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An Assessment of Vibration Exposure and its Health Effects on Stone Workers in Taiwan and China

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AN ASSESSMENT OF VIBRATION EXPOSURE AND ITS HEALTH EFFECTS ON STONE WORKERS IN TAIWAN AND CHINA

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ABSTRACT

Background: Stone workers were in high risk of vibration exposure that might lead to health problem. Studies and previous research have shown that there are correlations between whole body vibration, hand/arm vibration and several musculoskeletal disorders, neurological diseases, and different cumulative trauma disorders such as hearing loss and carpel tunnel syndrome. In order to study the health effects among stone workers, there were seven stone companies selected from Taiwan and China participated in this study.

Aim: The goal of this project was to study and assess the correlations between several exposure variables such as vibration and noise exposure and outcome variables such as white finger disorder and different musculoskeletal disorders by conducting variety of statistical analysis; also compare the safety practice differences between Taiwanese and Chinese workers.

Methodology: total of 92 participants from seven stone cutting companies. Self-estimate questionnaire was used to evaluate their exposure level, health conditions, health history and training experiences. Data was analyzed by using chi-square, odds ratio and logistic regression in SPSS and SAS.

Results: The result show that pain occurrence has correlated to vibration exposure, PPE and training in both severity and frequency. Seniority has positive correlation with both pain severity and frequency. Workers also reported hearing problem during or after work and the correlation between hearing problem and noise exposure was significant. Training style showed difference

in nationality, although Chinese workers have younger ages, unitary working style might still related to pain occurrence.

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INTRODUCTION

Occupational exposure to vibration has severe health effects. Workers who use vibrating tools and equipments may increase the risk of having hand-arm vibration syndrome (HAVS). HAVS includes peripheral neurological, vascular, and musculoskeletal symptom that affects finger and upper limb (Bovenzi 1994). Vibration induced white finger (VWF), carpal tunnel syndrome (CTS), Dupuytren's contracture, and Raynaud's phenomenon are vibration-related disorder (Bovenzi 1994, Negro 2007). Stone cutting workers are among the at-risk population regarding occupational vibration exposure. Stone cutting tasks in Taiwan have been divided to three categories. First category is primary processing; the workers are using huge pulling and sawing machine to cut the original stone. The second category includes stone cutting, grinding and drilling. Third processing includes fine grinding and gluing. Stone workers in secondary and third category needs to operate vibrating tools/equipments to polish the stone sculpture that is the third category of stone tasks. After visiting these three types of company, the first category company was excluded because the workers do not receive highly dose of vibration exposure because basically they just need to push the button rather than handling the tools. In this project, all companies were selected from secondary category companies, in which the workers are operating with small equipments and are exposed to different level of vibration. The aim of this project is to study and assess different vibration exposure variables on the health of stone workers in Taiwan and China.

Objective

Two different objectives are pursued in this project:

1- To assess the vibration exposure and its health effects among stone workers in Taiwan and Beijing area, China.

2- To study the differences in safety practices between stone workers in China and Taiwan

Significance

The previous studies were more focused on those who already diagnosed with vibration-related syndrome or some studies not only focusing on stone industry but investigated other industry such as forestry and art work industry. This research only focusing on stone workers and did not separate patient group or those who have medical prescription. This research also evaluated the training difference among stone workers in Taiwan and China.

Limitations

There were three limitations in this study. First of all, the vibration exposure was not measured objectively which means there is no direct measurement of vibration exposure in this study. Second, some of the participating workers were multitasking; which means they were using more than one vibrating tools or performing administrative tasks. The third limitation is that neither the NIOSH (National Institute of Occupational Safety and Health) nor OSHA (Occupational Safety and Health Administration) have established any exposure limit for vibration. Since the level of exposure can be affected by many factors such as type of tool, its weight, operating speed and the working posture (NIOSH 1989) it is difficult to determine exposure limit, or advice companies on how to control the exposure. However according to ISO 5439-1 Annex A exposure limits were set for frequencies is 8-1000Hz (Sutinen *et al*. 2006).

Delimitations

To delimiting the influence of limitations, the workers need to subjectively fill out the questionnaire, which has asked about self-estimated vibration and noise exposure level, health condition and history. Although there is no specific limit of vibration exposure, using personal protection equipment can reduce the exposure level therefore the workers were asked to answer the questions about personal protection equipment usage. The other delimitation is recruitment. The researcher chose the subjects from target group.

Definitions

Carpal Tunnel Syndrome (CTS): a condition caused by compression of the median nerve in the carpal tunnel and characterized especially by weakness, pain, and disturbances of sensation in the hand and fingers (United States National Library of Medicine, National Institutes of Health).

Hand-arm vibration (HAV): The transfer of vibration from a tool to a worker's hand and arm. The amount of HAV is characterized by the acceleration level of the tool when grasped by the worker and in use. The vibration is typically measured on handle of tool while in use to determine the acceleration levels transferred to the worker (NOISH No.97-141 1997).

Hand-arm vibration syndrome (HAVS): This term has been used to collectively define the disorders thought to be associated with exposure to hand-transmitted vibration (Palmer 1999).

Hand-transmitted vibration (HTV): Whole-body vibration: Vibration that is transmitted to a worker's body from vibrating surfaces on which a worker stands or sits.

Vibration: The oscillation on periodic motion of a rigid or elastic body from a position of equilibrium (NOISH 1989).

Vibration white finger (WVF): Raynaud's disease especially when caused by severe vibration (as in prolonged and repeated use of a chain saw) (United States National Library of Medicine, National Institutes of Health).

CHAPTER 2

LITERATURE REVIEW

A literature search was conducted from March 1st to June 30th, using stone worker, vibration, hand-transmitted vibration (HTV), hand-arm vibration syndrome (HAVS) as key words. The search was conducted on all resources and databases available through Indiana State University library and other online search engines including: EBSCO Host, ProQuest Science Journal, VIBRISKS (www.vibrisks.soton.ac.uk), The National Institute for Occupational Safety and Health (NIOSH), and Google Scholar.

Inclusion criteria were: *i.* papers in peer-reviewed journal, *ii.* government publication, *iii.* papers in English and Chinese, *iv.* papers/articles about hand-transmitted vibration or hand-arm vibration; and *v.* papers/articles published after 1990 to have more recent information. Government publication such as NIOSH and OSHA documents were the guidelines of standard and regulations. All articles were focus on hand-transmitted vibration or hand-arm vibration; whole-body vibration is not in the consideration. All selected articles were published after 1990 so the data, measurement, tools, and equipments were more close to present situation. Exclusion Criteria were: *i.* papers in other language, *ii.* descriptive papers; and *iii.* papers/articles published before 1990. There was no geographical exclusion criteria..

Result

The literature search resulted in four papers which are summarized in appendix A. All previous studies have reported that the use of vibrating tools in stone cutting industry had different health effects on workers. Vibration induced white finger, carpal tunnel syndrome, muscular weakness, and upper limb pain are the common health effects that mentioned in the literature review. Bovenzi's (1994) research on hand-arm vibration syndrome indicated that vibration induced white finger was correlated with vibration exposure, its duration, frequency, and lifetime dose exposure. The total subjects in this research have 823 active stone workers who employed in nine districts of North and Central Italy. There were 570 workers including 145 quarry drillers and 425 stone carvers, and 258 stone workers performed normal activities without vibration exposure. The health and workplace assessment questionnaire containing personal, medical records, work history, and health conditions; were given by professional physician. The researchers found that there were 172 workers (30.2%) in case group that had symptoms of vibration induced white finger, and 11 workers (4.3%) in control group. Stone workers in case group have higher percentage in having white finger, carpal tunnel syndrome, Dupuytren's contracture, muscular weakness, and upper limb pain.

In a different cross-sectional study researchers investigated whether vibration exposure can interfere with performance of daily activities (Cederlund *et al.* 2001). Total sample was 105 male workers exposed to vibration by using vibrating tools, and they were selected from different industries. Researchers evaluated workers' daily activities by Activities of Daily Living (ADL) and Evaluation of Daily Activities Questionnaires (EDAQ). The result showed that 42% (n=44) of total group (n=105) had one or more difficulties in performing daily activities, and 19 workers with hand-arm vibration syndrome had no ADL difficulties. Also there were a strong correlation between pain, reduced grip force, and difficulties in ADL performance, and Cederlund *et al.* suggested those factors may use to detect the activity limitation for hand-arm vibration exposed population.

The administration color chart and medical history are the two methods to diagnose finger whiteness, and so far there is no gold-standard test for diagnosis (Nergo *et al.* 2007). To assess the usefulness of color chart, Negro *et al*. (2007) selected 146 active hand-transmitted vibration workers who employed from four forestry companies (n=137) and 36 stone workers employed in one stone company, and investigated with questionnaires, cold test, administration of color chart, and clinical diagnosis. According to the study result, the researcher suggested that the administration of color chart may reduce the frequency of false positive response of finger whiteness, which means both health history and color chart should be used in finger whiteness diagnosis on vibration exposed population.

A prospective cohort study conducted by Rui *et al*. (2007) in Italy was a one-year follow-up study, which intended to investigate the relation between manipulative dexterity and vibration exposure among workers with hand-transmitted vibration exposure. The total population of this study was 115 HTV exposure workers and 64 workers employed in same company in the control group. All 115 workers took questionnaire, which is developed, from VIBRISKS (http://www.vibrisks.soton.ac.uk) in the first year, and then all workers participated in follow-up study. Manipulative dexterity was investigated by Purdue pegboard testing method (Rui *et al.* 2007, Tiffin and Asher 1948). Researchers assumed that finger whiteness, neck and upper-limb musculoskeletal disorders were correlated with vibration exposure; however the result showed no association for ergonomic risk factors. In the one-year follow-up period, the Purdue pegboard score were inversely related to age, vibrating tools usage, and smoke habit, which indicated that manipulative dexterity affected by vibration exposure in this study.

CHAPTER 3

RESEARCH METHODOLOGY

A questionnaire was prepared partly based on: VIBRISKS (Griffin and Bovenzi2007) and broken into two parts: 1- workers questionnaire (Appendix B), and 2- record keeping questionnaire (Appendix C). Health condition, vibration duration and personal lifestyle were answered by stone workers in the first part of questionnaire. Managers or supervisors of stone cutting companies filled out the second part of the questionnaire.

The input variables in the questionnaire were 1-demographic information such as age, gender, nationality, weight and height, 2-smoking habit, drinking habit, and drug usage, 3-vibration exposure such as self-estimate vibration/noise exposure, vibrating tool operating hours, working time, 4-identifying vibrating tools/equipments; and 5-personal protect equipment usage and training lesson. The output variables were: 1-severity and frequency of current pain in different body parts and joints, and 2-vision and hearing difficulties, numbness and tingling occurrence in severity and frequency.

Institutional Review Board (IRB) Approval

Before data collection, the study proposal and questionnaire were sent to The Institutional Review Board (IRB) office in Indiana State University for review and received the Exempt Approval on June 30 2010 (Appendix D).

Sample Selection

The recruitment and sample selection was conducted by researcher from July 1st to August 30th 2010. Seven out of eleven companies agreed to participate in this study, five of them from Taiwan and two from China. All companies were asked for permission to recruit volunteers. The total number of 45 questionnaires were given to those five stone companies in Taiwan and got 35 back (77.78% response rate) and from two companies in China 57 questionnaires out of 100 were returned (57% response rate). The total participation rate was 63.45%.

Statistical Analysis

Different statistical analysis was conducted such as chi-square tests, odds ratio analysis, and multinomial logistic regression analysis in order to study the correlation between exposure variables and each outcome variable. The statistical software PASW 17.0 and SAS were used in this project because the currently available PASW program in Indiana State University does not have the module for multinomial logistic regression therefore SAS program was used for that purpose. In demographic information section, nationality is a key element to distinguish the personal protection equipment and training efficiency from Taiwan and China. In order to see the effects of vibration on each body part, self-estimate vibration and noise exposure were compared with pain occurrence in severity and frequency. Vision and hearing difficulties were compared with hearing protection and other variables. The health history is another important input to identify the confounders in this project, so pain history would compare with current pain occurrence and vibration exposure. Beyond chi-square, the multinomial logistic regression will also be executed by using SAS. The purpose of using the multinomial logistic regression is to predict the probability of having musculoskeletal disorders after expose to vibration. Equation 1 is a typical multiple logistic regression model which will be used in this study (Hosmer and Lemeshow1989), and equation 3 is the multinomial logistic regression model.

$$\text{logit}\{P(\underline{X})\}=\beta_0 + \beta_1 X_1 + \cdots + \beta_r X_r \qquad (1)$$

r : The total number of exposure variables (independent variables).

The odds ratio for exposure variable *i* can be estimated by:

$$OR_i = e^{\beta_i} \qquad (2)$$

Multinomial logistic regression model

$$P\left(y^{(i)} = 1 \middle| x, \omega\right) = \frac{\exp\,(\omega^{(i)^T} x)}{\sum_{j=1}^{m} \exp\,(\omega^{(j)^T} x)} \qquad (3)$$

The probability *x* belongs to class *i*, and *i*$\in \{1, \dots., m-1\}$, where $\omega^{(i)}$ is the weight vector corresponding to *i*; the superscript ^{T} denotes vector/matrix transpose (Krishnapuram *et al.* 2005).

CHARTER 4

RESULTS

The literature review showed that there were some correlations between vibration exposure and discomfort on different body parts in certain levels.In the questionnaire, pain severity was rated on a scale of zero to ten, in which 0 means no pain and 10 means having severed pain. For data analysis purpose, the rating scales were decoded into 3-level scales where 0 to 3 were decoded into 1, 4 to 7 were decoded into 2, and 8 to 10 were decoded to 3.

Data on exposure and the different symptom were obtained from 92 participants in Taiwan and China. Demographic information is presented in Table 1. The majority of participants were male (n=90, 97.8%). There were 5 participants who marked out that their job title were not workers however they all worked with vibrating equipment few times per week or per day. The average age of workers was 30.42 years old. The average weight of the participants was 69.8 kilogram and the average height was 169.09 centimeter. Majority participants were smokers (n=79, 86.8%) and over half of them smoke daily (n=46). Only 7 workers reported they never drink alcoholic beverages, and 44 people drank daily. Most of the participants never use drugs, included medical or recreational drugs, and about 76% of participants reported they do not consume Bin-lang, which is Betel Nuts.

Table 2 shows the correlation between symptom severity and vibration exposure during daily work. The analysis revealed that there is no significantly increase pain severity on neck and knees when increasing the time working with vibrating tools. The data showed that seniority in current job and duration of using vibrating tools per day were significantly related to pain severity on all body part listed in the table 2. Workers were asked to self-estimate their vibration exposure level and the data showed that highly vibration exposure significantly might increase the pain severity. Operating power tools were common in stone cutting companies, and the data showed that people exposed to hand-transmitted vibration are more likely to show the musculoskeletal disorder symptoms. Stone cutting workers were required to wear personal protect equipments (PPE) while operating, and the data showed that use of vibration dampening tools and PPE usage could significantly lower the pain severity in different body parts. Receiving training about vibration-related health effects, protection method, personal protection equipment usage and tool maintenance were significantly related to pain severity except on neck and keens pain (p>0.05). Truck driving and self-estimated whole body vibration exposure was found no significant influences on back, neck and knees pain.

Table1

Demographic information

	Mean	SD	Never	Sometimes	Daily
Age	30.42	7.66			
Weight (Kg)	69.08	8.09			
Height (cm)	169.09	5.09			
Smoking[a]			13.18%	36.26%	50.54%
Drinking[a]			7.69%	89.00%	3.30%
Drug consume			52.17%	47.83%	NR
Betel-Nut consume			76.09%	20.65%	3.26%

[a] One missing data; NR: Not Report.

There were four specific symptoms mentioned on the questionnaire, which were vision problem, hearing problem, numbness or tingling on fingers/hands. Table 3 showed that whole-body vibration and truck driving were not significantly increase the symptom severity, and only receiving tool maintenance training was significantly related to those symptoms.

Table 2

Correlation between symptom severity and vibration-related questions

Exposure Questions		**Back**	**Shoulders**	**Neck**	**Wrists**	**Elbows**	**Knees**	**Head**
Working with vibrating tools in time duration	X^2	8.247	10.934	5.767	13.854	10.014	3.471	NR
	p	0.041	0.012	0.123*	0.003	0.018	0.748*	-
Seniority in current job	X^2	60.450	46.379	86.000	37.765	50.208	51.759	NR
	p	0.000	0.000	0.000	0.000	0.000	0.000	-
Using vibrating tools per day in hour	X^2	30.953	25.499	41.917	22.727	26.934	69.209	NR
	p	0.000	0.000	0.000	0.000	0.000	0.000	-
Self-estimated vibration exposure	X^2	86.000	65.147	60.104	52.151	70.960	36.195	NR
	p	0.000	0.000	0.000	0.000	0.000	0.000	-
Truck driving during work	X^2	3.339	4.426	2.335	5.609	4.054	1.405	NR
	p	0.068*	0.035	0.127*	0.018	0.044	0.495*	-
Whole body vibration exposure	X^2	3.577	4.742	2.501	6.009	4.343	1.505	NR
	p	0.059*	0.029	0.114*	0.014	0.037	0.471*	-
Hand-transmitted vibration	X^2	68.536	51.696	75.464	40.799	56.446	45.418	NR
	p	0.000	0.000	0.000	0.000	0.000	0.000	-
Protect method								
Use of vibration dampening on tools	X^2	23.454	31.215	16.465	39.552	28.588	9.909	NR
	p	0.000	0.000	0.000	0.000	0.000	0.007	-
Use of person protect equipment for vibration	X 2	86.000	64.869	60.140	51.195	70.829	36.195	NR
	p	0.000	0.000	0.000	0.000	0.000	0.000	-
PPE fitness	X^2	51.195	67.873	35.801	86.000	62.161	21.547	NR
	p	0.000	0.000	0.000	0.000	0.000	0.000	-
Receive training on…								
Health effects of vibration exposure	X^2	7.854	10.412	5.492	13.193	9.536	3.305	NR
	p	0.020	0.005	0.064*	0.001	0.008	0.508*	-
Vibration protection/reduction	X^2	7.854	10.412	5.492	13.193	9.536	3.305	NR
	p	0.020	0.005	0.064*	0.001	0.008	0.508*	-
Personal protective equipment	X^2	7.109	9.425	4.972	11.943	8.632	2.992	NR
	p	0.029	0.009	0.083*	0.003	0.013	0.559*	-
Tool maintenance	X^2	11.546	11.623	12.876	12.475	11.500	87.872	NR
	p	0.003	0.003	0.002	0.002	0.003	0.000	-

* *No Significant correlation (p >0.05)*; NR: Not Reported

Table 3

Correlation between additional symptom severity and vibration-related questions

Exposure Questions		Vision	Hearing	Numbness	Tingling
Working with vibrating tools in time duration	X^2	38.443	38.443	50.518	59.660
	p	0.000	0.000	0.000	0.000
Seniority in current job	X^2	59.019	59.019	74.257	68.353
	p	0.000	0.000	0.000	0.000
Using vibrating tools per day in hour	X^2	77.801	77.801	77.801	54.265
	p	0.000	0.000	0.000	0.000
Self-estimated vibration exposure	X^2	37.952	37.952	37.952	26.471
	p	0.000	0.000	0.000	0.000
Truck driving during work	X^2	1.898	1.898	1.898	1.324
	p	0.168*	0.168*	0.378*	0.516*
Whole body vibration exposure	X^2	2.031	2.031	2.031	1.417
	p	0.154*	0.154*	0.362*	0.492*
Hand-transmitted vibration	X^2	44.958	44.958	44.958	31.357
	p	0.000	0.000	0.000	0.000
Protect method					
Use of vibration dampening on tools	X^2	12.502	12.502	12.502	8.720
	p	0.000	0.000	0.002	0.013
Use of person protect equipment for vibration	X^2	37.952	37.952	37.952	26.471
	p	0.000	0.000	0.000	0.000
PPE fitness	X^2	24.940	24.940	24.940	17.395
	p	0.000	0.000	0.000	0.000
Receive training on:					
Health effects of vibration exposure	X^2	3.791	3.791	3.791	2.468
	p	0.15*	0.15*	0.15*	0.291*
Vibration protection/reduction	X^2	3.791	3.791	3.791	2.468
	p	0.15*	0.15*	0.15*	0.291*
Personal protective equipment	X^2	3.439	3.439	3.493	2.239
	p	0.179*	0.179*	0.179*	0.327*
Tool maintenance	X^2	58.267	58.267	58.267	89.000
	p	0.000	0.000	0.000	0.000

** No Significant correlation (p >0.05)*

Two aspects of pain on body part were studied; severity and frequency. Stone cutting workers reported pain frequency and the analysis result listed in Table 4. The data revealed that the pain frequencies in different body parts were significantly related to job seniority and vibrating tools usage per day. The data also showed that higher self-estimated vibration exposure was more likely to increase pain frequency than severity in seven body parts. Increasing whole-body vibration exposure did not significantly increase shoulder pain frequency, and the data also

Table 4

Correlation of pain frequency and vibration-related questions

Exposure Questions		Back	Shoulders	Neck	Wrists	Elbows	Knees	Head
Working with vibrating tools in time duration	X^2	77.745	46.293	58.558	131.764	93.386	102.727	14.269
	p	0.000	0.000	0.000	0.000	0.000	0.000	0.006
Seniority in current	X^2	55.873	44.640	12.078	68.444	90.210	128.843	65.364
	p	0.000	0.000	0.007	0.000	0.000	0.000	0.000
Using vibrating tools per day in hour	X^2	42.222	49.476	21.741	64.922	145.059	36.734	39.230
	p	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Self-estimated vibration exposure	X^2	54.718	39.104	65.224	82.348	79.519	57.164	88.000
	p	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Truck driving during work	X^2	8.394	4.663	12.078	20.925	49.103	6.231	3.922
	p	0.015	0.097*	0.001	0.000	0.000	0.044	0.048
Whole body vibration exposure	X^2	7.905	40.459	11.279	19.596	45.923	6.673	4.200
	p	0.019	0.108*	0.001	0.000	0.000	0.036	0.040
Hand-transmitted vibration	X^2	14.531	21.823	0.444	14.857	30.137	47.365	72.527
	p	0.001	0.000	0.505*	0.001	0.000	0.000	0.000
Protect method								
Use of vibration dampening on tools	X^2	4.658	5.944	1.775	6.373	13.411	42.406	26.693
	p	0.097*	0.051*	0.183*	0.041*	0.001	0.000	0.000
Use of person protect equipment for vibration	X^2	12.078	18.030	0.538	12.497	25.330	56.230	88.000
		0.002	0.000	0.463*	0.002	0.000	0.000	0.000
PPE fitness	X^2	7.905	11.491	0.855	8.657	17.602	88.000	55.394
	p	0.019	0.003	0.355*	0.013	0.000	0.000	0.000
Receive training on..								
Health effects of vibration exposure	X^2	4.717	3.564	5.435	10.273	23.477	14.539	9.152
	p	0.318*	0.468*	0.066*	0.036	0.000	0.006	0.010
Vibration protection/reduction	X^2	4.898	3.653	5.711	10.744	24.600	14.539	9.152
	p	0.298*	0.455*	0.058*	0.030	0.000	0.006	0.010
Personal protective equipment	X^2	5.406	3.787	6.655	12.243	28.212	13.179	8.296
	p	0.248*	0.436*	0.036	0.016	0.000	0.010	0.016
Tool maintenance	X^2	62.803	90.377	7.406	70.478	94.768	42.193	22.036
	p	0.000	0.000	0.025	0.000	0.000	0.000	0.000

** No Significant correlation (p >0.05)*

showed that exposed to hand-transmitted vibration did not increase the frequency of neck pain (p>0.05). Pain frequency on back, shoulders, neck and wrists did not significantly decreased by using vibration dampening equipment, also neck pain frequency was not significantly decreased related to personal protect equipment usage nor fitness. Receiving training on vibration's health effect, vibration deduction method and personal protective equipment were not decreased pain frequency on back, shoulders and neck. Injury history might affect present pain occurrences as shown in Table 5 the health history can affect the pain severity. The result revealed that only knee injury and head injury in the past might affect the current pain severity in six body parts (head is not reported).

Table 5

Health history and related pain severity in different body parts

Pain or injury in the past		**Back**	**Shoulders**	**Neck**	**Wrists**	**Elbows**	**Knees**	**Head**
Back	X^2	0.300	0.398	0.210	0.504	0.365	0.126	NR
	p	0.584*	0.528*	0.647*	0.478*	0.546*	0.939*	-
Shoulders	X^2	0.148	0.197	0.104	0.249	0.180	0.062	NR
	p	0.70*	0.657*	0.747*	0.618*	0.671*	0.969*	-
Neck	X^2	0.456	0.604	0.319	0.766	0.554	0.192	NR
	p	0.50*	0.437*	0.572*	0.382*	0.457*	0.909*	-
Wrists	X^2	0.779	1.032	0.544	1.308	0.945	0.328	NR
	p	0.378*	0.31*	0.461*	0.253*	0.331*	0.849*	-
Elbows	X^2	1.474	1.955	1.031	2.477	1.790	0.620	NR
	p	0.225*	0.162*	0.31*	0.112*	0.181*	0.733*	-
Knees	X^2	44.479	58.968	31.104	74.717	54.006	18.720	NR
	p	0.000	0.000	0.000	0.000	0.000	0.000	-
Head	X^2	68.539	51.696	75.464	0.766	56.446	45.418	NR
	p	0.000	0.000	0.000	0.000	0.000	0.000	-

* *No Significant correlation (p >0.05)*; NR: Not Reported

Table 6 shows that pain or injury on back, shoulders, neck, wrists and elbows did not related to knees and head pain frequency, and current neck pain frequency was not significantly.

Table 6

Health history and related pain frequency in different body parts

Pain or injury in the past		**Back**	**Shoulders**	**Neck**	**Wrists**	**Elbows**	**Knees**	**Head**
Back	X^2	88.000	43.513	57.984	33.972	14.326	0.564	0.355
	p	0.000	0.000	0.001	0.000	0.001	0.754*	0.551*
Shoulders	X^2	86.977	116.651	28.675	60.270	28.302	88.267	5.988
	p	0.000	0.000	0.000	0.000	0.000	0.000	0.050
Neck	X^2	57.933	28.709	88.000	51.588	21.741	0.855	0.538
	p	0.000	0.000	0.000	0.000	0.000	0.652*	0.463*
Wrists	X^2	34.019	16.913	51.588	88.000	37.108	1.460	0.919
	p	0.000	0.000	0.000	0.000	0.000	0.482*	0.338*
Elbows	X^2	18.112	9.165	27.263	46.585	70.177	2.761	1.738
	p	0.000	0.010	0.001	0.000	0.000	0.252*	0.187*
Knees	X^2	7.709	10.159	0.973	7.955	16.223	77.311	48.665
	p	0.029	0.006	0.324*	0.019	0.000	0.000	0.000
Head	X^2	14.531	21.823	0.444	14.857	30.137	47.365	72.527
	p	0.001	0.000	0.505*	0.001	0.000	0.000	0.000

** No Significant correlation (p >0.05)*

related to knee and head injury history. When operating vibrating tools, the equipments or machines also produce noise so in Table 7, the data revealed that self-estimated noise exposure, hearing protection usage and fitness were more significantly related to hearing problem severity.

Table 7

Correlation between hearing problem and…

		Hearing problem
Self-estimated noise exposure	X^2	13.111
	p	0.004
Use of hearing protection	X^2	19.735
	p	0.000
The hearing protection fitness	X^2	17.711
	p	0.000
Training about noise exposure	X^2	3.791
	p	0.15*
Training about noise exposure protection	X^2	3.612
	p	0.164*

** No Significant correlation (p >0.05)*

The correlation between self-estimated noise exposure and head discomfort frequency was listed in Table 8, which shows that increase in noise exposure might increase the frequency of head discomfort.

Table 8

Correlation between self-estimated noise exposure and …

		Head Pain Severity	**Head Pain** Frequency	**Hearing problem**
Self-estimated noise exposure	X^2	NR	28.046	13.111
	p	-	0.000	0.004

* *No Significant correlation (p >0.05)*; NR: Not Reported

The correlation between nationality and the training lessons workers received was showed in Table 9. Nationality has significant correlated with training lessons and the data showed that Chinese workers received training on health effects, vibration protection, noise exposure, noise protection and personal protective equipment issue less than one year ago, whereas over 80% of Taiwanese workers reported they have never received those training.

Table 9

Correlation between nationality difference and training

Receive training on…			**Nationality**	**Never**	**Over a year**	**Less than 1 year**
Health effects of vibration exposure	X^2	80.917	Taiwan	32(91.4%)	1(2.9%)	2(5.7%)
	p	0.000	China	0	0	54(100%)
Vibration protection/reduction	X^2	80.917	Taiwan	31(88.6%)	2(5.7%)	2(5.7%)
	p	0.000	China	0	0	54(100%)
Health effects of noise exposure	X^2	80.917	Taiwan	30(85.7%)	3(8.6%)	2(5.7%)
	p	0.000	China	0	0	54(100%)
Noise protection/reduation	X^2	77.089	Taiwan	28(80.0%)	4(11.4%)	3(8.6%)
	p	0.000	China	0	0	54(100%)
Personal protective equipment	X^2	73.392	Taiwan	28(80.0%)	3(8.6%)	4(11.4%)
	p	0.000	China	0	0	54(100%)
Tool maintenance	X^2	57.035	Taiwan	26(74.3%)	9(25.7%)	0
	p	0.000	China	0	50(92.6%)	4(7.4%)

* *No Significant correlation (p >0.05)*; Missing data: 3;

Among Chinese workers 92.6% were trained about tool maintenance over a year and 74.3% of Taiwanese workers never received tool maintenance training lesson.

Workers were asked about their equipment maintenance policy and the result is shown in table10; 31.4% of Taiwanese workers reported that they maintained the equipment only when damaged and 68.6% followed the regular maintenance schedule. Meanwhile 85.2% of Chinese workers stated that they followed the regular maintenance schedule, 5.6% of workers maintained the tools only when damage and 9.3% of workers said they have modified the tools to work better.

Table 10

Correlation between tool maintenance and nationality

			Nationality	**Only when tools break**	**Regular schedule**	**Modified to work better**
Maintenance Policies	X^2	13.023	Taiwan	11(31.4%)	24(68.6%)	0
	p	0.001	China	3(5.6%)	46(85.2%)	5(9.3%)

* *No Significant correlation (p >0.05);;* Missing data: 3;

Nationality has significant correlation with back pain severity (table 11); all Taiwanese workers (n=35) reported low back pain severity and 74.8% of Chinese workers said they also reported low back pain. 21.6% of Chinese workers reported moderate back pain which no Taiwanese workers reported. All of Taiwanese workers reported low shoulders pain and 27.5% of Chinese workers reported moderate shoulder; there was no significant correlation between nationality and pain frequency in back and shoulders. All Taiwanese workers reported low pain severity on back, shoulders, neck, wrists, elbows, and knees.

Table 11

Correlation between nationality and pain occurrence

Back pain			**Nationality**	**Low**	**Moderate**	**High**
Severity	X^2	8.656	Taiwan	35(100%)	0	0
	P	0.003	China	40(74.8%)	11(21.6%)	0
Frequency	X^2	4.358	Taiwan	2(5.7%)	33(94.3%)	0
	P	0.113*	China	0	51(96.2%)	2(3.8%)
Shoulder pain				**Low**	**Moderate**	**High**
Severity	X^2	11.476	Taiwan	35(100%)	0	0
	P	0.001	China	37(72.5%)	14(27.5%)	0
Frequency	X^2	3.513	Taiwan	1(2.9%)	34(97.1%)	0
	P	0.173*	China	0	50(94.3%)	3(5.7%)
Neck pain				**Low**	**Moderate**	**High**
Severity	X^2	6.053	Taiwan	35(100%)	0	0
	P	0.014	China	43(84.3%)	8(15.7%)	0
Frequency	X^2	4.703	Taiwan	3(8.6%)	32(91.4%)	0
	P	0.030	China	0	53(100%)	0
Wrists pain				**Low**	**Moderate**	**High**
Severity	X^2	14.541	Taiwan	35(100%)	0	0
	P	<0.001	China	34(66.7%)	17(33.3%)	0
Frequency	X^2	9.145	Taiwan	5(14.3%)	30(85.7%)	0
	P	0.010	China	0	51(96.2%)	2(3.8%)
Elbows pain				**Low**	**Moderate**	**High**
Severity	X^2	10.510	Taiwan	35(100%)	0	0
	P	0.001	China	38(74.5%)	13(25.5%)	0
Frequency	X^2	20.748	Taiwan	11(31.4%)	24(68.6%)	0
	P	<0.001	China	0	49(92.5%)	4(7.5%)
Knees pain				**Low**	**Moderate**	**High**
Severity	X^2	3.643	Taiwan	35(100%)	0	0
	P	0.162*	China	46(90.2%)	4(7.8%)	1(2.0%)
Frequency	X^2	16.002	Taiwan	35(100%)	0	0
	P	<0.001	China	34(64.2%)	18(34.0%)	1(1.9%)
Head pain				**Low**	**Moderate**	**High**
Severity	X^2	NR	Taiwan	NR	NR	NR
	P	NR	China	NR	NR	NR
Frequency	X^2	10.073	Taiwan	35(100%)	0	0
	P	0.002	China	40(75.5%)	13(24.5%)	0

* *No Significant correlation (p >0.05)*; There were 6 missing data in severity questions and 4 missing data in frequency questions;

84.3% of Chinese workers have low severity on neck, 15.7% of workers have moderate neck pain. The neck pain frequency has significant correlated to nationality, which 8.6% of Taiwanese workers have low pain, 91.4% Taiwanese workers have moderate pain frequency, and all Chinese workers (n=53) reported moderate neck pain frequency. In both wrists pain severity and frequency of wrists pain has significant correlation with nationality; 85.7% of Taiwanese workers reported moderate pain frequency, 96.2% of Chinese workers said they have moderate pain and 3.8% of Chinese workers have high wrists pain frequency. The correlation also can be seen in elbow pain, which 74.5% of Chinese workers have low pain severity, and 25.5% of them have moderate pain severity. Over 50% of workers claimed they have moderate elbow pain and 7.5% of Chinese workers have high pain frequency. No Taiwanese worker reported moderate or high severity or frequency on knees, and only one Chinese worker have high knees pain on both severity and frequency. There were non-reported data about headache severity on both nationality groups, and over 70% of workers reported low headache frequency; 24.5% of Chinese workers reported moderate headache frequency.

Table 12

Correlation between disorder occurrence and nationality

Vision			**Nationality**	**Low**	**Moderate**	**High**
	X^2	4.830	Taiwan	35(100%)	0	0
	P	0.028	China	48(87.3%)	7(12.7%)	0
Hearing				**Low**	**Moderate**	**High**
	X^2	4.830	Taiwan	35(100%)	0	0
	P	0.028	China	48(87.3%)	7(7.8%)	0
Numbness				**Low**	**Moderate**	**High**
	X^2	4.830	Taiwan	35(100%)	0	0
	P	0.089*	China	48(87.3%)	6(10.9%)	1(1.8%)
Tingling				**Low**	**Moderate**	**High**
	X^2	3.369	Taiwan	35(100%)	0	0
	P	0.186*	China	50(90.9%)	4(7.3%)	1(1.8%)

* *No Significant correlation (p >0.05)*;There were 2 missing data in severity question;

Table 12 shows that only vision and hearing problem has significant correlation with nationality. All Taiwanese workers still reported low severity on vision, hearing, numbness and tingling problem, however in China group, moderate severity on vision problem (12.7%) and hearing problem (7.8%) was reported.

For the next part of data analysis multinomial logistic regression models were created only for those exposure variables that were significantly correlated to their corresponding outcome variables and the results were presented in tables 13 to 21. According to the result, seniority in current job has positive correlation with both pain severity and frequency.

Table 13

Result of logistic regression and odds ratio for back pain severity and frequency

Back Pain Severity			**95% CI**	
Exposure factors	**Parameter**	**OR**	**LL**	**UL**
Working with vibrating tools in the time duration	-1.64	0.19	0.09	0.43
Seniority in current job	2.03	7.61	3.25	17.82
Using vibrating tools per day in hour	0.38	1.46	0.91	2.36
Self-estimated vibration exposure	-0.26	0.77	0.37	1.64
Hand-transmitted vibration	-0.85	0.43	0.09	1.92
Back Pain Frequency				
Working with vibrating tools in the time duration	-1.41	0.23	0.08	0.76
Seniority in current job	1.74	5.71	1.77	18.42
Using vibrating tools per day in hour	-0.12	0.88	0.45	1.73
Self-estimated vibration exposure	0.43	1.54	0.54	4.43
Truck driving during work	0.88	2.42	0.17	34.51
Whole body vibration exposure	-1.54	0.22	0.02	2.66
Hand-transmitted vibration	-3.38	0.03	0.003	0.45

Table 14

Result of logistic regression and odds ratio for shoulder pain severity and frequency

Should Pain Severity			**95% CI**	
Exposure factors	**Parameter**	**OR**	**LL**	**UL**
Working with vibrating tools in the time duration	-0.97	0.38	0.17	0.86
Seniority in current job	1.48	4.29	1.79	10.80
Using vibrating tools per day in hour	0.36	1.43	0.89	2.31
Self-estimated vibration exposure	0.20	1.23	0.58	2.59
Truck driving during work	-0.22	0.80	0.07	8.78
Whole body vibration exposure	-2.06	0.13	0.01	1.39
Hand-transmitted vibration	0.76	2.13	0.48	9.55
Shoulder Pain Frequency				
Working with vibrating tools in the time duration	-1.40	0.25	0.09	0.69
Seniority in current job	2.38	10.82	3.42	34.27
Using vibrating tools per day in hour	-0.26	0.77	0.40	1.51
Self-estimated vibration exposure	-1.25	0.88	0.29	2.71
Hand-transmitted vibration	-5.65	0.00	<0.01	0.13

Table 15

Result of logistic regression and odds ratio for neck pain severity and frequency

Neck Pain Severity			**95% CI**	
Exposure factors	**Parameter**	**OR**	**LL**	**UL**
Seniority in current job	0.77	2.16	1.19	3.91
Using vibrating tools per day in hour	-0.02	0.99	0.65	1.50
Self-estimated vibration exposure	0.01	1.01	0.49	2.08
Hand-transmitted vibration	1.06	2.88	0.69	11.97
Neck Pain Frequency				
Working with vibrating tools in the time duration	-0.52	0.59	0.23	1.50
Seniority in current job	0.34	1.40	0.53	3.74
Using vibrating tools per day in hour	0.22	1.25	0.68	2.29
Self-estimated vibration exposure	0.17	1.19	0.49	2.86
Truck driving during work	-1.49	0.23	0.02	2.80
Whole body vibration exposure	0.04	1.04	0.09	12.42

Table 16

Result of logistic regression and odds ratio for wrists pain severity and frequency

Wrist Pain Severity			95% CI	
Exposure factors	**Parameter**	**OR**	**LL**	**UL**
Working with vibrating tools in the time duration	-0.08	0.93	0.43	1.99
Seniority in current job	0.35	1.42	0.64	3.13
Using vibrating tools per day in hour	-0.17	0.85	0.53	1.35
Self-estimated vibration exposure	0.69	1.98	0.95	4.13
Truck driving during work	0.12	1.13	0.11	11.67
Whole body vibration exposure	-1.86	0.16	0.02	1.57
Hand-transmitted vibration	-1.04	0.36	0.08	1.57
Wrist Pain Frequency				
Working with vibrating tools in the time duration	-0.26	0.78	0.30	1.98
Seniority in current job	0.08	1.08	0.43	2.74
Using vibrating tools per day in hour	-0.69	0.50	0.28	0.91
Self-estimated vibration exposure	0.64	1.90	0.76	4.78
Truck driving during work	-0.42	0.66	0.06	7.05
Whole body vibration exposure	-0.34	0.71	0.07	6.86
Hand-transmitted vibration	-1.60	0.20	0.03	1.24

Table 17

Result of logistic regression and odds ratio for elbow pain severity and frequency

Elbow Pain Severity			95% CI	
Exposure factors	**Parameter**	**OR**	**LL**	**UL**
Working with vibrating tools in the time duration	-0.32	0.72	0.33	1.58
Seniority in current job	0.09	1.10	0.50	2.43
Using vibrating tools per day in hour	-0.02	0.98	0.62	1.57
Self-estimated vibration exposure	0.50	1.64	0.79	3.41
Truck driving during work	1.42	4.14	0.38	45.22
Whole body vibration exposure	-2.24	0.11	0.01	1.11
Hand-transmitted vibration	-1.27	0.28	0.06	1.25
Elbow Pain Frequency				
Working with vibrating tools in the time duration	-0.24	0.79	0.32	1.93
Seniority in current job	-0.56	0.58	0.22	1.46
Using vibrating tools per day in hour	0.13	1.14	0.64	2.04
Self-estimated vibration exposure	0.31	1.36	0.56	3.34

Truck driving during work	-1.12	0.33	0.03	3.14
Whole body vibration exposure	1.28	3.60	0.39	33.50
Hand-transmitted vibration	-1.90	0.15	0.03	0.89

Table 18

Result of logistic regression and odds ratio for knees pain severity and frequency

Knee Pain Severity			**95% CI**	
Exposure factors	**Parameter**	**OR**	**LL**	**UL**
Seniority in current job	0.63	1.87	0.92	3.81
Using vibrating tools per day in hour	-0.66	0.52	0.30	0.89
Self-estimated vibration exposure	-0.44	0.65	0.25	1.64
Hand-transmitted vibration	-0.81	0.45	0.07	2.98
Knee Pain Frequency				
Working with vibrating tools in the time duration	-0.75	0.47	0.18	1.22
Seniority in current job	0.54	1.72	0.64	4.64
Using vibrating tools per day in hour	-0.27	0.76	0.41	1.42
Self-estimated vibration exposure	-0.54	0.58	0.21	1.67
Truck driving during work	-1.23	0.29	0.03	2.97
Whole body vibration exposure	-0.57	0.57	0.06	5.44
Hand-transmitted vibration	-1.39	0.25	0.04	1.62

Table 19

Result of logistic regression and odds ratio for headache frequency

Headache Frequency			**95% CI**	
Exposure factors	**Parameter**	**OR**	**LL**	**UL**
Working with vibrating tools in the time duration	-2.29	0.10	0.02	0.52
Seniority in current job	1.99	7.31	1.68	31.84
Using vibrating tools per day in hour	0.73	2.07	0.87	4.94
Self-estimated vibration exposure	-0.71	0.49	0.14	1.76
Truck driving during work	-0.88	0.41	0.02	9.70
Whole body vibration exposure	1.32	3.74	0.18	78.59
Hand-transmitted vibration	-2.47	0.08	0.005	1.47

Table 20

Result of logistic regression and odds ratio for vision/hearing problem

Vision			**95% CI**	
Exposure factors	**Parameter**	**OR**	**LL**	**UL**
Working with vibrating tools in the time duration	-1.30	0.27	0.11	0.66
Seniority in current job	2.35	10.47	3.68	29.74
Using vibrating tools per day in hour	-0.02	0.98	0.58	1.64
Self-estimated vibration exposure	-0.92	0.40	0.15	1.05
Hand-transmitted vibration	0.07	1.07	0.22	5.37
Hearing				
Working with vibrating tools in the time duration	-1.19	0.30	0.13	0.72
Seniority in current job	1.75	5.75	2.17	15.24
Using vibrating tools per day in hour	0.29	1.34	0.80	2.26
Self-estimated vibration exposure	-0.93	0.40	0.15	1.05
Hand-transmitted vibration	0.16	1.17	0.23	5.88
Self-estimated noise exposure	0.17	1.18	0.54	2.61
Use of hearing protection	0.31	1.36	0.13	14.24
The hearing protection fitness	2.99	19.89	1.71	231.37

Table 21

Result of logistic regression and odds ratio of numbness/tingling problem

Numbness			**95% CI**	
Exposure factors	**Parameter**	**OR**	**LL**	**UL**
Working with vibrating tools in the time duration	-1.26	0.29	0.12	0.67
Seniority in current job	1.99	7.30	2.75	19.40
Using vibrating tools per day in hour	0.41	1.51	0.89	2.56
Self-estimated vibration exposure	-0.04	0.96	0.38	2.39
Hand-transmitted vibration	1.24	3.45	0.65	18.36
Tingling				
Working with vibrating tools in the time duration	-1.36	0.26	0.11	0.61
Seniority in current job	2.20	0.01	3.30	24.65
Using vibrating tools per day in hour	0.50	1.65	0.96	2.82
Self-estimated vibration exposure	-0.21	0.81	0.32	2.04
Hand-transmitted vibration	0.95	2.59	0.48	13.84

CHARTER 5

DISCUSSION AND CONCLUSION

Discussion

According to the result, time duration of using vibrating tools and job seniority can be the primary factors to predict the health effects of stone workers. The result showed that exposes to vibration not only in risk of having back pain and musculoskeletal disorder, but also can cause vision problem. Using of personal protect equipment might decrease the risk of having disorders; employee training is another factor that have correlation with pain severity and frequency.

According to the literature review, some research selected target from those who was diagnosed white finger syndrome, hand-arm vibration syndrome or people with medical history. However in this study, health history was estimated as pain/injury history in frequency; this study is to assess the health effects of stone worker, not just focusing on specific patient group.

The sample is not homogeneous, age difference showed in two countries. The workers in China (mean=26.25) are younger than workers in Taiwan (n=37.17). First of all, this age difference might affect the drug usage and some part of self-estimate body disorders. Secondary, the average age of two groups could be consider as young to middle age people so they might not have long working experience in current job or pervious job experiences. This factor might affect the correlation between working experiences and pain occurrence (table 20), so the negative correlation between working experience and pain could be explained by this reason.

The jobs they responded were also different. Taiwanese workers need to do both actual operation and administrative job. They were not only need to handle the equipments, they also need to teach and director other worker in other nationality such as Thailand, Philippine, Indonesia…etc. The business scale of five stone companies in China is much bigger than those two companies in Taiwan, so the Chinese workers each person has their own equipment to use. For example stone cutting workers only do stone cutting, they do not operate grinding machine, and however the workers in Taiwan are multitasking. This situation may affect on vibrating tools distinguish ability, and that is to say it is difficult to identify which vibrating tools might lead to sever health effect. Although the majority of Chinese workers have received training lessons less than a year, there were still high proportion of workers reported moderate pain in both severity and frequency. Multitasking could be consider as a factor to explain this result; Chinese workers were doing the same job and dealing with the same equipment during the working hours, however Taiwanese workers were not consistently expose to same vibrating equipments so that might causes differences.

The workers also reported their off work activities, smoking, drinking and gambling were the top three activities, part of them said they were exercise including swimming, playing ball game and jogging after work, so off work activity were not considered as confounder in this study.

This questionnaire contents several self-estimated questions including how they estimate the vibration exposure and noise exposure level, also the disorder severity and pain frequency were self-estimated. Each person may have different sensation so the result can only be the predictor that having vibration exposure relates to head, hand, upper limb and back discomfort. Training related questions are the last part of questionnaire. Some of the Taiwanese worker claimed they had never received any training about safety and vibration or received training more than one year. Almost all workers of China said they have received training session about how to use personal protection equipment and knowledge about safety and vibration/noise exposure. The result showed that although the Chinese workers do have related training experience, there is no significant difference in body pain severity and frequency between nationalities. According to the communications with company managers, China companies will have new employee orientation which includes employee training each time when they hiring new workers. These two companies in Taiwan were hiring foreigner worker as primary workers and Taiwanese workers basically having many years working experiences so they are not only operate equipment but also teach primary workers. The Taiwan government has regulations about safety training, the government also holds training session several times per year; join the training session is encouragement not command.

Some of the questions in questionnaire (Appendix B) has overlapped in options, that might cause confusion and inaccuracy.

Conclusion

In general the results of this project were in accord with previous research (Bovenzi 1994, Cederlund *et al.* 2001, Rui *et al.* 2007, Negro *et al.* 2007). However some of the detail results were inconclusive due to heterogeneous data set. Vibration exposure may cause several different disorders in hands and upper extremity, including white finger, cold intolerance, numbness, and tingling (Cederlund *et al*. 2001). To assess the health effects among stone workers in Taiwan and China, a questionnaire was distributed among stone cutting workers and answered subjectively. Base on the self-estimated pain severity results, workers had pain in back (97.7%), shoulder (98.8%), neck (97.7%), wrists (97.7%), and elbow (90.6%). Only 21% of worker reported they have different level of pain in knees and head. The pain frequency result showed that only 2.3% worker claimed they never had back pain, and never have pain in shoulder (1.2%), neck (3.4%), wrists (5.7%), and elbow (12.5%). 78.4% of workers reported they never felt pain on knees and head (85.2%). Compare these results with Bovenzi and the Italian study group's study in 1994, exposed to vibration was more likely to have pain in upper limb and in risk of having muscular weakness.

Although increase of cumulative vibration dose might affect hand dexterity (Rui *et al.* 2001), however the result showed that only 22.6% of workers have numbness or tingling symptoms in hand and fingers in different level. There was 27.7% workers reported hearing problem during or after work, and the correlation between hearing problem and noise exposure was significant. Use of hearing protection and the protection fitness can decrease the hearing problem; however receiving noise-related training sessions were not showed any significant correlation with hearing problem. In order to clarify whether the health history would affect the current pain severity, Table 5 and Table 6 showed that pain or injury in the past would affect pain frequency in back, shoulder and upper limb. Expose to vibration associated with pain on both severity and frequency, so as personal protect equipment (PPE) usage; use of PPE revealed a significant relation between pain severity and frequency (table 2, table 3 and table 4). Those factors could be seen as the potential factors that might cause some disorders. Vibration exposure duration, seniority, PPE usage, and receiving training session are the potential predictors to estimate the health effects caused by vibration exposure. An increased risk of having upper limb and musculoskeletal disorders has been reported in workers who operate vibrating equipment (NIOSH, 1997), and this study also indicate that expose to vibration would increase the risk of having pain in different body portion.

According to the logistic regression analysis result, working with vibrating tools has negative correlation with both pain severity and frequency in different body parts, however the time duration here was not only include the current job but also the previous job experiences so that might affect the trend. The seniority in current job has positive correlation with pain severity and frequency on all body parts except elbow pain frequency; when increasing the job seniority, the blow pain frequency would decrease. The other exposure questions such as using vibrating tools per day, self-estimated vibration exposure, and self-estimated hand-transmitted vibration exposure did not show the consistency, some of them have positive correlation some of them have negative correlation with the exposure factors.

Suggestion

For company managers, the employee training should be conduct once a time period and should obey the government regulation and standards. The employees should have health examination once a time period and should have extra examinations that specify vibration-related disorder in order to prevent vibration induced white finger, carpal tunnel syndrome, and hand-arm vibration syndrome occurrence. For future research, the researchers could use the measurement equipment to get the accurate data of vibration acceleration in meters per second squared (m/s^2) and estimate the risk level of vibration exposure.

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APPENDIX A

TABLE OF EVIDENCE- EPIDEMIOLOGIC STUDIES EVALUATING WORK-RELATED VIBRATION EXPOSURE

APPENDIX A: TABLE OF EVIDENCE- EPIDEMIOLOGIC STUDIES EVALUATING WORK-RELATED VIBRATION EXPOSURE

Reference	Study design	Sample size	Input variable	Output variable	Result	Comments
Bovenzi and the Italian Study Group (1994)	Case-control	Total population: 828 active stone workers employed in nine districts of North and Central Italy. Case group: 570 total; 145 quarry drillers and 425stonecarvers processing stone blocks. Control group: 258 stone workers performed normal activities without vibration exposure.	1. Tool type: Rock breaker, rock drill, stone hammer, angle grinder. 2. Mean magnitude of root mean square (RMS) of the frequency weighted and unweighted acceleration (m/s^2). 3. Duration of exposure (year) 4. Daily exposure (hour) 5. Yearly exposure(h/y) 6. Lifetime vibration($\ln(m^2h^3/s^4)$) 7. Age, cigarette smoking, alcohol, drug usages.	1. Health and workplace assessment questionnaire. 2. Sensorineural disturbances 3. Symptom of VWF 4. Signs and symptoms of CTS 5. Muscular weakness 6. Dupuytren's contracture 7. Pain in upper limbs.	1. Symptoms of VWF: case group (30.2%); control group(4.3%); ORs(9.33); 95%CI(4.91-17.8) 2. Signs and symptoms of CTS: case group(8.8%); control group(2.3%) 3. Dupuytren's contracture: case group (10.0%); control group (3.5%) 4. Muscular weakness: case group(6.8%); control group(0.8%) 5. Pain in upper limb: case group(34.0%); control group(17.4%)	Participation rate: 100% "All the active stone workers participated in the survey, so that self selection was not a source of bias in this study. Health and workplace assessment questionnaire which contained personal, medical, work history, and health condition were given by occupational physicians. Symptoms of VWF were found associated with vibration exposure such as duration, frequency exposure, lifetime dose.

APPENDIX A: (CONT.)

Cederlund *et al.* (2001)	Cross-sectional	Total population: 105 male workers exposed to vibration by using hand-held machines. Median age: 43 (range 19-64). Right handed: 97 workers; Left handed: 8 workers. Subjects came from different industries.	1. Hand-arm vibration exposure. 2. Vibration exposed workers (n=105) include industrial group (n=81) and patient group (n=24).	1. Performances of daily activities were evaluated by activities of daily living (ADL). 2. Evaluation of daily activities questionnaire (EDAQ).	1. 42% (n=44) of total group (n= 105) had one or more difficulties in performing daily activities. 2. 58 workers (72.5%) in industrial group had no ADL difficulties even though 19 workers had HAVS. 3. Strong correlation between pain (r_s=0.73), reduced grip force (r_s= -0.70) and difficulties in ADL performance, those factors may be detecting activity limitations.	This research is about to study the hand-arm vibration exposure influences performance of daily activities. All population was exposed to hand-arm vibration. 24 men from patient group have severe hand problem characterized by white fingers and/or sensory disturbances in the hand.

APPENDIX A: (CONT.)

Rui *et al*. (2007)	Prospective cohort study (cross-sectional survey in the first time)	Total population: 115 HTV workers. Case group: 82 forestry workers and 33 stone workers. Control group: 64 control men employed in same company.	1. Questionnaire. 2. Vibration exposure. 3. Age, BMI, smoking habit, drinking habit. 4. Daily vibration exposure (min) 5. Job seniority (years) 6. Total operating time with vibrating tools (hour) 7. Cumulative vibration dose ($m^2s^{-4}h$ x10^3)	1. Manipulative dexterity measured by Purdue pegboard. 2. Tingling 3. Numbness 4. White finger 5. Neck musculo-skeletal disorders 6. Upper-limb musculo-skeletal disorder	1. Purdue pegboard score were significantly lower in the HTV workers than in the control group ($0.001 < P < 0.05$). 2. In one-year follow-up period, Purdue pegboard score were inversely related to age, use vibratory tools, and smoking habit. 3. The Purdue pegboard score decreased significantly with the increase of cumulative vibration dose.	This is a one year follow-up study; subjects were examined twice a year during 2003-2005. Purdue pegboard test is to investigate the manipulative dexterity; subjects have to finish the test three times: preferred hand, other hand and two hands together. The standardized questionnaire was developed from VIBRISKS questionnaire. No association was found in ergonomic risk factors (neck-upper arm posture, hand-intensive work, total ergonomic load).

APPENDIX A: (CONT.)

Negro *et al.* (2007)	Cohort study (Cross-sectional survey in the first time)	Total population: 146 forestry and stone workers Active HTV workers employed in four companies of forestry workers (n=137), and one company of stone workers (n=36); all located in the Tuscany Region, Italy. 113(82.5%) forestry workers and 33(91.6%) stone workers participated in one-year follow-up study.	1. Questionnaire. 2. Cold test: performed by subjects in supine position; this test consisted of strain-gauge plethysmographic measurement of FSBP. 3. Vibration exposure: investigated by VIBRISK questionnaire (dose-response).	1. Administration of color chart 2. Clinical diagnosis of finger whiteness.	1. Average age of HTV workers: 41.8(SD 8.1) years. 2. Mean of duration of exposure to HTV: 16.2(CD 8.1) years. 3. 23 HTV workers (15.8%) reported VWF at the medical interview alone. 4. 15 of 23(10.3%) HTV workers with color chart positive; 8 of 23 (5.5%) with color chart negative.	This research is to assess the administration of color chart and its practicability on diagnosis VWF. Researchers suggest that the administration of color chart may reduce the frequency of false positive responses for finger whiteness CI 95%; *P*=0.05(two-tailed).

VWF = Vibration induced white finger; CTS = carpal tunnel syndrome; HAVS = hand-arm vibration syndrome; HTV= hand-transmitted vibration; FSBP = finger systolic blood pressure

APPENDIX B

VIBRATION AND NOISE ASSESSMENT QUESTIONNAIRE

Vibration and Noise Assessment Questionnaire

Attention: Fill this questionnaire anonymously and all your answers will remain confidential.

Serial Number: …… Date: … / … / 2010

Section 1 – Demographic information

Age: ___

Gender: ☐ male ☐ female

Ethnicity/Nationality:

☐ Taiwanese ☐ Aborigine ☐ Thai. ☐ Vietnamese ☐ Others …..

Weight: ____ kg

Height: ____ cm

Job Title: ____

What is your smoking habit?

☐ never smoke ☐ smoke rarely ☐ smoke occasionally ☐ smoke daily ☐ smoke heavily

What is your drinking habit?

☐ never drink ☐ drink rarely ☐ drink occasionally ☐ drink daily ☐ drink heavily

Do you use drugs (medical or recreational)?

☐ never use drugs ☐ use drugs rarely ☐ use drugs occasionally ☐ use drugs daily ☐ use drugs heavily

Do you use Betel Nuts “Bin-lang” (Taiwanese Chewing Gum)?

☐ never use Bin-lang ☐ use Bin-lang rarely ☐ use Bin-lang occasionally ☐ use Bin-lang daily ☐ use Bin-lang heavily

List your top 3 daily activities outside the work place:

1- ________________________________

2- ________________________________

3- ________________________________

Section 2 – Exposures

How long have you been working with vibrating tools/equipment (current and previous jobs)?

☐ less than 1 year ☐ 1 to 2 years ☐ 2 to 5 years ☐ 5 to 10 years ☐ more than 10 years

How long have you been on your current job?

☐ less than 1 year ☐ 1 to 2 years ☐ 2 to 5 years ☐ 5 to 10 years ☐ more than 10 years

How long do you use your vibrating tools/equipment each day?

☐ less than 1 hour ☐ 1 to 2 hours ☐ 2 to 4 hours ☐ 4 to 6 hours ☐ more than 6 hours

Based on your own opinion, how do you rate your exposure to vibration?

☐ extremely less than standard ☐ somewhat less than standard ☐ standard exposure ☐ somewhat above standard ☐ extremely above standard

Based on your own opinion, how do you rate your exposure to noise?

☐ extremely less than standard ☐ somewhat less than standard ☐ standard exposure ☐ somewhat above standard ☐ extremely above standard

Are you driver of any kind of truck? ☐ Yes ☐ No

Do you have whole body vibration exposure (such as truck drivers)? ☐ Yes ☐ No

Do you have hand-transmitted vibration exposure (such as power tools)? ☐ Yes ☐ No

List the top 3 vibrating tools/equipments that you use in your job:

1- ______________________________

2- ______________________________

3- ______________________________

Section 3 – Health Conditions

Do you currently have any pain in any of the joints/parts listed below and how often?

	pain severity (0 means "*no pain*" and 10 means "*severe pain*")	never	rarely	sometimes	often	always
back	0 |---|---|---|---|---5---|---|---|---|---|10					
shoulders	0 |---|---|---|---|---5---|---|---|---|---|10					
neck	0 |---|---|---|---|---5---|---|---|---|---|10					
wrists	0 |---|---|---|---|---5---|---|---|---|---|10					
elbows	0 |---|---|---|---|---5---|---|---|---|---|10					
knees	0 |---|---|---|---|---5---|---|---|---|---|10					
head	0 |---|---|---|---|---5---|---|---|---|---|10					

Do you currently have any of the following?

	severity (0 means "*no difficulty*" and 10 means "*severe difficulty*")
vision problems	0 |---|---|---|---|---5---|---|---|---|---|10
hearing problems	0 |---|---|---|---|---5---|---|---|---|---|10
numbness in hands/fingers	0 |---|---|---|---|---5---|---|---|---|---|10
tingling in hands/fingers	0 |---|---|---|---|---5---|---|---|---|---|10

In the past, have you ever had pain or injury in the following joints/parts?

	never	rarely	occasionally	sometimes	usually
back	☐	☐	☐	☐	☐
shoulders	☐	☐	☐	☐	☐
neck	☐	☐	☐	☐	☐
wrists	☐	☐	☐	☐	☐
elbows	☐	☐	☐	☐	☐
knees	☐	☐	☐	☐	☐
head	☐	☐	☐	☐	☐

<u>Section 4 – Protection Methods</u>

Do you currently use any vibration dampening on tools and equipment?	☐ Yes	☐ No
Do you currently use any vibration dampening personal protective equipment such as gloves and etc.?	☐ Yes	☐ No
Do all your personal protective equipments for vibration fit you?	☐ Yes	☐ No
Do you currently use any hearing protection equipment such as ear plugs and ear muffs?	☐ Yes	☐ No
Do all your hearing protective equipments fit you?	☐ Yes	☐ No

Have you ever received training about …… ?

	never	more than a year ago	less than a year ago
health effects of vibration exposure	☐	☐	☐
vibration protection/reduction	☐	☐	☐
health effects of noise exposure	☐	☐	☐
noise protection/reduction	☐	☐	☐
other personal protective equipment	☐	☐	☐
maintenance of your tools/equipment	☐	☐	☐

How are your tools/equipment maintained?

☐ only when they break ☐ only the regular scheduled maintenance ☐ they are modified to work better

APPENDIX C

VIBRATION AND NOISE ASSESSMENT RECORDS KEEPING

Vibration and Noise Assessment Records Keeping

Company Name/Department: ___________________________________

Date: __ / __ / 2010

Record Keeping

Do you keep the records of maintenance of tools and equipment?	☐ Yes	☐ No
Do you measure and keep the records of tools/equipment vibration?	☐ Yes	☐ No
Do you keep the records of employees' training?	☐ Yes	☐ No
Do you keep the records of employees' health conditions?	☐ Yes	☐ No
Do you keep the records of employees' exposure to vibration?	☐ Yes	☐ No
Do you keep the records of employees' exposure to noise?	☐ Yes	☐ No

APPENDIX D

INSTITUTIONAL REVIEW BOARD EXEMPT FORM

Indiana State University
More. From day one.
Institutional Review Board

Terre Haute, Indiana 47809
812-237-3088
Fax 812-237-3092

June 30, 2010

Yuan-Hsin Cheng
Farman Moayed, Ph.D.
Department of Health, Safety, and Environmental Health Science
College of Nursing, Health, and Human Services
Indiana State University

RE: AN ASSESSMENT ON VIBRATION AND ITS HEALTH EFFECTS ON STONE WORKERS IN TAIWAN (IRB #10-148)

Dear Ms. Cheng:

The IRB has determined that your proposed study listed above, pursuant to Indiana State University's Policies and Procedures for the Review of Research Involving Human Subjects and 45 CFR 46, falls within an exempt category and is therefore considered exempt from Institutional Review Board Review. You do not need to submit continuation requests or a completion report. Should you need to make modifications to your protocol or informed consent forms that do not fall within the exempt categories, you will have to reapply to the IRB for review of your modified study.

Your study falls within the following exempt categories:

☐ 45 CFR 46.101 (b) 1 Educational Research	☒ 45 CFR 46.101 (b) 4 Existing Data
☒ 45 CFR 46.101 (b) 2 Survey Research	☐ 45 CFR 46.101 (b) 5 Evaluation Research
☐ 45 CFR 46.101 (b) 3 Survey of Public Officials	☐ 45 CFR 46.101 (b) 6 Consumer Research

Informed Consent: All ISU faculty, staff, and students conducting human subjects research within the "exempt" category are still ethically bound to follow the basic ethical principles of the Belmont Report: a) respect for persons; 2) beneficence; and 3) justice. These three principles are best reflected in the practice of obtaining informed consent.

If you have any questions, please contact the Office of Sponsored Programs at 812-237-3088, or irb@indstate.edu, and your question will be directed to the appropriate person. I wish you well in completing your study.

Sincerely,

Thomas L. Steiger, Ph.D.
Chair, Institutional Review Board

cc: Dawn Underwood, IRB Administrator