

Impact of Workplace Ergonomics, Musculoskeletal Disorders, and Productivity among Office Employees

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Received: 29-12-2025

Revised: 17-01-2026

Accepted: 22-02-2026

Published: 06-03-2026

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DOI: 10.63056

ABSTRACT

Increasingly, workplace ergonomics is considered a factor that decides employee health and organization performance. The aim of this study was to determine the effect of ergonomic workplace conditions on musculoskeletal disorders (MSDs), and the productivity of office workers, in a quantitative (quantitative cross-sectional) design. A purposive sampling of 280 office workers of the public and private sector organizations was selected. A structured questionnaire with Ergonomic Assessment Checklist, Nordic Musculoskeletal Questionnaire (NMQ) and a validated productivity scale were used to collect data. The analysis techniques that were used are descriptive statistics, pearson correlation analysis and the method of structural equation modeling (SEM) using Amos software. Internal reliability of scale (Cronbach's α coefficients: .80–.84) indicated scale sufficiency. The results of the correlation analysis showed that there was a highly significant negative correlation between ergonomic conditions and MSDs ($r = -.55, p < .001$), while a highly significant positive correlation was found between Ergonomic condition and productivity ($r = .52, p < .001$). The total direct and indirect effect of ergonomic conditions on productivity through the mediation of MSD was $\beta = .51$, and was confirmed by SEM. Model fit was satisfactory ($\chi^2/df = 2.07$; CFI = .96; RMSEA = .062). The results of this study clearly show that poor ergonomic environments cause increased workload stress and reduction in worker productivity, thus pointing to the business and health motivations to implement systematic (ERP) ergonomic studies in the office.

Keywords: workplace ergonomics, musculoskeletal disorders, employee productivity, Nordic Musculoskeletal Questionnaire, structural equation modeling, occupational health

INTRODUCTION

The modern office has integrated a number of physical hazards connected to work with prolonged sitting, keyboard and mouse activity, poorly adjusted work stations and lack of posture support to make occupational health risk a new form of chronic cumulative strain injuries. MSDs are the most common type of work-related condition in countries around the world, and they include, but are not limited to, pain, discomfort and functional impairment in regions such as the neck, shoulder, back, wrist or lower extremities. ILO (2019) suggests that about 37% of all work-attributable diseases are work related MSDs and are the most common cause of work disability in developed and developing countries. Even with this extra cost burden, many organizations are not investing in ergonomic interventions because they overestimate the up-front cost, and don't realize that the financial and productivity losses due to MSD-related absenteeism, presenteeism and turnover can be compound.

The International Ergonomics Association's definition for workplace ergonomics is a "science which aims to design work, products, services, equipment, and workplace to fit the physical and cognitive property of the person to improve efficiency, safety, and wellbeing" (IEA, 2021). Ergonomic risk factors in office environment conditions include for example static/harmful sitting and standing positions, poor chair support, incorrect monitor height or poor monitor placement outside neutral visual range, lack of adjustment of the workstation, repetitive fine motor task, and insufficient use breaks for computer exposures (Hartvigsen et al., 2018). Each of these can collectively place a strain on musculoskeletal structures, causing microtrauma which if left untreated, will move forward to form a clinically significant pain syndrome, limitation of motion and neurologic symptoms including carpal tunnel syndrome and cervicogenic headache.

The downstream effects of MSD presence on the productivity of employees are known and unfortunately poorly understood in organizations. Productivity as part of occupational health includes objective performance measures and worker is the decision maker's subjective perceptions of work performance and efficiency and/or ability to complete a task. MSDs reduce productivity in various ways: they are associated with absenteeism including acute pain episodes; cognitive-behavioural factors, namely concentration and fine motor precision which are likely to be affected by chronic low level pain symptoms; fear-avoidance behaviour which prevents voluntary participation in cognitively challenging activities; and psychological co-morbidities associated with low back pain (LBP) such as anxiety and depression, which are also common with chronic pain and are acknowledged to have a negative impact on occupational functioning (Burton et al., 2004). By quantifying these pathways with structural models, organizations can have proof to action for investing in ergonomics.

Various conceptual approaches have been used to deal with the relationship between ergonomics, MSD and productivity. The NIOSH Work Organization Model (Sauter et al., 1990) also suggests that workplace stressors (e.g., ergonomic shortcomings) evoke immediate "strains" (e.g., fatigue, pain), which, if left unaddressed, produce long-term "strains" of health losses (e.g., chronic pain) and organisational losses (e.g., lowered productivity, higher labour turnover). This approach is consistent with the demand-resources model where lack of ergonomic resources heightens job demands and results in less than optimal performance. In the current study, the operationalization of this framework is done by using MSD as the mediating mechanisms of ergonomic quality influencing productivity in a structural equation modeling.

The three specific objectives of this study were: (1) to describe the conditions of the working environment, MSD prevalence, and productivity of office workers in public and private sector organisations; (2) to investigate bivariate relationships between the workplace conditions, MSD prevalence, and office workers' productivity; and (3) to test a structural model of the relationships between workplace conditions, MSD prevalence, and office workers' productivity, where MSD prevalence is the mediator between the independent variables (conditions of the working environment) and the dependent variable (office workers' productivity). The study adds value to the field of occupational health in terms of its provision of the structural evidence supporting the MSD-mediated pathway in a particular context of rapid growth of employment in the office sector in a country in South Asia where ergonomic standards and enforcement practices are still in their infancy. Findings are to be used to help guide organizational policy, OH practice and regulatory regimes about workplace safety.

LITERATURE REVIEW

There has been a large amount of research that has looked into the link between ergonomic work conditions and MSD's in various job settings. Punnett and Wegman (2004) undertook a large systematic review of

world literature and estimated that 37% of all cases of back pain could be explained by occupational factors, and that awkward postures and overuse/repetitive work movements were particularly significant. This basic research provided the foundation for ergonomic intervention as a key preventative measure against MSD and led to several decades of pragmatic research in the field of computer and office-based work interfaces.

Computer-based office tasks have a unique ergonomic risk profile unlike manual or industrial tasks. Dimmers are the MSD most particularly associated with the sitting of computer workers. Gerr et al. (2002) carried out a prospective cohort study of cadets hired as computer workers and identified that approximately 22% developed some kind of neck and shoulder MSD within 12 months to their computer working, both workstation dimensions and time spent on the keyboard being most powerful predictors. The prevalence is similar to that of the Asian office worker population. In the study conducted by Sharan et al. (2011), 54% of office workers in India experienced neck pain and 45% had low back pain as a result of lack of monitor's height and not being able to adjust seating. These consistencies in a cross cultural way strengthen the sense of universality of ergonomic risk in computer-dominated work places.

Nordic Musculoskeletal Questionnaire (Kuorinka et al., 1987) has been used to monitor work-related MSDs for epidemiological studies, and has been accepted as the gold standard in the field. The NMQ measures the presence of pain, aching, or discomfort in nine body regions for 12-month and 7-day recall periods, and exhibits satisfactory test-retest reliability (kappa ranging from .60 to .80 across regions) and criterion validity to clinical exam findings. It has been widely used, allowing for cross-study observations and sufficient meta-analytical syntheses to progress the understanding of MSD epidemiology in office environments.

Ergonomic interventions for workstation design have been proven to have an impact on MSD symptom burden on an ongoing basis. Very recent findings out of a larger Cochrane review by Amick et al. (2012) indicate that adjustable workstations, ergonomic alternatives to keyboard and mouse, and combination training plus equipment programs can reduce the prevalence of symptoms of the neck and upper extremities by 20–40%, compared to usual. But, the review also pointed out that single-component interventions invariably also proved less effective than multi-component programmes, reinforcing the need for a whole ergonomic system approach to interventions.

Some of the more widely studied ergonomic variables associated with the most costly and common MSD category in offices is sitting posture and more specifically – lumbar support. O'Sullivan et al. (2012) showed in a controlled laboratory experiment that a forward-inclined dynamic sitting posture with the correct amount of lumbar support had significantly less disc compression forces and muscle activity than less desirable sitting postures. The biomechanical evidence showed that maintaining a forward-inclined dynamic sitting posture with proper lumbar support was important for biomechanics when designing ergonomic seating standards. These results have been confirmed by show data in the field; adjustable lumbar support is among the strongest equipment level predictors of overall reduced low back pain.

The economic losses resulting from MSDs have been estimated using various methodological approaches. Hemp (2004) estimated that cost to US employers of "presenteeism," or impairment from compromise of productivity due to health issues at work is roughly \$150 billion per year, and musculoskeletal pain is one of the three most frequent causes of "presenteeism" losses. In particular in the office setting, Stewart et al. (2003) analyzed a nationally representative timeseries of workers with neck and back pain and concluded that those workers were missing 3–10% of their productive work days even on days when they were not reporting sick. These estimates further highlight the productivity impact of MSDs goes beyond just reporting absenteeism, and is best measured using tools that record on-the-job impairment.

Demographic adjusters that moderate the relation between ergonomics and MSD are important: job tenure and age. Longitudinal studies consistently show the prevalence of MSD to be higher with greater length of computer work exposure and a dose-response relationship between symptom prevalence and computer work exposure duration, with those of workers with >5 years of continuous computer-based work having substantially higher prevalence of neck and upper extremity symptoms compared to newer entrants to the computer work field (Bongers et al., 2006). All problems of musculoskeletal resilience, even when they are due to age-related factors such as reduced hydrated properties of the discs, delayed healing rates, and lost elasticity of muscles, are magnified in the older worker and are important in designing an ergonomic program by age.

Gender differences in MSD have been repeatedly reported with higher prevalence of disorders of the neck and upper extremities (UE) among female workers and higher prevalence of low back pain (LBP) among males (Nordander et al., 2008). Some of these differences can be explained by anthropometric and biomechanical considerations, such as the smaller height of women compared to the standard parameters for a workstation; other differences stem from psychosocial factors such as the higher mental load of emotional labour and reduced working domain autonomy and decision making in many office jobs. Historically, ergonomics design guidelines have been derived from male anthropometric standards that may not fully address the characteristics of female workers, resulting in a body of research that is also gender specific. Ergonomics design standards have traditionally been developed to address male norms, and may not adequately address the norms of females which may contribute to gender differences in MSD risk.

Studies on the relationship between ergonomics with MSD have increasingly focused on the role of work factors. Social and psychosocial aspects of work have recently been studied and discussed in relation to ergonomics and MSD. In an early review Bongers et al. (1993) concluded that there was a basis for establishing associations between low job control, high job demands, and poor social support and heightened MSD risk, beyond the physical ergonomic exposures. Follow-up studies confirmed interactions between the psychosocial and physical factors, thus furthering the challenges with ascribing causation for MSDs and highlighting the importance of a comprehensive physical-psychosocial approach to OH interventions.

Some of the best supported behavioural ergonomic interventions for office workers are rest breaks and micropauses. In 2000, Galinsky et al. did a randomized controlled trial that showed that supplemental rest breaks led to higher productivity ratings and lower musculoskeletal discomfort than standard break schedules and that there was no effect on the overall amount of time lost to breaks. In newer studies software-assisted microbreak programs have led to comparable effects with only short breaks in static postures and repetitive motor patterns proven to be sufficient to get musculoskeletal benefits.

Structural Equation Modeling (SEM) has found application in a number of occupational health studies, which have sought to identify the relationship between ergonomic conditions and later health and performance outcomes. Building on this, Hoe et al. 2012 used SEM to test the hypothesis that workstation discomfort is a crucial mechanism that reduces productivity as a result of poor ergonomics, with a result that about 60% of the total, effect of ergonomic risk score on self-reported productivity impairment was explained by workstation discomfort. The current research takes this analytical approach and applies it to an organizational environment within Pakistan where these dynamics foster an environment vulnerable to intervention research because of the brass-brass environment of the office sector and the lack of ergonomic awareness.

The studies on occupational health in the office constructions in Pakistan are still in infancy stage but moving forward. In a survey of 350 employees from banks in Lahore conducted by Iqbal et al. (2020) demonstrated that 61% experienced pain in their neck and 54% experienced pain in their lower back, where the height of the workstation and adjustability of the chair were found to be the most modifiable risk factors. Even with high level of syndrome symptom prevalence, less than 15 percent of sample organisations employed formal ergonomic assessment protocols and less than 10 percent trained their staffs on ergonomic issues. These results identified one major area for gap between evidence based ergonomic best practices and real life activities in the Pakistani context, which the current study would attempt to bridge by providing detailed empirical evidence on ergonomics-MSD-productivity pathway.

Return on investment (ROI) studies of ergonomic interventions consistently show positive ROI. In a systematic review of 45 economic studies of ergonomic interventions, Tompa et al. (2010) reported results of benefit to cost ratios ranging from 2:1 to 17:1, depending on the study context, with the majority associated with decreased workers' compensation claims, costs of sick leave, and the reduction of productivity losses. These economic arguments and the growing clinical and epidemiological evidence forms a strong multi-stakeholder rationale for investing in ergonomic workplace design, which the results of the present study will help to strengthen, in the South Asian organizational context.

METHODOLOGY

Research Design

A research design was used is quantitative, cross sectional which is used to examine the relationship between Work Place Ergonomics and MSD among employees. This design allowed data to be efficiently gathered from a large and diverse sample at one point in time, and assess relationships and structural pathways between the study variables. Cross-sectional designs are commonly used in epidemiological occupational health to characterize the prevalence of MSD and to determine the population level risk factors of the workplace (Levin, 2006). The study was guided by a post-positivist epistemological approach that gives priority to objective measurement and the use of statistics as the ways of generating knowledge.

Study Population and Sampling

The target population consisted of office workers who work at a computer for at least four hours daily in public and private sector organisations. The minimum sample size was obtained with GPower 3.1 software using a medium effect size ($f^2 = .15$), $\alpha = .05$, power = .80, and five predictors. There was a design provision for a final sample of 280 who were recruited to account for non-response and data quality problems. A purposive sampling technique was used and it targeted organizations that had an employee base available, of which 50 or more were employed in their office setting. To provide diversity in the workplace conditions, organisations were chosen from banking, telecom, public administration and educational sectors. In each organisation, employees were recruited and the study invitations were sent out by the HR coordinators from each department. The inclusion criteria were: current employment in an office, computer-based job for at least 6 months, age ≥ 18 y and informed consent. To reduce the risk of reverse causality bias, employees who were on Medical absences stemming from MSD were not included.

Data Collection Instrument

Structured, self administered, four-part questionnaire was used to gather data. Data relevant to demographic features was collected during Section A, which included age, gender, job tenure (in years), working hours

per day, and organizational sector (public, or private). Section B measured ergonomic work conditions with a modified Ergonomic Assessment Checklist (EAC) that included 12 questions that measured the adjustability of the chair, the height and distance of the monitor, the position of devices such as keyboard and mouse, the surface quality of the desk, lighting conditions in the work area, and rest break provision and use. A five point Likert scale (from Very Poor (1) to Excellent (5)) was used to rate items. For the last 12 months and 7 days, Section C used Nordic Musculoskeletal Questionnaire (Kuorinka et al., 1987) to determine the prevalence and severity of musculoskeletal symptoms in nine body regions: neck, shoulders, upper back, lower back, elbows, wrists/hands, hips/thighs, knees, ankles/feet. For the present study, a composite of MSD severity scores on the nine regions was derived in order to have a continuous outcome measure for SEM analysis. Employee productivity was measured in Section D with a validated productivity scale from Lerner et al (2001) Work Limitations Questionnaire, with items pertaining to time management, physical demands performance, mental-interpersonal demands performance, and output demands performance. The questionnaire was initially administered to 25 jobs outside of the study (pilot testing) and slight revisions to the wording of items were made in response to feedback from cognitive interviews.

Procedure

The data were collected after ethical clearance was given by an Institutional Review Board. Research assistants were trained and handed out questionnaire packets to participating organizations, and explained the guidelines for distribution and return to HR coordinators. Information sheets were distributed giving participants detailed information about the purpose of the study, that it was voluntary, and confidentiality plans with regards to data. The questionnaires were anonymous to minimise disruption caused to the work schedule and reduce the social desirability bias. Unopened questionnaires were returned to the researcher in a confidential manner. The data collection process lasted 4 weeks in some of the implementing organisations.

Data Analysis

A double verification of the data was performed in order to avoid transcription errors, and the data was entered into the IBM SPSS Statistics (Version 26) software. Less than 3% of responses contained missing data which were dealt with using expectation-maximisation imputation for scale items. Descriptive data such as frequencies, percentages, mean scores and standard deviations were obtained for all study and demographic variables. An acceptable internal reliability of each scale was determined through Cronbach's alpha values, with $\alpha \geq .70$ being acceptable. To investigate the bivariate relationships between ergonomic conditions, MSD severity and productivity, the Pearson product-moment correlation was computed. Then, the researchers carried out the Structural Equation Modeling which used IBM SPSS AMOS version 24. The two-step Anderson and Gerbing (1988) procedures were applied: the first step – confirmatory factor analysis (CFA) to examine the adequacy of the measurement model and second step – full structural model estimation. The model fit was assessed based on χ^2/df (acceptable < 3.0), CFI (acceptable $\geq .95$), TLI (acceptable $\geq .95$), RMSEA (acceptable $\leq .08$), and SRMR (acceptable $\leq .08$). Confidence intervals for the indirect effect of ergonomics on productivity via MSD were constructed using bootstrap resampling with 5000 iterations with 95% bias-corrected confidence intervals.

RESULTS

Demographic Characteristics

A demographic profile of the 280 participants is presented in Table 1. Gender balance in the sample was about even (49.3% male, 50.7% female). The 31–40 years age group was most prevalent (35.0%), followed by 41–50 years (26.4%). The greatest number of respondents (34.3%) had jobs for 1-5 years and 20.7% held their positions for over 10 years. The 7–8 hours per day group was the largest (49.3%) and 28.2% worked 9–10 hours daily. Of the sample, 53.2% were employees within the private sector.

Table 1: Sociodemographic Characteristics of Participants (N = 280)

Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	138	49.3
	Female	142	50.7
Age Group	18–30 years	72	25.7
	31–40 years	98	35.0
	41–50 years	74	26.4
	Above 50	36	12.9
Job Tenure	< 1 year	42	15.0
	1–5 years	96	34.3
	6–10 years	84	30.0
	> 10 years	58	20.7
Working Hours/Day	≤ 6 hours	35	12.5
	7–8 hours	138	49.3
	9–10 hours	79	28.2
	> 10 hours	28	10.0
Sector	Public	131	46.8
	Private	149	53.2

Descriptive Statistics and Internal Reliability

Descriptive statistics and reliability coefficients are presented in Table 2 for three main constructs. On average, ergonomic workplace conditions scored: 3.58 (SD = 0.77) which falls within the moderate-to-good range of the ergonomic conditions score. Across the sample, the severity score of MSD was moderate with a mean severity score of 2.94 (SD = 0.85). The mean (SD) value for employees' productivity was 3.21 (0.88). All scales had satisfactory internal consistency, indicated by Cronbach's alpha values between .80 and .84.

Table 2: Descriptive Statistics and Reliability Coefficients (N = 280)

Variable	N	Mean	SD	Cronbach's α
Workplace Ergonomic Conditions	280	3.58	0.77	0.82
Musculoskeletal Disorders (NMQ)	280	2.94	0.85	0.80
Employee Productivity	280	3.21	0.88	0.84

Correlation Analysis

The correlation matrix, using Pearson's correlation coefficient, is shown in Table 3 for the three main variables of the study. The severity of MSD was strongly and negatively related ($r = -.55, p < .001$) with ergonomic work conditions, suggesting that worse work ergonomic conditions were associated with higher MSD symptom burden. Employee productivity was statistically significantly correlated positively with ergonomic conditions ($r = .52, p < .001$); that is, higher levels of productivity were related to better ergonomic conditions. More severity of the MSD in this study points to lower productivity, as evidenced by a significant and negative correlation ($r = -.57, p < .001$). All of these associations were of moderate to large size, and were statistically significant at the .001 level, and lend good preliminary support to the hypothesized structural relationships.

Table 3: Pearson Correlation Coefficients Among Study Variables

Variable	1	2	3
1. Workplace Ergonomics	—		
2. Musculoskeletal Disorders	-.55**	—	
3. Employee Productivity	.52**	-.57**	—

Note. ** $p < .001$ (two-tailed).

Structural Equation Modeling

The measurement model prior to the structural estimation fit well. The results of full SEM are presented in Table 4. Ergonomic conditions had a significant negative association with MSD severity ($\beta = -.51, SE = .08, CR = -6.38, p < .001$) and findings of the workers exposed to poorer ergonomic conditions experienced significant higher musculoskeletal symptoms. The severity of MSD was a significant and negative predictor of employee productivity ($\beta = -.46, SE = .07, CR = -6.57, p < .001$). The effect of ergonomic conditions to productivity was significant and positive ($+ \beta = .28, SE = .09, CR = 3.11, p = .002$). $\beta \sim 0.23$, (95% CI: [0.14, 0.33]), was the indirect effect of ergonomics on productivity as mediated by MSD, and it was confirmed to be statistically significant by bootstrapping. The overall impact of the ergonomic conditions on productivity was $\beta = .51$. This was in acceptable ranges: $\chi^2/df = 2.07, CFI = .96, TLI = .95, RMSEA = .062, SRMR = .051$; collectively these fit indices suggested that the model fit was acceptable.

Table 4: Structural Equation Modeling Path Estimates – Workplace Ergonomics Study

Path	β	SE	CR	p
Ergonomics → Musculoskeletal Disorders	-.51	.08	-6.38	<.001
Musculoskeletal Disorders → Productivity	-.46	.07	-6.57	<.001
Ergonomics → Productivity (direct)	.28	.09	3.11	.002
Ergonomics → Productivity (indirect via MSD)	.23	.05	4.60	<.001
Total Effect	.51	.08	6.38	<.001

Note. Model fit: $\chi^2/df = 2.07; CFI = .96; TLI = .95; RMSEA = .062; SRMR = .051$.

DISCUSSION

The results of this study support the case for structural factors in the workplace to strongly affect both the burden of MSDs and the productivity of employees in an office environment. The strong negative relation with severity of MSD and ergonomic conditions ($r = -.55$; $\beta = -.51$) corroborates the general findings from epidemiological and interventional studies that point to ergonomic risk factors as causal factors in the development of MSD (Gerr et al., 2002; Punnett & Wegman, 2004). The SEM results suggest that ergonomic conditions may play an indirect effect on productivity via MSD burden ($\beta = .23$), as well as additional direct effects ($\beta = .28$) indicated in the SEM results. The direct pathway may represent the cognitive and performance effects that occur immediately with ergonomic failures, without clinically significant MSD symptoms, such as distraction, fatigue, and postural discomfort in a task. Total effect of the ergonomic conditions on productivity reaches a level that can be called practical ($\beta = .51$), and has a clear organizational implication.

These findings corroborate that of Hoe et al., (2012) who also concluded that the pathway from productivity limitation through ergonomic discomfort was explained by a significant proportion in a Singaporean office population, where occupational training and formal occupational health support structures are quite underdeveloped compared to current Pakistan context. The findings of the mean NMQ score ($M = 2.94$) is in line with those of Iqbal et al. (2020) who reported high prevalence of neck and back symptoms among the workers in the banks of Pakistan. The acceptable model fit indicators (RMSEA = .062; CFI = .96) confirm the structural validity of the proposed model and indicate that it is a good representation of the theorized pathway between ergonomic quality and productivity through musculoskeletal health. The findings directly facilitate designing organisations for ergonomics, and occupational health policy for alleviating the increasing problem of work-induced musculoskeletal disorders in office-based settings in southern Asian countries.

CONCLUSION AND RECOMMENDATIONS

The study demonstrated that the ergonomic conditions of workplaces were important structural variables affecting both the burden of musculoskeletal disorders in the workplace and productivity, and, in part, that the severity of the musculoskeletal disorders had a mediating effect. The overall impact of ergonomic conditions on productivity ($\beta = .51$) highlights the monetary losses that can occur due to the neglect of ergonomic factors by an organization, as well as the potential gains from systematic measures to reduce that loss. Recommendations expressed: Carrying out systematic ergonomic evaluations of all computer-based workstations using standardized computer workstation checklists, focusing on adjustability of the chair, monitor position and dimensions of workstation surfaces. The subgroup with high tenure at the employer and those employees that currently have MSD symptoms are considered to have the highest burden of occupational health risk and cumulative productivity loss and should be prioritized for ergonomic equipment upgrades. There should be a low cost 'high bang for your buck' approach to implementing structured rest break policies with micro-pause breaks mandated. Organisational health services should include an annual screening process for MSD problems with the use of the NMQ for early identification and timely referral for physiotherapy or required workstation changes. Policy level, the occupational health regulatory framework in Pakistan needs to be streamlined and consistent with the introduction of binding ergonomic requirements for the workstation, which should be backed by employer requirements to train users and provide worker safeguards. Longitudinal designs and introducing objective measurements of ergonomics, along with self-reports, in future studies would provide additional support for drawing causal inferences

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