	.28	432	.05	.00	-.01	-.05	-.29**	.08	.19**	-.08	-.17**	-.37**	-.22**	-					
13. Workplace Harassment (T1)	10.09	2.89	432	-.05	.07	-.01	-.01	-.36**	.22**	.30**	-.09	-.15**	-.32**	-.18**	.40**	-				
14. Depressive symptoms (T1)	3.59	4.09	432	.08	.04	-.16**	-.05	-.32**	.02	.19**	-.14**	-.18**	-.30**	-.19**	.25**	.31**	-			
15. Burnout (T1)	15.15	7.42	432	.14**	.00	.03	.02	-.36**	.03	.39**	-.05	-.23**	-.33**	-.15**	.21**	.38**	.54**	-		
16. Pain (T2)	2.07	.64	432	-.04	.15**	-.11*	-.11*	-.09	.12*	.05	-.15**	.01	-.04	-.05	.04	.08	.24**	.12**	-	
17. MSDs (T2)	0.25	.43	432	-.13**	.02	.06	.01	-.10*	.05	.13**	-.01	.01	-.07	.01	.11*	.13**	.05	.09	.24**	-
18. Work-related Injuries (T2)	0.05	.22	432	-.03	-.07	-.07	-.04	-.05	.15**	.05	-.08	-.15**	.04	.03	0	.04	.02	.04	.14**	.16**

Note: M = Mean, SD = Standard Deviation, Age (years), Gender (Male =1, Female=2), Income (7= $60,001 - $80,000/yrs.), Education (6= Certificate / Diploma), T = Time, PSC = Psychosocial Safety Climate, MSD = Musculoskeletal Disorders, * $p < .05$, ** $p < .01$. Education T2 was provided due to drop in education level from T1, that may contribute to increased individual risk factors (2-tailed).

Table 2
Predicting MSDs Pain at T2 from T1 Measures.

Model	T1	B	SE	p	2.5%	97.5%	Chi-Square (*df*)	p	R^2	Chi-Square Change (*df*)	p
0	#PSC	−0.02	0.01	0.06	−0.04	0.00	3.43 (1)	0.06	.008		
I	#PSC	−0.02	0.01	0.08	−0.04	0.00	9.80 (2)	0.007	0.02	6.37 (1)	.02
	Physical Demands	0.13	0.05	0.01	0.03	0.23					
II	#PSC	−0.02	0.01	0.21	−0.04	0.01	16.91 (8)	0.031	0.038	13.48 (7)	.10
	Psych Demands	0.01	0.02	0.64	−0.03	0.05					
	Skill discretion	−0.07	0.02	0.00	−0.11	−0.03					
	Decision authority	0.04	0.02	0.04	0.00	0.08					
	Supervisor support	0.04	0.08	0.64	−0.11	0.18					
	Co-worker support	0.00	0.08	1.00	−0.16	0.16					
	Bullying	0.08	0.38	0.84	−0.67	0.82					
	Harassment	0.04	0.04	0.34	−0.04	0.11					
III	PSC	−0.01	0.01	0.51	−0.03	0.02	40.67 (10)	0.000	0.09	23.76 (2)	.005
	Psych Demands	0.01	0.02	0.75	−0.04	0.05					
	Skill discretion	−0.07	0.02	0.00	−0.11	−0.03					
	Decision authority	0.04	0.02	0.02	0.01	0.08					
	Supervisor support	0.06	0.08	0.40	−0.09	0.22					
	Co-worker support	0.02	0.08	0.84	−0.14	0.17					
	Bullying	0.01	0.39	0.99	−0.75	0.77					
	Harassment	0.00	0.04	0.91	−0.07	0.08					
	Depressive symptoms	0.13	0.03	0.00	0.07	0.19					
	Burnout	0.00	0.02	0.99	−0.03	0.03					
IV	PSC	−0.00	0.01	0.09	−0.03	0.02	45.72 (11)	0.010	0.07	28.81 (3)	.10
	Physical Demands	0.11	0.06	0.05	0.00	0.22					
	Psych Demands	0.01	0.02	0.69	−0.03	0.05					
	Skill discretion	−0.04	0.02	0.13	−0.08	0.01					
	Decision authority	0.03	0.02	0.12	−0.01	0.07					
	Supervisor support	0.04	0.08	0.59	−0.11	0.20					
	Co-worker support	−0.01	0.08	0.89	−0.17	0.15					
	Bullying	0.02	0.40	0.95	−0.76	0.81					
	Harassment	0.01	0.04	0.77	−0.07	0.09					
	Depressive symptoms	0.13	0.03	0.00	0.07	0.19					
	Burnout	0.00	0.02	0.90	−0.03	0.04					
V	PSC	−0.01	0.01	0.28	−0.04	0.01	50.22 (15)	0.000	0.12	22.62 (2)	.001
	Physical Demands	0.14	0.06	0.01	0.03	0.25					
	Psych Demands	0.00	0.02	0.87	−0.05	0.04					
	Skill discretion	−0.04	0.02	0.08	−0.09	0.01					
	Decision authority	0.03	0.02	0.08	0.00	0.07					
	Supervisor support	0.08	0.08	0.32	−0.08	0.24					
	Co-worker support	0.01	0.08	0.88	−0.15	0.18					
	Bullying	−0.01	0.41	0.97	−0.81	0.78					
	Harassment	−0.03	0.04	0.50	−0.11	0.05					
	Depressive symptoms	0.12	0.03	0.00	0.06	0.19					
	Burnout	0.01	0.02	0.63	−0.03	0.04					
	Female	0.60	0.22	0.01	0.16	1.04					
	Age (Yr of Birth)	−0.01	0.01	0.59	−0.03	0.01					
	Education	−0.09	0.07	0.23	−0.23	0.06					
	Income	0.02	0.05	0.76	−0.08	0.11					
VI	MSD Pain	0.96	0.17	0.00	0.62	1.29	83.14 (16)	0.000	0.18	66.23 (15)	.001
	PSC	−0.01	0.01	0.47	−0.04	0.02					
	Physical Demands	0.14	0.06	0.01	0.03	0.26					
	Psych Demands	−0.01	0.02	0.57	−0.06	0.03					
	Skill discretion	−0.04	0.02	0.12	−0.09	0.01					
	Decision authority	0.03	0.02	0.11	−0.01	0.07					
	Supervisor support	0.09	0.08	0.28	−0.07	0.25					
	Co-worker support	−0.02	0.09	0.77	−0.19	0.14					
	Bullying	0.02	0.42	0.96	−0.79	0.83					
	Harassment	−0.02	0.04	0.62	−0.10	0.06					
	Depressive symptoms	0.12	0.03	0.00	0.05	0.18					
	Burnout	0.00	0.02	0.96	−0.04	0.03					
	Female	0.53	0.23	0.02	0.08	0.97					
	Age (Yr of Birth)	0.00	0.01	0.94	−0.02	0.02					
	Education	−0.06	0.07	0.40	−0.21	0.08					
	Income	0.01	0.05	0.77	−0.09	0.12					

Note: N =432, T =Time, PSC = Psychosocial Safety Climate, MSD = Musculoskeletal Disorders, R^2 = Cox and Snell pseudo r-sq, *df* = degree of freedom.

Against expectations supervisor support was significantly positively related to injuries. Model III, IV and V were not significant. With all variables in the model (Model V), physical demands and decision authority remained significant in the model, along with older age, male and lower income (see Table B in the supplementary materials).

3.1.4. Predicting physical demands at T2 from T1 measures

Model 0 showed that PSC was not directly associated with physical

demands. Physical demands T1 were significantly positively related to future physical demands (Model I) B = 0.76, SE = 0.05, p <.001. Model II showed that at T1, skill discretion B = -0.11, SE = 0.03, p <.001 was negatively related and harassment B = 0.16, SE = 0.05, p <.001 was positively related to physical demands at T2. Poor psychological health (depressive symptoms) was not associated with future exposure to physical demands (Model III). When controlling for baseline physical demands, harassment was no longer significant implying a relationship between harassment and physical demands T1 and a possible mediation process (Model IV) (see Table C in the supplementary materials). Demographics were not significant. A summary of findings for physical demands is shown in Fig. 2.

3.2. Results for analysis strategy 2

3.2.1. Comparison of Alternative models

Analysis strategy 2, structural equation modelling (SEM) was used to formally test mediation effects and control for measurement error (Holmbeck, 1997). We included variables in the model when significant relations were found in the regression analyses. PSC was found as a latent variable indicated by the four subscales. Decision authority, skill discretion, harassment and physical demands, depressive symptoms and MSDs were observed variables (to save degrees of freedom). The structural model allowed covariation between the structural residuals of all variables at T1 that had no specified paths between them, and between all MSDs at T2.

We used goodness-of-fit indices to assess model fit (cf. Jöreskog & Sörbom, 1993); the $\chi 2$ goodness-of-fit statistic; the root mean square error of approximation (RMSEA); the goodness of fit index (GFI); the comparative fit index (CFI); and the normed fit index (NFI). Values of 0.95 or higher for GFI, CFI and NFI are indicative of a very good fit (Hoyle, 1995) and RMSEA-values less than or equal to 0.05 indicate a good fit (Schermelleh-Engel, Moosbrugger, & Muller, 2003). We also assessed relative fit with the AIC, Akaike information criterion, (lower values indicate better fit). In predicting future demands (prior test), it appeared that harassment was related to future demands and that this was mediated by T1 demands, this path was also included in the model. Also, a covariance path was added between two PSC subscales given their high degree of correlation. At the first pass, income, gender, and age were not associated with work injury and these paths were removed from the model. Model M1 is represented in Table 3 as the mediated model demonstrating the fit is very good and is represented in Fig. 3. We tested a PSC direct effects model against this model, estimating PSC to MSD outcomes, retaining the demographic paths and setting all other paths to zero. The direct effects Model 2 was a significantly inferior model than the mediated model, but PSC was significantly related to MSD pain and MSD diagnosis. M3 added to M1 paths from psychosocial to depressive symptoms path, which did not improve model fit. Accepting M1 as the final model, Table 4 shows the mediation paths and the significance of the indirect effects.

3.2.2. Hypothesis Results: Proposed mediation paths and significance of Indirect effects

Path 1: Hypothesis 1: PSC-physical pathway: PSC relates to physical factors that in turn relate to MSDs. There is no support for Hypothesis 1. There is no direct relationship between PSC and physical demands (section 3.1.4) so there is no support for this hypothesis.

Path 2: Hypothesis 2: PSC psychosocial pathway: PSC relates to psychosocial factors (demands and resources) that in turn relate to MSDs. There is some support for Hypothesis 2, where PSC is related to decision authority that in turn relates to work injury (Path 2, Table 4).

Path 3: Hypothesis 3: PSC extended psychosocial pathway predicting MSDs): PSC relates to psychosocial factors that relate to psychological health and in turn MSDs. Since M3 did not improve M1 (strategy 2; also strategy 1, Table 2, MIII added depressive symptoms and did not reduce the main effects of psychosocial factors), Hypothesis 3 is not supported. Rather PSC is related to MSD pain through depressive symptoms (Path 3, Table 4).

Path 4: Hypothesis 4: PSC relates to MSDs through psychosocial factors (demands and resources) and in turn physical demands. There is support for this transition effect, Hypothesis 4. PSC is mediated by skill discretion and harassment in its relationship to physical demands and in turn MSDs (Path 4, see Table 4).

A summary of all the strategy 2 results are provided in Fig. 3.

4. Discussion

The current study aimed to investigate Psychosocial Safety Climate (PSC) as a distal cause of MSDs through physical and psychosocial process paths to MSDs over six years. We found that MSDs could be predicted by working conditions six years earlier. Further, we found evidence for several psychosocial paths; PSC was related to future MSD (work injury) through decision authority; PSC was related to MSD pain through depressive symptoms; PSC was related to MSDs through psychosocial factors that in turn related to physical demands. For example, PSC was related cross-sectionally to skill discretion and harassment which predicted future physical demands and in turn MSD pain and workplace injuries. For future doctor diagnosed MSDs, PSC was directly negatively related, and age positively. A novel finding was the linkage between skill discretion and future MSD related pain via physical demands, highlighting a new pathway – how psychosocial pathways relate to physical pathways. In terms of doctor-diagnosed MSDs, PSC was a direct effect rather than a mediated effect. Overall poor PSC was found as a distal antecedent of MSDs. Workplace autonomy (decision authority and skill discretion) was a critical factor in predicting future pain and workplace injury.

The findings broadly support other studies in this area linking workplace physical and psychosocial risk factors and MSDs (e.g., Hauke et al., 2011; Lang et al., 2012; Leka et al., 2015; Macdonald & Oakman, 2015). However, what our research demonstrates, not tested by Bailey et al. (2015) is the transition from psychosocial to physical in the progression to MSDs. Moreover, our study showed that resources in the form of job control were just as important as other research highlighting the critical effects of job demands (i.e., Bailey et al., 2015). Another

Table 3
Comparison of Alternative Models.

	χ^2	*df*	GFI	CFI	NFI	RMSEA	AIC	$\Delta\chi^2$ (df) sig
M0. Null model	313.34	58	.91	.84	.82	.10	407.34	
M1. Fully mediated	95.64	48	.97	.97	.94	.05	209.05	M1 vs M0 217.70 (1), $p < .001$
M2. Direct effect	305.76	55	.92	.84	.82	.10	405.76	M1 vs M2 210.12 (7), $p < .001$.
M3. Plus Psychosocial	157.94	49	.95	.93	.91	.07	269.94	M1 vs M3 62.30 (9), $p < .001$.

Note. $\chi 2$ goodness-of-fit statistic; GFI = Goodness of Fit Index; CFI = Comparative Fit Index; NFI = Normed Fit Index; AIC, Akaike information criterion; RMSEA = Root Mean Square Error of Approximation.

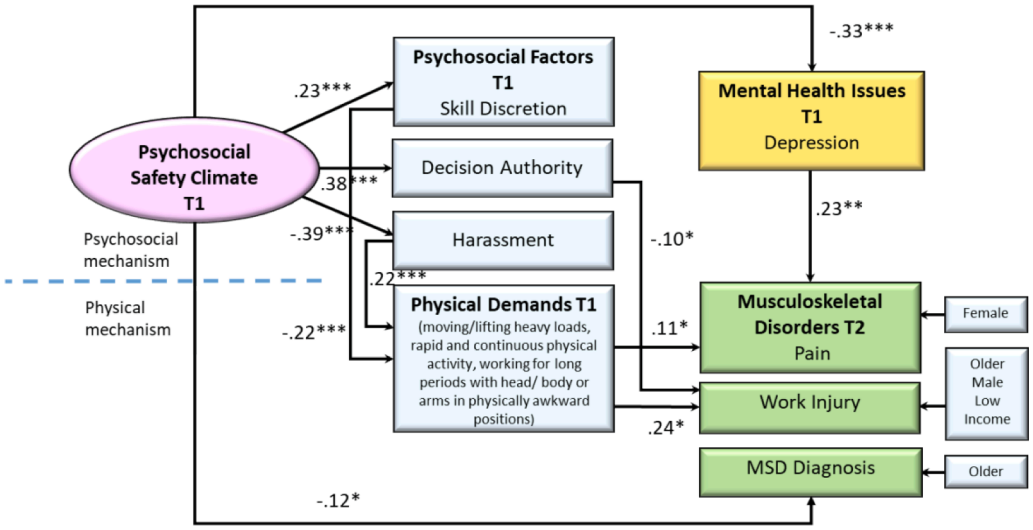

Fig. 3. Predicting Future MSDs.

Table 4
Mediation Paths and the Significance of Indirect Effects.

Path^	Indirect Mediation Paths	LL	UL	p
Path 4	PSC→ Skill Discretion →Physical Demands	−.08	−.02	.01
Path 4	PSC→Harassment→Physical Demands	−.12	−.05	.02
Path 4	Skill Discretion→Physical Demands→Workplace Injury	−.003	.000	.03
Path 4	Skill discretion→Physical Demands→MSD pain	−.007	−.001	.02
Path 3	PSC→Depressive→MSD Pain	.000	−.016	.01
Path 2	PSC→Decision Authority→Work Injury	−.01	−.002	.01
Path 4	Harassment→Physical Demands→Work Injury	.001	.004	.03
Path 4	Harassment→Physical Demands→MSD Pain	.002	.010	.02

Note. ^ refer to Figure 1; paths relate to Hypothesis of the same number.

noteworthy point is that the results varied according to the MSD outcome under consideration which could explain mixed results in previous studies. Still, the results generally support the study model, suggesting that the combination of work-related psychosocial and physical pathways are essential in accounting for MSD outcomes, and that MSDs can be potentially traced to the corporate climate for worker psychological health and safety (PSC). The results support previous studies demonstrating that PSC and psychosocial risk factors impact work-related injury causation and rehabilitation (Bailey et al., 2015). Knowing about PSC, the evidence suggests that levels of psychosocial risk factors such as low job control (skill discretion, decision authority) can be estimated. The reason psychosocial risk factors were linked to MSDs was not through mental health issues, but rather directly (decision authority) or indirectly (skill discretion) through physical demands. Independent of these findings, PSC was also found to be related to MSD pain through the experience of mental health issues (burnout, depressive symptoms).

While physical demands are well recognised as precursors to MSDs, there is growing evidence of the critical role of psychosocial factors potentially due to biochemical stress responses, involving muscle tension (Bongers et al., 2006), reduced blood supply (Visser & van Dieën, 2006), less opportunity for muscle repair, and muscle fibre weakness increasing susceptibility to injuries (Theorell et al., 2002).

The effects noted were over and above other demographic effects found, with few demographic effects noted in the final model (see Table 2). Our results show that physical demands predicted future physical demands. Over and above this effect, low skill discretion was related to future physical demands at work (the effects of harassment were mediated by physical demands). Mental health issues (burnout, depressive symptoms) Time 1 were not related to future exposure to physical demands. This is an important finding since it gives weight to working conditions as the cause of future physical demands, rather than an individual worker's vulnerabilities.

4.1. *Theoretical implications*

This research is indicative of three major theoretical contributions. First, our research provides further insight into the critical role of PSC as a corporate climate within organisations and provides an understanding of MSDs as an outcome of combined physical and psychosocial pathways and their interplay. This accords with previous literature that suggests a dual process. Research by Zadow et al. (2017) highlighted the dual role of physical and psychosocial safety climates in predicting future registered injury rates. Additionally, the critical role of psychosocial risks is also highlighted in a recent literature review by James et al. (2021). They found that psychosocial factors of workplace support, job control and job demands are related to MSDs. Our research suggests that job demands (physical only) and job resources (such as skill discretion and decision authority) are essential precursors to MSDs. Second, in terms of psychosocial factors, job resources seem more important as precursors to MSDs. While psychosocial demands are likely important our research suggests psychosocial resources are more important. This implies that theorizing about MSDs should include and emphasise job resources. Third, we theories a transition from psychosocial to physical risks in the development of MSDs. In a low PSC context, with low skill discretion, physical demands emerge which result in MSDs. It is likely that the employee has little opportunity to use different skills which may result in carrying out tasks in a repetitive or continuous fashion for long periods or moving/lifting heavy loads without being able to use skills to modify tasks, and working for long periods with head/ body or arms in

physically awkward positions.

4.2. Practical implications

The finding that psychosocial factors play a role in MSDs supports a fresh preventive approach. A novel intervention not yet tried to improve MSD status among employees would be to focus on enhancing PSC. Since PSC is an antecedent to many risk factors, enhancing PSC would be an efficient focus. As illustrated by Dollard & Bailey, 2021, PSC intervention is achievable within a short period, and would be imperative in the optimisation of workplace mental health. Increasing PSC would entail improving communication systems, participation, and management to reduce psychosocial risks.

In occupations where workers are exposed to low skill discretion, this may imply that employees have little agency and cannot take local actions to reduce or manage physical demands. Low income likely indicates fewer personal resources to seek and receive early treatment. Given the predictability of workplace factors on MSDs and health, and that those factors identified are preventable or modifiable, action should be taken to target these in order to eliminate and/or reduce risk, such as improve PSC and skill discretion and reduce harassment. Although we have identified some associated factors with MSDs, the predictive effects are small but targeting each may have an incremental impact. Further, though we cannot tell from the current design, it should be considered that effects could be larger at time intervals less than six years.

The finding that MSDs can be predicted from working conditions six years earlier despite that those employees may be working for a different organisation, should raise concerns about long range effects, where costs may be transferred to other organisations, the health care system, and the individual employee.

4.3. Limitations and future directions

Innovative research conducted within the current study was to test the role of PSC as a leading indicator of MSDs (a 'cause of the causes' of other risk factors). The results align with this notion, but we could not establish a longitudinal relationship between PSC and risk factors, possibly due to the long-time lag and limited sample size. Many other studies have found support for the longitudinal association between PSC and risk factors when assessed at shorter intervals (for a review, see Loh et al., 2020), therefore we do not suggest a revision of the assumptions of this relationship.

A limitation for the research was securing responses to requests for a telephone interview. The timing of the research was during the COVID-19 pandemic. The final number of responses was smaller than desired. We could not find longitudinal associations between PSC, risk factors and outcomes except that PSC predicted future MSD diagnosis. It might be that the length of time between measures (six years) rendered this relationship too small to detect. Assessing risk levels of PSC may prove beneficial for assessing relations across time (e.g., predicting new major depression, Zadow et al., 2021). Future research could focus on designing and evaluating interventions that focus on leading indicators of MSDs.

5. Conclusion

MSDs are predictable outcomes of PSC, physical demands, skill discretion, decision authority, harassment, and psychological health status from many years earlier. The results suggest a much greater focus in any MSD strategy on interventions to reduce psychosocial risk factors since these factors directly predicted MSD outcomes or physical demands, which is the primary cause of MSDs. The study also supports data-driven approaches to intervention and evaluation to ensure the right risk factors are targeted.

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CRediT authorship contribution statement

Ali Afsharian: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Maureen F. Dollard:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Nick Glozier:** Writing – review & editing, Supervision, Methodology, Funding acquisition, Formal analysis, Conceptualization. **Richard W. Morris:** Writing – review & editing, Visualization, Methodology, Formal analysis, Data curation. **Tessa S. Bailey:** Writing – review & editing, Methodology, Investigation, Conceptualization. **Ha Nguyen:** Writing – review & editing, Methodology. **Cherie Crispin:** Writing – review & editing, Investigation, Data curation.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ssci.2023.106177.

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Work-related psychosocial and physical paths to future musculoskeletal disorders (MSDs)

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ABSTRACT

Given the human, industrial and societal costs of Musculoskeletal Disorders (MSDs) we evaluated antecedents to MSDs (assessed as pain, doctor diagnosis, and workplace injury) over a six-year period T1 (2014/2015) and T2 (2020/2021). The purpose of the study was to examine the role of the organisational climate (i.e., psychosocial safety climate, PSC) for employees' psychological health and safety as an antecedent to physical demands, and psychosocial risks (e.g., low control, harassment) that in turn might relate to MSDs using a longitudinal design. We used matched data from follow-up telephone interviews of 432 Australian employees. We found evidence for several psychosocial paths; PSC was related to future workplace injuries through decision authority; PSC was related to MSD pain through depressive symptoms. For future doctor diagnosed MSDs, PSC was directly negatively related. Older age, being male and low income was related to work injury; being female associated with MSD pain; and being older was associated with MSD diagnosis. A novel finding was the linkage between psychosocial risks (low skill discretion and harassment) and future physical demands leading to future MSD pain and work injury highlighting a new pathway linking psychosocial and physical aspects. Overall poor PSC was found as a distal antecedent of all MSDs. Decision authority and skill discretion were most critical psychosocial risks in predicting future pain and injuries. Psychosocial factors predicted future demands. Actions should target improving PSC and autonomy and reducing harassment and physical demands, to decrease the incidence of MSDs.

1. Introduction

Musculoskeletal Disorders (MSDs) are some of the most prevalent types of occupational injuries and diseases worldwide incurring tremendous costs for both employees and their organisations (Bonfiglioli et al., 2022; Caponecchia et al., 2020; Oakman et al., 2018; Safe Work Australia, 2020; Serna Arnau et al., 2023). MSDs refer to 'a range of conditions that affect joints, spinal vertebrae and intervertebral discs, the synovium, muscles, tendons and related tissues, soft tissues, and connective tissues' (Safe Work Australia, 2016; p. 4). In Australia, physical injuries including MSDs accounted for 87% of serious workers' compensation claims for injury or disease during 2019-20. Muscle/tendon injuries and traumatic joint/ligament specifically accounted for 43% of all serious claims (Safe Work Australia, 2019-20). In the European Union, work-related MSDs remain the most typical problem at work, with roughly three out of every five employees in the EU-28 reporting MSD related complaints, the most reported forms including backache and muscular pain in the upper limbs, shoulders, and neck (Jan de Kok et al., 2019). Further, in 2020/2021 an estimated 470,000 workers across Great Britain were affected by work-related musculoskeletal disorders, accounting for 28% of all work-related ill-health, both upper limb, neck or back the most commonly reported work-related MSD (Health & Safety Executive, 2021). With musculoskeletal conditions significantly limiting mobility and dexterity and overall levels of functioning, dramatically impacting a person's ability to work, preventing work-related MSDs requires identifying and controlling relevant physical and psychosocial work-related factors contributing to these injuries (Harris-Adamson et al., 2022; Oakman et al., 2022).

1.1. Aetiology: What we know

Over the past two decades, a substantial body of literature has

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supported the complex and multifactorial aetiology of work-related MSDs. The workplace risk factors that put an individual at increased risk of MSD development are characterized into three broad categories, 1) physical or biomechanical risks related to physical activities or ergonomic characteristics in the workplace (e.g., repetitive movements, improper postures and heavy lifting); 2) psychosocial risks (e.g., high demands, low control and poor social supports); and 3) individual risks (e.g., age, gender, income, education) (Hernandez & Peterson, 2013). Though, researchers have investigated relationships between individual, psychosocial and biomechanical factors in the genesis of MSDs, both separately and through their interactions (Eijckelhof et al., 2013; Hauke et al., 2011; Harris-Adamson et al., 2022), distal determinants preceeding these factors, and the aetiological pathways that follow, require further investigation.

Understanding the pathways by which these factors manifest and then interact in any given work environment has been theorized as a dual process via physical and psychosocial pathways. The physical pathway proposition is that physical demands are a direct antecedent to MSDs. By contrast, the psychosocial pathway proposition is that psychosocial risk factors such as lack of autonomy, excessive work demands, and poor social support are precursors to MSDs. Contemporary efforts towards effective prevention of developing MSDs requires the investigation of dual aetiological pathways involving both psychosocial and physical risks (Eatough et al., 2012; Gerr et al., 2014a, 2014b; McLinton et al., 2019; Robertson et al., 2021). There is substantial evidence linking physical demands to MSD development (Converso et al., 2018; Wahlström, 2005; Welch et al., 2009). While evidence demonstrating how psychosocial factors at work contribute to prevalence of MSDs continues to grow (Robertson et al., 2021; Zare et al., 2021) psychosocial risks leading to MSDs are less widely recognised and researched (Leka et al., 2015; Macdonald & Oakman, 2015).

1.2. What is the gap

Understanding the kinds of work-related psychosocial and physical risk factors that are detrimental to workers' physical health is necessary to prevent MSDs. However, while integrative theoretical frameworks linking the dual pathways (physical and psychosocial) have been proposed (e.g., Bailey et al., 2015; Hämmig, 2020; Mateos-González et al., 2023) an integrative framework with PSC as the source of the pathways is missing. In an effort to establish the cause of the dual-process pathways, the 'cause of the causes' of physical and psychosocial risks, we include PSC. Although aspects such as leadership and organisational climate are implicated (Christensen et al., 2018), these factors are considered mainly as co-occurring proximal factors rather than potential distal determinants of MSDs and physical and psychosocial risk factors at work, leaving a gap in the explanation about more distal causes. Without optimal information about aetiology, efforts to prevent MSDs may be inefficient and misguided.

Given the prevalence and costs of MSDs, this paper aims to understand whether the psychosocial safety climate as the corporate climate for employees' psychological health is a distal cause of MSDs via the dual-process pathways due to its link to work conditions. Moreover, we aim to address the dearth of longitudinal studies in the field and shine more light on the causation of MSDs and the role of PSC, job demands and resources, by using longitudinal two-wave Australian population-based interview data from employees with a six-year lag. We extend the foundational work by Bailey et al. (2015) in the following ways (1) exploration of a time lag beyond one year between measurement points to enable exposure and time for causes to have effects, (2) investigate the role of job resources beyond job demands, and (3) exploration of more severe psychological health effects beyond emotional exhaustion (burnout) to include depressive symptoms. In this paper, we operationalize MSDs in three ways, in terms of (1) pain associated with MSDs, (2) doctor diagnosis of MSDs, and (3) workplace injury.

1.3. Current evidence and pathways leading to MSDs

A two process (physical and psychosocial) pathway (or mechanism) has been theorized to explain how work-related factors manifest and interact to impact physical health.

1.3.1. Physical pathways leading to MSDs

First, the physical pathway posits that biomechanical demands are a proximal antecedent to MSDs. It is well established that heavy lifting, frequent bending and twisting, and whole-body vibration are associated with frequencies for back and neck disorders (Coenen et al., 2014; Parreira et al., 2018). Further, combinations of push and pull activities, which frequently occur in manufacturing and office-based roles, are associated with hand/arm disorders (Gerr et al. 2014b; Hoozemans et al., 2014;). Conditions such as carpal tunnel syndrome, hand-arm vibration syndrome and tendonitis, are linked with exposure to repetitive tasks, forceful tasks, the combination of repetition and force, the combination of repetition and cold, and hand vibration (National Research Council and Institute of Medicine, 2001). Computer-based work involving increased mouse usage and poor seated posture are also known risk factors in MSD development (Wahlström, 2005).

For MSDs in other body regions (i.e., neck, shoulder, and knee) with pain, tenderness and stiffness, there is evidence that these conditions are associated with exposure to repetitive movement, improper static postures, and awkward positions (such as kneeling, squatting). Symptoms of MSDs are exacerbated by limited access to adequate resources such as appropriate ergonomic supports (Wahlström, 2005; Welch et al., 2009). In this study, physical risks are assesed in terms of physical demands, moving/lifting heavy loads, rapid and continuous physical activity, and working for long periods with the head/ body or arms in physically awkward positions. The current study expects physical demands to be positively related to MSDs.

1.3.2. Psychosocial pathways leading to MSDs

In addition to physical risks, research evidence shows the risk of developing MSDs from exposure to a range of psychosocial factors (i.e., Eijckelhof et al., 2013; Hauke et al., 2011; Lang et al., 2012; López-González et al., 2022). High levels of workload, monotonous tasks, low levels of job control, poor supervisor and coworker support are associated with disorders across multiple body regions including back neck and/or shoulder, upper and lower extremities (Hauke et al., 2011; Lang et al., 2012; National Research Council and Institute of Medicine, 2001; Yulita et al., 2014).

A recent systematic literature review focusing on the associations between psychosocial risk factors and the risk of MSDs at work, found that low job control, low job decision authority and low job satisfaction were significantly associated with an increase in the risk of MSDs (James et al., 2021). Psychosocial risk factors like inadequate social support, lack of control at work and high workload were also associated with increased risk of MSDs (Tang et al., 2022). Additionally, exposure to bullying, harassment, and violence is also a potential link to stress responses. Bullying at work has a detrimental impact on employee personal resources leading to an erosion of personal resources and decreased individual energy (Tuckey & Neall, 2014). Further, workers with less social support often express prolonged recovery time after superficial acute musculoskeletal injuries (Bailey et al., 2015).

One line of reasoning concerning why psychosocial factors relate to MSDs is that psychosocial stressors trigger physiological reactions, including biochemical stress responses potentially giving rise to increased muscle tension, co-activation and load on the musculoskeletal system (Bongers et al., 2006), decreased blood supply in the extremities (Visser & van Dieën, 2006), and prohibition of muscle repair (Theorell et al., 2002). There is evidence showing that psychosocial stressors make muscle fibres more susceptible to injuries, likely by permanently activating low-threshold motor units. An accumulation of these psychosocial factors increases the risk of future MSDs due to sustained exposure

and the depletion of resources and/or coping pathways over time (Bailey et al., 2015; Tuckey & Neall, 2014). Work stress is often associated with MSDs (Bongers et al., 1993). Research evidence from a review study on 54 longitudinal studies concluded that psychosocial factors contribute to the development of MSDs and should be regarded as a separate risk factor for MSDs (Hauke et al., 2011). López-González et al. (2022) investigated the interrelationships between physical and psychosocial risks and MSDs. They found that high exposure to both physical and psychosocial risks significantly predicts the likelihood of MSDs. Further, research by Eijckelhof et al. (2013) supports the hypothesis of synergistic effects between psychosocial factors and biomechanical factors that influence the MSDs. In the current study, psychosocial risks are assessed in the broad scope of job demands and resources. We expect psychosocial demands will positively relate and psychosocial resources to negatively relate to MSDs.

Additionally, early tests of elements of the psychosocial pathway (mechanism) showed that work demands related to emotional exhaustion (burnout), a state of psychological weariness, tiredness, or fatigue, but also impact physical health (Yulita et al. 2014). Similarly, research shows that psychosocial factors and depression are significant predictors of MSDs (Ng et al., 2019). Therefore, in the current study, we expect mental health issues (depressive symptoms and burnout) to positively relate to MSDs. In cross sectional research in health professionals (Hämmig, 2020), it was found that MSDs were most often the consequence of physical demands at work, followed by mental health issues (general stress). These propositions are integrated into the mediation hypotheses in Section 1.6.

1.4. Psychosocial safety climate as a common source of MSD causes

Psychosocial Safety Climate (PSC) is potentially a common cause of the dual-process pathways. PSC theory is an innovation in the field of work and organisational psychology (Dollard & Bakker, 2010; Dollard & Karasek, 2010; Law et al., 2011) and reflects the corporate climate to support employees psychological health and safety. PSC refers to 'policies, practices and procedures for the protection of worker psychological health and safety' (Dollard & Bakker, 2010, p. 579). PSC is specifically concerned with managerial values and action and incorporates management commitment, management priority, organisational communication, and organisational participation and involvement in the protection of employee psychological health and safety. PSC theory has promoted interdisciplinarity research through integrating work stress and safety science, bridging the construct of PSC. The construct is empirically distinct from related constructs such as team psychological climate, organisational social support, and safety climate (Idris et al., 2012). Whereas the safety climate construct predicts safety behaviour and injuries (Griffin & Curcuruto, 2016), PSC predicts psychosocial risks in work design and work conditions that in turn affect worker health, particularly psychological health. Previous research provides evidence that PSC is a leading indicator for psychosocial factors that impact psychological health, but also MSDs and physical health outcomes. This research includes evidence by Bailey et al., 2015 who found PSC to be a precursor to psychosocial risks (including workplace bullying, harassment and pressure), that in turn related to MSD's, supporting the psychosocial-physical pathway. However, it should be noted that although Bailey et al. (2015) had the potential to uncover longitudinal effects between psychological health and MSD, only cross-sectional effects of this linkage were found. Additionally, Garrick et al. (2014) also found support of PSC as a predictor of physical health problems mediated through increased job demands.

Other research has also investigated the relationship between PSC and physical health outcomes, including musculoskeletal issues, work-related injuries, and workers' compensation claims (Loh et al., 2020). Evidence found by Zadow et al. (2017) emphasized poor PSC plays a critical role in the psychological health erosion pathway, culminating in greater work-related injuries and underreporting of both physical and psychological injury, highlighting the need for future research to consider the physical-psychosocial safety explanation. PSC is specifically concerned with psychological health but reasonably it could have an expanded role, linking MSDs through psychosocial pathways. If so this provides even stronger science driven argument for better workplace PSC. Given the above we expect PSC to be negatively related to physical and psychosocial demands, and positively related to psychosocial resources. For efficiency these propositions are integrated into mediation hypotheses in Section 1.6.

1.5. PSC as a predictor of 'Causal' pathways

PSC research has supported the psychosocial pathway (Bailey et al., 2015; Garrick et al., 2104; Yulita et al., 2014; Zadow et al., 2017). In light of this research, the psychosocial pathway has been supported in combination with a physical pathway in relation to MSDs, though most findings have been limited to cross-sectional effects even where there has been the potential to uncover longitudinal effects (Bailey et al., 2015). This evidence has substantiated a new proposition that the PSC framework extends the health erosion pathway (Dollard & Bakker, 2010) of the Job Demands Resources Model (Demerouti et al., 2001) as a predictor of psychological health. The evidence also revealed an expanded function of PSC as a potential predictor for physical injuries at work via emotional exhaustion. Exposure to the psychosocial risk factors (i.e., bullying, harassment, and violence) affects the capacity to act safely or feel supported by safety systems at work, thus leading to more employee accidents (Tuckey & Neall, 2014). Therefore, it is necessary to understand workplace factors (psychosocial and physical factors) in the work environment to prevent work-related injuries.

The significance of these contributions was mirrored in later research integrating physical and psychosocial pathways to explain MSD risks in health care settings (Bronkhorst & Vermeeren, 2016). This multilevel cross-sectional study investigated the relationship between organisational safety climate (PSC and physical safety climate) and organisational health performance outcomes (i.e., absenteeism, presenteeism, health care utilisation) mediated by individual worker health (MSDs and emotional exhaustion/burnout). Three pathways were tested: a physical pathway commencing with physical safety climate mediated by MSDs; a psychosocial pathway commencing with PSC mediated by emotional exhaustion, and a pathway commencing with PSC mediated by emotional exhaustion → MSDs effect. Their findings did not support the physical pathway because the physical safety climate was unrelated to MSDs. The psychosocial pathway was supported in relation to health outcomes (absenteeism and presenteeism). The combined physical and psychosocial pathway explained differences in the third outcome: health care utilisation. The findings confirmed a cross-sectional psychosocial process mechanism, PSC → emotional exhaustion → MSDs (Bronkhorst & Vermeeren, 2016), but again these paths were cross-sectional.

1.6. The current study

In this study we focused on MSDs through the lens of psychosocial and physical mechanisms. As shown in Fig. 1, we use a dual-process framework to examine MSDs, with PSC as a lead indicator, and including a (1) physical and (2) psychosocial paths. Four hypothesised process paths are proposed as outlined in Fig. 1:

Path 1 (a + b): *Hypothesis 1* (PSC-physical pathway): PSC relates to physical factors that in turn relate to MSDs.
Path 2 (a + b): *Hypothesis 2* (PSC-psychosocial pathway): PSC relates to psychosocial factors (demands and resources) that in turn relate to MSDs.
Path 3 (a + b + c): *Hypothesis 3* (PSC extended psychosocial pathway predicting MSDs): PSC relates to psychosocial factors that relate to psychological health and in turn MSDs.

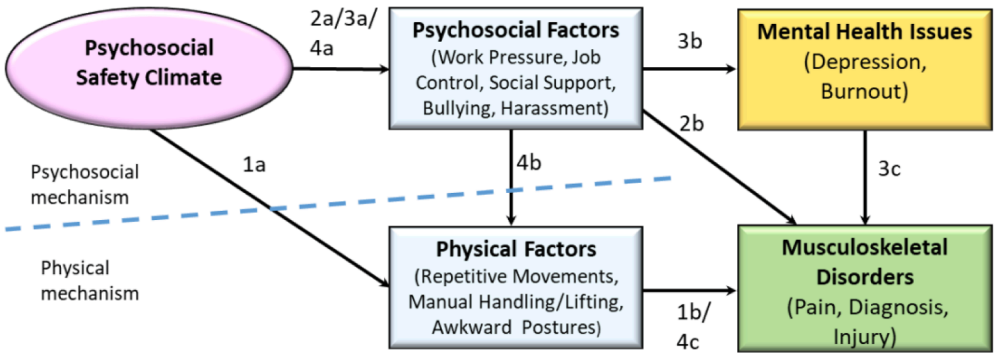

Fig. 1. Proposed Study Framework with Process Paths.

Path 4 (a + b + c): *Hypothesis 4* (PSC psychosocial mechanism predicting physical demands and MSDs): PSC relates to MSDs through psychosocial factors (demands and resources) and physical demands (transition hypothesis).

Note each of these hypotheses pertain to the three MSDs as per: (a) pain, (b) diagnosis, and (c) injury.

Mental ill-health symptoms such as emotional exhaustion are related to MSDs but only cross-sectionally (Bailey et al., 2015). Therefore, we included depressive symptoms as a stronger example of poor mental health to investigate any significant predictive (longitudinal) role in mediating the association of PSC or psychosocial and physical risk factors to MSDs (Zamri et al., 2017). We further extend Bailey et al. (2015) by exploring the role of resources in addition to demands, and explicitly investigating kinds of MSDs, pain, doctor diagnosis, and workplace injury.

We explored the relationships over a six-year period. It is likely that MSDs take time to manifest and short time intervals between antecedents and MSDs may lead to null results. Previously Bailey et al. (2015) found several links over a 12-month period, but not in relation to the impact of poor mental health on MSDs.

2. Research method

2.1. Design and participants

2.1.1. Participants and data collection

The data collection is part of a larger cohort Australian Workplace Barometer (AWB) study (with data collection in 2009, 2014–15 and 2020–21). We used the longitudinal data collected in 2014–15 and 2020–2021, recruited randomly from the Australian Electronic White Pages and a directory of Australian mobile phone numbers. We recontacted people who had previously participated in the AWB since 2009. Prospective participants received letters/SMS informing them of the study's purpose and the interview procedure. In the AWB study, a population-based random sampling approach ensured a representative sample (via post-stratification) of workers (18–65 year) across a range of organisations and industries.

The (name withheld for anonymity) cohort study, evaluated prior psychosocial risks for (i) MSDs and (ii) reported workplace physical risk factors in workers continuously (both T1 and T2) employed in three Australian states (NSW, WA and Vic) since Time 1. The matched sample (n = 432) was collected at Time 1 (2014/2015) and Time 2 (2020/2021) from employed workers over the age of 18 (Mean = 54 years), randomly selected at T1 via the Electronic White Pages from a wide range of occupations and industries (Bailey et al., 2015). The sample was approximately 45 per cent males (n = 193) and 55 per cent females (n = 239), with 65 per cent (n = 280) working full-time with an average income over $80 k. Most of the participants had higher education (bachelor's degree or higher, 51.6 per cent, n = 223; Certificate/Diploma, 27.8 per cent, n = 120) in 2014–2015. A further split of matched data from employees who remained within the same organisation across T1/T2, resulted in n = 269. The University XX's Human Research Ethics Committee approved this longitudinal study through different projects and ethics applications in each research time.

2.1.2. Survey method

Data were gathered using Telephone Interviews at T1 and T2. The interview method allowed for high-quality data due to the comparatively low response bias and good generalisability compared to web- or social media-based surveys and online self-report techniques (Kurniawan, 2018; Szolnoki & Hoffmann, 2013).

2.2. Measures

2.2.1. Potential risk factors for MSDs

The potential risk factors for MSDs were assessed by developing a list of risks and a range of responses in collaboration between the authors and based upon a priori hypotheses and previous research.

2.2.2. Demographics

These included age, gender, income, and education as used previously in the AWB. Age was measured based on year of birth. Gender identification was questioned by 'Do you identify as ….?' ranged as 1 (*Male*), 2 (*Female*), 3 (*Non-binary*), 4 (*Transgender Male*), and 5 (*Transgender Female*). However, only male and female groups were included due to the limited number of other gender groups in this study. Income was probed by 'Before tax is taken out, which of the following best describes your income from your main job in the last 12 months?' ranged from 1 (Up to $12,000) to 11 (More than $200,000). Education was discovered by asking 'What best describes the highest educational qualification you have obtained?' on a range of responses from 1 (Still at school) to 7 (Bachelor's degree or higher).

2.2.3. Psychosocial safety climate (PSC)

Psychosocial safety climate was assessed with the PSC-12 (Hall et al., 2010), which consists of four themes; management commitment, management priority, organisational communication, and organisational participation (see Table D in the supplementary materials). An example item is "Senior management considers employee psychological health to be as important as productivity". Responses were on a Likert scale from 1 (*strongly disagree*) to 5 (*strongly agree*) and summed up to present as PSC total score ($\alpha = 0.95$).

2.2.4. Psychosocial factors (Demands)

2.2.4.1. Work pressure.. *Work pressure* was measured using the five-item job demands scale from the new Job Content Questionnaire (JCQ 2.0; Karasek et al., 1998, https://www.jcqcenter.org). An instance item is "My job requires working very hard". We measured sum of all items on

a Likert scale, varying from 1 (*strongly disagree*) to 4 (*strongly agree*); α = 0.65.

2.2.4.2. Workplace harassment. We used seven items from Richman et al.'s (1996) scale to measure workplace harassment (e.g., "I have been sworn and/or yelled at.") and violence (i.e., "I have experienced being physically assaulted/threatened"). All the responses were on a 5-point Likert scale, varying from 1 (*very rarely/never*) through to 5 (*very often/always*) and summed up to present as workplace harassment (α = 0.70).

2.2.4.3. Workplace Bullying.. We assessed workplace bullying through an amended version of the QPSNordic Bullying Questionnaire (Dallner et al., 2000): Participants were asked, "Have you been subjected to bullying at the workplace during the last six months?" If they said yes, they were asked about length, frequency, and the position of the bully at work (a manager and/or a co-worker).

2.2.5. Psychosocial factors (Resources)

2.2.5.1. Job Control.. Scales from the JCQ 2.0 were used to measure two job control constructs; *skill discretion* (e.g., "I have an opportunity to develop my own special abilities.") α = 0.73; and *decision authority* (e.g., "My job allows me to make a lot of decisions on my own"); α = 0.76. A Likert response format was used for all items summed up for both scales (skill discretion and decision authority), with responses ranging from 1 (*strongly disagree*) to 4 (*strongly agree*).

2.2.5.2. Social Support.. The JCQ 2.0 scales were used to measure *supervisor social support* (e.g., "My supervisor/manager is helpful in getting the job done"); α = 0.85, and *co-worker social support* (e.g., "I am treated with respect by my co-workers"); α = 0.83. Responses ranged from 1 (*strongly disagree*) to 4 (*strongly agree*) summed up on both supervisor social support and co-worker social support scales.

2.2.6. Physical factors (Demands)

2.2.6.1. Physical job risks were measured using three items adapted from the JCQ-2.0 (Karasek et al., 1998). These are assessed as physical demands, moving/lifting heavy loads, rapid and continuous physical activity, and working for long periods with head/ body or arms in physically awkward positions. An example item is "My job requires lots of physical effort". We measured all the responses on a four-point Likert scale, extending from 1 (*strongly disagree*) to 4 (*strongly agree*) and summed up the items to present as physical job demands (α = 0.80).

2.2.7. MSD outcomes

2.2.7.1. MSD Pain.. MSD Pain was assessed with three items from the Nordic Musculoskeletal Questionnaire (NMQ; Kuorinka et al., 1987). This scale includes symptoms of pain in the back, neck, muscles, arms, legs, or joint areas like knee or hips, with an example item "[During the past 7 days] how much were you bothered by back or neck pain?". We evaluated the responses on a four-point Likert scale from 1 (*not at all)*, 2 (*a little*), 3 (*some*) to 4 (*a lot*), α = 0.68. From the four-point scale we constructed three pain levels, "*Not at all*", "*Some or a little*", and "*A lot*". We did this by defining: "*A lot*" as a respondent reporting this across any responses to neck or back, limb or joint or muscle soreness pain; "*Not at all*" by a match across all responses; and "*Some or little*" by any other match.

2.2.7.2. Doctor diagnosed musculoskeletal Disorders.. MSDs diagnosed were assessed with a list of common MSD conditions and asking the participants, "Has a doctor EVER told you that you have a musculoskeletal condition?" If yes: "what was it?". Thirteen common MSDs like "Carpal Tunnel Syndrome", "Tendonitis", "Muscle and or Tendon and/ or Ligament Strain", were provided with "*yes"* (1), "*no"* (0) responses. The number of MSDs diagnosed were added as the total score for this measure.

2.2.7.3. Physical injuries at Work.. Was assessed with a question asking, "Have you had a significant physical injury in the past 12 months?" that has arisen from inside the workplace. Response was 0 = no and 1 = yes.

2.2.8. Mental health issues

2.2.8.1. Depressive symptoms. Depressive symptoms were assessed using all nine items from the Patient Health Questionnaire (PHQ-9; Spitzer et al., 1999). The PHQ-9 is a self-report measure used for making diagnoses based on depressive episodes under DSM-IV criteria for a depressive disorder. The time reference for this study was modified to the last four weeks. Items were measured on a 4-point Likert scale, ranging from 1 (*not at all*) to 4 (*nearly every day*).

2.2.8.2. Burnout. Burnout was assessed with the five items from the Maslach Burnout Inventory (MBI; Schaufeli et al., 1996). Items were measured on a 7-point Likert scale, ranging from 1 *(never)* to 7 *(always)*.

2.3. Statistical analysis

SPSS-28 and AMOS-28 software (IBM Corp, 2021) were used to test hypotheses and perform all statistical analyses.

2.3.1. Analysis strategy 1

Depending on the nature of the outcome measure we used a logistic regression model (doctor diagnosis, injury), ordinal regression (pain) and linear regression (physical demands) to assess the multivariate association between workplace factors (psychosocial and/or physical) with MSDs.

To test Hypothesis 1 to 3 and the process paths depicted in Fig. 1, the effect of each component was tested in a series of nested multivariate regression models. All independent variables were at Time 1 with the dependent MSD measures at Time 2. The models and the Likelihood Ratio Test [LRT, Chi-Square Change] comparison models are:

Model 0: PSC.

Model I: PSC + physical risk. The LRT between Model I and Model 0 tells us whether there is a path between physical risk factors and MSD (path 1b). The amount and direction of change in the PSC estimate between Model 0 (without physical risk factors) and Model I (with physical risk factors) provides information about whether PSC predicts MSD *independently* of physical factors or *via* physical factors.

Model II: PSC + psychosocial risk. The LRT between Model II and Model 0 tells us whether there is a path between psychosocial risk factors and MSD (path 2b). The amount and direction of change in the PSC estimate between Model 0 (without psychosocial risk) and Model II (with psychosocial risk) will tell us whether PSC predicts MSD *independently* of the psychosocial risk or *via* the psychosocial risk factors.

Model III: PSC + psychosocial risk + mental health issues. The LRT between Model III and Model II tells us whether there is a path between mental health issues and MSD (path 3c). The amount and direction of change in the PSC or psychosocial risk estimates between Model II (without mental health issues) and Model III (with mental health issues) tells us whether PSC or psychosocial risk (path 2b) predicts MSD independently of mental health issues or via the mental health issues.

Model IV: PSC + physical risk + psychosocial factors + mental health issues. The LRT between Model IV and Model II tells us whether there is a path between physical risk factors and MSD that is independent of psychosocial factors (path 1b or 4c). The amount and direction of change in the PSC estimate between Model II (without physical risk) and Model IV (with physical risk) informs whether PSC predicts MSD independently of this path.

Model V: PSC + physical risk + psychosocial risk + mental health issues + demographics (gender, age, education, and income). Significant effects are over and above demographic effects.

Model VI: Model with MSD pain only as outcome; Baseline MSD pain + PSC + physical risk + psychosocial risk + mental health issues + demographics. Significance of effects are over and above baseline levels of MSD pain.

In addition, to test Hypothesis 4, we controlled for T1 physical hazards in an attempt to predict future work environments from prior work environments. We selected into this analysis workers from within the same organisation six years later (n = 269). The outcome was on an interval scale (Stevens, 1946), so we used linear regression, and applied the models as noted above (See Fig. 2).

Given the long time-lag between T1 and T2 and the expectation of small effects, and considering all hypothesised effects were directional, we used a liberal p value of 0.1 for bidirectional test significance. Considering half the p-value (i.e., p / 2) for the unidirectional test will still control for Type-I error at p =.05 Also as noted by Thiese et al. (2016) 'consideration of low p values (e.g., $p < 0.10$) as "trending toward statistical significance" may be clinically relevant for improving practice, particularly in smaller studies' (p. 929).

2.3.2. Analysis strategy 2

Next, we integrated all of the results into one SEM model (with the full sample, n = 432) (tests path 2a, 3a, 4a, 3b, 4b and all others). We used structural equation modelling (SEM) and AMOS 28 software to test mediation effects controlling for measurement error (Holmbeck, 1997).

3. Results

Means, standard deviations and correlations between variables at T1 (i.e., cross-sectional) and MSDs at T2 are shown in Table 1.

3.1. Results for analysis strategy 1

3.1.1. Predicting MSD pain at T2 from T1 measures

With MSD pain as the outcome, in the lagged Model 0, PSC was significantly negatively related B = -0.02, SE = 0.01, p =.06 (considering the conservative p =.1 adopted in the study, see Table 2). Physical demands added significantly to the model with PSC, (Model I), Chi-Square = 9.80, df = 2, p =.007. Chi-Square change = 6.37 > Critical value of 5.02, df = 1, p =.02, and positively related to MSD pain in the future, B = 0.13, SE = 0.05, p =.01. Model II added significantly to Model 0 which included PSC, Chi-square change = 13.48 > critical value 12.02 at df = 7, p =.10, with skill discretion negatively related B = -0.07, SE = 0.02, p =.005. A significant negative relationship between decision authority and MSD pain was not consistent with the hypotheses. Likewise, no psychosocial demands were related to MSD pain. Since PSC remained significant in the Model I with physical demands, but not psychosocial factors (Model II) this implies PSC is not mediated by physical demands but is via psychosocial factors.

Model III added burnout and depressive symptoms to Model II, and the fit was significantly improved with Chi-square change = 23.76 > critical value at 10.60, df = 2, p =.005. Depressive symptoms at T1 were significantly and positively associated with MSD pain at T2. Skill discretion remained negatively related to future MSD pain implying an independent path to MSD (not via mental health issues).

Model IV added physical demands to Model II, Chi-square change = 28.81 > Critical value of 16.26, df = 3, p =.001 with physical demands significant, B = 0.11, SE = 0.06, p <.05, reaffirming the strong direct effect of this on MSDs. Note in this model, skill discretion becomes not significant implying a possible path to MSDs through physical demands. Females also reported more future MSD pain than men, B = 0.56, SE = 0.22, p =.01. With physical demands and being female in the model, skill discretion and decision authority were no longer significant.

In Model V, adding depressive symptoms and burnout to the psychosocial + physical model was a significant improvement, Chi-Square change = 22.62, greater than the critical value of 13.82, df = 2, p =.001 with depressive symptoms, being female, and physical demands still significant in this model.

In the final model (Model VI), we added MSD pain T1 to Model V (note we did not have T1 measures for doctor diagnosed or workplace injury measures)with a significant improvement in model fit, Chi-square change = 66.23, greater than the critical value of 7.88, df = 15, p =.001. MSD Pain T1 was significantly positively associated with MSD Pain T2. Physical demands, depressive symptoms, being female were also significant. All together these preliminary tests imply that PSC could relate to future MSDs through psychosocial factors, physical factors, individual factors (gender) or mental health issues.

3.1.2. Predicting diagnosed MSDs at T2 from T1 measures

Model 0 PSC was significantly and negatively related to future MSD diagnosis, B = -0.02, SE = 0.01, p =.05 such that higher levels of PSC were associated with a lower likelihood of MSD diagnosis in the future. Other models were not significant. Aside from PSC, older workers reported more MSDs diagnosed, B = 0.03, SE = 0.01, p =.02 (see Table A in the supplementary materials).

3.1.3. Predicting physical injuries at work at T2 from T1 measures

Model 0 was not significant, PSC T1 was not related to future physical injuries. Model I added significantly to Model 0 with physical demands T1 significantly positively related to future physical injuries at work T2, B = 0.31, SE = 0.11, p <.001. Model II showed significant improvement on Model 0, Chi-square change = 14.01 df = 7, greater than the critical value of 12.02 at p =.05. Decision authority T1 was negatively related to physical injuries T2, B = -0.11, SE = 0.04, p <.01.

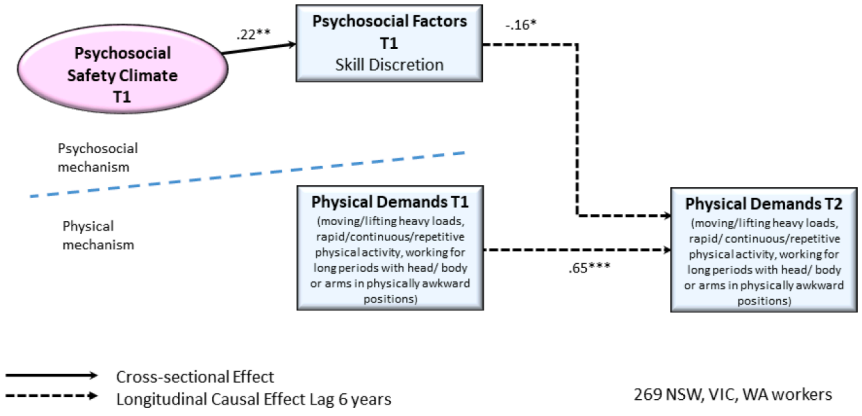

Fig. 2. Predicting Future Physical Demands.

Table 1
Means, Standard Deviations and Correlations.

	M	SD	N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1. Age (T1)	54	10.56	432	-																
2. Gender (T1)	1.55	.50	432	-.10*	-															
3. Income (T1)	6.77	2.39	409	-.12*	-.36**	-														
4. Education (T2)	5.97	1.50	432	.14**	.04	.16**	-													
5. PSC (T1)	40.44	9.70	432	.01	.01	.01	-.09	-												
6. Physical Demands (T1)	5.93	1.9	432	.02	-.01	-.19**	-.16**	-.06	-											
7. Psychological Demands (T1)	31.29	5.13	432	-.07	.07	.15**	.15**	-.36**	.11*	-										
8. Skill Discretion (T1)	35.27	5.19	432	-.05	-.01	.29**	.29**	.22**	-.23**	.03	-									
9. Decision Authority (T1)	35.56	6.15	432	-.13**	.01	.15**	.05	.35**	-.17**	-.10*	.45**	-								
10. Supervisors Support (T1)	9.36	1.69	432	.07	-.01	-.01	.03	.53**	-.09*	-.28**	.25**	.38**	-							
11. Co-workers Support (T1)	9.79	1.39	432	.02	.02	.03	.08	.31**	-.12*	-.12*	.30**	.24**	.47**	-						
12. Workplace Bullying (T1)	0.09	.28	432	.05	.00	-.01	-.05	-.29**	.08	.19**	-.08	-.17**	-.37**	-.22**	-					
13. Workplace Harassment (T1)	10.09	2.89	432	-.05	.07	-.01	-.01	-.36**	.22**	.30**	-.09	-.15**	-.32**	-.18**	.40**	-				
14. Depressive symptoms (T1)	3.59	4.09	432	.08	.04	-.16**	-.05	-.32**	.02	.19**	-.14**	-.18**	-.30**	-.19**	.25**	.31**	-			
15. Burnout (T1)	15.15	7.42	432	.14**	.00	.03	.02	-.36**	.03	.39**	-.05	-.23**	-.33**	-.15**	.21**	.38**	.54**	-		
16. Pain (T2)	2.07	.64	432	-.04	.15**	-.11*	-.11*	-.09	.12*	.05	-.15**	.01	-.04	-.05	.04	.08	.24**	.12**	-	
17. MSDs (T2)	0.25	.43	432	-.13**	.02	.06	.01	-.10*	.05	.13**	-.01	.01	-.07	.01	.11*	.13**	.05	.09	.24**	-
18. Work-related Injuries (T2)	0.05	.22	432	-.03	-.07	-.07	-.04	-.05	.15**	.05	-.08	-.15**	.04	.03	0	.04	.02	.04	.14**	.16**

Note: M = Mean, SD = Standard Deviation, Age (years), Gender (Male =1, Female=2), Income (7= $60,001 - $80,000/yrs.), Education (6= Certificate / Diploma), T = Time, PSC = Psychosocial Safety Climate, MSD = Musculoskeletal Disorders, * $p < .05$, ** $p < .01$. Education T2 was provided due to drop in education level from T1, that may contribute to increased individual risk factors (2-tailed).

Table 2
Predicting MSDs Pain at T2 from T1 Measures.

Model	T1	B	SE	p	2.5%	97.5%	Chi-Square (*df*)	p	R^2	Chi-Square Change (*df*)	p
0	#PSC	−0.02	0.01	0.06	−0.04	0.00	3.43 (1)	0.06	.008		
I	#PSC	−0.02	0.01	0.08	−0.04	0.00	9.80 (2)	0.007	0.02	6.37 (1)	.02
	Physical Demands	0.13	0.05	0.01	0.03	0.23					
II	#PSC	−0.02	0.01	0.21	−0.04	0.01	16.91 (8)	0.031	0.038	13.48 (7)	.10
	Psych Demands	0.01	0.02	0.64	−0.03	0.05					
	Skill discretion	−0.07	0.02	0.00	−0.11	−0.03					
	Decision authority	0.04	0.02	0.04	0.00	0.08					
	Supervisor support	0.04	0.08	0.64	−0.11	0.18					
	Co-worker support	0.00	0.08	1.00	−0.16	0.16					
	Bullying	0.08	0.38	0.84	−0.67	0.82					
	Harassment	0.04	0.04	0.34	−0.04	0.11					
III	PSC	−0.01	0.01	0.51	−0.03	0.02	40.67 (10)	0.000	0.09	23.76 (2)	.005
	Psych Demands	0.01	0.02	0.75	−0.04	0.05					
	Skill discretion	−0.07	0.02	0.00	−0.11	−0.03					
	Decision authority	0.04	0.02	0.02	0.01	0.08					
	Supervisor support	0.06	0.08	0.40	−0.09	0.22					
	Co-worker support	0.02	0.08	0.84	−0.14	0.17					
	Bullying	0.01	0.39	0.99	−0.75	0.77					
	Harassment	0.00	0.04	0.91	−0.07	0.08					
	Depressive symptoms	0.13	0.03	0.00	0.07	0.19					
	Burnout	0.00	0.02	0.99	−0.03	0.03					
IV	PSC	−0.00	0.01	0.09	−0.03	0.02	45.72 (11)	0.010	0.07	28.81 (3)	.10
	Physical Demands	0.11	0.06	0.05	0.00	0.22					
	Psych Demands	0.01	0.02	0.69	−0.03	0.05					
	Skill discretion	−0.04	0.02	0.13	−0.08	0.01					
	Decision authority	0.03	0.02	0.12	−0.01	0.07					
	Supervisor support	0.04	0.08	0.59	−0.11	0.20					
	Co-worker support	−0.01	0.08	0.89	−0.17	0.15					
	Bullying	0.02	0.40	0.95	−0.76	0.81					
	Harassment	0.01	0.04	0.77	−0.07	0.09					
	Depressive symptoms	0.13	0.03	0.00	0.07	0.19					
	Burnout	0.00	0.02	0.90	−0.03	0.04					
V	PSC	−0.01	0.01	0.28	−0.04	0.01	50.22 (15)	0.000	0.12	22.62 (2)	.001
	Physical Demands	0.14	0.06	0.01	0.03	0.25					
	Psych Demands	0.00	0.02	0.87	−0.05	0.04					
	Skill discretion	−0.04	0.02	0.08	−0.09	0.01					
	Decision authority	0.03	0.02	0.08	0.00	0.07					
	Supervisor support	0.08	0.08	0.32	−0.08	0.24					
	Co-worker support	0.01	0.08	0.88	−0.15	0.18					
	Bullying	−0.01	0.41	0.97	−0.81	0.78					
	Harassment	−0.03	0.04	0.50	−0.11	0.05					
	Depressive symptoms	0.12	0.03	0.00	0.06	0.19					
	Burnout	0.01	0.02	0.63	−0.03	0.04					
	Female	0.60	0.22	0.01	0.16	1.04					
	Age (Yr of Birth)	−0.01	0.01	0.59	−0.03	0.01					
	Education	−0.09	0.07	0.23	−0.23	0.06					
	Income	0.02	0.05	0.76	−0.08	0.11					
VI	MSD Pain	0.96	0.17	0.00	0.62	1.29	83.14 (16)	0.000	0.18	66.23 (15)	.001
	PSC	−0.01	0.01	0.47	−0.04	0.02					
	Physical Demands	0.14	0.06	0.01	0.03	0.26					
	Psych Demands	−0.01	0.02	0.57	−0.06	0.03					
	Skill discretion	−0.04	0.02	0.12	−0.09	0.01					
	Decision authority	0.03	0.02	0.11	−0.01	0.07					
	Supervisor support	0.09	0.08	0.28	−0.07	0.25					
	Co-worker support	−0.02	0.09	0.77	−0.19	0.14					
	Bullying	0.02	0.42	0.96	−0.79	0.83					
	Harassment	−0.02	0.04	0.62	−0.10	0.06					
	Depressive symptoms	0.12	0.03	0.00	0.05	0.18					
	Burnout	0.00	0.02	0.96	−0.04	0.03					
	Female	0.53	0.23	0.02	0.08	0.97					
	Age (Yr of Birth)	0.00	0.01	0.94	−0.02	0.02					
	Education	−0.06	0.07	0.40	−0.21	0.08					
	Income	0.01	0.05	0.77	−0.09	0.12					

Note: N =432, T =Time, PSC = Psychosocial Safety Climate, MSD = Musculoskeletal Disorders, R^2 = Cox and Snell pseudo r-sq, *df* = degree of freedom.

Against expectations supervisor support was significantly positively related to injuries. Model III, IV and V were not significant. With all variables in the model (Model V), physical demands and decision authority remained significant in the model, along with older age, male and lower income (see Table B in the supplementary materials).

3.1.4. Predicting physical demands at T2 from T1 measures

Model 0 showed that PSC was not directly associated with physical

demands. Physical demands T1 were significantly positively related to future physical demands (Model I) B = 0.76, SE = 0.05, p <.001. Model II showed that at T1, skill discretion B = -0.11, SE = 0.03, p <.001 was negatively related and harassment B = 0.16, SE = 0.05, p <.001 was positively related to physical demands at T2. Poor psychological health (depressive symptoms) was not associated with future exposure to physical demands (Model III). When controlling for baseline physical demands, harassment was no longer significant implying a relationship between harassment and physical demands T1 and a possible mediation process (Model IV) (see Table C in the supplementary materials). Demographics were not significant. A summary of findings for physical demands is shown in Fig. 2.

3.2. Results for analysis strategy 2

3.2.1. Comparison of Alternative models

Analysis strategy 2, structural equation modelling (SEM) was used to formally test mediation effects and control for measurement error (Holmbeck, 1997). We included variables in the model when significant relations were found in the regression analyses. PSC was found as a latent variable indicated by the four subscales. Decision authority, skill discretion, harassment and physical demands, depressive symptoms and MSDs were observed variables (to save degrees of freedom). The structural model allowed covariation between the structural residuals of all variables at T1 that had no specified paths between them, and between all MSDs at T2.

We used goodness-of-fit indices to assess model fit (cf. Jöreskog & Sörbom, 1993); the $\chi 2$ goodness-of-fit statistic; the root mean square error of approximation (RMSEA); the goodness of fit index (GFI); the comparative fit index (CFI); and the normed fit index (NFI). Values of 0.95 or higher for GFI, CFI and NFI are indicative of a very good fit (Hoyle, 1995) and RMSEA-values less than or equal to 0.05 indicate a good fit (Schermelleh-Engel, Moosbrugger, & Muller, 2003). We also assessed relative fit with the AIC, Akaike information criterion, (lower values indicate better fit). In predicting future demands (prior test), it appeared that harassment was related to future demands and that this was mediated by T1 demands, this path was also included in the model. Also, a covariance path was added between two PSC subscales given their high degree of correlation. At the first pass, income, gender, and age were not associated with work injury and these paths were removed from the model. Model M1 is represented in Table 3 as the mediated model demonstrating the fit is very good and is represented in Fig. 3. We tested a PSC direct effects model against this model, estimating PSC to MSD outcomes, retaining the demographic paths and setting all other paths to zero. The direct effects Model 2 was a significantly inferior model than the mediated model, but PSC was significantly related to MSD pain and MSD diagnosis. M3 added to M1 paths from psychosocial to depressive symptoms path, which did not improve model fit. Accepting M1 as the final model, Table 4 shows the mediation paths and the significance of the indirect effects.

3.2.2. Hypothesis Results: Proposed mediation paths and significance of Indirect effects

Path 1: Hypothesis 1: PSC-physical pathway: PSC relates to physical factors that in turn relate to MSDs. There is no support for Hypothesis 1. There is no direct relationship between PSC and physical demands (section 3.1.4) so there is no support for this hypothesis.

Path 2: Hypothesis 2: PSC psychosocial pathway: PSC relates to psychosocial factors (demands and resources) that in turn relate to MSDs. There is some support for Hypothesis 2, where PSC is related to decision authority that in turn relates to work injury (Path 2, Table 4).

Path 3: Hypothesis 3: PSC extended psychosocial pathway predicting MSDs): PSC relates to psychosocial factors that relate to psychological health and in turn MSDs. Since M3 did not improve M1 (strategy 2; also strategy 1, Table 2, MIII added depressive symptoms and did not reduce the main effects of psychosocial factors), Hypothesis 3 is not supported. Rather PSC is related to MSD pain through depressive symptoms (Path 3, Table 4).

Path 4: Hypothesis 4: PSC relates to MSDs through psychosocial factors (demands and resources) and in turn physical demands. There is support for this transition effect, Hypothesis 4. PSC is mediated by skill discretion and harassment in its relationship to physical demands and in turn MSDs (Path 4, see Table 4).

A summary of all the strategy 2 results are provided in Fig. 3.

4. Discussion

The current study aimed to investigate Psychosocial Safety Climate (PSC) as a distal cause of MSDs through physical and psychosocial process paths to MSDs over six years. We found that MSDs could be predicted by working conditions six years earlier. Further, we found evidence for several psychosocial paths; PSC was related to future MSD (work injury) through decision authority; PSC was related to MSD pain through depressive symptoms; PSC was related to MSDs through psychosocial factors that in turn related to physical demands. For example, PSC was related cross-sectionally to skill discretion and harassment which predicted future physical demands and in turn MSD pain and workplace injuries. For future doctor diagnosed MSDs, PSC was directly negatively related, and age positively. A novel finding was the linkage between skill discretion and future MSD related pain via physical demands, highlighting a new pathway – how psychosocial pathways relate to physical pathways. In terms of doctor-diagnosed MSDs, PSC was a direct effect rather than a mediated effect. Overall poor PSC was found as a distal antecedent of MSDs. Workplace autonomy (decision authority and skill discretion) was a critical factor in predicting future pain and workplace injury.

The findings broadly support other studies in this area linking workplace physical and psychosocial risk factors and MSDs (e.g., Hauke et al., 2011; Lang et al., 2012; Leka et al., 2015; Macdonald & Oakman, 2015). However, what our research demonstrates, not tested by Bailey et al. (2015) is the transition from psychosocial to physical in the progression to MSDs. Moreover, our study showed that resources in the form of job control were just as important as other research highlighting the critical effects of job demands (i.e., Bailey et al., 2015). Another

Table 3
Comparison of Alternative Models.

	χ^2	*df*	GFI	CFI	NFI	RMSEA	AIC	$\Delta\chi^2$ (df) sig
M0. Null model	313.34	58	.91	.84	.82	.10	407.34	
M1. Fully mediated	95.64	48	.97	.97	.94	.05	209.05	M1 vs M0 217.70 (1), $p < .001$
M2. Direct effect	305.76	55	.92	.84	.82	.10	405.76	M1 vs M2 210.12 (7), $p < .001$.
M3. Plus Psychosocial	157.94	49	.95	.93	.91	.07	269.94	M1 vs M3 62.30 (9), $p < .001$.

Note. $\chi 2$ goodness-of-fit statistic; GFI = Goodness of Fit Index; CFI = Comparative Fit Index; NFI = Normed Fit Index; AIC, Akaike information criterion; RMSEA = Root Mean Square Error of Approximation.

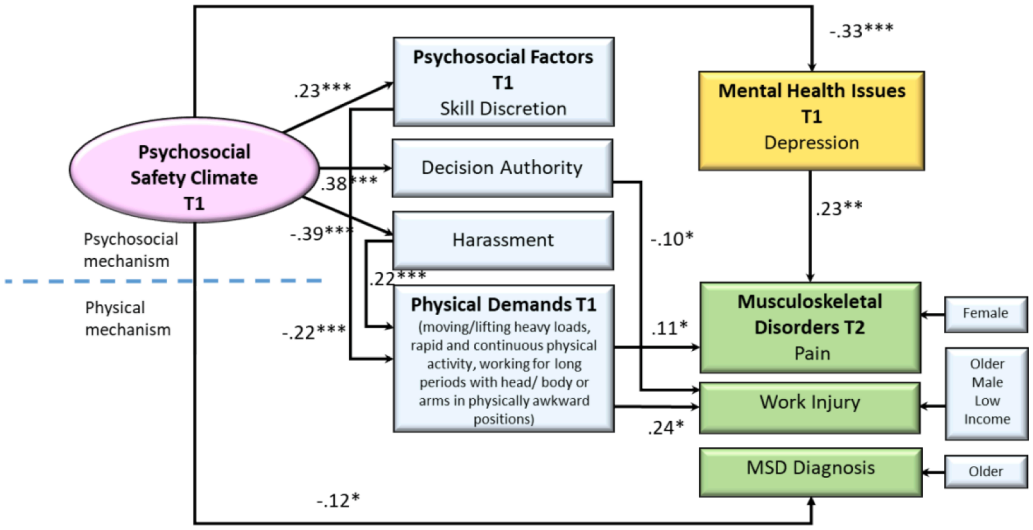

Fig. 3. Predicting Future MSDs.

Table 4
Mediation Paths and the Significance of Indirect Effects.

Path^	Indirect Mediation Paths	LL	UL	p
Path 4	PSC→ Skill Discretion →Physical Demands	−.08	−.02	.01
Path 4	PSC→Harassment→Physical Demands	−.12	−.05	.02
Path 4	Skill Discretion→Physical Demands→Workplace Injury	−.003	.000	.03
Path 4	Skill discretion→Physical Demands→MSD pain	−.007	−.001	.02
Path 3	PSC→Depressive→MSD Pain	.000	−.016	.01
Path 2	PSC→Decision Authority→Work Injury	−.01	−.002	.01
Path 4	Harassment→Physical Demands→Work Injury	.001	.004	.03
Path 4	Harassment→Physical Demands→MSD Pain	.002	.010	.02

Note. ^ refer to Figure 1; paths relate to Hypothesis of the same number.

noteworthy point is that the results varied according to the MSD outcome under consideration which could explain mixed results in previous studies. Still, the results generally support the study model, suggesting that the combination of work-related psychosocial and physical pathways are essential in accounting for MSD outcomes, and that MSDs can be potentially traced to the corporate climate for worker psychological health and safety (PSC). The results support previous studies demonstrating that PSC and psychosocial risk factors impact work-related injury causation and rehabilitation (Bailey et al., 2015). Knowing about PSC, the evidence suggests that levels of psychosocial risk factors such as low job control (skill discretion, decision authority) can be estimated. The reason psychosocial risk factors were linked to MSDs was not through mental health issues, but rather directly (decision authority) or indirectly (skill discretion) through physical demands. Independent of these findings, PSC was also found to be related to MSD pain through the experience of mental health issues (burnout, depressive symptoms).

While physical demands are well recognised as precursors to MSDs, there is growing evidence of the critical role of psychosocial factors potentially due to biochemical stress responses, involving muscle tension (Bongers et al., 2006), reduced blood supply (Visser & van Dieën, 2006), less opportunity for muscle repair, and muscle fibre weakness increasing susceptibility to injuries (Theorell et al., 2002).

The effects noted were over and above other demographic effects found, with few demographic effects noted in the final model (see Table 2). Our results show that physical demands predicted future physical demands. Over and above this effect, low skill discretion was related to future physical demands at work (the effects of harassment were mediated by physical demands). Mental health issues (burnout, depressive symptoms) Time 1 were not related to future exposure to physical demands. This is an important finding since it gives weight to working conditions as the cause of future physical demands, rather than an individual worker's vulnerabilities.

4.1. *Theoretical implications*

This research is indicative of three major theoretical contributions. First, our research provides further insight into the critical role of PSC as a corporate climate within organisations and provides an understanding of MSDs as an outcome of combined physical and psychosocial pathways and their interplay. This accords with previous literature that suggests a dual process. Research by Zadow et al. (2017) highlighted the dual role of physical and psychosocial safety climates in predicting future registered injury rates. Additionally, the critical role of psychosocial risks is also highlighted in a recent literature review by James et al. (2021). They found that psychosocial factors of workplace support, job control and job demands are related to MSDs. Our research suggests that job demands (physical only) and job resources (such as skill discretion and decision authority) are essential precursors to MSDs. Second, in terms of psychosocial factors, job resources seem more important as precursors to MSDs. While psychosocial demands are likely important our research suggests psychosocial resources are more important. This implies that theorizing about MSDs should include and emphasise job resources. Third, we theories a transition from psychosocial to physical risks in the development of MSDs. In a low PSC context, with low skill discretion, physical demands emerge which result in MSDs. It is likely that the employee has little opportunity to use different skills which may result in carrying out tasks in a repetitive or continuous fashion for long periods or moving/lifting heavy loads without being able to use skills to modify tasks, and working for long periods with head/ body or arms in

physically awkward positions.

4.2. Practical implications

The finding that psychosocial factors play a role in MSDs supports a fresh preventive approach. A novel intervention not yet tried to improve MSD status among employees would be to focus on enhancing PSC. Since PSC is an antecedent to many risk factors, enhancing PSC would be an efficient focus. As illustrated by Dollard & Bailey, 2021, PSC intervention is achievable within a short period, and would be imperative in the optimisation of workplace mental health. Increasing PSC would entail improving communication systems, participation, and management to reduce psychosocial risks.

In occupations where workers are exposed to low skill discretion, this may imply that employees have little agency and cannot take local actions to reduce or manage physical demands. Low income likely indicates fewer personal resources to seek and receive early treatment. Given the predictability of workplace factors on MSDs and health, and that those factors identified are preventable or modifiable, action should be taken to target these in order to eliminate and/or reduce risk, such as improve PSC and skill discretion and reduce harassment. Although we have identified some associated factors with MSDs, the predictive effects are small but targeting each may have an incremental impact. Further, though we cannot tell from the current design, it should be considered that effects could be larger at time intervals less than six years.

The finding that MSDs can be predicted from working conditions six years earlier despite that those employees may be working for a different organisation, should raise concerns about long range effects, where costs may be transferred to other organisations, the health care system, and the individual employee.

4.3. Limitations and future directions

Innovative research conducted within the current study was to test the role of PSC as a leading indicator of MSDs (a 'cause of the causes' of other risk factors). The results align with this notion, but we could not establish a longitudinal relationship between PSC and risk factors, possibly due to the long-time lag and limited sample size. Many other studies have found support for the longitudinal association between PSC and risk factors when assessed at shorter intervals (for a review, see Loh et al., 2020), therefore we do not suggest a revision of the assumptions of this relationship.

A limitation for the research was securing responses to requests for a telephone interview. The timing of the research was during the COVID-19 pandemic. The final number of responses was smaller than desired. We could not find longitudinal associations between PSC, risk factors and outcomes except that PSC predicted future MSD diagnosis. It might be that the length of time between measures (six years) rendered this relationship too small to detect. Assessing risk levels of PSC may prove beneficial for assessing relations across time (e.g., predicting new major depression, Zadow et al., 2021). Future research could focus on designing and evaluating interventions that focus on leading indicators of MSDs.

5. Conclusion

MSDs are predictable outcomes of PSC, physical demands, skill discretion, decision authority, harassment, and psychological health status from many years earlier. The results suggest a much greater focus in any MSD strategy on interventions to reduce psychosocial risk factors since these factors directly predicted MSD outcomes or physical demands, which is the primary cause of MSDs. The study also supports data-driven approaches to intervention and evaluation to ensure the right risk factors are targeted.

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CRediT authorship contribution statement

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ssci.2023.106177.

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