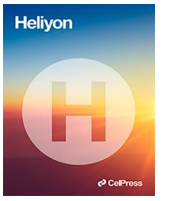
Heliyon 10 (2024) e24023

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon



Research article

Analysis of musculoskeletal pains and productivity impacts among hispanic construction workers

Krishna P. Kisi *, Rujan Kayastha

Department of Engineering Technology, College of Science and Engineering, Texas State University, San Marcos, TX, USA

ARTICLE INFO

Keywords:
Musculoskeletal pain
Construction worker
Productivity
Risk assessment

ABSTRACT

This study investigated the top three musculoskeletal pains (MSP) among Hispanic construction workers in Texas and the relationship between sleep hours, age, and MSPs on worker productivity. The study recruited 228 participants from 28 small construction companies and surveyed them on their occupation, age, sleep hours, MSP, and the impact of pain on productivity. The results indicated that Foot pain was the most common among these workers, followed by Back pain and others. Additionally, the study found that the Foot was the most common body part reported with MSP among roofers, drywall installers, laborers, and helpers. The study conducted a three-factor ANOVA test to analyze if there were any significant differences in productivity based on age, number of MSPs, and sleep hours. The study found that MSPs and sleep hours significantly impacted productivity. However, there was no significant effect of age. The results also showed that the number of MSPs significantly impacted productivity, with an increase in MSPs leading to a more severe impact on productivity. Additionally, those who slept less than 6 h per day had a more severe impact on productivity than those who slept more. The study suggests that targeted interventions to improve musculoskeletal health and productivity in this population are needed and highlights the importance of considering Hispanic construction workers' specific needs when implementing safety measures and addressing pain management in the workplace.

1. Introduction

Construction work is known to be physically demanding, with workers often performing laborious and strenuous manual tasks. These activities can lead to musculoskeletal strains and injuries, which are further compounded by harsh working conditions such as irregular hours, rugged environments, and exposure to heat. As a result, musculoskeletal pain (MSP) is a common condition affecting the muscles, bones, tendons, ligaments, and other musculoskeletal system structures. It can be caused by factors such as injury, overuse, poor posture, or arthritis and can be acute or chronic, ranging from mild to severe. In addition, MSP is often a symptom of a broader musculoskeletal disorder (MSD), which repetitive motions, forceful exertions, awkward postures, and vibration can cause. The origin of Work-Related Musculoskeletal Disorders (WMSDs) is intricate and multifaceted, shaped by both direct and indirect influences from a range of factors such as individual characteristics, biomechanics, psychosocial dynamics, and occupational features [1–5]. Notably, psychosocial factors, exemplified by job satisfaction and work-related stress, significantly impact the development of Musculoskeletal Pain (MSP) through stress responses [6,7].

Musculoskeletal conditions, including various inflammatory and degenerative conditions that affect muscles, tendons, ligaments,

* Corresponding author.
E-mail address: kpkisi@txstate.edu (K.P. Kisi).

https://doi.org/10.1016/j.heliyon.2024.e24023
Received 4 September 2023; Received in revised form 15 December 2023; Accepted 2 January 2024
Available online 3 January 2024

and joints, are commonly found in physically demanding occupations involving heavy lifting, vibration exposure, and awkward postures [8]. Construction workers, particularly those in manual and non-managerial roles, are at a high risk of experiencing high levels of bodily pain and regularly perform their duties while in pain [9–11]. This pain is often linked to musculoskeletal conditions and can be acute or chronic [12–14]. Studies have shown that construction is a high-risk industry for work-related MSP, and construction workers with these conditions are less likely to return to work and more likely to retire with a disability than workers in other occupations [9,14]. Project-based construction workers also experience poor work-family balance, which can lead to psychological distress, depression, anxiety, and sleep problems [15,16]. In addition, MSP can have social and family-related consequences, such as disrupting daily routines, impacting identity and enjoyment, and decreasing social interactions and leisure activities [17,18]. Research has also found that MSP can prevent people from participating in social or family events [19] and strain relationships [20]. However, there is a lack of research on the relationship between MSP and productivity among manual and non-managerial Hispanic construction workers in Texas despite being a high-risk group for these health-related issues.

According to the U.S. Bureau of Labor Statistics, older construction workers aged 45–54 reported fewer injuries in 2014 compared to their younger counterparts [21]. Physical labor-intensive jobs such as construction and manufacturing have higher injury rates and days out of work due to nonfatal injuries than other fields. Despite this, older workers have fewer injuries. However, they require more time off for recovery [22], which can lead to a shortage of younger workers and increased demand for construction workers [23].

Furthermore, WMSDs are a leading cause of nonfatal occupational injuries in the construction industry. They account for significant work absenteeism in all industries [13]. Symptoms of WMSDs can range from low Back pain to carpal tunnel syndrome, and they can cause chronic conditions, permanent disabilities, and direct and indirect costs in construction [24,25]. Therefore, it is essential to identify potential risk factors for WMSDs among construction workers and to implement effective and practical solutions to prevent them.

The current research on the relationship between sleep hours, MSP, and productivity among Hispanic construction workers in Texas needs to be more comprehensive. This study aims to address this gap in knowledge by investigating the top three MSPs among Hispanic construction workers in Texas and examining the interaction between sleep hours, age, and MSP on worker productivity. The study will also explore the relationship between MSP and productivity in this population to identify potential risk factors and create best practices for improving musculoskeletal health and productivity in the construction industry. This study answers the following specific research questions.

1. What are the top three MSPs among Hispanic construction workers in Texas?
2. How do sleep hours, age, and MSPs influence workers' productivity?

2. Literature review

Studies have shown a significant positive association between MSDs and factors such as fatigue, stress, psychosocial distress, and sleep disruption [26–29]. These disorders can lead to a loss of productivity at work and increased sickness absence. Theoutcomes of MSDs can range from symptoms to major impairment losses, such as reduced quality of life, productivity, and increased medical expenses due to disability [30]. Ng and their colleagues [31] mentioned that WMSDs contribute to presenteeism, which leads to loss of productivity.

WMSDs have significant consequences for employees and employers, including lost working days, early retirement, unemployment, a decline in productivity, increased sickness payments, and staff absenteeism [32,33].

Promoting health in society is crucial for sustainable and inclusive growth. Healthy and active individuals positively impact productivity and competitiveness [26]. In addition, workplace factors, including physical, psychosocial, and organizational factors, significantly impact individuals' health, particularly the musculoskeletal system [34,35].

A systematic review of musculoskeletal symptoms in the construction industry found that the one-year pain prevalence rate ranged from 15.1 % for the hip/thigh to 51.1 % for the low back [36]. Risk factors for pain included job-required repetitive lifting and fatigue, job-related stresses, age, physical workload, effort reward, and job strain [37,38]. Therefore, it is essential to study point prevalence to understand the proportion of workers who are in pain but still working.

Construction workers, particularly those in manual and non-managerial roles, are at a high risk of developing MSDs due to the nature of their work. Carpenters and masons are at risk due to static and awkward postures, heavy manual material handling, repetitive motions, and extreme weather conditions [39]. Drywall installers are also at risk of MSDs due to heavy manual material handling, repetitive motions, and awkward postures, which often result in injuries to the axial skeleton and shoulder [40,41]. Repetitive lifting can lead to low back muscle strain, ligament sprain, a bulging or herniated disc, or other low back pain [42]. Roofers are at a high risk of developing MSDs in their knees due to the time they kneel while working on sloped rooftops [43]. Studies have shown that kneeling is a potential risk factor for knee injuries and disorders. Common MSDs among roofers include the back, shoulders, hands/fingers, knees, and feet/ankles [44,45]. Overall, the physically demanding nature of construction work can lead to an increased risk of MSDs and reduced productivity.

3. Materials and methods

3.1. Study subjects

A total of 228 Hispanic construction workers were recruited from twenty-eight small construction companies in Texas, United

States. The research protocol was approved by the Institutional Review Board (IRB) of one of the Texas universities in the United States. Before participating in the study, the subjects read and completed an informed consent form. Participation was voluntary. The sample size using the standard equation, Eq. (1), with a 95 % confidence interval, a 5 % margin of error, and a population size of 681K construction workers in Texas [46]. Given that Hispanic construction workers constitute approximately 13 % [47] of the population, we used this as the estimated proportion. Applying the equation ($z = 1.96, p = 0.13, e = 0.05$) in the following equation (Eq. 1) [48], we obtained a sample size (n) of 174, further validated using an online sample size calculator.

$$n = \frac{z^2 p\, x\, (1-p)}{e^2} \quad \text{Eq. (1)}$$

Our study surveyed 228 individuals, surpassing 174, ensuring a robust representation of Hispanic construction workers in Texas.

3.2. Questionnaire survey

The survey asked all participants about their occupation, ages, sleep hours, and any MSP they were experiencing in various body parts. It also asked about the impact of the pain on their productivity, with options for low, mild, moderate, or severe impact. For example, the musculoskeletal related question included: 1) "Please select which part of your body areas had pain?" with response options: Head, Shoulder, Chest, Arm, Forearm, Hip, Back, Thigh, Knee, Leg, Ankle, Foot.

3.3. Variables

The variable chosen for this study were as follows.

3.3.1. Age

Participants' ages were categorized into three levels (less than 25 years, 25–35 years, and greater than 35 years) to explore potential productivity differences among these groups. Literature such as [10,49,50] used age groups for their analysis among construction workers.

3.3.2. Sleep hours

The sleep hours were categorized into two levels (less than 6 h and greater than 6 h). In this research, the question about hours of sleep is related to the average number of hours slept by the worker per night, not just the hours slept the previous night to assess their regular sleep patterns.

3.3.3. Musculoskeletal pain

The musculoskeletal pains were categorized into four levels by counting how many MSPs were recorded by the participants on their body (one pain, two pains, three pains, and four pains or more). Workers reported pain beyond the last 7 days, reflecting general discomfort while working. Meo and their colleagues [51] also examined work-related musculoskeletal symptoms based on working years in construction. Pain assessment was focused on the presence or absence of pain in specific body parts. The WMSD symptoms are referenced from a literature review that studied risk factors for work related musculoskeletal disorders [23,52,53].

3.3.4. Productivity

Productivity was recorded on a scale of four productivity impact levels. This response variable was measured by asking how independent variables (age, sleep hours, and MSPs) impacted their productivity. The scale was measured as low impact, mild impact, moderate impact, and severe impact.

3.4. Statistical analysis

The study aimed to answer two research questions. First, it wanted to know the three most common MSPs among Hispanic construction workers. To address this information, descriptive analysis was used to filter the top three MSPs.

Second, the study wanted to know how much sleep, age, and MSPs affected the workers' productivity. A three-factor ANOVA was applied to measure the interaction of factors such as sleep hours, age, and number of MSPs and their influence on the response variable (i.e., productivity). An interaction effect is said to occur when one factor's effect depends on another's level [54]. The main effect is the effect of one factor on a dependent variable averaged across the levels of any other factors [55].

Before analyzing the data, the study made sure it met certain criteria. First, this study used an ANOVA test using SPSS software tools to analyze the data. Then, once everything was in order, the study used three-factor ANOVA to study how sleep, age, and MSPs affected productivity. The study also examined how much the independent variable (sleep, age, and MSPs) could predict the total variance in the dependent variable (productivity) by calculating the effect size. The study used a partial eta squared (ηp2) to find the effect size [56], with 0.01 being a small effect, 0.06 being a medium effect, and 0.14 being a large effect [57]. The statistical significance was set at $p < 0.05$.

4. Results

4.1. Descriptive statistics

The study recruited 228 Hispanic construction workers from 28 small construction companies and surveyed them on their occupation, age, sleep hours, MSP, and the impact of pain on their productivity. Out of 228 respondent 227 reported were male and one female. Table 1 shows the result of responses to five categories of questions asked. The results showed that the largest group of participants was 25–35 years old (36 %), followed by those greater than 35 years old (36 %), and the smallest group was less than 25 years old (28 %). The occupational groups of the participants in this study are mutually exclusive. In the "occupation" category, the largest group of participants were drywall installers (41 %), followed by laborers and helpers (31 %). The smallest group is plumbers (3 %).

When construction workers were asked how many hours they slept, 37 % of the participants reported sleeping less than 6 h. Similarly, when asked how many multiple MSPs they had on the construction site, 36 % reported having one MSP, 31 % reported two pains, and the remaining frequency of pains is shown in Table 1.

Similarly, the results show that while 20 % said the MSP had no impact on their productivity, 36 % reported the MSP had a mild impact on their productivity, 32 % reported a moderate impact, and 12 % reported the MSP had a severe impact on their productivity. It is worth noting that while the table provides some helpful information, it is essential to consider the interaction effect of MSPs.

The construction industry is known for its high risk of work-related musculoskeletal injuries and disorders. In order to gain a better understanding of the prevalence of MSPs among different construction occupations, we conducted a study to determine which parts of the body had a higher number of MSPs. The results of this study are presented in Table 2. The data in the table shows the percentage of workers in various trades, such as Roofers, Drywall Installers, Plumbers, Masonry workers, Laborers, and Helpers, who reported MSPs in different body parts, including the Head, Shoulder, Chest, Arm, Forearm, Hip, Back, Thigh, Knee, Leg, Ankle, and Foot.

The percentage shown in Table 2 is calculated from the sum of the number of MSPs reported on different body parts by each occupation. For example, among Roofers, 81 MSPs were reported, 9 % of which were reported in the head, and 28 % were reported in the Foot. This approach aligns with literature such as [51], which investigated work-related musculoskeletal symptoms among building construction workers, including head heaviness as one of the symptoms in their study. As shown in Table 2, Foot and Back pain were the most commonly reported among all occupations. For example, the highest proportion of reported injuries among Roofers is in the Foot (28 %), and among Masonry workers are in the Back (26 %). Similarly, Plumbers had the highest percentage of reported injuries in the Back (33 %) among all the trades. Additionally, we can see that the highest proportion of reported injuries among Laborers and helpers is in the Foot (18 %).

4.2. Ranking of MSPs among hispanic construction workers

Table 2 also presents the results of a study on the top three musculoskeletal injuries and disorders (MSPs) among various construction occupations, including Roofers, Drywall Installers, Plumbers, Masonry Workers, and Laborers and Helpers. The result shows the percentage of workers in each occupation who reported MSPs in different body parts. For example, the top three MSPs among Roofers were in the Foot (28 %), Back (15 %), and Knee (14 %).

The table clearly shows that the most common body parts reported with MSPs vary across different occupations. For example, the most common body part reported with MSPs among Roofers is the Foot (28 %), and among Drywall Installers is the Foot (20 %). Similarly, the most common body part reported with MSPs among Plumbers is the Back (33 %). Additionally, we can see that the most common body part reported with MSPs among all the occupations is the Foot (28 % for Roofers, 20 % for Drywall Installers, 26 % for

Table 1
Respondents' characteristics.

Category	Description	Number(n)	Percentage(%)
Age	Less than 25 Years	64	28
	25–35 years	82	36
	Greater than 35 Years	82	36
Sleep hours	Less than 6 h	84	37
	Greater than 6 h	144	63
Number of musculoskeletal pains (MSP)	one MSP	81	36
	Two MSPs	71	31
	Three MSPs	48	21
	Four or more MSPs	18	12
Occupation	Drywall installer	94	41
	Laborers and helpers	71	31
	Roofer	40	18
	Masonry workers	16	7
	Plumber	7	3
Productivity	No impact	45	20
	Mild impact	83	36
	Moderate impact	73	32
	Severe impact	27	12

Table 2
Percentage of Musculoskeletal pain based on occupation.

	Roofer (n = 81)	Drywall installer (n = 204)	Plumber (n = 19)	Masonry workers (n = 36)	Laborers and helpers (n = 146)
Head	9 %	10 %	20 %	3 %	15 %
Shoulder	3 %	12 %	0 %	7 %	7 %
Arm	2 %	7 %	14 %	0 %	8 %
Forearm	8 %	5 %	0 %	6 %	6 %
Hip	6 %	9 %	0 %	10 %	11 %
Back	15 %	14 %	33 %	26 %	16 %
Thigh	4 %	7 %	0 %	3 %	4 %
Knee	14 %	5 %	7 %	13 %	5 %
Leg	5 %	6 %	0 %	3 %	4 %
Ankle	7 %	5 %	0 %	10 %	6 %
Foot	28 %	20 %	26 %	19 %	18 %

Note: "n" represents the sum of reported MSPs on various body parts for each occupation, not the count of individual workers.

Plumbers, 19 % for Masonry Workers, and 18 % for Laborers and Helpers).

These results provide valuable insights into the specific areas of the body most susceptible to MSPs in different construction occupations, which can help inform preventative measures and safety protocols to reduce the risk of MSPs in the construction industry. The most common body part reported by MSPs across all occupations was the Foot, which should be focused on preventative measures and safety protocols.

To gain a comprehensive understanding of the most common MSPs among Hispanic construction workers, we conducted a study that summarized all the reported pains among all construction workers. The results of this study are presented in Table 3, which shows the summary of all the reported pains. In addition, the table shows that the number and proportion of reported injuries vary across different body parts.

For example, the highest percentage of reported MSPs is in the Foot (21 %), whereas the lowest number of reported injuries is in the Thigh (4.5 %). To further illustrate these findings, a graphical representation of the data is provided in Fig. 1. This figure shows the rank of all MSPs reported among construction workers in this study. The most common injury is represented by the number "1," and the least common injury is represented by the number "10" on the graph. The graph provides a clear visual representation of the data, making it easy to understand the relative frequency of MSPs among different body parts.

4.3. Interaction effects of age, MSPs, and sleep hours

A three-factor analysis of variance (ANOVA) test was conducted to determine if there were any significant differences in productivity effect based on the variables such as age, MSPs, and sleep hours. The results of this test are presented in Table 4, which shows the three-way interaction results. Levene's homogeneity test of variances was violated for the three-factor ANOVA at a significance level of $p < 0.05$. Therefore, a more stringent significance level of $p < 0.01$ was used for determining whether there was significant difference in variances among groups. Literature such as by Hu and their colleagues [58] and by Parra-Frutos [59] mention that using a significance level of 0.01 might be appropriate in situations where study want to be more conservative in detecting differences in variances, especially when dealing with large sample sizes or when small differences in variances are of practical importance.

Table 4 presents the results of different sources of variation in the data, including the main effects of each variable (Age, MSPs, Sleep Hours) and their interactions (Age * MSPs, Age * Sleep Hours, MSPs * Sleep Hours, Age * MSPs * Sleep Hours). The main effects of MSP ($F = 29.614$, $p < 0.001$) and sleep hours ($F = 13.425$, $p < 0.001$) were found to be statistically significant, indicating that the number of MSPs and the number of hours of sleep have a significant effect on productivity. However, no significant effect of age was observed.

Additionally, there were no significant differences observed in the three-factor interaction. This result indicates that the effects of the number of sleep hours and the number of MSPs on productivity do not depend on the age groups. Furthermore, there was a

Table 3
Overall frequency of MSPs.

Body Parts	Number	Percentage
Head	50	10.7
Shoulder	38	8.1
Arm	29	6.2
Forearm	28	6.0
Hip	42	9.0
Back	77	16.5
Thigh	21	4.5
Knee	33	7.1
Leg	22	4.7
Ankle	28	6.0
Foot	98	21.0

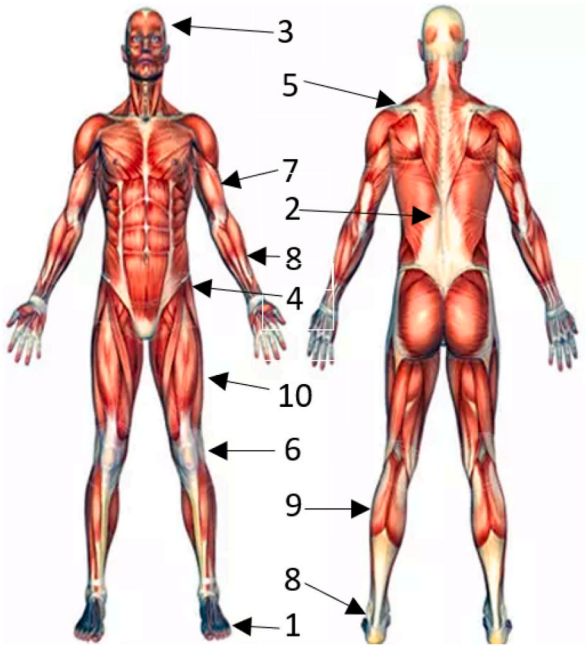


Fig. 1. Rank of musculoskeletal pain among construction workers in Texas.

Table 4
Three-factor ANOVA for the productivity effect as a function of i) age, ii) MSP, and iii) Sleep hours. The table shows the degrees of freedom (df), Type III Sum of Squares (SS), mean square (MS), F-statistic (F), p-value (p) and partial eta squared (ηp2).

Source	SS	df	MS	F	p	ηp2
Age (A)	.452	2	.226	.579	.561	.006
MSP (M)	34.673	3	11.558	29.614	<.001	.302
Sleep Hours (S)	5.239	1	5.239	13.425	<.001	.061
A * M	2.376	6	.396	1.015	.417	.029
A * S	1.320	2	.660	1.691	.187	.016
M * S	7.300	3	2.433	6.235	<.001	.084
A* M * S	1.333	5	.267	.683	.637	.016
Error	80.00	205	.390			
Total	1466.00	228				
Corrected Total	196.51	227				
a. R Squared = .593 (Adjusted R Squared = .549)						

significant simple two-way interaction between MSPs and sleep hours ($F(3,205) = 6.235$, $p = <0.001$, $\eta p2 = 0.084$), which suggests that at each number of MSPs, productivity effect at sleep hours less than 6 h and greater than 6 h were compared. The interaction effect was plotted in Fig. 2 and is described in the following section.

4.4. Interaction effect of sleep hours and musculoskeletal pain

According to Table 4, there was a significant interaction effect between the number of sleep hours and the number of MSPs on the productivity of construction workers. To further examine this interaction effect, the data was plotted using the Tukey-Kramer Post hoc test in SPSS, as shown in Fig. 2. The Tukey-Kramer post hoc test presented in Fig. 2 illustrates the relationship between MSPs and their impact on productivity, where a higher value on the vertical axis signifies a severe impact on productivity or lower productivity.

The results showed that when workers had one or two MSPs in their bodies, the impact on productivity was significantly higher for those who slept less than 6 h per day than those who slept more than 6 h per day. However, for workers with three or more MSPs, the difference in productivity between those who slept less than 6 h per day and those who slept more than 6 h per day was insignificant.

Among workers who slept less than 6 h per day, the productivity impact score was severely impacted when they had three MSPs compared to having one MSP. However, no significant difference was found in the productivity impact (severity) score between having three MSPs and four MSPs or more. Similarly, there was no significant difference in productivity impact score among workers who slept more than 6 h per day between having one MSP and two MSPs. Nevertheless, significant differences were found in productivity impact scores when they had three MSPs or more than two MSPs. To further elaborate, the interpretation is not that workers with many symptoms should sleep less to enhance productivity. Instead, the observed statistical insignificance in productivity differences when

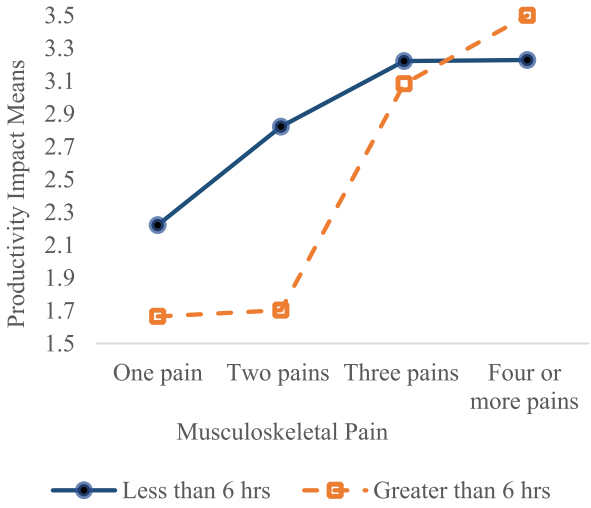


Fig. 2. Interaction effect of MSP and sleep hours on productivity impact.

individuals have three or more MSPs indicates that the relationship between sleep duration and productivity becomes less distinguishable under such conditions.

4.5. Main effect of number of MSPs

The study results indicated a significant main effect of musculoskeletal pains (MSPs) on the productivity of construction workers, as shown in Fig. 3. In addition, the data suggests that as the number of MSPs in the body increases, there is a corresponding increase in the impact on productivity severly. Specifically, it was observed that an increase in the quantity of MSPs in the body leads to a significant increase in the impact on productivity, moving from mild to severe. While the study recognizes the potential concerns associated with using means for ordinal data, the primary aim was not to convey precise numerical values but to offer a visual depiction of the general trends in productivity impact as MSPs varied.

4.6. Main effect of sleep

Based on the data presented in Fig. 4, it was found that there was a significant main effect of sleep hours on productivity. The results indicate that the impact on productivity is significantly higher for individuals who slept less than 6 h per day, as compared to those who slept more than 6 h per day. This can be observed by the higher scores (a higher score indicating a severe impact) in the group of individuals who slept less than 6 h per day. The figure offers a visual depiction of the general trends in productivity impact (severity) as sleep hour varied.

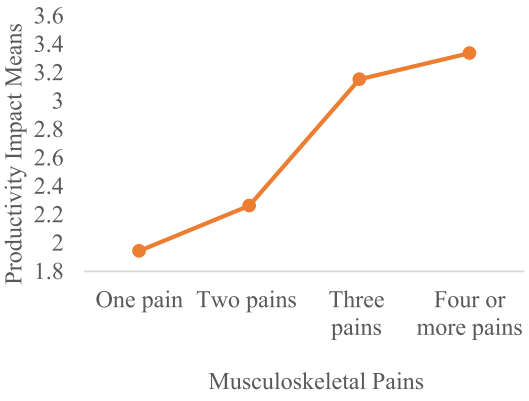


Fig. 3. Effect of MSP on productivity impact.

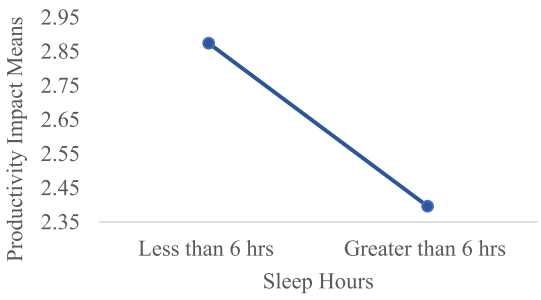


Fig. 4. Effect of sleep hours on productivity impact.

5. Discussion

The study found that the most common MSPs among Hispanic construction workers in Texas were in their feet, followed by Back pain, head, hip, shoulder, and other areas. The MSPs evaluated in this study specifically relate to work-related pain experienced by construction workers as a consequence of their occupational activities. Other studies have shown that Back pain is the most common pain among construction workers [12,60,61]. However, this study found that Back pain was the second most common pain, and Foot pain was the most common. This may be because the study focused on Hispanic workers rather than a diverse group of workers like other studies. Besides, the higher prevalence of foot problems among Hispanic construction workers, compared to back pain, is not due to inherent foot differences. Instead, it's influenced by tasks involving prolonged standing and walking, potentially stressful footwear choices, and working on uneven surfaces. Footwear choices emerge as another crucial factor influencing the prevalence of foot pain. Cultural preferences or economic considerations may lead Hispanic construction workers to opt for footwear that lacks the necessary support or cushioning. This choice can potentially exacerbate foot problems over time, thereby contributing to the observed disparity in foot pain prevalence.

The study also found that previous research has indicated that Back pain is the most common site of pain among construction workers in general. However, this study's findings show that this is different for Hispanic construction workers. The top three MSPs for roofers were Foot, Back, and Knee pain; for Drywall installers, Foot, Back, and shoulder pain; for plumbers, Back, Foot, and head pain; for masonry workers, Back, Foot, and Knee pain; and for laborers and helpers, Foot, Back, and head pain (as shown in Table 2). The study found Knee pain was particularly prevalent among roofers, which aligns with previous research [62,63]. Similarly, previous studies show the highest Back pain rate among masonry workers, roofers, and carpenters [53]. The top three MSPs' result suggests that there may be unique risk factors or work conditions that contribute to Foot pain among Hispanic construction workers that are not present in other populations of construction workers.

Additionally, the study investigated the impact of MSPs, sleep hours, and age on worker productivity. The study found that sleep hours and MSPs significantly impact worker productivity. However, the effects of sleep hours and the number of MSPs on productivity did not depend on the age groups. This aligns with previous research, which has shown that poor sleep quality is not associated with age but is associated with decreased work ability [29,64].

The study also found that multi-site MSP is associated with poor work ability and productivity loss, similar to previous studies [27,65,66]. In addition, the study found that the impact on productivity was significantly higher for those who slept less than 6 h a day than for those who slept more than 6 h a day. However, when sleep hours interacted with the number of MSPs, the study found that sleeping less than 6 h a day had a severe impact on productivity when workers had three MSPs. However, there was no significant difference between whether workers had three pains or more.

Previous studies have revealed that some aspects of productivity are related to musculoskeletal problems [67]. The results of this study showed a significant increase in the impact of productivity with the increase in the number of MSPs in the body, highlighting that multi-site MSPs influence productivity. To maintain a high level of work ability and productivity, preventative measures should be implemented in the workplace to promote good musculoskeletal health among Hispanic construction workers and minimize the risk of frequent work-related pain. Early identification and proper management of these symptoms are crucial, as pain can severely impact productivity.

6. Limitation of the study

Some potential limitations of the study include the following.

- The study only focused on Hispanic construction workers, so the findings may not be generalizable to other racial/ethnic groups or construction workers.
- The study did not investigate the specific factors contributing to the high Foot pain prevalence among Hispanic construction workers.

- The study assessed pain that was focused on the presence or absence of pain in specific body parts due to voluntary participation and budget constraints, precluding intensity details.
- The study did not examine the long-term effects of MSPs on worker productivity.
- The study relied on self-reported data for both MSPs and sleep hours, which may be subject to bias.
- The study did not include data on workers' overall physical activity levels and health history, which could impact their MSPs and productivity. Besides, the study refrained from requesting medical-related details such as metabolic conditions, cardiovascular issues, severe chronic obstructive pulmonary disease, overweight status, or neurological and mental health conditions.

The study did not investigate the impact of work-related stress on MSPs and productivity.

7. Conclusion

In conclusion, this study contributes to the existing literature by investigating the prevalence of MSPs among Hispanic construction workers in Texas. The study found that the most common site of pain among these workers was the Foot, followed by the Back, head, hip, shoulder, and other areas. Additionally, the study found that high foot problem prevalence among Hispanic construction workers, not due to inherent foot differences, resulted from prolonged standing, and footwear choices, influenced by culture and economics, contributed to the observed disparity.

The study identified common MSPs by occupation among Hispanic construction workers, noting that roofers experience a high prevalence of Knee pain. It also explored the impact of MSPs, sleep hours, and age on worker productivity, revealing significant effects of both MSPs and sleep hours. Interestingly, these effects on productivity were age independent.

Overall, the study provides valuable insights into the specific pain points and risk factors for MSPs among Hispanic construction workers and highlights the importance of targeted interventions to improve musculoskeletal health and productivity in this population in Texas. It would be beneficial for future research to investigate the specific factors that contribute to the high prevalence of Foot pain among Hispanic construction workers, and it would be valuable for employers and policymakers to take the specific needs of Hispanic construction workers into account when implementing safety measures and to address pain management in the workplace. Besides, future research employing longitudinal designs or intervention studies could provide a more comprehensive understanding of this population's complex interplay between sleep, musculoskeletal health, and productivity.

IRB approval/ethics declarations

This study was reviewed and approved by the Office of Research Integrity and Compliance in our institution, with the approval number: 8550. All participants provided informed consent to participate in the study.

Data availability statements

Data will be made available on reasonable request.

CRediT authorship contribution statement

Krishna P. Kisi: Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Rujan Kayastha:** Writing – original draft, Supervision, Software, Project administration, Investigation, Data curation.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:article publishing charges was provided by Translational Health Research Center.

Acknowledgments

The authors would like to thank all the participants and construction companies who assisted in the data collection. The authors appreciate the research support from the Translational Health Research Center, Texas State University, San Marcos,Texas, United States.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e24023.

References

[1] J. Bodin, R. Garlantézec, N. Costet, A. Descatha, J.F. Viel, Y. Roquelaure, Shoulder pain among male industrial workers: validation of a conceptual model in two independent French working populations, Appl. Ergon. 85 (2020) 103075, https://doi.org/10.1016/j.apergo.2020.103075.

[2] L.G.M. Bispo, C.F. Moreno, G.H. de Oliveira Silva, N.L.B. de Albuquerque, J.M.N. da Silva, Risk factors for work-related musculoskeletal disorders: a study in the inner regions of Alagoas and Bahia, Saf. Sci. 153 (2022) 105804, https://doi.org/10.1016/j.ssci.2022.105804.

[3] L.E. Charles, C.C. Ma, C.M. Burchfiel, R.G. Dong, Vibration and ergonomic exposures associated with musculoskeletal disorders of the shoulder and neck, Safety and health at work 9 (2) (2018) 125–132, https://doi.org/10.1016/j.shaw.2017.10.003.

[4] W.K. dos Santos Leite, A.J. da Silva Araújo, J.M.N. da Silva, L.A. Gontijo, E.M. de Araújo Vieira, E.L. de Souza, L.B. da Silva, et al., Risk factors for work-related musculoskeletal disorders among workers in the footwear industry: a cross-sectional study, Int. J. Occup. Saf. Ergon. (2019), https://doi.org/10.1080/10803548.2019.1579966.

[5] J.M. Souza, W.R. Tebar, L.D. Delfino, F.S. Tebar, L.A. Gobbo, R.Z. Pinto, D.G. Christofaro, et al., Relationship between physical activity domains and musculoskeletal disorders in public school teachers, Int. J. Ind. Ergon. 92 (2022) 103379, https://doi.org/10.1016/j.ergon.2022.103379.

[6] K. Baek, S. Yang, M. Lee, I. Chung, The association of workplace psychosocial factors and musculoskeletal pain among Korean emotional laborers, Safety and Health at Work 9 (2) (2018) 216–223, https://doi.org/10.1016/j.shaw.2017.09.004.

[7] J. Hartvigsen, S. Lings, C. Leboeuf-Yde, L. Bakketeig, Psychosocial factors at work in relation to low back pain and consequences of low back pain: a systematic, critical review of prospective cohort studies, Occup. Environ. Med. 61 (1) (2004) e2-e2.

[8] Centers for Disease Control and Prevention, Work-related Musculoskeletal Disorders & Ergonomics, Workplace Health and Promotion. https://www.cdc.gov/workplacehealthpromotion/health-strategies/musculoskeletal-disorders/index.html, 2023, 10th October 2023.

[9] V. Arndt, D. Rothenbacher, U. Daniel, B. Zschenderlein, S. Schuberth, H. Brenner, Construction work and risk of occupational disability: a ten-year follow-up of 14,474 male workers, Occup. Environ. Med. 62 (8) (2005) 559–566, https://doi.org/10.1136/oem.2004.018135.

[10] J.W. Chung, H.C. So, V.C. Yan, P.S. Kwok, B.Y. Wong, J.Y. Yang, A.P. Chan, A survey of work-related pain prevalence among construction workers in Hong Kong: a case-control study, Int. J. Environ. Res. Publ. Health 16 (8) (2019) 1404, https://doi.org/10.3390/ijerph16081404.

[11] A.J. Caban-Martinez, K.A. Lowe, R. Herrick, C. Kenwood, J.J. Gagne, J.F. Becker, Construction workers working in musculoskeletal pain and engaging in leisure-time physical activity: findings from a mixed-methods pilot study, Am. J. Ind. Med. 57 (7) (2014) 819–825, https://doi.org/10.1002/ajim.22332.

[12] J.S. Boschman, H.F. van der Molen, J.K. Sluiter, M.H. Frings-Dresen, Musculoskeletal disorders among construction workers: a one-year follow-up study, BMC Muscoskel. Disord. 13 (1) (2012) 1–10.

[13] S. Eaves, D.E. Gyi, A.G. Gibb, Building healthy construction workers: their views on health, wellbeing, and better workplace design, Appl. Ergon. 54 (2016) 10–18, https://doi.org/10.1016/j.apergo.2015.11.004.

[14] L.S. Welch, K.L. Hunting, L. Nessel-Stephens, Chronic symptoms in construction workers treated for musculoskeletal injuries, Am. J. Ind. Med. 36 (5) (1999) 532–540, https://doi.org/10.1002/(SICI)1097-0274(199911)36:5%3C532::AID-AJIM5%3E3.0.CO;2-9.

[15] P. Bowen, R. Govender, P. Edwards, K. Cattell, Work-related contact, work–family conflict, psychological distress and sleep problems experienced by construction professionals: an integrated explanatory model, Construct. Manag. Econ. 36 (3) (2018) 153–174, https://doi.org/10.1080/01446193.2017.1341638.

[16] Y. Kotera, P. Green, D. Sheffield, Work-life balance of UK construction workers: relationship with mental health, Construct. Manag. Econ. 38 (3) (2020) 291–303, https://doi.org/10.1080/01446193.2019.1625417.

[17] M. Dueñas, B. Ojeda, A. Salazar, J.A. Mico, I. Failde, A review of chronic pain impact on patients, their social environment and the health care system, J. Pain Res. 9 (2016) 457.

[18] J.C. Richardson, B.N. Ong, J. Sim, Experiencing and controlling time in everyday life with chronic widespread pain: a qualitative study, BMC Muscoskel. Disord. 9 (1) (2008) 1–8.

[19] D.E. Moulin, A.J. Clark, M. Speechley, P.K. Morley-Forster, Chronic pain in Canada: prevalence, treatment, impact and the role of opioid analgesia, Pain Res. Manag. 7 (4) (2002) 179–184, https://doi.org/10.1155/2002/323085.

[20] R.L. Oliver, A. Taylor, J.P. Schroeder, Family dynamics and chronic pain, Practical Pain Management 3 (3) (2003) 20–23.

[21] U.S. Bureau of Labor Statistics, Nonfatal Occupational Injuries and Illnesses Requiring Days Away from Work, 2015, p. 2014. https://www.bls.gov/news.release/pdf/osh2.pdf, 28th December 2022.

[22] M. Silverstein, Meeting the challenges of an aging workforce, Am. J. Ind. Med. 51 (4) (2008) 269–280, https://doi.org/10.1002/ajim.20569.

[23] A. Alwasel, E.M. Abdel-Rahman, C.T. Haas, S. Lee, Experience, productivity, and musculoskeletal injury among masonry workers, J. Construct. Eng. Manag. 143 (6) (2017) 05017003, https://doi.org/10.1061/(ASCE)CO.1943-7862.0001308.

[24] A. Bhattacharya, Costs of occupational musculoskeletal disorders (MSDs) in the United States, Int. J. Ind. Ergon. 44 (3) (2014) 448–454, https://doi.org/10.1016/j.ergon.2014.01.008.

[25] N. Inyang, M. Al-Hussein, M. El-Rich, S. Al-Jibouri, Ergonomic analysis and the need for its integration for planning and assessing construction tasks, J. Construct. Eng. Manag. 138 (12) (2012) 1370–1376, https://doi.org/10.1061/(ASCE)CO.1943-7862.0000556.

[26] H. Daneshmandi, A.R. Choobineh, H. Ghaem, M. Alhamd, A. Fakherpour, The effect of musculoskeletal problems on fatigue and productivity of office personnel: a cross-sectional study, Journal of Preventive Medicine and Hygiene 58 (3) (2017) E252.

[27] I.M. Hunt, A.J. Silman, S. Benjamin, J. McBeth, G.J. Macfarlane, The prevalence and associated features of chronic widespread pain in the community using the 'Manchester' definition of chronic widespread pain, Rheumatology 38 (3) (1999) 275–279, https://doi.org/10.1093/rheumatology/38.3.275.

[28] S. Njaka, D.M. Yusoff, S.M. Anua, Y.C. Kueh, C.O. Edeogu, Musculoskeletal disorders (MSDs) and their associated factors among quarry workers in Nigeria: a cross-sectional study, Heliyon 7 (2) (2021), https://doi.org/10.1016/j.heliyon.2021.e06130.

[29] J. Oakman, W. Macdonald, Prevention of Work-Related Musculoskeletal Disorders: Development of a Toolkit for Workplace Users, Institute for Safety Compensation and Recovery Research, Melbourne, 2012.

[30] L. Punnett, D.H. Wegman, Work-related musculoskeletal disorders: the epidemiologic evidence and the debate, J. Electromyogr. Kinesiol. 14 (1) (2004) 13–23, https://doi.org/10.1016/j.jelekin.2003.09.015.

[31] Y.G. Ng, S.B.M. Tamrin, W.M. Yik, I.S.M. Yusoff, I. Mori, The prevalence of musculoskeletal disorder and association with productivity loss: a preliminary study among labour intensive manual harvesting activities in oil palm plantation, Ind. Health 52 (1) (2014) 78–85, https://doi.org/10.2486/indhealth.2013-0017.

[32] K. Aumann, E. Galinsky, The State of Health in the American Workforce: Does Having an Effective Workplace Matter, Families and Work Institute, New York, NY, 2009.

[33] C. Phillips, C. Main, R. Buck, M. Aylward, G. Wynne-Jones, A. Farr, Prioritising pain in policy making: the need for a whole systems perspective, Health Pol. 88 (2–3) (2008) 166–175, https://doi.org/10.1016/j.healthpol.2008.03.008.

[34] L. Manzoli, G. Sotgiu, N. Magnavita, P. Durando, Evidence-based approach for continuous improvement of occupational health, Epidemiol. Prev. 39 (Suppl 1) (2015) 81–85, 5.

[35] J.P.L. Oliveira, J. Zangirolami-Raimundo, P.E. de Andrade, S.L.P. Lima, A.R.C. Lima, L.C. de Abreu, R.D. Raimundo, Relationship between musculoskeletal pain, sleep quality and migraine with level of physical activity in college students during the COVID-19 pandemic, Heliyon 8 (10) (2022), https://doi.org/10.1016/j.heliyon.2022.e10821.

[36] W. Umer, M.F. Antwi-Afari, H. Li, G.P. Szeto, A.Y. Wong, The prevalence of musculoskeletal symptoms in the construction industry: a systematic review and meta-analysis, Int. Arch. Occup. Environ. Health 91 (2) (2018) 125–144.

[37] M.F. Antwi-Afari, H. Li, D.J. Edwards, E.A. Pärn, J. Seo, A.Y.L. Wong, Biomechanical analysis of risk factors for work-related musculoskeletal disorders during repetitive lifting task in construction workers, Autom. ConStruct. 83 (2017) 41–47, https://doi.org/10.1016/j.autcon.2017.07.007.

[38] R.M. Herr, J.A. Bosch, A. Loerbroks, A.E. van Vianen, M.N. Jarczok, J.E. Fischer, B. Schmidt, Three job stress models and their relationship with musculoskeletal pain in blue-and white-collar workers, J. Psychosom. Res. 79 (5) (2015) 340–347, https://doi.org/10.1016/j.jpsychores.2015.08.001.

[39] S.D. Choi, L. Yuan, J.G. Borchardt, Critical analyses of work-related musculoskeletal disorders and practical solutions in construction, No. 1, in: Proceedings of the Human Factors and Ergonomics Society Annual Meeting, vol. 58SAGE Publications, Los Angeles, CA, 2014, pp. 1633–1637, https://doi.org/10.1177/1541931214581341. Sage CA.
[40] S.S. Chiou, C.S. Pan, P. Keane, Traumatic injury among drywall installers, 1992 to 1995, J. Occup. Environ. Med. (2000) 1101–1108. https://www.jstor.org/stable/44995775.
[41] H.J. Lipscomb, J.M. Dement, J.S. Gaal, W. Cameron, V. McDougall, Work-related injuries in drywall installation, Appl. Occup. Environ. Hyg 15 (10) (2000) 794–802, https://doi.org/10.1080/10473220050129437.
[42] D. Goldsheyder, S.S. Weiner, M. Nordin, R. Hiebert, Musculoskeletal symptom survey among cement and concrete workers, Work 23 (2) (2004) 111–121.
[43] H. Xu, S. Jampala, D. Bloswick, J. Zhao, A. Merryweather, Evaluation of knee joint forces during kneeling work with different kneepads, Appl. Ergon. 58 (2017) 308–313, https://doi.org/10.1016/j.apergo.2016.07.003.
[44] L. Welch, E. Haile, L.I. Boden, K.L. Hunting, Musculoskeletal disorders among construction roofers—physical function and disability, Scand. J. Work. Environ. Health (2009) 56–63. https://www.jstor.org/stable/40967755.
[45] T.K. Fredericks, O. Abudayyeh, S.D. Choi, M. Wiersma, M. Charles, Occupational injuries and fatalities in the roofing contracting industry, J. Construct. Eng. Manag. 131 (11) (2005) 1233–1240, https://doi.org/10.1061/(ASCE)0733-9364(2005)131:11(1233).
[46] United States Census Bureau, Decennial Census, Texas State, 2020. https://data.census.gov/profile/Texas?g=040XX00US48#populations-and-people, 10th November, 2023.
[47] A. Martin, Most Hispanics in Texas Work in Construction, Offices, and Business, The Dallas Morning News, 2023. https://www.dallasnews.com/business/2023/10/09/most-of-texas-new-workers-are-latino-and-4-charts-that-show-why-that-matters/, 11th November, 2023.
[48] W.G. Cochran, Sampling Techniques, John Wiley & Sons, 1997.
[49] X.S. Dong, A. Fujimoto, K. Ringen, Y. Men, Fatal falls among Hispanic construction workers, Accid. Anal. Prev. 41 (5) (2009) 1047–1052, https://doi.org/10.1016/j.aap.2009.06.012.
[50] X. Wang, X.S. Dong, S.D. Choi, J. Dement, Work-related musculoskeletal disorders among construction workers in the United States from 1992 to 2014, Occup. Environ. Med. 74 (5) (2017) 374–380, https://doi.org/10.1136/oemed-2016-103943.
[51] S.A. Meo, Z.F. Alsaaran, M.K. Alshehri, M.A. Khashougji, A.A.Z. Almeterk, S.F. Almutairi, S.F. Alsaeed, Work-related musculoskeletal symptoms among building construction workers in Riyadh, Saudi Arabia, Pakistan J. Med. Sci. 29 (6) (2013) 1394, https://doi.org/10.12669/pjms.296.4052.
[52] G.K. Lemasters, M.R. Atterbury, A.D. Booth-Jones, A. Bhattacharya, N. Ollila-Glenn, C. Forrester, L. Forst, Prevalence of work-related musculoskeletal disorders in active union carpenters, Occup. Environ. Med. 55 (6) (1998) 421–427, https://doi.org/10.1136/oem.55.6.421.
[53] S.P. Schneider, Musculoskeletal injuries in construction: a review of the literature, Appl. Occup. Environ. Hyg 16 (11) (2001) 1056–1064, https://doi.org/10.1080/104732201753214161.
[54] J. Pallant, SPSS Survival Manual: A Step by Step Guide to Data Analysis Using IBM SPSS, McGraw-Hill Education, UK, 2020.
[55] D.C. Howell, Factorial Analysis of Variance. Statistical Methods for Psychology, eighth ed., Wadsworth, Belmont, CA, USA, 2013, pp. 411–456. Cengage Learning.
[56] B.G. Tabachnick, L.S. Fidell, Using Multivariate Statistics, sixth ed., Pearson Education, Boston, 2013.
[57] J.T. Richardson, Eta squared and partial eta squared as measures of effect size in educational research, Educ. Res. Rev. 6 (2) (2011) 135–147, https://doi.org/10.1016/j.edurev.2010.12.001.
[58] F. Hu, H.R. Hepburn, Y. Li, M. Chen, S.E. Radloff, S. Daya, Effects of ethanol and water extracts of propolis (bee glue) on acute inflammatory animal models, J. Ethnopharmacol. 100 (3) (2005) 276–283, https://doi.org/10.1016/j.jep.2005.02.044.
[59] I. Parra-Frutos, The behaviour of the modified Levene's test when data are not normally distributed, Comput. Stat. 24 (2009) 671–693.
[60] I.W.H. Fung, V.W.Y. Tam, C.M. Tam, K. Wang, Frequency and continuity of work-related musculoskeletal symptoms for construction workers, J. Civ. Eng. Manag. 14 (3) (2008) 183–187, https://doi.org/10.3846/1392-3730.2008.14.15.
[61] U. Latza, W. Karmaus, T. Stürmer, M. Steiner, A. Neth, U. Rehder, Cohort study of occupational risk factors of low back pain in construction workers, Occup. Environ. Med. 57 (1) (2000) 28–34, https://doi.org/10.1136/oem.57.1.28.
[62] S.P. Breloff, A. Dutta, F. Dai, E.W. Sinsel, C.M. Warren, X. Ning, J.Z. Wu, Assessing work-related risk factors for musculoskeletal knee disorders in construction roofing tasks, Appl. Ergon. 81 (2019) 102901, https://doi.org/10.1016/j.apergo.2019.102901.
[63] L.A. Merlino, J.C. Rosecrance, D. Anton, T.M. Cook, Symptoms of musculoskeletal disorders among apprentice construction workers, Appl. Occup. Environ. Hyg 18 (1) (2003) 57–64, https://doi.org/10.1080/10473220301391.
[64] S. Marklund, C.S. Mienna, J. Wahlström, E. Englund, B. Wiesinger, Work ability and productivity among dentists: associations with musculoskeletal pain, stress, and sleep, Int. Arch. Occup. Environ. Health 93 (2020) 271–278, https://doi.org/10.1007/s00420-019-01478-5.
[65] A. Lindegård, P. Larsman, E. Hadzibajramovic, G. Ahlborg, The influence of perceived stress and musculoskeletal pain on work performance and work ability in Swedish health care workers, Int. Arch. Occup. Environ. Health 87 (2014) 373–379.
[66] H. Miranda, L. Kaila-Kangas, M. Heliövaara, P. Leino-Arjas, E. Haukka, J. Liira, E. Viikari-Juntura, Musculoskeletal pain at multiple sites and its effects on work ability in a general working population, Occup. Environ. Med. 67 (7) (2010) 449–455, https://doi.org/10.1136/oem.2009.048249.
[67] K. Taylor, N. Green, D. Physio, What Are the Productivity Losses Caused by Musculoskeletal Disorders (MSDs)? A Review of the Current Literature, Wellnomics Ltd, 2008, pp. 1–5.