Association of Individual Risk Factors and Workplace Factors to Self-Reported Body Discomfort of Filipino Small-Scale Gold Miners

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Abstract – *Work-related Musculoskeletal Disorder (WMSD) was identified as a significant and costly health and safety problem for the large-scale mining industry. WMSD is often characterized by discomfort such as pain, tingling, numbness, stiffness, and aching perceived on the different body parts. The risk factors of WMSD in large scale mining can also be observed in small-scale gold mining. However, there is little information on the association of individual and workplace risk factors to the perceived body discomfort of the workers in the small-scale gold mining and extraction in the Philippines.*

This study aimed to provide a baseline data on the prevalence of body discomfort and its association to individual and workplace risk factors. To achieve this, a survey of 124 small-scale gold mining and extraction workers in seven different mining and extraction sites from selected regions in the Philippines was conducted.

The results showed that ninety-five percent (95%) of the survey participants perceived body discomfort in at least one part of their bodies. The highest percentage of discomfort on body parts were on the lower back (65.32%), shoulders (59.68%), and neck (54.03%). Using correlation analysis, results showed that the severity of lower back discomfort and the estimated alcohol consumption per week has low positive correlation. Likewise, the frequency and severity of knee discomfort have a low positive correlation to years of experience in mining. Furthermore, by using binary logistic regression, it was found that drinking alcohol and the Rapid Entire Body Assessment (REBA) score which characterizes physical demand were found to be significantly associated with presence of discomfort on the lower back; years of experience in mining and estimated height were significantly associated to the presence of discomfort on the knees.

Further analysis of workplace factors and other possible risk factors of the body discomfort is recommended.

Keywords—Body discomfort, Individual risk factors, Workplace risk factors, Filipino Small-Scale Gold Miners

I. INTRODUCTION

Mining is considered by the International Labor Organization as one of the most hazardous and physically demanding occupations. Physically demanding working conditions have commonly been associated with Musculoskeletal Disorders (MSDs) (Podniece et.al., 2008). Work-related Musculoskeletal Disorder (WMSD) is defined as discomfort, damage, or persistent pain in body structures, such as muscles, tendons, joints, ligaments, bones, nerves, and the circulatory system caused or aggravated by occupational risk factors (Bernal et.al., 2014). Studies often characterize WMSD with body discomfort like pain, tingling, numbness, stiffness, and aching perceived on the different body parts.

Work-related Musculoskeletal Disorder (WMSD) is a significant and costly health and safety problem for the large-scale mining industry (Torma-Krajewski et.al., 2006). MSDs are reported to have high prevalence among miners in Spain, Sweden, India, Iran, USA and Australia. Coal and metal mining in British Columbia reported 182 claims on MSD injuries of the back due to overexertion amounting to $2,106,974 from 1993 to 1997. New South Wales coal mining reported 831 new musculoskeletal claims each year from 2002 to 2005. Cases of MSDs for Gold and Platinum mining in South Africa constitute 16.2% of the 1235 medical records in 2005. In Ontario, MSDs due to mining account for 41% of all injuries, a loss of more than 5,700 working days and more than $1 million in 2010. In Spain, 378 occupational diseases due to mining were reported in 2010. (Elgstrand, 2013).

Bending forward or to the side, twisting or hyperextending of the neck or back, forearms resting on sharp edges, unsupported abducted elbows, working with elbows above shoulders, tossing motions at extremes of range of motion, and unaided lifting of more than 50 pounds are the most common conditions that overload large scale mine workers (Wiehagen, Turin, 2004). Although large-scale mining is highly mechanized, the conditions that burden the workers are found in manual labor tasks. These conditions are also present and may be more prevalent in small-scale gold mining, as it is defined as the extraction of minerals that relies heavily on manual labor using simple implements and methods and does not use explosives or heavy mining equipment (*definition taken from DENR Department Administrative Order 2015-03).* This affirms the potential exposure of small-scale gold miners to WMSD risk factors.

Occupational risk factors that were commonly found to be associated to WMSD include individual factors and workplace factors such as physical workload (Li and Buckle, 1999).

Several studies have shown that individual factors such as age, career length, height, smoking, and alcohol consumption are associated with WMSD. A study of 420 medical secretaries found age and length of employment to be significantly related to neck pain (Kamwendo et al., 1991). A study on rockblastors, bricklayers and foreman in large construction firms found that years of manual labor seems to be one of the risk factors for an MSD called osteoarthrosis (Stenlund et al., 1992). Other studies found that people with back pain are generally taller than those without it (Merriam et. al., 1980, Biering-Sorensen, 1983). In an analysis of the risk factors of MSDs among Japanese nurses, tobacco smoking, alcohol consumption, and having children were shown to be significant risk factors (Smith et.al., 2006).

Workplace factors such as physical demand was also found to be significantly associated with WMSD. The hazards of physical demand include awkward posture, heavy lifting, and carrying repetitive tasks. Forceful arm and shoulder exertions, handling heavy and awkward objects, and working in awkward postures were common for a variety of jobs in a study of musculoskeletal risk factors in an underground coal, surface copper, surface phosphate, and underground limestone mines (Wiehagen, et.al, 2004).

An evaluation of the interaction between workplace factors for low back symptoms (LBS) done amongst Indonesian coal mining workers concluded that permanent employment, smokers, and night shift work increase the odds of LBS and its consequences (Widanarko et.al., 2014). In a study on the underground coal miners in the Eastern Coalfield mines of India, the analysis of the correlation between the occupational factors and their WMSDs found that 36 out of 55 miners (65.45%) feel discomfort in different body parts; the risk factors for the development of WMSDs from the analysis were age, awkward postures, and repetitive operations (Bandyopadhyay et.al., 2012).

In the case of small-scale gold mining and extraction in the Philippines, there is little information on the association of individual and workplace risk factors to the body discomfort perceived by the workers (Custodio et.al, 2016, Custodio, 2017). Operations are usually illegal and unregulated, nonetheless, the issue on hazardous working conditions is highly recognized.

Around 80% of gold production in the Philippines is accounted to the artisanal and small-scale gold mining sub-sector, and there are an estimated 350,000 workers involved in the industry (ILO). Since small-scale gold mining and extraction remains to be a major economic contributor especially in remote communities, where thousands of people are engaged in gold production, reducing exposure to occupational risks is vital for maintaining the quality of life. Reducing these risks involves awareness which starts with identification of the risk factors. Thus, this study aims to provide a baseline data of the prevalence of body discomfort and its association to individual and workplace risk factors in selected small-scale gold mining and extraction in the Philippines. This would substantiate the presence of WMSD in the industry and help pinpoint the problematic risk factors where preventive measures and corrective actions should be directed.

II. METHOD

2.1 Participants

Data gathering was done in observation sites located in the provinces of Abra, Benguet, Compostela Valley, and Agusan del Norte. These sites were chosen for their reputation as being engaged in small-scale gold mining and extraction activities for many decades. The locations of the observation sites and the relevant boundaries are shown in **Figure 1**. Due to many factors including the informality of the sector, safety, and lack of official statistics, samples were taken by convenience sampling. Interviews of 124 small-scale gold mining and extraction workers in the observation sites were conducted.

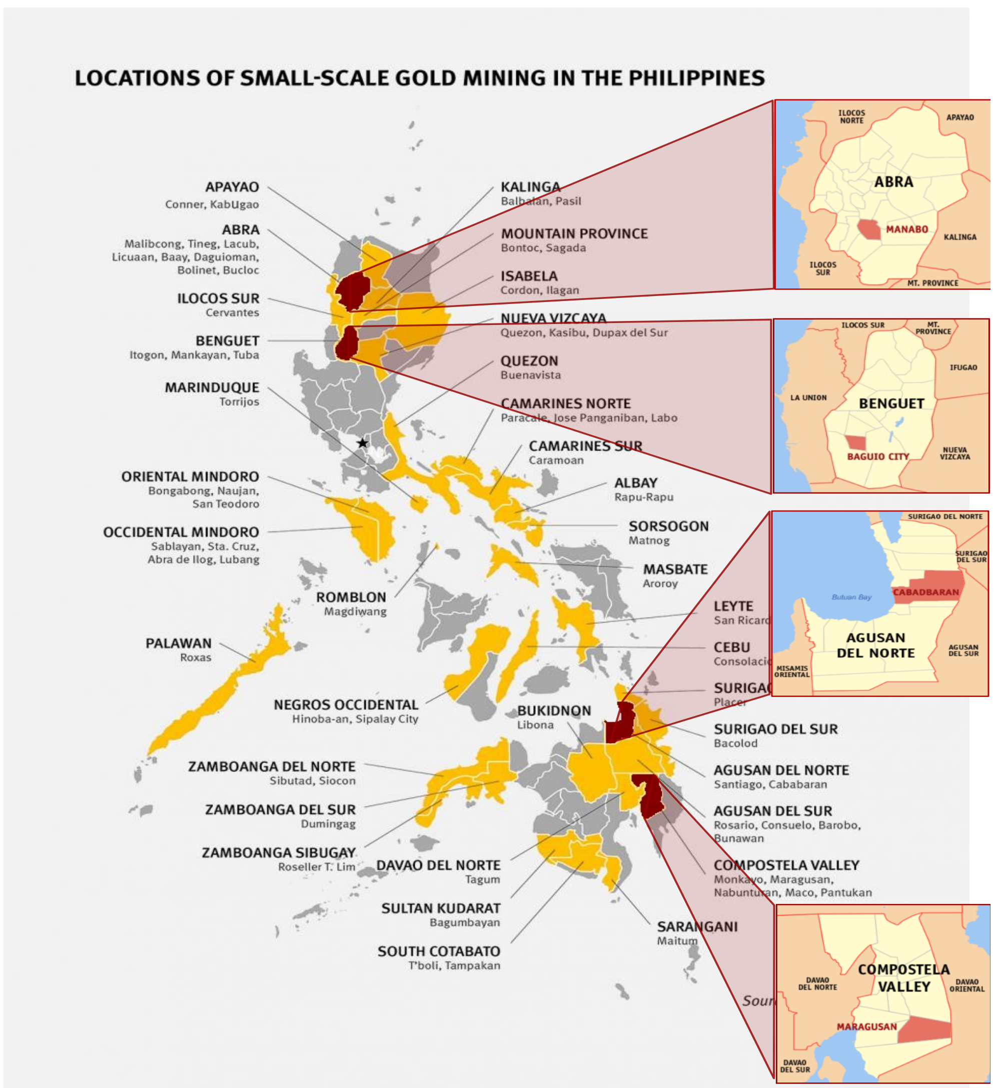

Figure 1. Map showing the location of the municipalities and their respective provincial boundaries *(Map taken from Ban Toxics, provincial maps taken from Wikipedia.org)*

2.2 Body Discomfort Questionnaire

The body discomfort questionnaire uses a 5-point scale rating on the frequency and severity of symptoms perceived during the last 12 months in different parts of the body such as neck, shoulders, upper back, lower back, arms, elbows, hands or wrist, hips, thighs, knees, legs, and feet or ankle (Custodio et.al, 2016). The questionnaire was based on the modified version of the Nordic Musculoskeletal Questionnaire (NMQ) (Kuorinka et al.,1987) which requires a response of yes or no if the participant perceives musculoskeletal aches, pains, discomfort, or numbness in specific parts of the body in the last 12 months (Widanarko, et.al., 2014). NMQ was developed to aid the detection and analysis of musculoskeletal symptoms of different individuals in different countries using indirect methods through standard evaluation questions (Lopez- Aragon, et.al., 2017). The confirmed validity of NMQ causes its inclusion in studies that identify symptoms and musculoskeletal maladies as well as studies of diverse fields of knowledge from health activities (24%) to construction (1%) (Lopez-Aragon, et.al., 2017).

2.3 Individual Risk Factors Questionnaire

Personal information, namely: age, estimated height, years of work experience as a miner, estimated alcohol consumption per week, and number of cigarette sticks smoked per week for the estimated tobacco consumption, were included in the questionnaire (Custodio, 2017).

2.4 Physical Demand Exposure Assessment

The physical demand of a work is characterized by the postures adopted, forces exerted, and repetition done during the performance of the task. Postures and work tasks that are sustained for the longest period, perceived to be the most difficult, or exerted with the highest force load were observed.

Rapid Entire Body Assessment (REBA) was done for each posture and corresponding average REBA score for each worker was computed. REBA is a posture-based technique used for assessment of physical workload and associated exposure to WMSD risks. The tool incorporates in the assessment the postures, forces, and repetition during the performance of the task. It is appropriate for the assessment of tasks where postures are static, dynamic, or where there are gross changes in position. The evaluation is done by selecting the posture or activity to be assessed and scoring the body alignment using the REBA diagrams; action levels are suggested to indicate necessary ergonomic interventions (Li And Buckle, 1999).

2.5 Data Analysis

To identify which among the considered risk factors are associated to the body discomfort, Spearman correlation and binary logistic regression were used.

To assess the individual relationship of frequency and severity of body discomfort (neck, shoulders, upper back, lower back, arms, elbows, hands or wrist, hips, thighs, knees, legs, and feet or ankle) and individual factors (age, estimated height, years of work experience as a miner, estimated alcohol consumption per week, and number of cigarette sticks smoked per week) and workplace factors (REBA score), the Spearman correlation was used.

Spearman's rank correlation coefficient is a nonparametric measure of statistical dependence between two variables and is appropriate for both continuous and discrete variables, including ordinal variables (Daniel, 1990).

To quantify the association between the risk factors and the presence of body discomfort, binary logistic regression was used. The use of logistic regression analysis is widely applicable to epidemiologic studies concerned with quantifying an association between a study factor (i.e., an exposure variable) and a health outcome (i.e., disease status) (Kleinbaum, D.G., 1982). The presence or absence (presence=1, absence=0) of body discomfort was used as the dependent variable, and individual factors (age, estimated height, years of work experience as a miner, alcohol drinker/ non-alcohol drinker, and smoker/non-smoker) and workplace factors (REBA score) were used as the independent variables. The strength of associations was estimated by odds ratio and corresponding 95% confidence interval. Analyses were carried out separately for each body discomfort (neck, shoulders, upper back, lower back, arms, elbows, hands or wrist, hips, thighs, knees, legs, and feet or ankle). All statistical analyses were conducted using Minitab.

III. RESULTS AND DISCUSSION

3.1 Participant Individual Characteristics

All survey participants were male. Some mining sites do not allow female to go inside the tunnel due to the belief that gold inside will disappear if a female enters the tunnel. Others state that the heaviness of work is not suited for a female's strength.

The youngest small-scale gold miner and extraction worker interviewed was 17 years old and the oldest was 59 years old. The participants had an average age of 32 years old.

The height of the participants ranged from 134 cm. (~4'4") to 183 cm (~6'), and an average estimated height of 164 cm. (~5'4").

The miners and extraction workers interviewed have an average of 6 years experience in mining, with a maximum of 38 years and a minimum of 1 month experience.

Gin and beer were the most common alcoholic beverage taken by the workers. The participants have an average alcohol consumption of 118 mL per week (approximately 1 bottle of gin or 7 bottles of beer in a week), and a maximum of 840 mL per week. 18.54% of the participants do not drink any alcohol.

It was also found that forty-four percent (44%) of the participants do not smoke. Those who do smoke an average of 8 sticks per day, with a maximum of 60 cigarette sticks per day.

3.2 Physical Demand

Workers are assigned in mining of ore from the tunnel, crushing and milling of ore, and extracting of gold from ore with the aid of gravity, chemicals, or both (see Figure 2). Mining involves digging tunnel to reach gold deposits, extracting gold ores usually through the use of hand tools and equipment, and transporting the ores to the extraction site either by carrying or using of cart. Workers assigned in crushing and milling processes use mallet, crushers, and milling machines. When crushing and milling machines are used, workers are tasked to carry and load the sack of ores into the crusher and mill, and unload the crushed ores and milled slurry. Gravitational method, cyanidation, and heap leaching were the extraction methods utilized by the sites.

Figure 2. Sample pictures of workers involve in mining and extraction processes

Small-scale mining and extraction sites observed in Abra and Agusan del Norte utilize gravitational method of sluicing and panning for the extraction of gold (see Figure 3). In sluicing, workers recover the gold by letting the milled slurry passed through the sluice box with fabric to catch gold. In panning, the workers scoop the milled slurry into a wooden or metal pan where it is gently agitated in water, and the gold sinks to the bottom of the pan.

Figure 3. Workers performing sluicing and panning

Two of the sites in Benguet utilize gravitational method and heap leaching. Other site in Benguet and Compostella Valley uses gravitational method and cyanidation for extraction of gold. In heap leaching, workers stack the dried milled slurry into a heap where it is irrigated with a chemical solution that dissolves the gold, and unload the milled slurry from the heap after the process was completed. In cyanidation, the workers are assigned to load the milled slurry, carbon, cyanide and other chemical in the leaching tank, afterwhich, they collect the carbon (see Figure 4).

Figure 4. Work in heap leaching and cyanidation

Work varies between mining and extraction sites, and assignment of responsibilities differ between workers as well. The REBA score ranges from 3 to 13, signifying a low risk to a very high risk level of exposure to WMSD.

3.3 Self-reported Body discomfort

Ninety five percent (95%) of the interviewees perceived body discomfort in at least one part of their bodies. Lower back (65.32%), shoulders (59.68%), and neck (54.03%) have the highest percentage (see Figure 5) (Custodio, et.al, 2016).

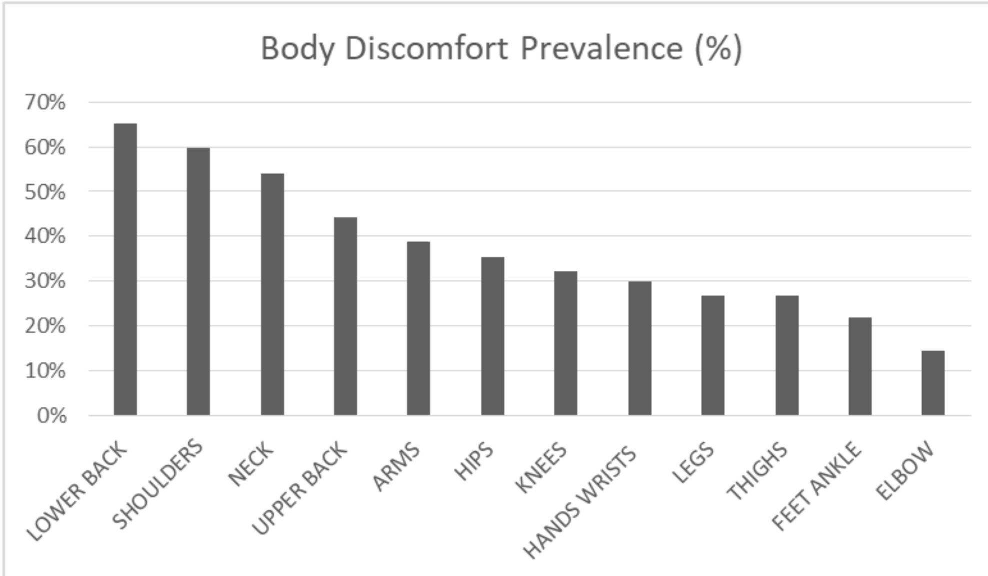

Figure 5. Percentage of Prevalence of Body Discomfort

Spearman correlation was used to check for correlations between the frequency and severity of body discomfort and risk factors considered (Custodio, 2017).

Results showed that as the estimated alcohol consumption increases, lower back severity also increases; a low positive correlation (0.347). Frequency (0.315) and severity (0.305) of knee discomfort have a low positive correlation to years of experience in mining. As years of experience in mining/ extraction increases, knee frequency and severity also increases. Other risk factor are not correlated to body discomfort of the workers.

To further determine how the risk factors are numerically related to the presence of body discomfort, binary logistic regression was used. Age was excluded in running the data due to the assumption of no multicollinearity for binary logistic regression; age and year of experience were found to be correlated (Pearson correlation coefficient: 0.425).

No individual and workplace factors were found to be significantly associated with presence of neck, upper back, shoulder, elbows, arms, hands/wrists, hips, thigh, legs, and feet/ ankle discomfort (see Tables 1 to 4).

Drinking alcohol (OR=4.872, 95% CI 1.7969, 13.2072, p-value= 0.001) and REBA score (OR=1.46, 95% CI 1.0418, 2.0469, p=0.015) were found to be significantly associated with presence of discomfort on the lower back (see Table 2).

Table 1. Risk Factors for Neck, Shoulder, and Upper Back Discomfort

	NECK			SHOULDERS			UPPER BACK		
	P-Value	Odds Ratio	95% CI	P-Value	Odds Ratio	95% CI	P-Value	Odds Ratio	95% CI
ESTIMATED HEIGHT (cm)	*0.663*	*1.014*	*(0.9535, 1.0779)*	*0.616*	*1.016*	*(0.9540, 1.0827)*	*0.935*	*1.0026*	*(0.9428, 1.0661)*
YEARS OF EXPERIENCE IN MINING	*0.933*	*1.002*	*(0.9478, 1.0602)*	*0.119*	*0.956*	*(0.9009, 1.0135)*	*0.403*	*0.976*	*(0.9209, 1.0343)*
REBA SCORE	*0.23*	*1.188*	*(0.8881, 1.5879)*	*0.227*	*1.187*	*(0.8921, 1.5804)*	*0.187*	*1.2138*	*(0.8958, 1.6446)*
ALCOHOL DRINKER/ NON-ALCOHOL DRINKER	*0.526*	*1.348*	*(0.5363, 3.3862)*	*0.633*	*0.793*	*(0.3031, 2.0719)*	*0.246*	*1.745*	*(0.6705, 4.5412)*
SMOKER/ NON-SMOKER	*0.235*	*0.637*	*(0.3008, 1.3476)*	*0.546*	*0.791*	*(0.3692, 1.6958)*	*0.985*	*1.0074*	*(0.4765, 2.1300)*

Participants who drink alcoholic beverages had 4.872 times higher risk of lower back discomfort that those who do not (see Table 2). Studies found that alcohol interferes with calcium and bone metabolism; acute alcohol consumption can lead to an increased urinary calcium excretion and a transient PTH deficiency which result to loss of calcium in the body (Laitinen, K., et.al, 1991). Chronic heavy drinking can result to inadequate absorption of dietary calcium because of disturbance in vitamin D metabolism, (Bjorneboe, A., 1988). Calcium deficiency can also lead to bone diseases, such as osteoporosis characterized by a substantial loss of bone mass and, consequently, increased risk of fractures (Rico, H., 1990). Long term excessive drinking of alcohol and/or nutritional deficiency or both can result to a condition called alcoholic neuropathy, a condition which can be characterized by chronic pain due to damage to nerves (Chopra, K., et.al., 2012). Another potential cause of back pain linked to alcohol consumption is gout, one of the most common inflammatory arthritis. Episodic consumption of alcohol including moderate amounts was found to be associated with an increased risk of recurrent gout attacks (Neogi, T., et.al., 2015).

An increase in REBA score results to 46% increase in the odds of having discomfort on the lower back (see Table 2). High REBA score corresponds to awkward posture, forceful exertion, and repetitive task. Half of the workers observed have a REBA score of 11 or higher, which require immediate corrective action including further assessment. The workers are exposed to a very high risk level which can be aggrevated by exposure for years of work.

Table 2. Risk Factors for Lower Back, Elbow, and Arms Discomfort

	LOWER BACK			ELBOW			ARMS		
	P-Value	Odds Ratio	95% CI	P-Value	Odds Ratio	95% CI	P-Value	Odds Ratio	95% CI
ESTIMATED HEIGHT (cm)	*0.916*	*0.996*	*(0.9317, 1.0656)*	*0.478*	*1.036*	*(0.9384, 1.1434)*	*0.459*	*1.024*	*(0.9613, 1.0909)*
YEARS OF EXPERIENCE IN MINING	*0.644*	*0.985*	*(0.9242, 1.0495)*	*0.181*	*1.046*	*(0.9801, 1.1169)*	*0.405*	*0.9752*	*(0.9179, 1.0361)*
REBA SCORE	**0.015**	**1.46**	**(1.0418, 2.0469)**	*0.619*	*1.121*	*(0.6992, 1.7967)*	*0.188*	*1.224*	*(0.8883, 1.6867)*
ALCOHOL DRINKER/ NON-ALCOHOL DRINKER	**0.001**	**4.872**	**(1.7969, 13.2072)**	*0.089*	*4.472*	*(0.5552, 36.0179)*	*0.314*	*1.6448*	*(0.6125, 4.4172)*
SMOKER/ NON-SMOKER	0.216	1.684	(0.7351, 3.8578)	0.53	1.427	(0.4665, 4.3671)	0.685	0.8535	(0.3975, 1.8330)

Table 3. Risk Factors for Hands/Wrists, Hips, and Thigh Discomfort

	HANDS/WRISTS			HIPS			THIGHS		
	P-Value	Odds Ratio	95% CI	P-Value	Odds Ratio	95% CI	P-Value	Odds Ratio	95% CI
ESTIMATED HEIGHT (cm)	0.478	1.025	(0.9571, 1.0974)	0.333	1.033	(0.9667, 1.1029)	0.769	1.0105	(0.9421, 1.0839)
YEARS OF EXPERIENCE IN MINING	0.692	1.012	(0.9547, 1.0725)	0.449	0.977	(0.9197, 1.0385)	0.186	0.9531	(0.8817, 1.0303)
REBA SCORE	0.511	1.113	(0.8004, 1.5462)	0.203	1.229	(0.8752, 1.7255)	0.594	1.0883	(0.7913, 1.4968)
ALCOHOL DRINKER/ NON-ALCOHOL DRINKER	0.629	1.286	(0.4569, 3.6206)	0.833	0.902	(0.3478, 2.3400)	0.197	2.086	(0.6426, 6.7717)
SMOKER/ NON-SMOKER	0.802	1.109	(0.4927, 2.4978)	0.509	1.301	(0.5952, 2.8445)	0.676	1.1949	(0.5171, 2.7613)

Table 4. Risk Factors for Knees, Legs, Feet/Ankle Discomfort

	KNEES			LEGS			FEET/ANKLE		
	P-Value	Odds Ratio	95% CI	P-Value	Odds Ratio	95% CI	P-Value	Odds Ratio	95% CI
ESTIMATED HEIGHT (cm)	**0.003**	**1.124**	**(1.0349, 1.2202)**	0.264	1.042	(0.9677, 1.1229)	0.225	1.0501	(0.9684, 1.1388)
YEARS OF EXPERIENCE IN MINING	**0.018**	**1.083**	**(1.0081, 1.1641)**	0.163	1.044	(0.9832, 1.1075)	0.184	1.0425	(0.9808, 1.1081)
REBA SCORE	0.172	1.314	(0.8602, 2.0080)	0.539	0.91	(0.6768, 1.2236)	0.053	1.5613	(0.9473, 2.5731)
ALCOHOL DRINKER/ NON-ALCOHOL DRINKER	0.409	1.578	(0.5240, 4.7494)	0.307	1.806	(0.5549, 5.8757)	0.255	2.0708	(0.5487, 7.8154)
SMOKER/ NON-SMOKER	0.287	1.597	(0.6710, 3.8004)	0.692	0.843	(0.3629, 1.9599)	0.482	0.7156	(0.2812, 1.8209)

The number of years working in mining (OR=1.083, 95% CI 1.0081, 1.1641, p-value= 0.018) and estimated height (OR=1.124, 95% CI 1.0349, 1.2202, p-value= 0.003) were found to be significantly associated with presence of discomfort on the knees (see Table 4). A year increase in experience as a miner results to 8.3% increase in the odds of having discomfort on the knees. Taller workers are more prone to having knee discomfort; one unit increase in height results to 12.4% increase in the odds of having discomfort on the knees.

Common tunnel size of the mines visited had around 3-5 feet height opening. It is very common for the workers to stoop down when entering, leaving, and while working inside the tunnel. Thus, the miners are in awkward posture for a long period of time.

IV. CONCLUSION

Similar to the large-scale mining, body discomfort is prevalent in the selected small-scale gold mining and extractions sites. From the results of the study, body discomfort is perceived to be present in at least one part of the worker's body. The main areas of discomfort have been identified to be present in the following body parts: lower back, shoulders and neck.

The study also revealed that alcohol consumption and years of experience in mining are correlated to lower back and knee discomfort, respectively. Furthermore, the study also showed that drinking alcohol and physical demand, years of experience in mining and estimated height are the main factors that increase the odds of having discomfort on the lower back and knees, respectively.

To reduce or prevent the risk of WMSD, the study suggests that emphasis should be made on monitoring and regulating alcohol consumption, on ensuring proper adherence to standard height of the tunnels and facilities, and proper work design of the mining and extraction processes.

The limitations of this study should be acknowledged when interpreting the results. The study relied on self-reported body discomfort. Proper examination and testing by an occupational health expert is needed to accurately diagnose the presence of WMSD in a participant. As mentioned, the data presented here came from convenience sampling of selected mining sites in four regions of the Philippines. Although, the processes of small-scale mining and extraction in the Philippines are more or less the same, design of work and facilities may be different. Thus, an in-depth analysis of the workplace risk factors, devising corrective actions and development of proper work design are needed. Convenience sampling may result in estimates which is not representative of Philippine small-scale gold miners and extraction workers in general. In addition, there are other possible risk factors that studies found to be associated to body discomfort: psychosocial factors such as high job demand and low job satisfaction (Xu, G.X., et.al., 2012), sleep deprivation (Lautenbacher, S., et. al., 2006), nutrient deficiency (Helde-Frankling, et. al, 2017; Hammond, N. et.al., 2013), genetics as risk factor for hereditary diseases such as fibromyalgia and ostearthritis (Lier, et.al, 2016; Spector T.D., et.al., 2004), etc. Further analysis of these possible risk factors is recommended. The aforementioned limitations indicated that the results in this study be interpreted with caution and can be overcome through further research.

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