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Health, Physical Activity and Musculoskeletal Symptoms among Stone, Sand, and Gravel Mine Workers: Implications for Enhancing and Sustaining Worker Health and Safety

Todd D. Smith [1,*], Abdulrazak O. Balogun [2], Zuojin Yu [3] and Charmaine Mullins-Jaime [4]

[1] Department of Applied Health Science, Indiana University School of Public Health—Bloomington, Bloomington, IN 47405, USA
[2] Department of Safety and Occupational Health Applied Sciences, Keene State College, Keene, NH 03435, USA; abdulrazak.balogun@keene.edu
[3] Department of Health Sciences, College of Health Professions, Towson University, Towson, MD 21252, USA; zyu@towson.edu
[4] Department of Built Environment, College of Technology, Indiana State University, Terre Haute, IN 47809, USA; Charmaine.Mullins-Jaime@indstate.edu
* Correspondence: smithtod@indiana.edu

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Abstract: There is little data delineating relationships between health and worker musculoskeletal symptoms (MSS), particularly among stone, sand, and gravel mine (SSGM) workers. There is also little data detailing the relationships between physical activity and MSS among these workers. A cross-sectional study using data from 459 SSGM workers was completed. Logistic regression analyses assessed relationships between health factors, physical activity, and low back, neck, shoulder, and knee MSS. Those who reported their health as very good/excellent were less likely to suffer low back and knee MSS. Those who indicated their health was poor/fair were more likely to suffer shoulder, neck, and knee MSS. Obese workers were more likely to experience knee MSS and those who smoked in the past had higher odds of neck MSS. Vigorous physical activity was mostly protective, but those performing more than 5 h of moderate physical activity each week had greater odds of shoulder and neck MSS. Given these results, workers in SSGM may benefit from targeted interventions that bolster vigorous physical activity and improve health. Further, health protection efforts need to be initiated by SSGM operations to address work issues and to sustain health as job roles and work hours impacted MSS as well.

Keywords: musculoskeletal symptoms; musculoskeletal disorders; workplace health; physical activity; safety; ergonomics; Total Worker Health; mining; sustainability

1. Introduction

Musculoskeletal symptoms (MSS) and associated musculoskeletal disorders (MSDs) are common in many industries. These musculoskeletal problems negatively impact the ability of workers to maintain wellness and sustain health. In 2018, MSD accounted for approximately 273,000 nonfatal occupational injuries in the United States [1]. Musculoskeletal problems are problematic across many industrial sectors, including mining [2–4]. In a recent study within the mining industry, Balogun and Smith determined MSS were problematic in stone, sand, and gravel mining (SSGM) operations [4]. In fact, they determined multiple anatomical body parts and regions are impacted, as many workers reported MSS to the low back, shoulders, neck, and knees [4]. Because of these problems and given that

SSGM constitutes the vast majority (over 80%) of mining operations in the United States, with more than 101,000 employees working at nearly 11,000 SSGM sites [5], more attention needs to be paid to identifying risk factors and curtailing musculoskeletal problems to protect workers, to enhance and sustain health, and to ensure the efficiency of SSGM operations.

Research has found associations between physical activity and MSS or MSD among workers outside of the mining industry. Significant inverse associations between physical activity and musculoskeletal disorders have been found in military personnel [6], police officers [7], physical education teachers [8], and middle-aged to older women [9]. Findings suggest that those who engage in higher levels of physical activity and are more fit have a lower prevalence of musculoskeletal problems [6–9]. Despite this common interpretation, some researchers have proposed that the influence is u-shaped, implying low levels of physical activity and high levels of physical activity may be associated with low back pain [10]. Other health-related factors such as smoking and high BMI have also been associated with increased prevalence of and hospitalizations for musculoskeletal problems [11–13]. Obesity has been linked to an increased risk of chronic pain in the low back and neck/shoulders [13–15].

There is a dearth of information regarding the relationship between health status, physical activity, and MSS in the mining sector, especially among SSGM employees. An understanding of these risk factors associated with MSS in the SSGM industry will aid in laying the foundation for reducing the burden of not only MSD but possibly other chronic health problems. Individuals with MSD are also at higher risk of developing chronic health problems [16] and are less likely to participate in health-promoting physical activities [17].

The present study is an undertaking of a larger-scale research initiative focused on identifying and correcting musculoskeletal disorder risk and protective factors within SSGM operations. The present study was initiated in an effort to delineate risk and protective factors associated with MSS in the SSGM sector, particularly those related to health and physical activity. These factors have not yet been explored in prior research related to the overall project. Identifying these factors will provide empirical evidence that could influence programs, policies, and initiatives, which could be implemented to curtail MSS and associated MSD and foster and sustain worker health within SSGM operations. The present study expands the recent work by Balogun and Smith [4], who are members of the research team for the present study. Health-related factors not previously examined, including overall health status, BMI, and personal smoking status, including smoking behavior and past smoking experience, are examined in the present study. Further, the present study examines whether physical activity, outside the workplace or during times of leisure, are associated with increased or decreased odds of MSS among the workers sampled. Variables of importance from an initial prevalence study by Balogun and Smith [4] were included as control variables.

2. Materials and Methods

2.1. Participants

Cross-sectional data were collected from 459 employees working for SSGM operations in the Midwestern United States. Convenience sampling methods were utilized as participants were not randomly selected. The research team asked mine workers from small to medium-sized businesses completing Mine Safety and Health Administration (MSHA) annual refresher training with their employer or at a training facility in the Midwestern United States to complete the hard copy (paper) survey. Survey data were collected from participants during the fall and winter months of 2019 and early 2020, with data collection finishing in February 2020. As noted, 459 workers agreed to participate and complete the survey. Two workers declined to participate when asked to complete the survey. No participants dropped out once the survey was started; however, there was occasionally an item left blank or not answered by the participants.

A member of the research team discussed the purposes of the study and addressed consent with those recruited to complete the survey. The research team used a research script to ensure consistency between data collection visits. A member of the research team was always present while the participants completed the survey. All subjects gave their informed consent for inclusion before they participated in the study. The study was ethically conducted and the protocol for the study was approved by the Institutional Review Board at Indiana University-Bloomington on 22 February 2019 (IRB#1902635452). Participants are further described in the Results section of this publication and within Table 1.

Table 1. Summary of Study Participants.

	Frequency	Percentage
Age		
<25	40	8.71%
25–34	81	17.65%
35–44	96	20.92%
45–54	97	21.13%
55–64	113	24.62%
65+	25	5.45%
Unspecified	7	1.53%
Gender		
Male	427	93.03%
Female	31	6.75%
Unspecified	1	0.22%
Race		
African American or Black	4	0.87%
American Indian or Alaska Native	1	0.22%
Asian or Asian American	1	0.22%
Hispanic, Latino/a/x	17	3.70%
White	429	94.46%
Other	3	0.66%
Unspecified	4	0.87%
Education		
Some high school	44	9.59%
High school graduate or GED	189	41.18%
Some college or technical/vocational training	132	28.76%
Associate degree	44	9.59%
Bachelor's degree	39	8.50%
Master's degree or higher	8	1.74%
Unspecified	3	0.65%
Marital Status		
Single	98	21.35%
Divorced/Separated	44	9.59%
Widowed	1	0.22%
Married/Living with partner	315	68.63%
Unspecified	1	0.22%
Job Category		
Office/Clerical/Professional	71	15.47%
Maintenance	83	18.08%
Laborers and Equipment Operators	125	27.23%
Moving/Rubber Tire Equipment/Vehicle Operators	82	17.86%
Supervisors	51	11.11%
Miscellaneous/others/missing	47	10.24%

2.2. Measures

The present study examined self-reported musculoskeletal symptoms at four anatomic regions of the body to include low back, shoulders, neck, and knees. These four anatomic regions were targeted as they are the areas most associated with MSS or MSD in the stone, sand, and gravel mining industry [4] and other industrial operations [18–21]. The outcome variable MSS was assessed using a measure adapted from the validated Dutch Musculoskeletal Questionnaire (DMQ) [4,22]. For the present study, our outcome items were those that asked participants if they had experienced any pain or discomfort in the last 12 months at the low back, right shoulder, left shoulder, right knee, left knee, and neck. Those who answered "No" in the low back were coded "No" in the variable low back MSS, and the same rule applied to the neck MSS. Respondents who answered "No" in both the left shoulder and right shoulder were coded "No" in the variable shoulder MSS, while others were coded "Yes." The same rule applied to the variable knee MSS.

Sociodemographic factors examined in our study as control variables included age, gender, education, marital status, average hours of work per week, and job category. Education was collapsed into four categories including high school or GED, some college or technical/vocational, associate degree, and bachelor's or master's degree. Marital status was collapsed into four categories including single, divorced/separated, widowed, and married/living with a partner. Hours of work per week was categorized into less than 40, 40, 41–50, 51–60, and more than 60 h. In the present study, the reference group was those working 40 h per week. This differs slightly from prior analyses we conducted, which used a reference group that combined respondents who worked 40 h per week with those who worked less than 40 h per week [4].

Health factors and physical activity were not included in our prior analyses, which were more focused on assessing MSS prevalence [4]. Health factors examined in the present study included BMI, self-reported health status, smoking status, moderate physical activity, and vigorous physical activity. BMIs were calculated from self-reported height and weight. Respondents' BMIs were then categorized as normal/underweight (<25), overweight (25 to 29.99), and obese (30 or more). In order to measure participants' health status, they were asked, "In general, would you say your health is: poor, fair, good, very good, or excellent?" Responses were then collapsed into poor/fair, good, and very good/excellent. Smoking status was determined by the question, "Which best describes your smoking history or smoking activity?" Response options were, "I never smoked," "I smoked in the past, but not now," or "I am a current smoker." Moderate physical activity was collected by the question, "How often do you get moderate-intensity exercise (walking, slow cycling, etc.) each week?" and vigorous physical activity was collected by the question, "How often do you get high-intensity exercise (jogging, running, swimming, etc.) each week?"

2.3. Analysis

Data entry, data cleaning, and data processing were initially conducted using SPSS version 25. Statistical analysis was conducted using STATA MP version 14. Pairwise-deletion was used for cases with missing data in the present study. This differs from prior research using the same data, resulting in slight count differences [4]. Bivariate logistic regression was used to examine whether and how each individual sociodemographic or health factor related to low back MSS, shoulder MSS, neck MSS, and knee MSS. Then, we carried out four multiple regression analyses to predict MSS in each of the four body parts separately. All regression models were linked to the cumulative distribution functions of logistic distributions. Variance inflation factors of all independent variables ranged from 1.35 to 3.18, indicating multicollinearity was not an issue. Backward selection with pr = 0.2 was used to determine which independent variables, among all sociodemographic and health variables, were included in each regression model. Odds ratios and 95% confidence intervals are reported to demonstrate associations between sociodemographic or health factors and the prevalence of MSS. Significance is reported at 0.10, 0.05, and 0.01 levels. All multiple regression models passed Hosmer-Lemeshow goodness-of-fit tests.

3. Results

The mean age for participants was 45 (SD = 14). Of the participants, 93% reported their gender as male and 7% reported their gender as female. Most participants reported their race/ethnicity as White. With regard to education, most participants indicated their highest level of education was high school graduate/GED. With regard to the job category, most participants indicated their job as laborer/equipment operator (27%). Eighty-two (18%) were operators or drivers of moving/rubber tire or vehicles. Eighty-three (18%) were maintenance workers or mechanics. The next largest group were office, clerical, and professional employees. Additional details regarding the sample are presented in Table 1.

Analyses identified several factors that increase the likelihood of low back MSS, shoulder MSS, neck MSS and knee MSS. The overall results are presented in Tables 2 and 3. Specifically, Table 2 includes the odds ratios for low back MSS and shoulder MSS, and Table 3 includes the odds ratios for neck MSS and knee MSS.

Table 2. Odds Ratios and 95% Confidence Intervals for Low Back Musculoskeletal Symptoms (MSS) and Shoulder MSS.

	Low Back		Shoulder	
	OR1	**OR2**	**OR1**	**OR2**
Age	0.99 (0.97–1.00)	0.98 (0.97–1.00) *	1.02 (1.00–1.03) *	1.02 (1.00–1.03) *
Gender				
Male	—	—	—	—
Female	1.53 (0.70–3.33)	1.96 (0.75–5.14)	0.89 (0.42–1.91)	
Education				
High School or GED	—	—	—	—
Some college or technical/vocational	1.14 (0.74–1.76)		1.96 (1.26–3.06) **	2.20 (1.37–3.54) **
Associate Degree	2.68 (1.26–5.69) *	3.13 (1.41–6.92) **	1.60 (0.81–3.15)	2.03 (0.98–4.21)
Bachelor's/Master's Degree	1.20 (0.63–2.26)	1.90 (0.90–4.02)	2.07 (1.09–3.93) *	2.33 (1.16–4.68) *
Marital Status				
Single	—	—	—	—
Divorced/Separated/Widowed	0.72 (0.35–1.48)		1.97 (0.94–4.12)	
Married or Living w/Partner	1.33 (0.84–2.10)	2.05 (1.26–3.35) **	1.45 (0.89–2.35)	
Hours of work per week				
40	—	—	—	—
Less than 40	2.29 (0.67–7.82)	3.19 (0.78–13.07)	1.26 (0.36–4.40)	
41–50	1.87 (1.00–3.49) *	2.19 (1.08–4.44) *	1.45 (0.74–2.82)	
51–60	1.54 (0.80–2.98)	1.81 (0.86–3.80)	1.35 (0.67–2.73)	
more than 60	5.37 (2.15–13.44) **	5.21 (1.88–14.38) **	1.68 (0.73–3.88)	
BMI				
25–30	—	—	—	—
<25	1.44 (0.83–2.50)	1.66 (0.92–3.00)	1.38 (0.80–2.38)	1.64 (0.95–2.82)
>30	1.11 (0.73–1.68)		1.19 (0.77–1.83)	
Job Category				
Office/Clerical/Professional	—	—	—	—
Maintenance	1.95 (1.01–3.74) *	2.74 (1.38–5.47) **	1.03 (0.54–1.99)	
Laborers and Equipment Operators	1.36 (0.76–2.44)	1.82 (0.98–3.40)	0.73 (0.40–1.35)	
Moving/Rubber Tire Equipment/Vehicle Operators	1.58 (0.83–3.00)	2.44 (1.24–4.81) *	0.78 (0.40–1.52)	
Supervisors/Foremen	2.47 (1.15–5.28) *	2.88 (1.30–6.39) **	1.17 (0.56–2.44)	
Miscellaneous/Other/Missing	0.98 (0.47–2.08)		0.69 (0.32–1.51)	
Health Status				
Good	—	—	—	—
Fair/Poor	1.12 (0.63–1.99)		1.80 (1.03–3.15) *	1.70 (0.94–3.04)
Very Good/Excellent	0.60 (0.40–0.93) *	0.56 (0.35–0.90) *	1.01 (0.65–1.56)	
Smoking				
I never smoked	—	—	—	—
I smoked in the past, but not now	1.28 (0.83–1.99)	1.36 (0.86–2.15)	1.19 (0.77–1.86)	
I am a current smoker	1.05 (0.64–1.70)		1.23 (0.75–2.01)	
Vigorous Physical Activity				
None outside of work	—	—	—	—
30 min–1 h	0.66 (0.40–1.07)	0.62 (0.38–1.02)	0.74 (0.45–1.22)	0.68 (0.40–1.16)
1–5 h	0.93 (0.58–1.48)		0.73 (0.45–1.16)	0.62 (0.38–1.01)
More than 5 h	0.81 (0.40–1.64)		0.90 (0.45–1.83)	
Moderate Physical Activity				
None outside of work	—	—	—	—
30 min–1 h	0.91 (0.52–1.60)		0.72 (0.40–1.28)	
1–5 h	1.18 (0.69–2.03)		0.91 (0.53–1.58)	
More than 5 h	0.97 (0.53–1.80)		1.33 (0.72–2.47)	1.48 (0.87–2.51)

Notes: * $p < 0.05$, ** $p < 0.01$; OR1 are based on univariate binary logistic regression; OR2 are based on multiple logistical regression using backward selection method with Pr = 0.2.

Table 3. Odds Ratios and 95% Confidence Intervals for Neck and Knee MSS.

	Neck		**Knee**	
	OR1	**OR2**	**OR1**	**OR2**
Age	0.99 (0.98–1.01)	0.98 (0.97–1.00)	1.00 (0.99–1.01)	
Gender				
Male	—	—	—	—
Female	1.52 (0.73–3.15)	2.54 (1.04–6.16) *	0.52 (0.23–1.20)	
Education				
High School or GED	—	—	—	—
Some college or technical/vocational	1.37 (0.88–2.13)		1.26 (0.81–1.95)	1.40 (0.89–2.22)
Associate Degree	1.96 (1.01–3.81) *		1.49 (0.77–2.88)	1.67 (0.84–3.32)
Bachelor's/Master's Degree	1.88 (1.00–3.54)	1.70 (0.84–3.43)	0.97 (0.51–1.87)	
Marital Status				
Single	—	—	—	—
Divorced/Separated/Widowed	1.85 (0.89–3.86)	2.57 (1.10–6.02) *	1.02 (0.49–2.14)	
Married or Living w/ Partner	1.43 (0.88–2.32)	2.18 (1.21–3.93) **	1.15 (0.72–1.84)	
Hours of work per week				
40	—	—	—	—
Less than 40	0.78 (0.19–3.23)		1.93 (0.57–6.57)	
41–50	1.55 (0.77–3.10)	2.25 (1.10–4.58) *	1.63 (0.83–3.22)	
51–60	2.39 (1.16–4.92) *	3.76 (1.78–7.94) **	1.33 (0.65–2.73)	
more than 60	4.19 (1.78–9.91) **	6.76 (2.72–16.75) **	4.98 (2.10–11.81) **	3.57 (1.82–7.01) **
BMI				
25–30	—	—	—	—
<25	1.46 (0.85–2.52)		1.75 (1.01–3.03) *	2.62 (1.42–4.82) **
>30	1.32 (0.86–2.02)		1.80 (1.17–2.77) **	2.02 (1.26–3.23) **
Job Category				
Office/Clerical/Professional	—	—	—	—
Maintenance	1.27 (0.66–2.44)	1.79 (1.02–3.16) *	2.04 (1.04–4.02) *	
Laborers and Equipment Operators	0.84 (0.45–1.54)		1.87 (1.00–3.50)	
Moving/Rubber Tire Equipment/Vehicle Operators	1.21 (0.63–2.33)	1.79 (1.02–3.12) *	1.67 (0.84–3.30)	
Supervisors/Foremen	1.21 (0.58–2.52)		1.93 (0.91–4.13)	
Miscellaneous/Other/Missing	0.70 (0.32–1.54)		1.23 (0.55–2.76)	
Health Status				
Good	—	—	—	—
Fair/Poor	1.80 (1.02–3.17) *	1.87 (1.01–3.47) *	2.08 (1.18–3.65) *	2.04 (1.11–3.74) *
Very Good/Excellent	0.99 (0.64–1.54)		0.63 (0.40–0.99) *	0.63 (0.39–1.04)
Smoking				
I never smoked	—	—	—	—
I smoked in the past, but not now	1.28 (0.83–1.98)	1.56 (0.99–2.46)	1.48 (0.96–2.29)	
I am a current smoker	0.89 (0.54–1.48)		1.37 (0.83–2.23)	
Vigorous Physical Activity				
None outside of work	—	—	—	—
30 min–1 h	0.65 (0.40–1.08)	0.67 (0.40–1.10)	0.76 (0.47–1.25)	
1–5 h	0.91 (0.57–1.45)		0.81 (0.51–1.29)	
More than 5 h	0.79 (0.39–1.62)	0.45 (0.18–1.12)	0.79 (0.39–1.62)	
Moderate Physical Activity				
None outside of work	—	—	—	—
30 min–1 h	0.86 (0.49–1.53)		0.93 (0.53–1.64)	
1–5 h	0.91 (0.53–1.57)		0.87 (0.50–1.49)	
More than 5 h	1.28 (0.69–2.37)	1.92 (1.01–3.64) *	1.03 (0.56–1.91)	

Notes: * $p < 0.05$, ** $p < 0.01$; OR1 are based on univariate binary logistic regression; OR2 are based on multiple logistical regression using backward selection method with Pr = 0.2

3.1. Low Back MSS

Interestingly, it was found that increases in age were slightly protective with regard to reported low back MSS (OR = 0.98, 95% CI: 0.97–1.00, $p < 0.05$). Low back MSS was more likely among workers with an associate degree (OR = 3.13, 95% CI: 1.41–6.92, $p < 0.01$) compared to those with a high school or GED education. Additionally, those with a bachelor's/master's degree (OR = 1.90, 95% CI: 0.90–4.02, $p = 0.09$) had increased odds for low back MSS, although significance was at the $p < 0.10$ level. Workers who were married/living with a partner were associated with increased low back MSS (OR = 2.05, 95% CI: 1.26–3.35, $p < 0.01$), compared to single workers. Employees that worked more than 60 h per week were five times more likely to report low back MSS (OR = 5.21, 95% CI: 1.88–14.38,

$p < 0.01$) compared to those who worked 40 h per week. Workers who reported their health as very good/excellent were less likely to report low back MSS (OR = 0.56, 95% CI: 0.35–0.90, $p < 0.05$).

3.2. Shoulder MSS

Shoulder MSS were positively associated with age. A one-year increase in age increased the likelihood of reporting shoulder MSS by 2% (OR = 1.02, 95% CI: 1.00–1.03, $p < 0.05$). Workers with education levels higher than high school/GED were associated with increased odds of shoulder MSS. Compared to overweight workers who had a BMI between 25 and 30, workers who had a BMI less than 25 were at increased odds of shoulder MSS, albeit at higher significance levels (OR = 1.64, 95% CI: 0.95–2.82, $p = 0.07$). Workers who rated their health as fair/poor were 1.70 times more likely to report shoulder MSS (OR = 1.70, 95% CI: 0.94–3.04, $p = 0.08$) compared to those who rated their health as good. Those who had 1 to 5 h per week of vigorous physical activity outside of work were less likely to report shoulder MSD (OR = 0.62, 95% CI: 0.38–1.01, $p < 0.06$); although, significance was at the $p < 0.10$ level.

3.3. Neck MSS

Female workers had greater odds of reporting neck MSS (OR = 2.54, 95% CI: 1.04–6.16, $p < 0.05$). Divorced/separated/widowed workers (OR = 2.57, 95% CI: 1.10–6.02, $p < 0.05$) and married/living with a partner workers (OR = 2.18, 95% CI: 1.21–3.93, $p < 0.01$) had greater likelihood of neck MSS compared to single workers. Participants who worked over 40 h per week were more likely to report neck MSS than those who worked 40 h per week. Workers who reported their health status as fair/poor were at increased odds of neck MSS (OR = 1.87, 95% CI: 1.01–3.47, $p < 0.05$). With regard to smoking, workers who smoked in the past but not currently were 1.56 times more likely to experience neck MSS (OR = 1.56, 95% CI: 0.99–2.46, $p = 0.05$) compared to those workers who never smoked. Workers who reported moderate physical activity more than 5 h per week were more likely to have neck MSS (OR = 1.92, 95% CI: 1.01–3.64, $p < 0.05$).

3.4. Knee MSS

Employees working more than 60 h each week were more likely to have knee MSS compared to those working 40 h each week (OR = 3.57, 95% CI: 1.82–7.01, $p < 0.01$). Compared to workers who were overweight, both normal/underweight (OR = 2.62, 95% CI: 1.42–4.82, $p < 0.01$) and obese (OR = 2.02, 95% CI: 1.26–3.23, $p < 0.01$) workers had increased odds of knee MSS. Workers who reported fair/poor health had an increased likelihood of knee MSS compared to those workers indicating they were in good health (OR = 2.04, 95% CI: 1.11–3.74, $p < 0.05$).

4. Discussion

The analysis identified several significant findings, as noted in the results. Older employees and those with higher levels of education experienced more shoulder MSS. Possibly, experienced employees and those with more education tend to perform administrative activities and may be more sedentary, particularly with long bouts of sitting at computer workstations or desks. Those with higher levels of formal education also experienced more low back MSS, possibly due to sedentary work as well. It is known that workers with sedentary tasks may have higher prevalence rates of MSS, particularly if physical activities are minimal or sedentary [23].

An increase in age was found to be slightly protective of low back pain. A possible explanation is older workers tend to be more experienced and advance into positions that require more oversight duties and less physically strenuous activities such as manual material handling, while other older workers may have left the company through early retirement or changed jobs within the company due to MSDs [24].

Those who worked extended hours or overtime work hours experienced more musculoskeletal symptoms of the neck, low back, and knees. Overtime is a common practice in the United States, but one that can be costly to businesses and workers. Those who work longer work-weeks may find it more difficult to find the time and energy to exercise, participate in physical activity or make better health choices, which may further exacerbate their health conditions and predisposition to MSS. Working longer hours can cause stress and put a strain on the individual's personal life, potentially interfering with both workers and their families, particularly when overtime is mandatory [25,26]. The psychosocial strain could further exacerbate the experience of musculoskeletal pain [27].

Health factors were found to influence the likelihood of MSS among the stone, sand, and gravel mine workers surveyed. Obese workers were more likely to experience knee MSS. Interestingly, workers who were deemed to be of normal BMI or underweight had greater odds of having low back MSS, shoulder MSS, and knee MSS. Women and those with a history of smoking experienced more neck problems. This is consistent with other studies that found women have higher rates of neck pain than men [28,29] and tobacco smoke exposure as a common risk factor for neck pain [29,30] among general and worker populations.

While exercise has been linked to MSD prevention and minimization in both mining [27,31] and other industries [6,32], this study finds variation in the characteristics of exercise as having a divergent impact on MSS. Longer duration, specifically longer than 5 h of moderate physical activity each week, was associated with shoulder and neck MSS. However, vigorous physical activity was found to be protective.

Positive self-reported health status and positive health behaviors were associated with decreased MSS, giving weight for a Total Worker Health® (TWH) approach in the sand, stone, and gravel mining industry as a possible solution to minimize musculoskeletal symptoms and to enhance and sustain health among employees. With underlying health concerns being a significant predictor of MSS in the SSGM industry, they could see success in minimizing their musculoskeletal symptoms and associated disorders or injuries through a participatory TWH approach [33–35] aimed at gathering holistic input from front line workers at all stages of the assessment, design, and implementation of interventions. TWH also targets those factors associated with a higher prevalence of MSS in this study, including being obese and working long hours each week, through health-supporting policies and practices integrated into the organization's management system [35]. Longer work-weeks are not necessarily an indicator of productivity but are a stopgap measure to cover underlying inefficiencies that become the norm due to lack of opposition or prompts to dig deeper to find and correct the underlying cause. Health supporting policies put pressure on management to address the root causes of the need for overtime.

Merging participatory ergonomics with health promotion ensures people closest to the risk are involved in the design of any interventions or organizational changes. Additionally, health promotion and supporting programs such as paid personal days, education, counseling, and support services through an in-house wellness team or an EAP can help give employees the knowledge and resilience in balancing work, health, and personal life. Health education initiatives help workers understand the negative health impacts associated with both their jobs and personal life and help give them the tools necessary to make adjustments to their work activities and to make healthier choices in their personal life.

All interventions described are part of a well-rounded TWH approach which can, in turn, help bolster and sustain employee well-being, health, and resiliency against MSS. More broadly, these interventions may augment progress toward reaching Sustainable Development Goals (SDGs) adopted by the United Nations [36]. The workplace could be an essential vehicle to "ensure healthy lives and promote well-being for all" (SDG3) and "promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all" (SDG8) [36], given the significant amount of time employees spend on the job and the direct influence of management on workplace operations and activities. Ultimately, TWH may be an effective tool to aid in the pursuit of these Sustainable Development Goals [36].

As with all research, there are certain limitations that need to be considered when interpreting the results of the present study. Data are cross-sectional, which precludes us from making declarative causal inferences. These same data were collected as a convenience sample from stone, sand, and gravel mine workers in the Midwestern United States. Thus, we cannot fully guarantee these results will generalize to all miners throughout the United States and beyond and convenience sampling can introduce some biases depending on the availability of participants and because some work-groups may be under- or over-represented in the sample. Data were collected from respondents by means of paper surveys. Despite being anonymous, this could potentially result in social desirability bias. Although our sample size is fairly large, a sample size of 500 or more is sometimes recommended for logistic regression studies representing large populations. A post-hoc power analysis was completed using G*Power indicating the power achieved was 0.93, which is quite strong. Additionally, survey data were used to assess outcome data. Thus, outcomes are all self-reported symptoms. Outcomes were not assessed prospectively after data collection but were collected at the same time as the survey. Prospective data collected over time after completion of the survey would make for a stronger design, particularly if additional MSS and injury data could be collected using multiple methods. Lastly, we assessed significance at 0.10, 0.05, and 0.01 levels and report these statistics in our results. This differs from prior research using project data where significance was assessed at the 0.05 level or lower [4]. This needs to be given consideration when interpreting the findings of the present study, particularly those that were only significant at higher levels ($p < 0.10$).

Despite these weaknesses, the results are telling in that health factors associated with MSS were identified. Future research should continue to build on the present study and extend it. It appears personal health factors are associated with MSS. It would be beneficial to further examine psychosocial factors related to these relationships. Research related to kinesiophobia and catastrophizing has been linked to musculoskeletal symptoms and disability and to lower physical activity [37–40]. The presence of these factors, its impact upon MSS, and influences on physical activity were beyond the scope of the present study with stone, sand, and gravel mine workers, but this could be explored in future research studies. Additionally, psychosocial stressors should be examined. These could be examined in the context of the job demands-resources model [41,42]. It would be beneficial to know whether psychosocial stressors, along with physical stressors, influence MSS among SSGM workers. Research in this area is limited and it is not known if workers in the SSGM industry perceive their work as stressful. Further, it is not known if burnout is problematic within the industry. In the context of job demands-resources theory, it would be beneficial to explore health impairment as a result of both physical and psychosocial job demands in this industry and whether job resources effectively counter those job demands and help promote, protect, and/or sustain health. Additionally, researchers have not determined what specific job resources may be beneficial within SSGM operations. Since safety is of vast importance within the mining industry and because the safety climate positively influences organizational outcomes [43], an examination of safety-focused job demands may be beneficial. Research by Nahrgang and colleagues [44] may provide guidance on which measures to include in future research and may provide insights for intervention studies that could be integrated along with health promotion initiatives to foster a true TWH approach.

5. Conclusions

As reported, musculoskeletal symptoms of the back, shoulder, neck, and knee are problematic within the stone, sand, and gravel mining industry. As the present research illustrates, worker health and physical activity are related to these MSS reported by workers. Workers who reported their health as very good/excellent were less likely to suffer low back and knee MSS and workers who reported their health was poor/fair were more likely to report shoulder, neck, and knee MSS. Obese workers were more likely to experience knee MSS and those who smoked in the past were more likely to report neck MSS. Vigorous physical activity was mostly protective; however, those workers who performed more than 5 h of moderate physical activity each week were more likely to report shoulder and neck MSS. Health promotion, along with a safety and health protection approach, is suggested to reduce the prevalence of MSS, enhance and sustain the health and safety of workers in the stone, sand, and gravel mining industry, and to sustain these organizations.

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