Targeted Topics in Mining Safety and Health Research (AFC719)

ALPHA FOUNDATION FOR THE IMPROVEMENT OF MINE SAFETY AND HEALTH

Final Technical Report

1.0 Cover Page

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Title: Identifying and Assessing Risk Factors Associated with Musculoskeletal Disorders within Stone and Sand and Gravel Mining Operations

Organization:
Indiana University – Bloomington
Steven Allen Martin, Associate VP for Research Administration
509 E. 3rd St.
Bloomington, IN 47401-3654
812-855-0516
Fax: 812-855-9943

Principal Investigator:
Todd D. Smith, PhD, CSP, ARM, AIM
Department of Applied Health Science
Indiana University – Bloomington
School of Public Health
1025 E. 7th St., SPH Rm. 116
Bloomington, IN 47405
812-856-4887
smithtod@indiana.edu

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2.0 Executive Summary

There are approximately 102,000 employees working for 10,595 stone, sand and gravel mining (SSGM) operations in the United States (NIOSH, 2017). SSGM operations include physically demanding work tasks that may be detrimental to mine workers. These workers are potentially at risk for musculoskeletal disorders (MSD). Despite the increased adoption of mechanization and technology in mining, exposures, including those related to material handling, remain problematic (Weston et al., 2016). Little research has explored other factors that may contribute to MSD in SSGM operations. Given this dearth of information, we initiated a mixed-methods research project to identify specific risk factors for MSD, including those related to demographic factors, health factors, work characteristics, job demands and specific attributes of material handling. We also sought to identify protective factors that may reduce the likelihood of MSD. Qualitative research included deductive content analysis of focus group transcripts. Quantitative research involved collecting and analyzing cross-sectional survey data from 459 SSGM workers in the Midwestern United States to identify factors related to musculoskeletal symptoms (MSS). The survey instrument was a revised version of the Dutch Musculoskeletal Questionnaire (Hildebrandt et al. 2001, 2005).

The results of the deductive content analysis helped support many of the factors proposed in our model. Focus group members felt the following demographic and personal factors were associated with MSD: age, experience, physical fitness and attitudes. Work factors and job demands noted by the focus group included lifting, multi-tasking and specific operations related to maintenance and equipment operation. Members felt the following safety factors may help curtail MSD: fitness for duty, good pay and benefits, equipment and resource adequacy, the SLAM process and a positive safety culture.

Numerous results were obtained from the various logistic regression analyses completed. Key findings include, but are not limited to, the following:

1. Prevalence of MSS in the SSGM industry is high. Particularly, MSS of the low back (57%), neck (38%), shoulder (38%) and knee (39%) were highly prevalent among SSGM workers.
2. Mechanics and maintenance workers reported higher rates of MSS.
3. Overtime, particularly working more than 60 hours per week is problematic. Employees who worked more than 60 hours per week had approximately five times the odds of developing low back, knee and neck MSS compared to those who worked at or below 40 hours per week.
4. Overall health is an important determinant of musculoskeletal problems.
5. Obese workers were more likely to experience knee MSS.
6. Vigorous physical activity outside of work was protective against MSS.
7. Stress and burnout increased the likelihood of low back, knee, shoulder and neck MSS.
8. Job demands had a significant influence on the likelihood of MSS. Dynamic and static load exposures increased the likelihood of low back, neck/shoulder and wrist/hand MSS.

3.0 Problem Statement and Objective

3.1 Background and Problem Statement

This research is aligned with Alpha Foundation's *Critical Topics of Priority Interest* including the Injury & Disease Exposure and Risk Factor section and the priority topic titled "Identification of Mining Jobs and Operations with High Rates of Work-Related Musculoskeletal Disorders (WMSD), including the Evaluation of the Effectiveness of Measures Intended to Reduce or Prevent These Disorders."

There are approximately 102,000 employees working at 10,595 stone, sand and gravel mining (SSGM) operations in the United States (NIOSH, 2017). Recently publicized data indicate there are 4303 stone mines and 6292 sand and gravel mines operating in the United States (NIOSH, 2017). Stone, sand and gravel mining operations include physically demanding work tasks that may be detrimental to mine workers. Thus, a large group of American workers are at risk for ergonomic-related musculoskeletal disorders (MSD).

Musculoskeletal disorders include any acute or chronic injury that affects any part of a person's body such as muscles, tendons, ligaments, joints, blood vessels, or bones. Examples of debilitating MSD are carpal tunnel syndrome, rotator cuff injury, tendinitis, low back injury, muscle strains, sprains, bursitis, epicondylitis and the like. Within mining operations, many MSD are to the neck, shoulder and back (Winn et al. 1996). When ergonomic hazards are not controlled or countered, ergonomic exposures including, but not limited to, manual material handling, excessive lifting, excessive fine manipulation, forceful exertions, repetition, temperature extremes and vibration, among other factors, increase the likelihood that workers will develop these MSD. Often, these MSD require medical intervention and have long recovery times, resulting in millions of lost workdays each year (Weston et al., 2016). Moreover, there are social consequences to these occupational injuries and illnesses (Dembe, 2001) and economic implications to MSD. In 2004, the U.S. healthcare system treated over 16 million strains and sprains with estimated treatment costs totaling more than $127 billion (Weston et al., 2016).

Manual material handling accounts for a large percentage of nonfatal lost-time injuries in both underground and surface stone, sand and gravel mining operations. Despite the increased adoption of mechanization and technology in mining, material handling continues to be associated with MSDs (Weston et al., 2016). Material handling is the leading cause of nonfatal lost-time injuries in surface stone, sand and gravel mining operations, accounting for 39% of the overall 7780 cases (NIOSH, 2017). Material handling, as noted, is also problematic in underground stone, sand and gravel mining operations. Material handling, second to slips and falls, accounts for 27% of the overall cases in this sector (NIOSH, 2017). Despite knowing material handling is problematic, there is limited evidence delineating the specific risk factors associated with MSD (Weston et al., 2016).

Given this information, the dearth of information associated with MSD in stone, sand and gravel mining operations, we initiated our research project to identify specific risk factors for MSD, including those related to work characteristics, job demands and specific attributes of material handling. Beyond this, targeted interventions within the mining industry can only be enhanced once risk factors are identified and once targets for interventions are delineated. Thus, our proposed research also seeks to identify protective factors that may reduce the likelihood of MSD.

The consensus among safety professionals, along with academics, is that the implementation of safety and ergonomic interventions has observable and measurable benefits including injury prevention, enhanced worker quality of life, organizational enhancement and cost reduction. However, there has been little success in defining what interventions need to be executed in stone, sand and gravel mining operations to curtail injuries and MSD.

Monforton and colleagues (2010) evaluated the impact of a 1999 safety training regulation implemented by the Mine Safety and Health Administration (MSHA) on injuries in U.S. stone, sand and gravel mining operations, but were unable to show that the training requirement resulted in observed serious injury decreases including MSD. Further, Torma-Krajewski and colleagues (2007), in conjunction with the National Institute for Occupational Safety and Health (NIOSH) implemented interventions to reduce risk factor exposures (i.e. frequent neck and back twisting of workers when looking at rear mirror of loaders) at a large producer of construction aggregates. Although researchers were able to integrate ergonomics programs into existing safety and health programs, the effectiveness of the intervention was not determined as there was no follow-up data. Obviously, more intervention studies are needed in this industry, but we must first identify specific resources and safety programs that are protective and would effectively reduce MSD.

3.2 Research Objectives and Aims

As noted, musculoskeletal disorders, particularly strains and sprains, within stone, sand and gravel mining operations are problematic (NIOSH, 2017). In order to protect the nearly 102,000 miners working in these operations, exploratory research needs to be conducted to further identify factors that place these miners at risk for musculoskeletal disorders. The industry, stakeholders and researchers know it is a problem, but a knowledge gap exists as specific factors that place mine workers at risk for these disorders are not fully known or understood. Further, we do not fully understand the relationships between various protective factors, including job and safety resources, and musculoskeletal disorders.

Research exploring the impact of demographic and personal factors, work characteristic and job demands and safety resources on musculoskeletal disorder outcomes is necessary. Our proposed research specifically addresses a national problem and seeks to benefit the SSGM industry by providing guidance on demands that need to be countered or controlled to prevent MSD and by identifying factors and safety resources that may counter exposures and reduce the likelihood of MSD. These factors and safety resources should serve as a means to enhance miner safety, health and wellbeing and will provide guidance for research-to-practice (R2P) initiatives. Accordingly, we proposed four aims associated with protecting workers in the SSGM industry from musculoskeletal disorders. These aims include the following:

Aim 1: Verify and refine a model incorporating demographic variables, personal factors, work characteristics, job demands and safety resources, which is applicable to stone, sand and gravel mining operations. As part of this process, job demands associated with musculoskeletal disorders and safety resources that may counter demands will be identified.

Aim 2: Formalize a survey instrument that can be utilized within the stone, sand and gravel mining industry.

Aim 3: Test the finalized model and hypothesized relationships related to model factors and musculoskeletal symptoms and disorders.

Aim 4: Disseminate the results of this study through scholarly means and through other resources to enhance stone, sand and gravel mine worker safety, health and wellness and to bolster research-to-practice (R2P) initiatives, particularly identifying which resources can be enacted to curtail musculoskeletal disorders and to protect miners.

4.0 Research Approach

Our research was guided by the model presented in Figure 1. This model incorporates aspects of the job-demands resources theoretical framework (Demerouti & Bakker, 2007; Nahrgang, Morgeson, & Hofmann, 2011) but is an extension of that framework with outcomes focused on musculoskeletal problems. Additionally, the model incorporates broader job demands, to specifically incorporate physical stressors and factors deemed relevant within SSGM operations and those that may be directly related to MSD and associated musculoskeletal symptoms (MSS).

The present research project used a mixed-methods approach that included qualitative focus group research and quantitative survey research. The quantitative study was focused on examining model relationships using cross-sectional data that were collected from employees working in the SSGM industry. More details on the qualitative and quantitative data collection approaches are provided below, along with details of the survey instrument designed for the latter.

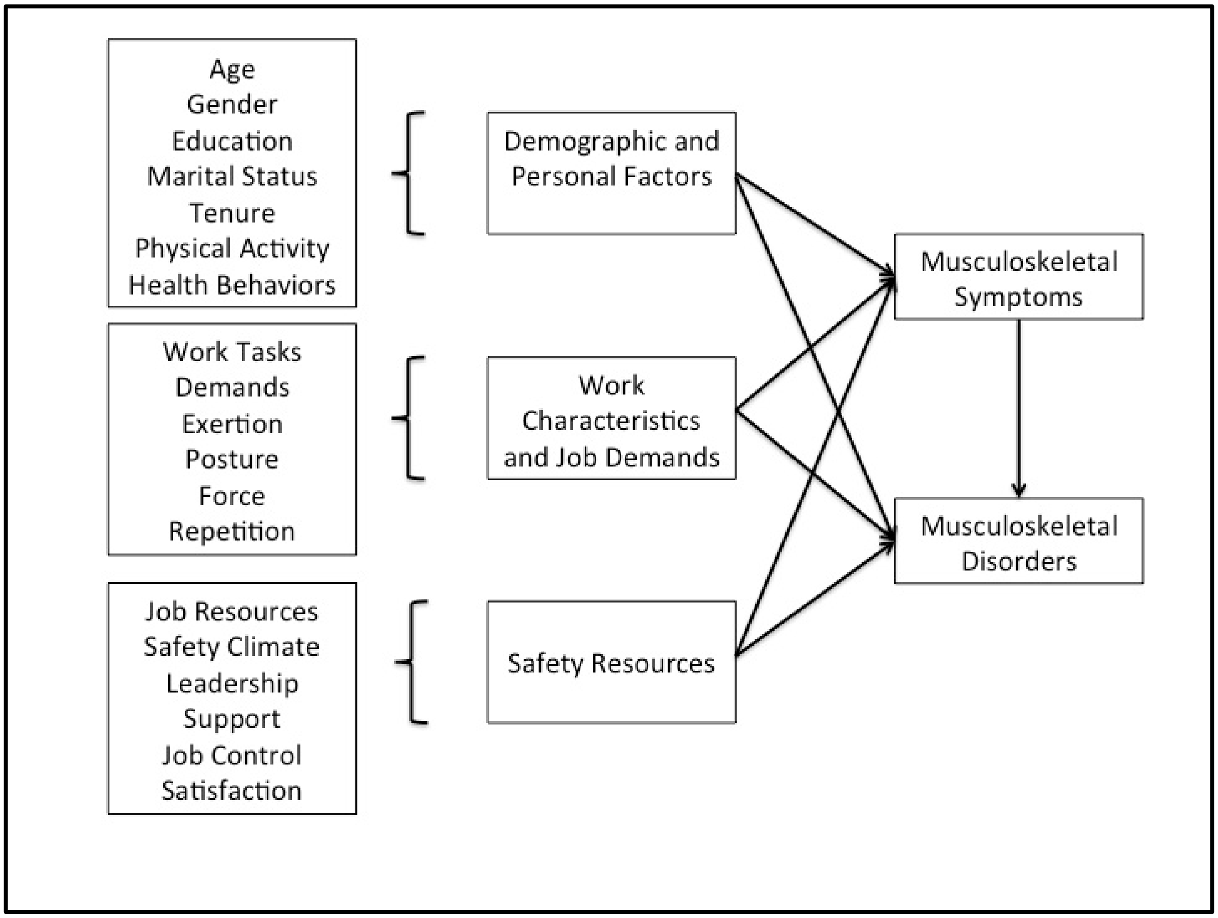

Figure 1: Study Model and Framework

4.1 Qualitative Study (Focus Group)

4.1.1 Participants

The researchers liaised with personnel at the Indiana Minerals Aggregates Association (IMAA) to assemble a focus group of mining safety experts. The focus group was comprised of 13 professionals employed in SSGM and were mostly representatives of IMAA's safety committee. Participants held positions such as executive officer, mining engineer, operations manager, safety manager, human resource manager and trainer, among others. Participants worked for a variety of small, medium and large SSGM businesses in the Midwestern United States. Participation in the focus group was voluntary and consent was obtained from all participants. This study received Institutional Review Board approval at Indiana University – Bloomington prior to initiation.

4.1.2 Focus Group Methodology

The focus group session was conducted in a conference room facility offered by IMAA. This conference room allowed all participants to gather and participate in the meeting.

Participants sat at tables arranged in a U-shape in the conference room. This allowed all participants to see each other and hear the discussion and questions. The session lasted approximately 45 minutes. At the end of the focus group meeting, participants were given $40 gift cards for their participation in the project.

A member of the research team served as the moderator. This individual presented research questions to the focus group participants and asked follow-up questions. Another member of the research team wrote notes on a white board so that participants were able to view key points made by participants and follow along with the discussion. Two student research assistants kept notes of the discussion for use in the research activity. The focus group meeting was recorded. The recording was transcribed into text for analyses.

Researchers introduced the focus group activity purpose. Participants were provided a copy of the model guiding the focus group questioning and discussion (Figure 2 below). The purpose was to identify risk factors associated with demographic and personal factors and risk factors associated with work operations, job tasks, job demands and the like. Lastly, researchers aimed to gain information about safety resources that were beneficial to the industry and would help curtail MSD within SSGM operations. The moderator asked three probing questions associated with these three main themes. Discussion continued until saturation was reached, which occurred when responses were not distinctively different or when no other comments were offered by participants.

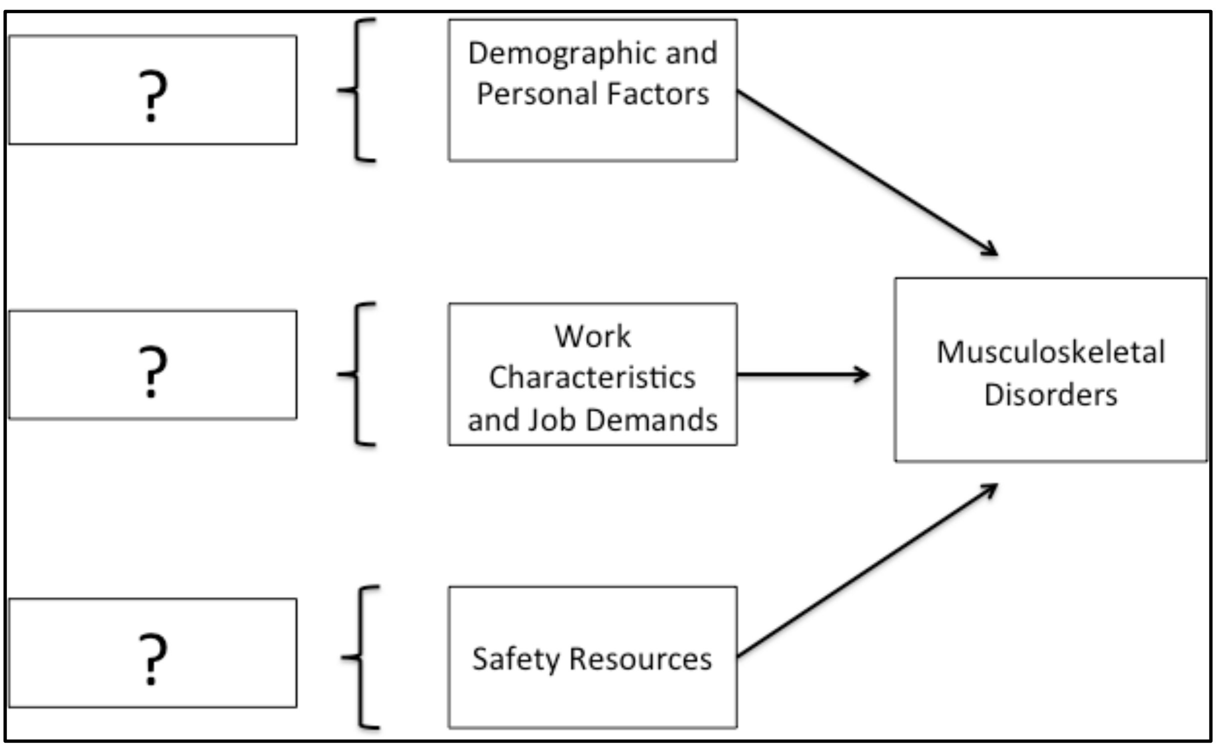

Figure 2. Focus Group Discussion Model

4.1.3. Focus Group Analysis

A deductive content analysis (DCA) of the focus group transcripts was completed. DCA follows a more standardized exploratory process, where the main themes have already been identified. Thus, our main themes included demographic and personal factors, work characteristics and job demands and safety resources. To complete the DCA, three research members analyzed the transcribed focus group recording. Each member identified and recorded what they believed were the dominant subcomponents to each theme in a table. Researchers recorded each subcomponent, identified its context in relation to the thematic area and then identified the page and line where the content was highlighted. Completed tables were provided to the principal investigator for this project. Dr. Smith then compiled the results from each member. Overall results were shared with the research team participating in the project to ensure agreement with the identified subcomponents and the context in which the content related to each subcomponent fit into the research model. Results are shared in Section 5 of this report. We were able to utilize the findings from the focus group analysis to triangulate and to develop a complete and valid understanding of our findings through a convergent parallel design methodology (Plano-Clark & Creswell, 2015).

4.2. Quantitative Study

4.2.1. Participants

Survey data were collected from 459 full-time workers employed in the SSGM industry. We were able to recruit these participants through personal contacts and through collaborative efforts with the IMAA and the Vincennes University Mining Program. Participants worked for small to medium-sized businesses in the Midwestern United States. Worker categories included office, administration and professional (n = 71), laborers and equipment operators (n = 125), moving/rubber tire equipment/vehicle operators (n = 82), maintenance/mechanics (n = 83), supervisors (n = 51), miscellaneous/others (n = 5), and not identified (n = 42).

4.2.2 Instrument

One of our main aims (Aim 2) was to formalize a survey instrument that could be used within the SSGM industry. In this effort, we sought to obtain the DMQ – Dutch Musculoskeletal Questionnaire (Hildebrandt et al. 2001, 2005) and expand its application within the research study (and potentially later within industry). The DMQ was first published in Dutch. The questionnaire, which has been validated, was translated into English, albeit versions were in the context of British studies and language. Our research team obtained the DMQ and reviewed the DMQ questionnaire. Through reviews and discussions, we determined that some items would need to be re-written, wording changed, and response options enhanced for effective use within our study. Further, it was indicated that instructions would need to be clarified for our audience. The research team worked to tailor and modify the DMQ, reassess and confirm a preliminary questionnaire. Following this modification, the DMQ was submitted to subject matter experts (SME) as suggested by Ramirez (2002) to determine if the items were now appropriate as written, made sense for stone, sand and gravel miners and workers in the aggregates mining industry. We were able to work with our SME's (*n*=9) to finalize the survey instrument for testing and utilization and to additionally include items associated with the job demands-resources model as we proposed. We have included a copy of the final survey instrument utilized for this study in the appendices.

The survey contains 12 sections. The contents of which include the following:

Section 1: Safety climate
Section 2: Supervisor support
Section 3: Job satisfaction and turnover intention
Section 4: Worker autonomy
Section 5: Workload
Section 6: Demographic and work-related questions
Section 7: Health
Section 8: Burnout
Section 9: Stress
Section 10: Injury data
Section 11: 7-day and 12-month MSS/MSD
Section 12: Physical job demands

Some measures within the instrument were adapted from previously validated questionnaires. The primary outcome measure, albeit the literature is disparate in its terminology, is associated with musculoskeletal symptoms (MSS) associated with musculoskeletal disorders (MSD). The outcome was assessed in two ways: 1) MSS prevalence in the past 7 days and MSS prevalence and severity in the past 12 months. Measures were adapted from the validated Dutch Musculoskeletal Questionnaire (DMQ) authored by Hildebrandt et al. (2001, 2005). The survey instrument takes most individuals about 15 to 20 minutes to complete.

4.2.3. Data Collection

Prior to data collection, a member of the study team gave a brief description of the survey, project goals and objectives to potential participants and answered their questions before distribution of the survey. The research team used a script to ensure consistency between data collection visits. Consent was obtained from all participants prior to survey data collection and participation was voluntary. Data collected were anonymous. Institutional Review Board approval was granted through Indiana University – Bloomington prior to the initiation of this research. The research team distributed paper surveys, and pens if needed, to all participants. A member of the research team was always present while participants completed the survey, which occurred either prior to scheduled safety training sessions or during a training session break. Each participant received a $20 gift card for participating in the survey.

4.2.4. Analyses

Generally, descriptive statistics delineating mean (and standard deviation) or percentage frequency values were used to analyze the prevalence of MSS across different body parts within the sample of workers, as well as across age groups and job categories. Logistic regression analyses were mostly used to examine the relationships between various model factors and MSS across primarily affected body parts, adjusting for potential covariates and confounders. SPSS version 25 and STATA MP version 14 were used to conduct analyses.

5.0 Summary of Accomplishments

To our knowledge, this was the first known comprehensive, mixed-methods study to examine relationships between multiple risk factors and musculoskeletal symptoms and disorders among workers in the SSGM industry. A summary of our results and accomplishments are presented in this section.

5.1 Research Model Verification (Aim 1)

Aim 1 of this project was focused on refining and verifying a model that incorporated demographic variables, personal factors, work characteristics, job demands and safety resources, which would be applicable to SSGM operations. Additionally, we were focused on identifying job demands that place workers at risk for musculoskeletal disorders and safety resources that may counter demands present at work.

Focus group results helped support and verify our proposed model and many of its posited factors (Figure 1). The focus group methodology was presented above in Section 4. The results of the deductive content analysis are presented in Table 1. As is evident, we were able to support many of the factors proposed in our model, which was based on an extensive literature review and initial guidance from subject matter experts.

Table 1. Themes and Identified Subcomponents

Demographic & Personal Factors	Work Factors & Job Demands	Safety Resources and Protective Factors
Age	Job/Position – Maintenance/Mechanics	Fitness for Duty (mental, physical, technical aptitude)
Experience	Job/Position – Equipment Operators	Equipment/Resources
Physical Stature	Lifting	Pay/Benefits
Mentality / Attitude	Multi-tasking/Performing Multiple Jobs	Safety Culture
	Production Oriented	SLAM
	Resource Adequacy	

Focus group respondents overwhelmingly agreed that age was a potential risk factor for MSD. They believed older workers had lower levels of flexibility and were at risk from material handling activities. They believed younger workers were at risk as well; however, as this topic was further explored, it was evident that the focus group participants were more concerned with lack of experience versus age. There was concern with physical fitness, physical preparedness or what they termed “physical stature.” Given the complexity of job demands, focus group participants indicated that good physical health is necessary to curtail MSD. They agreed that it is problematic when workers are not physically ready or able to perform required job tasks associated with SSGM operations. In addition, mentality and attitude emerged as a subcomponent. In this context, focus group members felt that sometimes the perception of invincibility is problematic as these workers may place themselves at risk. One focus group member indicated that administrators need to remind workers that they do not have to be “rock stars” and that they need to perform the job as expected and not “try too hard.”

With regard to work factors and job demands, the focus groups pointed to two main job categories where they believed MSD were problematic. They felt maintenance workers or mechanics were likely at risk for MSD and they also indicated that equipment operators were more likely to suffer MSD at work. With regard to specific job tasks or activities, the focus group members commented on heavy lifting as a concern. They mentioned lifting exposures associated with maintenance activities, including pulling wire. Also, a concern specifically noted by the members was the lifting and carrying of buckets by quality control personnel. They indicated this job needs to be further evaluated. In addition to lifting, several members of the committee commented about concerns with multi-tasking. They mentioned that it was not uncommon for many workers to perform multiple job tasks, including those outside of their normal job. This seems to be a significant concern among small employers, particularly those with limited resources. This may be exacerbated too as focus group members opined that SSGM operations are often production oriented.

With regard to safety resources and protective factors, the focus group members provided good insights into programs and initiatives important and necessary to prevent MSD. As noted, the focus group members concurred that low levels of physical fitness or overall health were factors that may increase the likelihood of MSD. The focus group members were also in agreement that fitness for duty then was essential to prevent MSD. In the context of “fitness for duty” members indicated that workers need to be mentally and physically fit. Further, they indicated that a technical aptitude is preferred within their industry.

The focus group members spoke supportively to the benefits of having a positive safety culture and how it improved overall safety. There was interesting discussion too with regard to what factors were part of a positive safety culture. Members spoke about the importance of open communication, caring leadership and having a family atmosphere. Members also spoke to the benefits of the SLAM (Stop, Look, Analyze and Manage) process, which has been heavily promoted in the SSGM industry. They felt that the application of this process was a positive and illustrated an organization’s commitment to safety, which is often a key determinant of safety culture/climate. Along with these factors, there was discussion about the importance of organizational factors such as pay and benefits. Focus group members concurred that pay and benefits within SSGM operations are very good. Although they felt this was a positive in that it helped maintain an experienced workforce, it was noted that it may impact MSD in the long term as they believed older workers may be at increased risk of MSD.

5.2 SSGM Worker Safety and Health Survey (Aim 2)

Details regarding the development of the survey and its formalization were highlighted in Section 4. The survey instrument formalized by the research team facilitated the collection of a wide range of data for each participant, which has aided the understanding of the burden of musculoskeletal problems among SSGM workers. A copy of the survey instrument is provided in the Appendices.

5.3 Quantitative Research Results (Aim 3)

Data were collected from 459 participants working in SSGM operations. Descriptive statistics summarizing the participants are presented in Table 2.

Table 2. Participant sociodemographic characteristics and job categories

Variable	Mean (SD) / Frequency (%)
Age	45 (14)
Sex	
Male	423 (93%)
Female	31(7%)
Education	
Some High School	43 (9.5%)
High School Graduate/GED	188 (41.3%)
Some College or Technical/Vocational Training	130 (28.6%)
Associate degree	44 (9.7%)
Bachelor's degree	39 (8.6%)
Master's degree	8 (1.8%)
Race	
African American / Black	4 (0.9%)
American Indian / Alaskan Native	1 (0.2%)
Asian/Asian American	1 (0.2%)
Hispanic, Latino/a/x	17 (3.7%)
White	426(93.6%)
Job Category	
Office/Clerical/Professional	71 (15.6%)
Maintenance/Mechanics	81 (17.8%)
Laborers and Equipment Operators	125 (27.5%)
Moving/Rubber Tire Equipment/Vehicle Operators	82 (18.0%)
Supervisors	51 (11.2%)
Miscellaneous/Others	5 (1.1%)

Aim 3 of the research project was focused on testing the finalized model, particularly examining the relationships between demographic and personal factors (including health factors), work characteristics and job demands, safety resources and musculoskeletal disorder symptoms. The results below highlight our findings with each of the model aspects.

5.3.1 Prevalence

The anatomic body parts or regions most impacted within SSGM workers were the low back, neck, shoulder and knees. Fifty-seven percent of all workers surveyed reported low back MSS, 38% reported neck MSS, 38% reported shoulder MSS and 39% reported knee MSS.

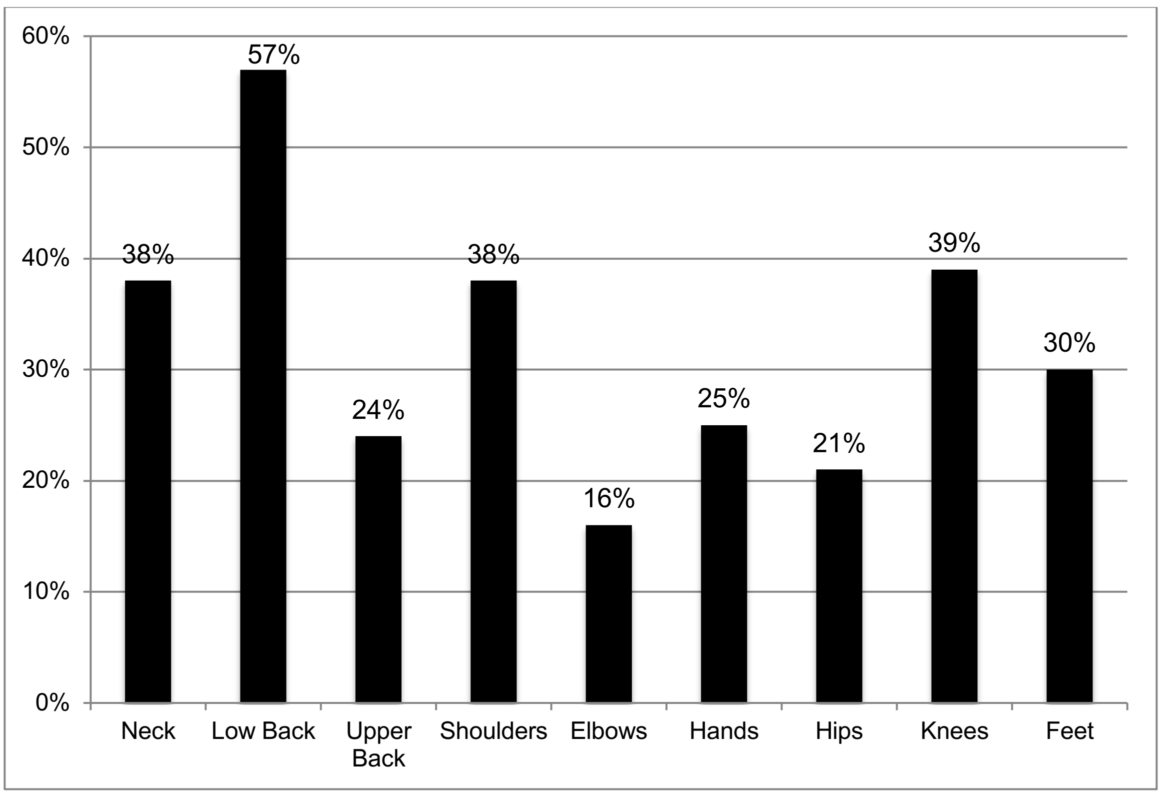

Figure 3. Percentage of SSGM employees who experienced MSS over the past 12 months at different body parts**.**

5.3.2 Demographic and Personal Factors

Table 3 illustrates MSS prevalence across all age groups. Workers aged 35–44 had the highest prevalence of MSS at five body parts (low back, upper back, shoulders, elbows and hands). Workers aged 45–54 reported the lowest prevalence at three body parts (low back, elbows and hands). Workers aged 35–44 reported the highest prevalence of low back MSS (69%) followed by workers aged 25–34 (61%) and workers aged 55–64 (60%). For knee MSS, workers aged 65 and above reported the highest prevalence at 52%

followed by workers aged 25–34 (44%) and workers aged less than 25 (43%). Workers aged 55–64 reported the lowest prevalence of knee MSS (32%).

Table 3. Prevalence of reported 12-month MSS by age group.

Age	Neck	Low back	Upper back	Shoulders	Elbows	Hands	Hips	Knees	Feet
< 25 (n=40)	13(33%)	21(53%)	8(20%)	14(35%)	6(15%)	9(23%)	10(25%)	17(43%)	12(32%)
25-34 (n=81)	30(37%)	49(61%)	19(24%)	27(34%)	16(20%)	14(18%)	13(16%)	36(44%)	30(37%)
35-44 (n=96)	39(43%)	63(69%)	28(31%)	40(43%)	19(21%)	35(38%)	19(21%)	39(42%)	28(30%)
45-54 (n=97)	33(34%)	46(48%)	20(21%)	36(38%)	9(9%)	16(17%)	19(20%)	33(34%)	25(26%)
55-64 (n=113)	51(46%)	67(60%)	30(28%)	41(37%)	17(16%)	29(26%)	28(25%)	36(32%)	28(25%)
65+ (n=25)	7(28%)	14(56%)	5(22%)	10(42%)	5(20%)	7(28%)	5(20%)	13(52%)	8(32%)

Interestingly, we did not find significant differences related to MSS at the four main body parts when examining differences (at $p<.05$) between those that were aged less than 25 (reference group) and the other categories. This is evident in Table 4.

Table 4. Odds ratios of MSS by Age**.**

Age	Low Back OR	Knees OR	Shoulder OR	Neck OR
< 25 (n = 40)	Ref	Ref	Ref	Ref
25–34 (n = 81)	1.4 (0.6,3.0)	1.1 (0.5,2.3)	1.0 (0.4,2.3)	1.1 (0.5,2.6)
35–44 (n = 96)	1.8 (0.3,3.8)	1.0 (0.5,2.2)	1.6 (0.7,3.5)	1.5 (0.7,3.3)
45–54 (n = 97)	0.8 (0.4,1.7)	0.7 (0.3,1.5)	1.3 (0.6,2.7)	1.1 (0.5,2.3)
55–64 (n = 113)	1.3 (0.6, 2.6)	0.6 (0.3,1.3)	1.2 (0.6,2.6)	1.6 (0.8,3.5)
65+ (n = 25)	1.2 (0.4, 2.3)	1.3 (0.5,3.7)	1.5 (0.5, 4.4)	0.8 (0.3,2.5)

*p<0.05

Additional bivariate logistic regression analyses were completed to examine relationships between individual sociodemographic and health factors and low back MSS, shoulder MSS, neck MSS and knee MSS. We then completed four multiple logistic regression analyses to predict MSS in each of the four body parts separately. Backward selection with pr = 0.2 was used to identify which independent variables, among all sociodemographic and health variables, were included in each regression model. Odds ratios and 95% confidence intervals are presented to delineate associations between sociodemographic factors, health factors and MSS. Significance is reported at 0.1, 0.05, and 0.01 levels. Regression models passed Hosmer-Lemeshow goodness-of-fit tests. Multicollinearity was examined among all sociodemographic and health variables with a minimum tolerance level 0.5 and were appropriate. In these analyses, we did find that age, gender, education, marital status, education, perception of health status, physical activity, smoking, and BMI were significantly associated with MSS. See Table 5 for these findings.

Increases in age were slightly protective with regard to reported low back MSS (OR = 0.98, 95% CI: 0.97 – 1.00, p = 0.043). Low back MSS was more likely among workers with an associate degree (OR = 3.13, 95% CI: 1.41 – 6.92, p = 0.005) and bachelor's/master's degrees (OR = 1.90, 95% CI: 0.90 – 4.02, p = 0.093) than those with a high school diploma or GED. Workers who were married/living with partner were associated with increased low back MSS (OR = 2.05, 95% CI: 1.26 – 3.35, p = 0.004), compared to single workers. 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 = 0.017).

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). 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, p = 0.074). Workers who rated their health as fair/poor were 1.70 times more likely to report shoulder MSS (OR = 1.70, p = 0.077) compared to those who rated their health as good. Those who had 1 to 5 hours per week of vigorous physical activity outside of work were less likely to report shoulder MSS (OR = 0.62, 95% CI: 0.38 – 1.01, p = 0.055); although, significance was at the $p < 0.1$ level.

Female workers had greater odds of reporting neck MSS (OR = 2.54, 95% CI: 1.04 – 6.16, p = 0.040). Divorced/separated/widowed workers (OR = 2.57, 95% CI: 1.10 – 6.02, p = 0.030) and married/living with partner workers (OR = 2.18, 95% CI: 1.21 – 3.93, p = 0.009) had greater likelihood of neck MSS compared to single workers. 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 = 0.047).

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, p = 0.053) compared to those workers who never smoked. Workers who reported moderate physical activity more than 5 hours per week were more likely to have neck MSS (OR = 1.92, 95% CI: 1.01 – 3.64, p = 0.045). Compared to workers who were overweight, both normal/underweight (OR = 2.62, 95% CI: 1.42 – 4.82, $p < 0.001$) and obese (OR = 2.02, 95% CI: 1.26 – 3.23, $p < 0.001$) 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, $p < 0.05$).

Table 5. Odds Ratios and 95% Confidence Intervals for Low Back, Shoulder, Neck and Knee MSS

	Low Back		**Shoulder**		**Neck**		**Knee**	
	OR1	**OR2**	**OR1**	**OR2**	**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)**	0.99 (0.98-1.01)	0.98 (0.97-1.00)*	1.00 (0.99-1.01)	
Gender								

Male	—	—	—	—	—	—	—	—
Female	1.53 (0.70-3.33)	1.96 (0.75-5.14)	0.89 (0.42-1.91)		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	1.14 (0.74-1.76)		1.96 (1.26-3.06)***	2.20 (1.37-3.54)***	1.37 (0.88-2.13)		1.26 (0.81-1.95)	1.40 (0.89-2.22)
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)*	1.96 (1.01-3.81)**		1.49 (0.77-2.88)	1.67 (0.84-3.32)
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)**	1.88 (1.00-3.54)*	1.70 (0.84-3.43)	0.97 (0.51-1.87)	
Marital Status								
Single	—	—	—	—	—	—	—	—
Divorced/Separated/ Widowed	0.72 (0.35-1.48)		1.97 (0.94-4.12)*		1.85 (0.89-3.86)	2.57 (1.10-6.02)**	1.02 (0.49-2.14)	
Married or Living w/ Partner	1.33 (0.84-2.10)	2.05 (1.26-3.35)***	1.45 (0.89-2.35)		1.43 (0.88-2.32)	2.18 (1.21-3.93)***	1.15 (0.72-1.84)	
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)*	1.46 (0.85-2.52)		1.75 (1.01-3.03)**	2.62 (1.42-4.82)***
>30	1.11 (0.73-1.68)		1.19 (0.77-1.83)		1.32 (0.86-2.02)		1.80 (1.17-2.77)***	2.02 (1.26-3.23)***
Health Status								
Good	—	—	—	—	—	—	—	—
Fair/Poor	1.12 (0.63-1.99)		1.80 (1.03-3.15)**	1.70 (0.94-3.04)*	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	0.60 (0.40-0.93)**	0.56 (0.35-0.90)**	1.01 (0.65-1.56)		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 (0.83-1.99)	1.36 (0.86-2.15)	1.19 (0.77-1.86)		1.28 (0.83-1.98)	1.56 (0.99-2.46)*	1.48 (0.96-2.29)*	
I am a current smoker	1.05 (0.64-1.70)		1.23 (0.75-2.01)		0.89 (0.54-1.48)		1.37 (0.83-2.23)	
Vigorous Physical Activity								
None outside of work	—	—	—	—	—	—	—	—
30 minutes -1 hour	0.66 (0.40-1.07)*	0.62 (0.38-1.02)*	0.74 (0.45-1.22)	0.68 (0.40-1.16)	0.65 (0.40-1.08)*	0.67 (0.40-1.10)	0.76 (0.47-1.25)	
1 hour – 5 hours	0.93 (0.58-1.48)		0.73 (0.45-1.16)	0.62 (0.38-1.01)*	0.91 (0.57-1.45)		0.81 (0.51-1.29)	
More than 5 hours	0.81 (0.40-1.64)		0.90 (0.45-1.83)		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 minutes-1 hour	0.91 (0.52-1.60)		0.72 (0.40-1.28)		0.86 (0.49-1.53)		0.93 (0.53-1.64)	
1 hour- 5 hours	1.18 (0.69-2.03)		0.91 (0.53-1.58)		0.91 (0.53-1.57)		0.87 (0.50-1.49)	
More than 5 hours	0.97 (0.53-1.80)		1.33 (0.72-2.47)	1.48 (0.87-2.51)	1.28 (0.69-2.37)	1.92 (1.01-3.64)**	1.03 (0.56-1.91)	

Notes: *p < 0.1, **p < 0.05, ***p < 0.01; OR 1 are based on univariate binary logistic regression; OR 2 are based on multiple logistical regression using backward selection method with Pr= .2

5.3.3 Work Characteristics and Job Demands

The distribution of MSS by job category is presented below in Table 6.

Table 6. Distribution of musculoskeletal symptoms by job category.

Job Category	Neck	Low back	Upper back	Shoulders	Elbows	Hands	Hips	Knees	Feet
Office/Clerical Professional (n = 71)	27 (39%)	35 (49%)	11 (16%)	28 (41%)	8 (11%)	12 (17%)	12 (17%)	20 (28%)	19 (27%)
Maintenance/Mechanics (n = 81)	36 (46%)	52 (66%)	23 (30%)	33 (42%)	15 (19%)	30 (39%)	21 (27%)	36 (46%)	25 (32%)
Laborers & Equipment Operators (n = 125)	42 (34%)	70 (57%)	34 (28%)	41 (34%)	16 (13%)	36 (29%)	27 (22%)	52 (42%)	37 (30%)
Moving/Rubber Tire Equipment Operators (n = 82)	35 (43%)	49 (61%)	19 (24%)	29 (35%)	13 (16%)	18 (23%)	17 (21%)	32 (40%)	24 (30%)
Supervisors (n = 51)	22 (43%)	36 (71%)	15 (31%)	23 (45%)	11 (22%)	11 (22%)	11 (22%)	22 (43%)	15 (29%)

Job category was significantly associated with MSS when we examined the four most prevalent anatomical or body regions impacted. Logistic regression analyses with job category as the independent variable showed that mechanics/maintenance workers had twice the odds of developing low back MSS (OR: 2.1, 95% CI: 1.1–4.2) and knee MSS (OR: 2.2, 95% CI: 1.1–4.6) compared to office/clerical/professional personnel, the reference group. Supervisors were at higher risk of MSS at the low back (OR: 2.8, 95% CI: 1.3–6.2) compared to the reference group. Equipment operators and laborers had higher odds of knee MSS (OR: 2.0, 95% CI: 1.0–3.9) compared to the reference group. These findings are presented in Table 7.

Table 7. Odds ratios of MSS by Job Category**.**

Job Category	Low Back OR	Knee OR	Shoulder OR	Neck OR
Office/Clerical/Professional	Ref	Ref	Ref	Ref
Maintenance/Mechanics	2.1 (1.1,4.2)*	2.2 (1.1,4.6)*	0.9 (0.5,1.8)	1.4 (0.7,2.8)
Laborers & Equipment Operators	1.6 (0.8,2.9)	2.0 (1.0,3.9)*	0.6 (0.3,1.2)	0.9 (0.5,1.8)
Moving/Rubber Tire Equipment Operators	1.7 (0.9,3.4)	1.7 (0.8,3.5)	0.7 (0.3,1.3)	1.3 (0.6,2.5)
Supervisors	2.8 (1.3,6.2)*	2.0 (0.9,4.4)	1 (0.5,2.2)	1.3 (0.6,2.8)

*p<0.05

With regard to the relationship between hours worked per week and MSS (Table 8), we found that employees who worked more than 40 hours per week had higher odds of developing musculoskeletal symptoms. A major finding was that employees who worked more than 60 hours a week had approximately five times the odds of developing low back MSS (OR: 4.7 95% CI: 1.9–11.5), knee MSS (OR: 4.5, 95% CI: 2.0–10.3) and neck MSS (OR: 5.1, 95% CI: 2.2–11.8) compared to those who worked at or below 40 hours per week, which is the reference group. Employees who worked 51-60 hours per week also had significantly higher odds of developing neck MSS (OR: 2.7, 95% CI: 1.3–5.3) compared to the reference group.

Table 8. Odds ratios of MSS by hours worked per week.

Work Hours/Week	Low Back OR	Knees OR	Shoulder OR	Neck OR
Up to 40 (n = 64)	Ref	Ref	Ref	Ref
41–50 (n = 213)	1.7 (0.9, 3.0)	1.4 (0.7, 2.5)	1.3 (0.7, 2.5)	1.7 (0.9, 3.3)
51–60 (n = 128)	1.4 (0.7, 2.5)	1.1 (0.6, 2.2)	1.3 (0.6, 2.4)	2.7 (1.3, 5.3)**
More than 60 (n = 47)	4.7 (1.9, 11.5)**	4.5 (2.0, 10.3)**	1.6 (0.7, 3.6)	5.1 (2.2, 11.8)**

*p < 0.05; **p < 0.01

Table 9 presents the results of our logistic regression analyses related to job demands. These analyses are modeled and based on the work by Hildebrandt et al. (2001, 2005). Workers exposed to dynamic load with wrist/hand were 2.26 times (p = 0.01, 95% CI: 1.22-4.19) more likely to experience MSS in the same area. Wrist/hand MSS were also 1.39 times (p < 0.01, 95% CI: 1.11 – 1.73) more likely among workers that carried static loads using wrist/hand. Similar results were also found in the neck/shoulder area. Workers exposed to dynamic load and static load at neck/shoulder were 1.66 times (p = 0.01, 95% CI: 1.12-2.43) and 1.22 times (p = 0.04, 95% CI= 1.01-1.47) more likely to report neck/shoulder MSS. Low back MSS were more likely among workers whose torso or trunk were exposed to dynamic load (OR = 1.91, 95% CI: 1.15-3.16) and static load (OR = 1.33, 95% CI: 1.01-1.74). Workers exposed to repetitive load were less likely experience neck/shoulder MSS (OR = 0.70, 95% CI: 051-0.98).

Table 9. Work/Job Demands and MSS

	Wrist/Hand MSS		Neck/Shoulder MSS		Low Back MSS	
	Odds Ratio	95% CI	Odds Ratio	95% CI	Odds Ratio	95% CI
Forceful Exertions	1.07	(0.88, 1.31)	1.29	(0.81, 2.05)	0.94	(0.79, 1.11)
Dynamic Load	2.26*	(1.22, 4.19)	1.66*	(1.13, 2.43)	1.91*	(1.15, 3.16)
Static Load	1.39**	(1.11, 1.73)	1.22*	(1.01, 1.47)	1.33*	(1.01, 1.74)
Repetitive Load	1.57	(0.99, 2.49)	0.70*	(0.51, 0.98)	0.99	(0.61, 1.61)
Vibration	0.54	(0.28, 1.04)	0.72	(0.43, 1.21)	1.32	(0.81, 2.15)

*p<0.05, **p<0.01

Bivariate analyses, as presented in Table 10, found that lifting heavy loads more than 51 pounds at work was significantly associated with increased odds of neck/shoulder MSS (OR = 1.50, 95% CI: 1.03-2.18) and wrist/hand MSS (OR = 2.06, 95% CI: 1.33-3.20). Carrying heavy loads more than 51 pounds at work was significantly associated with 2.06 times increased prevalence of wrist-hand MSS (OR= 2.06, 95% CI: 1.33-3.20). Pushing or pulling heavy loads more than 51 pounds was significantly associated with MSS in all three areas – low back, neck/shoulder, and wrist/hand. Bending or twisting of the torso/truck, neck, and wrists/hands were respectively associated with increased likelihood of low back, neck/shoulder and wrist/hand MSS. Workers who often reach with their arms or hands were 3.05 times ($p < 0.01$, 95% CI: 1.47-6.34) more likely to report wrist/hand MSS. Workers who often worked in a bent, stooped or twisted posture at the torso/truck, neck, and wrists/hands were more likely to report low back, neck/shoulder and wrist/hand MSS. Similar results were also found for making repetitive movements with torso/truck and wrists/hands. Wrist/hand MSS were more prevalent among workers who often worked with their hands above shoulder level (OR = 2.47, 95% CI: 1.59-3.84), below shoulder level (OR = 2.19, 95% CI: 1.42-3.38), making repetitive movements with arms, hands, and fingers (OR = 3.02, 95% CI: 1.54-5.90), and holding vibrating tools or materials (OR = 1.78, 95% CI: 1.15-2.78).

Table 10. Results of Bivariate Analysis

	Low Back		**Neck/ Shoulder**		**Wrist/ Hand**	
	OR	95% CI	OR	95% CI	OR	95% CI
Forceful Exertions						
Lift heavy loads more than 51 lbs.	1.31	(0.90, 1.91)	1.50*	(1.03, 2.18)	2.06**	(1.33, 3.20)
Carry heavy loads of more than 51 lbs.	1.41	(0.97, 2.06)	1.42	(0.98, 2.06)	2.21**	(1.43, 3.42)
Push or pull heavy loads more than 51 lbs.	1.56*	(1.07, 2.27)	1.68**	(1.15, 2.44)	2.59**	(1.66, 4.03)
Dynamic Load						
Bend or twist torso or trunk	2.36**	(1.55, 3.58)	--	--	--	--
Bend or twist neck	--	--	1.82**	(1.21, 2.73)	--	--
Bend or twist wrists/hands	--	--	--	--	10.52**	(3.77, 29.36)
Reach arms and hands	--	--	1.49	(0.91, 2.43)	3.05**	(1.47, 6.34)
Static Load						
Work in a bent, stooped or twisted posture with torso or trunk	2.04**	(1.39, 3.00)	--	--	--	--
Work in a bent, stooped or twisted posture with neck	--	--	1.77**	(1.21, 2.58)	--	--
Work in a bent, stooped or twisted posture with wrists/hands	--	--	--	--	4.47**	(2.79, 7.17)
Hold arms at or above shoulder level	--	--	1.22	(0.84, 1.77)	2.51**	(1.58, 3.97)

Work in uncomfortable postures	2.07**	(1.41, 3.05)	1.81**	(1.24, 2.65)	--	--
Sit in long period of time	1.03	(0.67, 1.60)	1.22	(0.79, 1.88)	--	--
Work with your hands above shoulder level?	--	--	1.21	(0.83, 1.76)	2.47**	(1.59, 3.84)
Work with your hands below shoulder level?	--	--	--	--	2.19**	(1.42, 3.38)
Repetitive Load						
Make repetitive movements with torso or trunk	1.67**	(1.14, 2.46)	--	--	--	--
Make repetitive movements with neck	--		1.13	(0.77, 1.65)	--	--
Make repetitive movements with wrists/hands	--	--	--	--	5.25**	(2.56, 10.77)
Make frequent repetitive movements with your arms, hands and fingers	1.56	(0.98, 2.47)	1.06	(0.67, 1.68)	3.02**	(1.54, 5.90)
Vibration: Holding vibrating tools or materials	1.81**	(1.24, 2.65)	1.28	(0.88, 1.87)	1.78*	(1.15, 2.78)

*p<0.05, **p<0.01

Lastly, analyses were completed to examine relationships between workplace organizational and psychosocial factors related to work and health impairment. Logistic regression analysis determined that workload, stress and burnout were all significantly related to low back, knee, shoulder and neck MSS. These results are presented in Table 11.

Table 11. Workload and Health Impairment Results

	Low Back MSS		**Knee MSS**		**Shoulder MSS**		**Neck MSS**	
	OR	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
Workload	**1.79***	(1.34, 2.39)	**2.0***	(1.49, 2.69)	**1.37***	(1.04, 1.80)	**1.98***	(1.48, 2.65)
Stress	**1.54***	(1.20, 1.97)	**1.55***	(1.22, 1.97)	**1.32***	(1.04, 1.68)	**1.87***	(1.46, 2.39)
Burnout	**1.63***	(1.21, 2.18)	**1.66***	(1.26, 2.19)	**1.69***	(1.27, 2.23)	**1.92***	(1.45, 2.55)

*p <0.05; Models adjusted for age, sex and BMI.

5.3.4 Safety Resources

The impact of safety factors in research models are often examined as predictors of more proximal safety outcomes, such as safety motivation, knowledge, safety consciousness and safety performance or behaviors. For this study, and based on our posited model, we were interested in examining direct relationships between common safety-oriented job resources and musculoskeletal problems, particularly MSS given our instrument and outcome measure. Direct influences on MSS, for the most part, were not observed. As is evident in Table 12, safety climate, supervisor support, coworker support and autonomy were not generally associated with MSS of the low back, knee, shoulder or neck. Safety climate was protective against neck MSS. Additional analyses may be beneficial to determine specific relationships between safety factors and MSS. Potentially these factors may be moderating factors and may buffer the effects of job demands on outcomes.

Table 12. Safety Resources and MSS.

	Low Back MSS		**Knee MSS**		**Shoulder MSS**		**Neck MSS**	
	OR	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
Safety Climate	0.88	(0.67, 1.15)	0.89	(0.68, 1.17)	1.08	(0.82, 1.42)	**0.76***	(0.58, 0.99)
Supervisor Support	0.97	(0.77, 1.21)	0.88	(0.70, 1.10)	1.04	(0.82, 1.30)	0.88	(0.70, 1.10)
Coworker Support	0.96	(0.76, 1.22)	0.87	(0.69, 1.10)	0.98	(0.77, 1.24)	1.05	(0.82, 1.33)
Autonomy	0.89	(0.68, 1.16)	0.82	(0.63, 1.07)	0.96	(0.74, 1.26)	0.97	(0.75, 1.26)

*p <0.05; Models adjusted for age, sex and BMI.

In addition to its usual impact on safety outcomes, safety climate has been linked to improved organizational outcomes, including job satisfaction and reduced turnover intention (Huang et al. 2016; Smith 2018). As part of the project, particularly given the role turnover intention plays in employee productivity and performance, we decided to examine how safety climate perceptions among SSGM workers impacted perceptions of job satisfaction and turnover intention. These relationships are evident in the path diagram that illustrates the mediating role of job satisfaction on the association between safety climate and turnover intention (Figure 4). Our findings help elucidate the importance of safety climate to employee retention and business performance within SSGM operations.

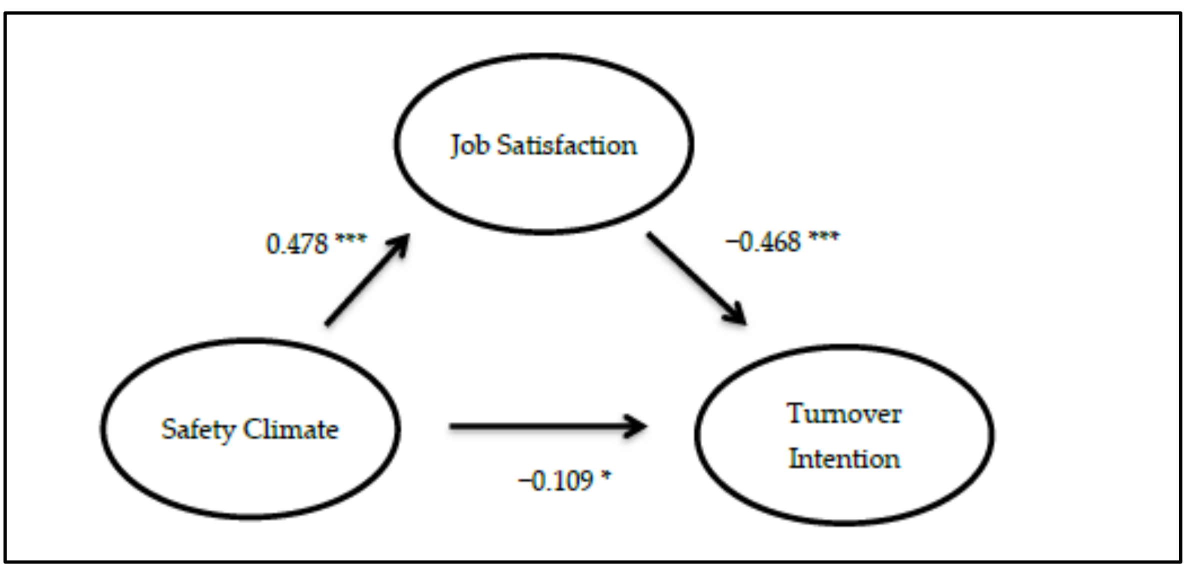

Figure 4. Path diagram; *p < 0.05; ***p < 0.001.

5.4. Building New Relationships in the SSGM Industry (Aims 1 – 4)

Cooperation between academia and industry is a mutually beneficial association, with the ultimate beneficiaries being the employees whose safety and health is improved. While this project was mostly exploratory in nature, the research team made new connections and leveraged old ones within the SSGM industry, which facilitated the collection of qualitative and quantitative data. Our dissemination efforts to ultimately enhance SSGM worker safety, health and wellbeing are addressed in the next section.

6.0 Dissemination Efforts and Highlights

Aim 4 of our project was focused on dissemination. We indicated we would disseminate our results through scholarly means and through other resources to enhance SSGM worker safety, health and wellness and to bolster research-to-practice initiatives. Our dissemination plan includes disseminating our findings through scholarly peer-reviewed publications and presentations.

6.1 Publications

So far, two research papers, based on this project's findings, have been peer-reviewed and published. The two publications are published open-access and are freely available. These publications include:

Balogun, A. O., Andel, S. A., & Smith, T. D. (2020). "Digging Deeper" into the Relationship Between Safety Climate and Turnover Intention Among Stone, Sand and Gravel Mine Workers: Job Satisfaction as a Mediator. *International Journal of Environmental Research and Public Health, 17*(6), 1925. https://doi.org/10.3390/ijerph17061925

Balogun, A. O., & Smith, T. D. (2020). Musculoskeletal Symptoms among Stone, Sand and Gravel Mine Workers and Associations with Sociodemographic and Job-Related Factors. *International Journal of Environmental Research and Public Health*, *17*(10), 3512. https://doi.org/10.3390/ijerph17103512

On June 22, 2020 we submitted an open-access manuscript to the journal *Sustainability* titled "Health, physical activity and musculoskeletal symptoms among stone, sand and gravel mine workers: Implications for enhancing and sustaining worker health."

Additional manuscripts are in preparation and expect to be submitted summer / fall 2020 for publication.

The proposed title or topic for these manuscripts, authors, and targeted journals are indicated below in Table 13. It should be noted that submissions do not guarantee publication and alternate journals may be selected based on special issues, invitations, initial reviews, and/or revisions. Titles are subject to change due to the editing and/or review process.

Table 13. Manuscripts in Progress

Title / Topic	**Authors**	**Target Journal**
Moderating effects of safety climate and safety resources on the relationship between job demands and musculoskeletal disorders.	Balogun, A.O., Andel, S.A. & Smith, T.D.	*Applied Ergonomics*
An examination of job demands, physical stressors and musculoskeletal symptoms among stone, sand and gravel mine workers.	Smith, T.D., Balogun, A.O. & Yu, Z.	*Ergonomics*
Focus group results: Management perspectives on musculoskeletal disorder risk factors and protective safety resources within the stone, sand and gravel mining industry	Smith, T.D. Balogun, A.O. & Dillman, A.	*International Journal of Industrial Ergonomics*

Beyond these manuscripts, the research team plans to work on additional manuscripts, which should be submitted for review in scholarly, peer-reviewed journals late 2020/early 2021.

6.2 Presentations

Our research team presented three presentations in November 2019. Two were given at research conferences and one presentation was given at the Southwestern Indiana Holmes Safety Association quarterly meeting. Presentations completed to date include the following:

Smith, T.D., Balogun, A.O. & Dillman, A.L. (2019, November). *Musculoskeletal disorder risk and protective factors within the stone, sand and gravel mining industry.* Oral presentation given at the Southwestern Indiana Holmes Safety Association Quarterly Meeting. Fort Branch, IN.

Balogun, A.O., Smith, T.D. & Slates, K. (2019, November). *Injury rates and musculoskeletal symptoms among workers in the stone, sand and gravel mining industry.* Poster presentation given at the American Public Health Association's (APHA) 2019 Annual Meeting & Expo. Philadelphia, PA.

Balogun, A.O., Smith, T.D. & Slates, K. (2019, November). *Associations between safety climate, job satisfaction and turnover intention among workers in the stone, sand and gravel mining industry.* Poster presentation given at the 13th International Conference on Occupational Stress and Health – Work, Stress and Health 2019: What Does the Future Hold? Philadelphia, PA.

In addition to the above presentations, additional presentations have been scheduled in 2020 and 2021 to include the following:

Balogun, A.O., Smith, T.D., Le, A.B., & Slates, K.J. (2020, August). *Exploring the distribution of musculoskeletal disorder symptoms in the stone, sand and gravel mining industry and strategies for prevention.* 23rd Annual Applied Ergonomics Conference 2020. (Virtual due to COVID-19)

Smith, T.D., Balogun, A.O. & Slates, K.J. (2021, January). *Understanding and preventing musculoskeletal disorders and injuries among stone, sand and gravel mine workers.* Annual Conference for the Indiana Minerals Aggregates Association – IMAA Safety Committee Meeting.

Progress with presentations was hampered by the COVID-19 pandemic. We had planned to submit and/or present at other conferences; however, some of these were postponed or canceled. We may pursue additional presentation opportunities if funding and support is available and if meetings/conferences are held. Possible venues for presentation in the near future may include the 2021 National Holmes Mining Safety and Health Conference, the 2021 American Society of Safety Professionals Annual Meeting and PDC, the National Occupational Injury Research Symposium and the 2021 Work, Stress and Health Conference.

In addition to presentations and publications, our dissemination plans include the development of resources that can be accessed by administrators, safety practitioners, managers and workers in the stone, sand and gravel mining industry. We plan to distribute a presentation or webinar through Indiana University – Bloomington's School of Public Health's Public Health and You website.

Further, an additional resource document is being written for dissemination. A white paper summarizing our study outcomes and highlighting recommendations for the prevention of musculoskeletal disorders will be made available by the Indiana Mineral Aggregates Association and will be published on the Indiana University – Bloomington's safety management program website.

We also aim to disseminate our findings to other state associations and national associations affiliated with stone, sand and gravel mining. Training slides have been developed and will be disseminated to both the Indiana Mineral Aggregates Association and the Vincennes University Miner Safety Program to incorporate into their safety training programs.

7.0 Conclusions and Impact Assessment

7.1 Conclusions

Our research project focused on identifying relationships between demographic and personal factors, work characteristics and job demands, safety resources and musculoskeletal symptoms. A comprehensive survey instrument was developed, as an extension of the Dutch Musculoskeletal Questionnaire (Hildebrandt et al. 2001, 2005) to collect data and to complete the study. Additionally, qualitative data derived from focus group analyses identified and supported findings related to these same areas.

Key findings and conclusions from our project include:

1. Prevalence of MSS in the SSGM industry is high. Particularly, MSS of the low back (57%), neck (38%), shoulder (38%) and knee (39%) were highly prevalent among SSGM workers.
2. Mechanics and maintenance workers are at increased risk of suffering MSD and reported higher rates of MSS. Management and safety-focused participants in the focus group identified this job category as particularly at risk for musculoskeletal problems. Our study did identify that those working as a mechanic/maintenance worker had higher likelihood of low back and knee musculoskeletal symptoms.
3. Overtime, particularly working more than 60 hours per week is problematic. Employees who worked more than 60 hours a week had an increased likelihood of musculoskeletal symptoms at the low back, neck and knee. These workers were at approximately 5 times the risk compared to those working 40 hours or less each week.
4. Overall health is an important determinant of musculoskeletal problems. 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.
5. Also, with regard to health, obese workers were more likely to experience knee MSS and those who smoked in the past had higher odds of neck MSS.
6. Vigorous physical activity was mostly protective, but those performing more than 5 hours of moderate physical activity each week had greater odds of shoulder and neck MSS.
7. Health impairment, including both stress and burnout, increased the likelihood of low back, knee, shoulder and neck MSS.
8. Job demands had a significant influence on the likelihood of MSS. Dynamic and static load exposures increased the likelihood of low back, neck/shoulder and wrist/hand MSS.
9. Workload perceptions were associated with an increased likelihood of low back, neck, shoulder and knee MSS.
10. Job satisfaction significantly mediated the relationship between safety climate and turnover intention in our sample of SSGM workers. This suggests that bolstering safety programs and increasing safety climate perceptions will help increase job satisfaction and reduce turnover intention among workers in the SSGM industry.
11. Safety climate and safety resources for the most part did not have significant direct influences on MSS outcomes. Relationships between safety-related job resources need to be further examined.
12. There is an urgent need to implement and evaluate interventions that could be integrated by SSGM organizations to reduce MSD among SSGM workers. Such interventions could include enhanced training on situational awareness and

hazard identification, the use of exoskeletons, robots and/or other related technology to reduce or abate hazards and Total Worker Health® interventions that address both safety and worker health promotion. A comprehensive all-stakeholder approach towards the design, implementation, monitoring and evaluation of these interventions is necessary to ensure continued effectiveness.

7.2 Impact Assessment

The ultimate goal of this research is to improve the health and safety of mine workers, particularly those working in the SSGM industry. Impact assessments are generally examined over longer periods and seek to examine more distal outcomes. Particularly we are interested in the long-term impact of improving health and safety and reducing work-related injuries and illnesses. Particularly, in our case, we are interested in the prevention of musculoskeletal disorders. Below, we present guidance on assessing the impact of our project over time. Additionally, we present evaluation information on factors that are more proximal and that could be assessed during the scope of the research project.

7.2.1 Inputs

Funding from the Alpha Foundation allowed us to complete this study. Extensive time and effort have been put into this research project by the research team from the time funding was initiated on June 1, 2018 through the end of June 2020, when the final report was submitted. Work will continue after the initial submission of the final report as the research team remains committed to submitting additional manuscripts, presentation abstracts and will continue with dissemination and evaluation activities.

Faculty leading this project were funded to complete the work associated with this project, with Dr. Todd D. Smith leading all research activities. Despite some delays to the start of this project, because of a change in leadership with one of our major collaborators, the funding allowed us to hire multiple students and to mentor/train future safety researchers as part of this project. Up to three doctoral students participated in aspects of this project during its period of performance. Particularly, Mr. Abdulrazak Balogun (Dr. Balogun as of summer 2020) worked as the primary research assistant on the project learning about and contributing to all aspects of a major research effort including participant recruitment, data collection, data entry, data analyses, manuscript development and manuscript publishing. This project allowed Dr. Balogun to develop as a researcher in the area of safety and ergonomics and in the mining industry. As Dr. Balogun enters into his own career as a professor and researcher, he plans to continue research within the mining industry.

In addition to doctoral students, multiple graduate safety management students and undergraduate safety students participated in aspects of this project. These students gained valuable experience related to research, but also safety science, ergonomics and human factors. Additionally, these students were introduced to the mining industry and have benefitted by increasing their knowledge, skills and abilities in the context of mining safety. These students have contributed to the mining safety field through their work activities on the research project including publications and presentations.

Multiple partnerships were initiated as part of this research project. The research team established relationships with the Indiana Mineral Aggregates Association and the Vincennes University Mining Program, in Fort Branch, Indiana. These partners were invaluable to the success of this project. These relationships will allow us to advance our future research within the mining industry as we work together to protect and promote the health and wellbeing of mine workers in Indiana and beyond.

Lastly, this study would not have been completed if it weren't for the mining organizations and workers that participated in this research project throughout Indiana. We are grateful for their participation and their desire to bolster workplace safety and health.

7.2.2 Outputs

7.2.2.1 Research Activities

Research activities completed are presented in Section 4 of this report. This section describes qualitative and quantitative research initiatives that were completed as part of the study. It describes the development of the instrument, data collection processes (qualitative and quantitative), methods and statistical analyses applied to complete this project.

7.2.2.2 Direct Products

As a result of this study, multiple publications and presentations were completed. For additional details related to these products, please refer back to Section 6 of this report, which highlights publications and presentations produced or conducted as part of this project. As noted in that same section, additional products are in progress at the time of this report. Future evaluation of these products will assess citations, intervention research or intervention activities designed as a result of these publications and the establishment of other future research activities based on these products. Additionally, to the extent possible, practitioner utilization of these products will be evaluated.

In addition to the products noted, a “white paper” has been developed and will be disseminated to our collaborators and stakeholders for distribution. Additionally, we are in the process of developing a presentation that will be freely disseminated. PowerPoint slides to bolster training among our collaborators and stakeholders have been created and will be distributed. These can be used to supplement numerous training activities within the mining industry, particularly among SSGM stakeholders.

As a result of our findings, we anticipate conducting additional research studies to address risk factors identified in our project and/or to enhance safety initiatives that were found to be protective in our study. Additional details regarding suggested research can be found in Section 8 of this report.

7.2.2.3 Reach

Outputs include those individuals, groups or stakeholders that we reach through the study and its dissemination. We have multiple stakeholders that participated in the project and are recipients of the products of this research. Our stakeholders include the

IMAA, Vincennes University Mining Program, SSGM organizations and more. These recipients will receive directly or indirectly the content that we will disseminate including training materials that can be used to train workers in the SSGM industry. This information is freely available to educators and those conducting safety training for SSGM operations or internally within those operations. Additionally, our research findings are available to government officials, labor organizations, researchers, practitioners and the like. Thus, the findings of our research can be utilized to create change at multiple levels including policies/programs at multiple levels (society, organization, work group, individual, etc.). Ultimately, we hope the consumers of our research are those that practice and influence safety within the SSGM industry as these individuals can have direct impact within their work organizations through safety program initiatives, company policy directives, training, hazard identification and correction, etc. We will continue to monitor and evaluate the reach of our products. This can be done through observations, measures of product utilization, informal interviews with collaborators and stakeholders, among other means.

7.2.3 Outcomes / Impact

As previously noted, the ultimate goal of this research is to improve the health and safety of mine workers, particularly those working in the SSGM industry. The impact of this research on distal outcomes are usually only visible after a long period. We will continue to evaluate how our research influences these long-term outcomes and impacts the industry. Long-term interests to evaluate includes the following:

1. Reductions in musculoskeletal disorders and the prevalence of musculoskeletal symptoms among workers in the SSGM industry.
2. Reductions in health impairment that may be associated with physical and psychosocial stressors among SSGM workers.
3. Economic improvement through more cost effective and productive operations and through reductions associated with medical treatment and workers' compensation costs. As we suggest in Section 8, Total Worker Health® approaches should be integrated to protect workers, prevent injuries/illnesses, but to also promote and improve health. Thus, we would expect to see reductions in workers' compensation costs, medical and healthcare costs and insurance premiums.
4. Enactment of standards that specifically abate hazards identified as part of this research effort.

More proximal outcomes, based upon our findings, should be more evident in the near term. These outcomes may include the following:

1. Utilization of our survey instrument to evaluate prevalence of MSD and associated MSS within SSGM organizations.
2. Utilization of our survey instrument to help identify MSS risk factors within SSGM organizations.
3. Incorporation of our research findings and products in training efforts among our collaborators and stakeholders.

4. Increased knowledge of MSD risk and protective factors among administrators, safety professionals and workers within SSGM operations as an outcome related to our dissemination efforts.
5. Integration of safety programs and initiatives aimed at curtailing risk factors or hazards that increase the likelihood of MSD within SSGM operations, particularly as it relates to physical hazards and job characteristics delineated in our research.
6. Integration of policies that curtail work above 60 hours per week.
7. Improvements in job satisfaction and reductions in turnover among workers in the SSGM industry.
8. Integrating Total Worker Health® approaches within SSGM operations, given the observed associations between personal health factors and musculoskeletal problems.
9. Incorporation of guidance documents to reduce the burden of MSD among SSGM employees.

8.0 Recommendations for Future Work

8.1 Recommended Future Research

This project’s findings thus far have provided results showing the burden of musculoskeletal problems among SSGM workers. Employees most at risk, body parts commonly affected, risk factors and protective factors have been identified. Despite these findings, further research is needed. Suggested research studies include those recommended below.

1. Conduct additional research with mechanics/maintenance workers to identify specific job tasks that pose the greatest MSD risk and conduct more targeted analyses using ergonomic tools such as the Rapid Entire Body Assessment (REBA), Rapid Upper Limb Assessment (RULA), Rodgers Muscle Fatigue Analysis, etc. Additionally, conduct job safety or job hazard analyses (JSA/JHA) to identify hazards associated with job tasks and to identify controls to abate or control exposures, including ergonomic exposures. Risk assessments should be conducted with all of these assessments to define actions aimed at reducing hazards so that job tasks requirements are performed at levels that are safe.

2. Development, implement and evaluate a Total Worker Health® (TWH) oriented intervention aimed at addressing job risk factors identified in this project, psychosocial and organizational factors (job demands, work hours, etc.) and health factors (BMI, physical activity, smoking). TWH provides an effective blend of two disciplines: occupational safety (health protection) and health promotion. This presents an opportunity for interdisciplinary and multidisciplinary research developing, implementing and evaluating initiatives aimed at improving the overall health and wellness of employees.

3. Conduct research to examine the initiation and use of current safety, ergonomic and human factors technology and tools. Given the high prevalence of MSD among SSGM employees and giant strides in science and technology over the last decade, especially in the field of robotics and artificial intelligence, the time is ripe for research evaluating the effectiveness of worker-aid technologies such as exoskeletons in reducing MSD. For successful deployment of new safety initiatives/technology, management commitment and employee buy-in is essential. Thanks to the current project, the research team has established relationships with key stakeholders in the SSGM industry including safety professionals, engineers, supervisors, senior management and business owners while also cementing old relationships with SSGM stakeholders, such as the Indiana Minerals and Aggregates Association (IMAA). These relationships would enable us to foster productive discussions related to techniques and strategies to introduce the application of new technologies such as exoskeletons. Fruitful discussions such as these would lead to the deployment and evaluation of these technologies among employees at high risk and for job tasks that are problematic.

4. An interesting scientific discussion emerged as part of this research. There is a discrepancy within the literature with regard to whether outcomes should be defined as musculoskeletal symptoms (MSS) or musculoskeletal disorders (MSD). This debate exists as the term is used interchangeably, even when using the same instrument, including research using the DMQ. It would be valuable for researchers to conduct an exhaustive review of the literature to examine this discrepancy. Guidance should be provided too so that terminology is consistent in future research.

8.2 Recommendations for Employers

This project’s findings suggest implications for the SSGM industry to curtail MSD and to bolster organizational efficiencies and sustainability. Below, we make recommendations for employers to move our research findings into practice.

1. Use the short-version of the DMQ or our modified instrument as a tool to examine prevalence of musculoskeletal symptoms among workers within a work organization and to identify specific factors within the organization that may be associated with musculoskeletal symptoms.

2. Implement safety management practices/programs that provide appropriate job resources, equipment and an enabling environment that reduces hazards associated with all mining operations. The National Institute for Occupational Safety and Health’s Mining program (https://www.cdc.gov/niosh/mining/) and the Mine Safety and Health Administration (https://www.msha.gov/training-education/safety-health-materials) provides resources to aid in these efforts.

3. Institute policies/programs that actively support worker health/wellness in addition to safety. The integration of safety (health protection) and health promotion is commonly referred to as Total Worker Health® (TWH). Resources related to TWH within the mining industry, particularly the SSGM sector, are limited; however, guidance on the

establishment of these programs can be gained from the NIOSH TWH resource page at https://www.cdc.gov/niosh/twh/default.html/.

4. Overtime work policies and programs need to be internally examined by SSGM organizations. Employees working more than 40 hours per week had higher odds of musculoskeletal symptoms. Particularly, workers working 51-60 hours per week had significantly greater odds of neck MSS. Evidence suggests that employers should not work employees more than 60 hours per week. Workers working more than 60 hours each week were 5 times more likely to report low back, neck and knee musculoskeletal symptoms. Human resource management and management/worker collaboration is needed to maintain pay, so not to burden workers. Additionally, job design changes may be necessary to maintain production.

5. The importance of the SLAM (Stop, Look, Analyze, Manage) process was identified during our qualitative research. SLAM appears to be highly integrated into safety within the mining industry and has influenced perceptions of safety culture/climate. As such, SSGM organizations that have not yet implemented and/or trained on SLAM should implement this program to bolster safety practices, to curtail musculoskeletal disorders among other occupational injuries and illnesses and to bolster perceptions of safety climate and the overall safety culture.

6. Hazard identification training should be routinely administered to employees through formal mediums (e.g. annual safety training) and informal avenues (e.g. weekly safety talks, toolbox talks, etc.). SSGM organizations could utilize the NIOSH EXAMiner program as part of their training efforts. Information on EXAMiner is found here: https://www.cdc.gov/niosh/mining/works/coversheet2050.html. Particularly, safety training efforts should be focused on identifying psychosocial and physical stressors associated with SSGM job tasks as identified in our project.

7. Mining organizations may be hesitant to participate in research being conducted by researchers. Participation in continued research efforts aimed at hazard identification, designing and implementing new safety initiatives, evaluating the effectiveness of occupational safety/ergonomic processes and interventions among many other research opportunities is essential to ensure progress with protecting mine workers in SSGM operations.

9.0 References

Balogun, A. O., Andel, S. A., & Smith, T. D. (2020). “Digging Deeper” into the Relationship Between Safety Climate and Turnover Intention Among Stone, Sand and Gravel Mine Workers: Job Satisfaction as a Mediator. *International Journal of Environmental Research and Public Health, 17*(6), 1925. https://doi.org/10.3390/ijerph17061925

Balogun, A. O., & Smith, T. D. (2020). Musculoskeletal Symptoms among Stone, Sand and Gravel Mine Workers and Associations with Sociodemographic and Job-Related

Factors. *International Journal of Environmental Research and Public Health*, *17*(10), 3512. https://doi.org/10.3390/ijerph17103512

Dembe, A. E. (2001). The social consequences of occupational injuries and illnesses. American journal of industrial medicine, 40(4), 403-417.

Demerouti, E., Bakker, A., Nachreiner, F., & Schaufeli, W. (2001). The Job Demands-Resources model of burnout. Journal of Applied Psychology, 86(3), 499-512.

Hildebrandt, V.H. (2005). The Dutch Musculoskeletal Questionnaire (DMQ). In N. Stanton, A. Hedge, K. Brookhuis, E. Salas & H. Hendrick (Eds.), Handbook of human factors and ergonomics methods (5-1 – 5-7), Boca Raton, FL: CRC Press.

Hildebrandt, V. H., Bongers, P. M., Van Dijk, F. J. H., Kemper, H. C. G., & Dul, J. (2001). Dutch Musculoskeletal Questionnaire: description and basic qualities. Ergonomics, 44(12), 1038-1055.

Huang, Y. H., Lee, J., McFadden, A. C., Murphy, L. A., Robertson, M. M., Cheung, J. H., & Zohar, D. (2016). Beyond safety outcomes: An investigation of the impact of safety climate on job satisfaction, employee engagement and turnover using social exchange theory as the theoretical framework. *Applied ergonomics*, *55*, 248-257.

Monforton, C., & Windsor, R. (2010). An impact evaluation of a federal mine safety training regulation on injury rates among US stone, sand, and gravel mine workers: an interrupted time-series analysis. American journal of public health, 100(7), 1334-1340.

Nahrgang, J. D., Morgeson, F. P., & Hofmann, D. A. (2011). Safety at work: A meta-analytic investigation of the link between job demands, job resources, burnout, engagement, and safety outcomes. Journal of Applied Psychology, 96(1), 71-94.

NIOSH. (2017). Stone and Sand & Gravel Industry Sector. Retrieved from https://www.cdc.gov/niosh/mining/works/statistics/factsheets/miningfacts2015.html (accessed on April 10, 2020)

Plano - Clark, V. L. & Creswell, J. W. (2015). *Understanding research: A consumer's guide*. Upper Saddle River, NJ: Pearson Higher Ed.

Ramirez, C. (2002). *Strategies for Subject Matter Expert Review in Questionnaire Design*. Paper presented at the Questionnaire Design, Evaluation and Testing Conference. Charleston, SC.

Smith, T. D. (2018). An assessment of safety climate, job satisfaction and turnover intention relationships using a national sample of workers from the USA. *International journal of occupational safety and ergonomics*, *24*(1), 27-34.

Torma-Krajewski, J., Hipes, C., Steiner, L., & Burgess-Limerick, R. (2007). Ergonomic interventions at Vulcan Materials Company. Pittsburgh (PA): National Institute for Occupational Safety and Health (NIOSH).

Weston, E., Nasarwanji, M. F., & Pollard, J. P. (2016). Identification of work-related musculoskeletal disorders in mining. Journal of safety, health and environmental research, 12(1), 274-283.

Winn Jr, F. J., Biersner, R. J., & Morrissey, S. (1996). Exposure probabilities to ergonomic hazards among miners. International journal of industrial ergonomics, 18(5-6), 417-422.

10.0 Appendices

The appendices incorporate documents and resources relevant to this final report. The items in the appendices of this report include the following:

1. Survey Instrument
2. Focus group script
3. Focus group model
4. Focus group questions

11.0 Acknowledgment/Disclosure:

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Stone, Sand & Gravel Worker Safety and Health Survey

INDIANA UNIVERSITY
SCHOOL OF PUBLIC HEALTH
BLOOMINGTON

INDIANA UNIVERSITY STUDY INFORMATION SHEET FOR RESEARCH

Identifying and Assessing Risk Factors Associated with Musculoskeletal Disorders within Stone and Sand and Gravel Mining Operations

About this research
You are being asked to participate in a research study to help us improve workplace safety and health.

This page and the next will give you information about the study to help you decide if you want to participate. Please read this information carefully, and ask any questions you have, before agreeing to be in the study.

Taking part in this study is voluntary.

You may choose not to take part or may leave the study at any time. Leaving the study will not result in any penalty or loss of benefits to which you are entitled. Your decision whether or not to participate in this study will not affect your current or future relations with your employer or the Indiana Mineral Aggregates Association. *This research is intended for individual 18 years of age or older. If you are under age 18, do not complete the survey*.

Why is this study being done?
The purpose of this study is to identify potential hazards associated with strains and sprains among workers in stone, sand and gravel or aggregates mining operations. The end goal is to reduce worker injuries associated with strains and sprains.

You were selected as a possible participant because you work in the stone, sand and gravel mining or aggregates industry.

The study is being conducted by Dr. Todd D. Smith, Assistant Professor of Safety within the Department of Applied Health Science, School of Public Health at Indiana University – Bloomington. It is funded by the Alpha Foundation for the Improvement of Mine Safety and Health, Inc.

What will happen during the study?
If you agree to be in the study, you will do the following:
1. You will complete a short survey answering questions about the work you do, your general health, work demands and safety.

Participants completing the survey will provide responses to questions presented in the survey. Completion of the survey should take approximately 10-15 minutes.

What are the risks and benefits of taking part in this study?
The risks of participating in this research are minimal. No discomfort, stress or risks are expected beyond possibly feeling uncomfortable answering questions about your general health, work activities, work demands and safety. This survey is anonymous. We will **not** collect personally identifiable information during this survey.

This research is expected to benefit workers in the stone, sand and gravel mining industry. We want to enhance worker safety and health and reduce worker injuries associated with strains and sprains in this industry.

How will my information be protected?
Information collected in this study will be anonymous and cannot be linked to you personally. Most research includes at least a small risk of loss of confidentiality and we cannot guarantee complete confidentiality, but our study does not collect personal identifiers associated with your data. Study data including any information collected may be disclosed if required by law. With regard to data, we make every effort to keep our research data secure, including storing the data on secure and password-protected servers. Organizations that may inspect and/or copy your research data for quality assurance and data analysis include groups such as the study investigator and his research associates, the Indiana University Institutional Review Board or its designees, the study sponsor, Alpha Foundation, and any state or federal agencies who may need to access your research records (as allowed by law).

Will I be paid for participation?
If you participate and complete the survey, you will be given a gift card in the amount of $20.

Who should I call with questions or problems?
For questions about the study, contact the researcher Dr. Todd D. Smith at (812) 856-4887 or via email at smithtod@indiana.edu.

For questions about your rights as a research participant or to discuss problems, complaints or concerns about a research study, or to obtain information, or offer input, please contact the IU Human Subjects Office at 800-696-2949 or at irb@iu.edu.

<u>GENERAL INSTRUCTIONS:</u> *Please answer each question or statement by circling the number of* the response *that best represents your opinion. If none of the choices fits exactly, choose the option that comes closest. Please answer all questions in each part of the survey even if some of the questions appear to be similar. There are no right or wrong answers, and it is very important that you answer each question as honestly as possible. Your responses are <u>anonymous</u>, as we do not collect any personally identifiable information in this survey.*

<u>SAMPLE QUESTION:</u>

1 = Strongly Disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly Agree

Proper lifting techniques are important to reduce the risk of back injuries.	1	2	3	(4)	5

Section 1

1 = Strongly Disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly Agree

In my workplace, workers learn quickly that they are expected to follow good safety and health practices.	1	2	3	4	5
In my workplace, workers are told when they do not follow good safety practices.	1	2	3	4	5
Where I work, workers, supervisors and management work together to ensure the safest possible working conditions.	1	2	3	4	5
In my workplace, there are no significant compromises or shortcuts taken when worker health and safety are at stake.	1	2	3	4	5
The health and safety of workers is a high priority with management where I work.	1	2	3	4	5
I feel free to report safety problems or violations where I work.	1	2	3	4	5

Section 2

1 = Strongly Disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly Agree

My supervisor tries to make my job as safe as possible.	1	2	3	4	5
My supervisor often tells management about unsafe situations.	1	2	3	4	5
My supervisor shows personal concern about worker safety.	1	2	3	4	5
My supervisor places worker safety as a top priority.	1	2	3	4	5
My coworkers are prepared to stop others from working dangerously.	1	2	3	4	5
My coworkers are ready to talk to fellow workers who fail to use safety equipment or procedures.	1	2	3	4	5
My coworkers encourage each other to work safely.	1	2	3	4	5

Section 3

This portion of the survey asks for your perceptions and feelings about your job and about working for your company. Please answer each question as it applies to your current work situation.

1 = Strongly Disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly Agree

Generally speaking, I am very satisfied with my job.	1	2	3	4	5
I am generally satisfied with the kind of work I do in this job.	1	2	3	4	5
I frequently think of quitting my job.	1	2	3	4	5

Section 4

1 = Almost Never 2 = Rarely 3 = Sometimes 4 = Often 5 = Almost Always

Do you have freedom in carrying out your work activities?	1	2	3	4	5
Do you have influence in the planning of your work activities?	1	2	3	4	5
Do you have influence on the pace of work?	1	2	3	4	5
Can you decide how your work is completed on your own?	1	2	3	4	5
Can you interrupt your work for a short period if you find it necessary to do so?	1	2	3	4	5
Can you decide the order in which you carry out your work on your own?	1	2	3	4	5
Can you participate in the decision about when something must be completed?	1	2	3	4	5
Can you personally decide how much time you need for a specific activity?	1	2	3	4	5
Do you resolve problems arising in your work yourself?	1	2	3	4	5
Can you organize your work yourself?	1	2	3	4	5
Can you decide on the content of your work activities yourself?	1	2	3	4	5

Section 5

1 = Almost Never 2 = Rarely 3 = Sometimes 4 = Often 5 = Almost Always

Do you feel you have to work very fast?	1	2	3	4	5
Do you feel you have too much work to do?	1	2	3	4	5
Do you feel you have to work extra hard in order to complete something?	1	2	3	4	5
Do you feel you work under time pressure?	1	2	3	4	5
Do you feel you have to hurry?	1	2	3	4	5
Can you do your work with ease?	1	2	3	4	5
Do you find that you are behind in your work activities?	1	2	3	4	5
Do you find that you do not have enough work?	1	2	3	4	5
Do you have problems with the work pace?	1	2	3	4	5
Do you have problems with the work pressure?	1	2	3	4	5
Would you prefer a calmer work pace?	1	2	3	4	5

Section 6: Demographic and Work Questions

Please answer each item by filling in the blank or checking the appropriate box of the response that best represents your answer.

1. How old are you? ________ years old

2. What is your gender?
[ ] Male
[ ] Female

3. What is your race? Please check all that apply.
[ ] African American or Black
[ ] American Indian or Alaska Native
[ ] Asian or Asian American
[ ] Hispanic, Latino/a/x or of Spanish Origin
[ ] Native Hawaiian or other Pacific Islander
[ ] White
[ ] Other ___________

4. What is your highest educational background?
[ ] Some high school
[ ] High school graduate or GED
[ ] Some college or technical/vocational training
[ ] Associate's degree (2 years)
[ ] Bachelor's degree (4 years)
[ ] Master's degree
[ ] Terminal degree (PhD, MD, EdD, etc.)

5. What is your marital status?
[ ] Single
[ ] Divorced/Separated
[ ] Widowed
[ ] Married/Living with Partner

6. What is your current job title or position? Please print clearly.

____

7. How long have you worked in your current job?
[ ] Less than 1 year
[ ] More than 1 year, but less than 2 years
[ ] 2 years or more, but less than 5
[ ] 5 years or more, but less than 10
[ ] 10 years or more, but less than 15
[ ] 15 years or more, but less than 20
[ ] 20 years or more, but less than 25
[ ] 25 years or more

8. How many years have you worked in the aggregates or stone, sand & gravel industry?
[ ] Less than 1 year
[ ] More than 1 year, but less than 2 years
[ ] 2 years or more, but less than 5
[ ] 5 years or more, but less than 10
[ ] 10 years or more, but less than 15
[ ] 15 years or more, but less than 20
[ ] 20 years or more, but less than 25
[ ] 25 years or more

9. Which best describes your work shift?
[ ] Regular day shift
[ ] Regular evening shift
[ ] Regular night shift
[ ] Rotating shifts

10. How many hours, in your main job, do you work each week? Include regular overtime.
[ ] Less than 30 hours per week
[ ] 30 to 39 hours per week
[ ] 40 hours per week
[ ] 41-50 hours per week
[ ] 51-60 hours per week
[ ] More than 60 hours per week

11. What is your height in feet and inches?
______ feet ______ inches

12. What is your weight in pounds?
_______ lbs.

Section 7

Please answer the following questions about your overall health by filling in the blank or checking the appropriate box of the response that best represents your answer. Again, your answers are anonymous and cannot be linked to you personally.

1. In general, would you say your health is:
[ ] Poor
[ ] Fair
[ ] Good
[ ] Very Good
[ ] Excellent

2. How physically tired are you normally at the end of the workday?
[ ] Very tired
[ ] Rather tired
[ ] A little tired
[ ] Not tired

3. How mentally tired are you normally at the end of the workday?
[ ] Very tired
[ ] Rather tired
[ ] A little tired
[ ] Not tired

4. Which best describes your smoking history or smoking activity?
[ ] I never smoked
[ ] I smoked in the past, but not now
[ ] I am a current smoker

5. How often do you get high intensity exercise (jogging, running, swimming, etc.) each week? [ ] None outside of work [ ] 30 minutes – 1 hour [ ] More than an hour, but less than 3 hours [ ] 3 hours or more, but less than 5 hours [ ] 5 hours or more, but less than 7 hours [ ] More than 7 hours
6. How often do you get moderate intensity exercise (walking, slow cycling, etc.) each week? [ ] None outside of work [ ] 30 minutes – 1 hour [ ] More than an hour, but less than 3 hours [ ] 3 hours or more, but less than 5 hours [ ] 5 hours or more, but less than 7 hours [ ] More than 7 hours

Section 8

When you think about your work overall, how often do you feel the following?

1 = Almost Never 2 = Rarely 3 = Sometimes 4 = Often 5 = Almost Always

Tired	1	2	3	4	5
Disappointed with people	1	2	3	4	5
Hopeless	1	2	3	4	5
Trapped	1	2	3	4	5
Helpless	1	2	3	4	5
Depressed	1	2	3	4	5
Physically weak or sickly	1	2	3	4	5
Worthless or like a failure	1	2	3	4	5
Difficulties sleeping	1	2	3	4	5
"I've had it"	1	2	3	4	5

Section 9

In the last month, how often have you:

1 = Almost Never 2 = Rarely 3 = Sometimes 4 = Often 5 = Almost Always

Been upset because of something that happened unexpectedly at work?	1	2	3	4	5
Felt that you were unable to control the important things at work?	1	2	3	4	5
Felt nervous and stressed because of work?	1	2	3	4	5
Found that you could not cope with all the things you had to do at work?	1	2	3	4	5
Been angered because of things that had happened at work that were outside of your control?	1	2	3	4	5
Felt that difficulties at work were piling up so high that you could not overcome them?	1	2	3	4	5

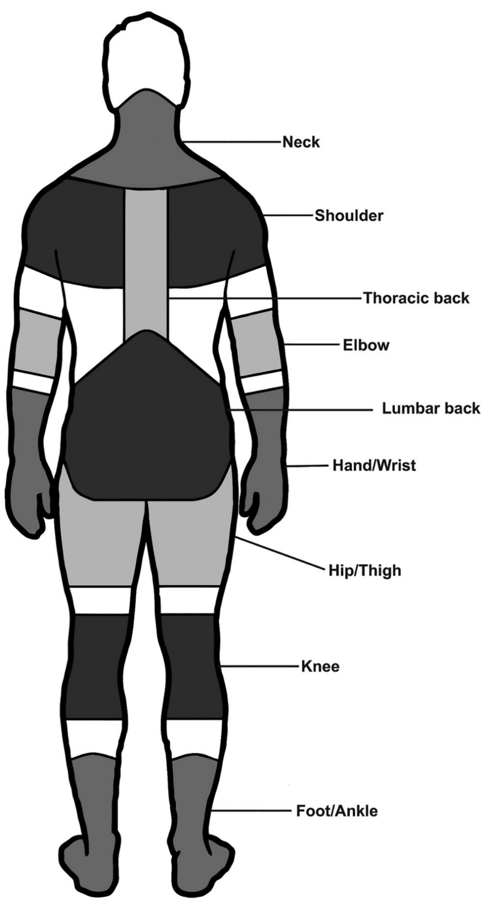
Section 10

In the past 12 months have you been:

Injured at work?	Yes	No
If yes, how many times have you been injured at work?		
If yes, did you miss any days from work because of your injury or injuries?	Yes	No

Section 11

For the questions in this section, refer to the figure to identify parts of the body included within the questions. Circle the response that is most correct.



In the past 7 days have you had trouble (pain, discomfort, aches, etc.) from your:

Neck	Yes	No
Shoulder	Yes	No
Upper (thoracic) back	Yes	No
Lower (lumbar) back	Yes	No
Elbows	Yes	No
Wrists/Hands	Yes	No
Hips/thighs	Yes	No
Knees	Yes	No
Ankles/feet	Yes	No

In the past 12 months have you had trouble (pain, discomfort, etc.) from your:

Neck	No	Yes, Sometimes	Yes, Regularly	Yes, Constantly
Upper (thoracic) back	No	Yes, Sometimes	Yes, Regularly	Yes, Constantly
Lower (lumbar) back	No	Yes, Sometimes	Yes, Regularly	Yes, Constantly
Right Shoulder	No	Yes, Sometimes	Yes, Regularly	Yes, Constantly
Left Shoulder	No	Yes, Sometimes	Yes, Regularly	Yes, Constantly
Right elbow	No	Yes, Sometimes	Yes, Regularly	Yes, Constantly
Left elbow	No	Yes, Sometimes	Yes, Regularly	Yes, Constantly
Right wrist/hand	No	Yes, Sometimes	Yes, Regularly	Yes, Constantly
Left wrist/hand	No	Yes, Sometimes	Yes, Regularly	Yes, Constantly
Right hip/thigh	No	Yes, Sometimes	Yes, Regularly	Yes, Constantly
Left hip/thigh	No	Yes, Sometimes	Yes, Regularly	Yes, Constantly
Right knee	No	Yes, Sometimes	Yes, Regularly	Yes, Constantly
Left knee	No	Yes, Sometimes	Yes, Regularly	Yes, Constantly
Right ankle/foot	No	Yes, Sometimes	Yes, Regularly	Yes, Constantly
Left ankle/foot	No	Yes, Sometimes	Yes, Regularly	Yes, Constantly

Section 12

For the questions below, answer yes or no. Do not think too long about each question. Some questions may look similar, but be sure to complete all questions. Mark only one answer.

Do you, in your work, often?

Lift heavy loads more than 11 pounds?	Yes	No
Push or pull heavy loads more than 11 pounds?	Yes	No
Carry heavy loads of more than 11 pounds?	Yes	No
Lift heavy loads more than 51 pounds?	Yes	No
Push or pull heavy loads more than 51 pounds?	Yes	No
Carry heavy loads of more than 51 pounds?	Yes	No

Do you, in your work, often have to bend or twist with your:

Torso or trunk (core part of your body from waist to neck)?	Yes	No
Neck?	Yes	No
Wrists / Hands?	Yes	No

Do you, in your work, often have to work in a bent, stooped or twisted posture for long periods with your:

Torso or trunk (core part of your body from waist to neck)?	Yes	No
Neck?	Yes	No
Wrists?	Yes	No

Do you, in your work, often have to make repetitive movements with your:

Torso or trunk (core part of your body from waist to neck)?	Yes	No
Neck?	Yes	No
Wrists / Hands?	Yes	No

Do you, in your work, often have to:

Reach with your arms and hands?	Yes	No
Hold your arms at or above shoulder level?	Yes	No
Work in uncomfortable postures?	Yes	No
Work in the same posture for long periods of time?	Yes	No
Make frequent repetitive movements with your arms, hands and fingers?	Yes	No
Hold vibrating tools or materials?	Yes	No

Do you, in your work, often for long periods of time, have to:

Stand?	Yes	No
Sit?	Yes	No
Walk?	Yes	No
Kneel or squat?	Yes	No
Work with your hands above shoulder level?	Yes	No
Work with your hands below your knees?	Yes	No

Thank you for completing this survey. Your participation is greatly appreciated and will help improve worker safety and health.

For questions about the study, contact Dr. Todd D. Smith at (812) 856-4887 or via email at smithtod@indiana.edu.

INDIANA UNIVERSITY
SCHOOL OF PUBLIC HEALTH
BLOOMINGTON

Script for Focus Group Participation

Good morning (afternoon, evening). My name is Todd Smith/Kevin Slates. I am a professor in the area of safety management at Indiana University – Bloomington in the School of Public Health. I (we) am/are conducting research to study various risk factors and safety factors associated with strains and sprains or musculoskeletal disorders within the stone, sand and gravel or aggregates mining industry. I am asking you to participate because you work in this industry.

I'm asking you to participate in our focus group. As a focus group member you will be asked to share your thoughts about factors that may influence musculoskeletal disorders or strains and sprains within your industry. We will ask group participations to respond to approximately 8 questions on this topic. There are no right or wrong answers.

The focus group session will take about 45 minutes, but we may finish sooner or it may take up to one hour. We do not ask for any information that would personally identify you as a participant. Your participation is anonymous. We also ask that you not share your name or names of individuals, companies, associations, and the like when responding. If you participate in the focus group, you will receive gift cards in the amount of $40.

We will be digitally recording the focus group sessions so that we can transcribe and conduct content analyses of the written documents to complete our research. When we share the results of our study, results will not identify individuals. Our general conclusions will be in aggregate, but, given the focus of qualitative research, we may include individual quotes in our findings. The source of those quotes will not be known and thusly, not identified.

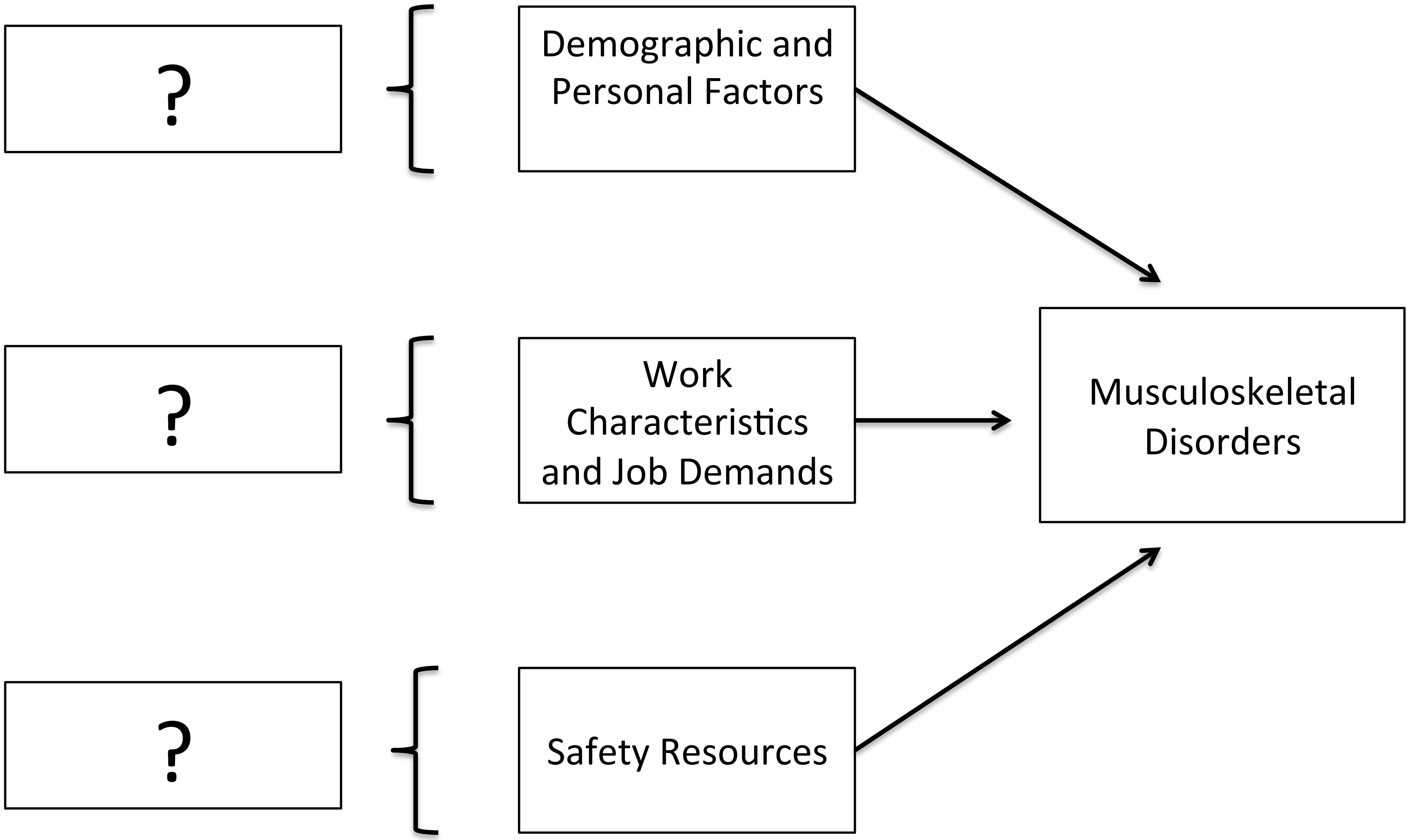
Do you have any questions at this time? *(Answer questions if any)*

At this time, we will turn on our recorders. We ask that there be no additional video or audio recording. I will provide a copy of our research model that will give insights into the questions that will be asked by Dr. Smith/Dr. Slates. (*Handout (copy of model) is provided to participants).*

I'd like to thank you all again for participating in the focus groups. Again, we ask that you please respect the privacy and anonymity of those participating and that you avoid using individual names, companies, associations and the like.

Conduct focus group activity – see questions to be asked of participants

That concludes the focus group activity. Again, thanks for your help. If you have any questions please let me know. I'll also provide you with my contact information should you have questions in the future. I can be reached at 812-856-4887 or by email at smithtod@indiana.edu *(or Dr. Slates contact information when leading – 812-856-3766 or by email at klates@indiana.edu).*


?
?
?
Demographic and Personal Factors
Work Characteristics and Job Demands
Safety Resources
Musculoskeletal Disorders

Focus Group Questions

Dr. Smith/Dr. Slates to present the questions verbally after first defining the definition of MSDs offered below.

Musculoskeletal Disorders or MSDs are injuries and disorders that affect the human body's movement or musculoskeletal system including muscles, tendons, ligaments, discs in the vertebral column, nerves, blood vessels, etc.

<u>Questions</u>

1. What demographic or personal factors do you think are associated with MSDs in aggregates mining operations, including stone, sand, gravel, etc.?
2. What jobs or work tasks do you think are most associated with MSDs?
3. What work characteristics do you think are most associated with MSDs?
4. What job demands do you think are most associated with MSDs?
5. What physical stressors do you think are associated with MSDs?
6. What emotional or psychological stressors do you think might be associated with MSDs, if at all?
7. What safety resources do you think would help curtail, buffer or control the factors you mentioned were associated with MSDs?
8. How can MSDs be prevented in stone, sand and gravel mining operations?