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HAND MUSCLE STRENGTH AND HAND DEXTERITY AFTER EXPOSURE TO HAND AND ARM FROM GRINDER VIBRATION AMONG GRINDING WORKERS

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ABSTRACT

This research was a quasi-experimental study designed for thirty female workers performing a grinding operation with another other thirty female workers as the control group. Hand muscle strength was measured by assessing hand grip strength (HGS) and pinch strength (PS) while hand dexterity was measured by the maximum tapping ability in 10 seconds (MTA). The study participants were asked to perform the tests at (1) initial time at 08.00 a.m., (2) before morning rest break at 10.00 a.m., (3) after morning rest break at 10.10 a.m., (4) before lunch at 12.00 a.m., (5) after lunch at 13.00 p.m., (6) before afternoon rest break at 15.00 p.m., (7) after afternoon rest break at 15.10 p.m. and (8) end of work at 17.00 p.m.. In contrast, the control group was measured only at before work (08.00 a.m.). The result showed that the HGS, PS and MTA of the dominant hand were generally stronger than those of the non-dominant hand (p-value <0.05). The MTA on the initial time of the study group was lower than that of the control group. The MTA was statistically significantly different (p-value <0.05). Both the study group and the control group did not show statistically significant difference of HGS and PS of both right and left hands (p-value >0.05). Percent changes (%) from initial time in MTA, PS and HGS of right and left hands in all time intervals were lower than for the initial time except that MTA of the left hand in each time interval was not different from the initial time. These tests confirmed the changes of hand strength and dexterity. The result shows that after the workers were exposed to vibration from the grinding process, they were affected by decreased hand muscle strength and decreased hand maximal tapping ability. However, the strength and maximal tapping ability was able to recover after taking a break. Furthermore, in all tests there was reduced hand strength and maximal tapping ability at the end of work (17.00 p.m.), so there may be an accumulation of tissue damage and fatigue of hand muscles by hand and arm vibration from continuous work with grinding. The vibration could influence muscle strength and maximal tapping ability. This result can be used for considering appropriate work duration to the

time to rest break for reducing possible accumulation of tissue damage and muscular fatigue of hand in grinding workers.

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KEY WORDS: hand muscle strength/ hand dexterity/ hand and arm vibration/ grinding workers

INTRODUCTION

Many automobile parts factories are located in Rayong province, Thailand. In the auto parts production processes, vibration from grinder is a major risk of workers. People who regularly and frequently work with powered hand-held tools or other working processes exposed to vibration through their hand and arm. They are at risk of developing permanent disability diseases of hands and arms (referred to Hand Arm Vibration Syndrome: HAVS). HAVS is a condition which can affect to the vascular, neurological, muscular and skeletal symptoms, is well known problems in workers who use hand-held vibrating tools. Muscle weakness, affecting the long finger flexors and affecting grip strength, may occur in association with long-term vibration exposure from hand-held tools.(1-4) In a rat lower leg vibration model, more proximally located muscles were relatively spared compared to distal muscles closer to the vibration source (5). This difference between the proximal and distal muscles was attributed to the direct contact between plantar surface of the foot and the vibration plate. Biopsy of the abductor pollicis brevis (APB) muscle in a population of workers with a history of chronic vibration which may be due to the use of hand-held tools demonstrated mixed pictures of degeneration and regeneration (6). The most striking finding was malalignment of myofibrils, which could explain their inability to generate full voluntary muscle tension. There are few reports in the literature relating to the functions of intrinsic hand muscles after chronic vibration exposure, which is surprising that there are good reasons to believe that both motor nerves of intrinsic and extrinsic hand muscles are damaged from chronic vibration. It is likely that all the tissues of the hand are affected by chronic vibration exposure, causing deterioration in hand functions (7)

Hands and fingers problems can be caused by numerous sources. One of source is a long exposure to hand-held vibrating tools but still lack of injury cause verification from Hand and Arm vibration Syndrome (HAVS). The actual number of diseases caused by vibrating tools could not be identified. In Thailand, The Workmen's Compensation Fund Office Statistics reported statistics from The Ministry of Labor that there were 73,891 (37.2%) and 77,014 (37.2%) cases of occupational accident with finger and hand problems in 2005 and 2006, respectively. In 1998, the research study of S.T.S. Engineering Consultant Co, Ltd. found that the vibration from jack - hammer ranging from 45.38 – 76.13 m/s2 (8).

Therefore the purposes of this study are to compare the changes of hand grip strength, pinch strength, maximum tapping ability between before and after grinding of the worker and study the magnitude of hand and arm vibration exposure among grinding workers in automobile parts factory which may be a guideline to establish a suitable procedure for monitoring, preventing hand and arm vibration syndrome control and solving the health problems among grinding workers.

Objectives of this study were :

1. To compare the different of hand grip strength, pinch strength, maximum tapping ability between the grinding worker group and the control group.

2. To compare the different of hand grip strength, pinch strength, maximum tapping ability between before and after grinding of the worker and also during rest in an 8 hr representative working day.

MATERIALS AND METHODS

This study was quasi-experimental study which was conducted to study of hand strength and hand dexterity after daily using of grinders among grinding workers. The objectives of this study were to study hand grip strength, pinch strength, maximum tapping ability between before and after grinding of the workers.

The study group was measured for 8 time intervals as following: (1) initial time at 08.00 a.m., (2) before morning rest break at10.00 a.m., (3) after morning rest break at 10.10 a.m., (4) before lunch at 12.00 a.m., (5) after lunch at13.00 p.m., (6) before afternoon rest break at 15.00 p.m., and (7) after afternoon rest break at 15.10 p.m. and (8) end of work at 17.00 p.m.. In contrast, the control group was measured only at before work (08.00 a.m.).

This research study was conducted in female workers of an automobile parts factory in Rayong Province, Thailand.The samples were divided into 2 groups as follows:

1. The study group: 30 female workers who were grinding operators
2. The control group: 30 female workers who were office workers such as interpreter, accountant, bookkeeper, secretary, stock clerk.

The inclusion criteria in this study were consisted of the age of subjects workers were greater than 20 years old. The workers had experience of work at least six months. Beside, they had healthy and strong, no personal disease such as liver disease, bladder disease, cardiovascular disease, renal disease, diabetes disease, severe organic disease, mental disturbance and had no hand and finger injury and menstruation in experimental day before measurement. Their medical history interviewed before the experiment. All subjects gave written informed consent prior to their inclusion in the study. The study was approved by the Committee on Human Rights Related to Human Experimentation, Mahidol University, Bangkok.

Some pieces of researeh instrument .

1. **Hand grip dynamometer** (*Takei A5401)*was used formeasuring flexion of the wrist; the handgrip dynamometer is able to give an accurate reading of grip strength, also estimating a general value for upper body strength. The dynamometer must be adjustable for hand size.

2. **Pinch gauge meter** (*B&L engineering*) was used formeasuring palmar pinch, key pinch and tip pinch.

3. **Tapping meter** (*The Denominator Company Inc. Woodbury, CT*) was used for measuring maximum finger speed tapping ability test.

4. **Digital stopwatch** *(Casio 507Qo4 Digital Stopwatch, China)*was applied to record the maximum tapping ability in 10 second.

5. **Caliper** *(CD20PS Mitutoyo Corp, Japan)*was used formeasuring hand size

6. This study used interview data sheet to collect data. This interview clearly stated the confidentiality of the response with no identification of name or contact information, adapted from Orawan Kaewbooncho, et al (1998) (9). Interview data sheet consisted of 4 parts as follows: Part I : Personal characteristics,Part II : History of work,Part III : Health status,Part IV : Subjective symptoms of hand injury

The subjects signed a written informed consent form after receiving a detail explanation of the study objectives and procedures. The subjects have been interviewed to obtain general information characteristics, history of work, health status and subjective symptoms of hand injury of questionnaire in the end of work.

The grip strength (HGS)of both the dominant hand and non-dominant hand was measured by the digital hand grip dynamometer (Takei Tokyo Japan) in the position of shoulder adduction, 90-degree elbow flexion, and 30- degree wrist flexion. The dynamometer handle was adjusted so that the line of the subject's proximal interphalangeal joints rested exactly on top of the adjustable handle. The subjects were asked to put maximal force on the dynamometer three times from both sides of the hand and were recorded in kilograms.

- The hand grip strength(HGS) was measured in the same time scheduleasmentioned above.

The subjectscomfortably seated on a chair without armrest. The shoulder was adducted and neutrally rotated. The elbow was flexed at 90 degree. The forearm was in neutral position. The wrist was put in place between 0-30 degree dorsiflexion and between 0-15 degree ulnar deviations. Testing position was also followed through the recommendation of The American Society of Hand Therapy (ASHT). The examiner demonstrated the corrected position of the subjects' fingers before each test. Subjects were examined on her palmar pinch (thumb pad to pads of index and long fingers, key pinch (thumb pad to lateral aspect of middle phalanx of the index finger) and tip pinch (thumb tip to index finger tip) strength. This protocol was repeatedly during each test. The reading scores of the three successive trials were recorded for each hand. The scores were read on the needle side of the readout marker. The maximal force was recorded in kilograms and used as pinch strength value. The dominant hand was tested first. A minimum of 30 seconds rest was allowed between each test. (In each hand were performed 3 trials).The pinch strength was measured recommendation mentioncol above.

The subjectscomfortably seated on a chair without armrest. Have the subjects place the preferred hand, palm down, with fingers extends and the index finger placed on the key. Direct the subjects to the tap as quickly as she can, moving for 10 seconds. she was instructed to tap as fast as possible and stopped at 10 second. Both dominant and non dominant hands were tested. The examiner gave verbal instruction and demonstrated before testing. Before the time start, the subject was first given a warning verbal signal "Nurng" (one), "Song" (two), "Sarm" (three) and then "Ream" (start) which meant that the subjects tapped as quickly as possible until stopped [which examiner say "Yud" (stop)] at 10 second. The maximum number of taps of each 10 second interval of each subjects of each dominant hand and non-dominant hand were recorded. (In each hand were performed 2 trials). The maximum tapping abilitywas measured in the same time schedule of HGS measurement mentioned aboul.

Data were analyzed by using the Statistical Package for Social Science version 13.0 (SPSS Inc, 2001). The statistical analysis was used as follows:

The descriptive statistics were used to describe the general characteristics of the study group and the control group such as percentage, mean ($\overline{X}$), and standard deviation (SD). To describe all measurement by using mean values ± standard error of mean (SEM).

The Chi-square test and the t-test were used to differentiate the factors between the study and the control group.

One-Way ANOVA was used to compare maximum tapping ability, pinch strength and hand grip strength at each time intervals with the initial time (08.00 am.). Level of significantly at α = 0.05 (p-value $\leq$ 0.05 was considered statistically significant).

RESULTS

Data were collected from the female workers of an automobile parts factory in Rayong Province, Thailand. The details of the study method are presented above. The subjects comprised 30 female workers from grinding line were selected as the study group and 30 female workers who work in the office were selected as the control group. The study results were presented in 5 main parts as the following.

1.The description analysis of the study group and the control group.

2.The comparison of maximum tapping, pinch strength, ability and hand grip strength between dominant hand and non- dominant hand.

3. The comparison of maximum tapping, pinch strength, ability and hand grip strength between the study group and the control group.

4. Percentage changes (%) of each subject from initial time (08.00 a.m.) of maximum tapping ability /10 sec, pinch and hand grip strength in the study group throughout 8 hours of working day.

The largest age group in both the study group and the control group was 25-34 years (53.3% and 53.3% respectively). The smallest age group in both the study group and the control group was less than 25 years. The average ages of the study group and control group were 31.43±5.197 years and 31.60 ± years respectively.

The majority of both the study group and the control group had body mass index between18.5-22.9 kg/m2 (50.0% and 60.0% respectively) and body mass index group less than 18.5 kg/m2 was the smallest group (6.7% and 16.7% respectively). The mean of body mass index (± SD) in the study group and the control group were 23.122±(4.037) and 21.735 ±(3.153) respectively.

The majority of the study group was secondary school (70.0%). The smallest numbers of study group were vocational certificate/bachelor's degree (3.3%). In the control group, the largest of subjects were vocational certificate/bachelor's degree and the smallest of the control group were primary school (56.7% and 6.7% respectively).

The majority of the study group and control group was married (96.7and 53.3% respectively.

In women who have been married, the majority group of study group who had only one child (55.2%). Having more than one child were the largest in the control group (56.2%) while having no children was the smallest group (20.7% of the study group and 18.8% of the control group) .The average numbers of children were 1.03 for the study group and 1.38 for the control group. The most number of children that most commonly found in the study group were 2 and in the control group were 3.

The majority of both the study group and the control group were right hand dominance (96.7% and 70.0% respectively).

The most of common method of traveling to work in both study group and the control group were company's bus (96.7% and 100.0 respectively).

The most of both study group and control group did not have other jobs (100.0 % and 100.0% respectively).

Most of the study group had worked in Quality Control (QC) (100.0%), while the control group was the largest group who has worked in Finishing/Quality Assurance (QA) (36.7%).The majority of both the study group and the control group had duration of work between 12-60 months (53.3% of the study group and 36.7% of the control group) and more than 60 months was the smallest group (20.0% of the study group and 30.0% of the control group). The average duration of work among the study group and the control group were

35.30 ± 24.3 month and 54.90 ± 63.153 month respectively. The minimum and maximum of duration of work among the study group were 8 months and 84 months respectively, while the control group was 8 month and 228 month respectively.

The majority of both the study group and the control group had the total operational time of work between 2,000 – 5,000 hours (40.0% of the study group and 33.3% of the control group). While less than 2,000 hours represented smallest group (10.0% of the study group and 20.0% of the control group). The average total operational time of the study group and the control group were 6,777.6 ± 4,666.7 hours and 10,540.8 ± 12,126.2 hours respectively. The median of total operational time among the study group and the control group were 5,184 hours and 4,800 hours, respectively.

The majority of both of the study group and the control group had worked overtime. The largest group of both the study group and control group had less than 2,000 hours of overtime (40.0% and 73.3% respectively).While more than 6,000 hours of overtime was the smallest group (26.7% of the study group and 6.7% of the control group).The average overtime of the study group and the control group were 4,060 ± 3,612.4 hours and 2,296.8 ± 3,654.9 hours respectively. The median overtime of both the study group and the control group were 2,940 hours and 1,296 hours respectively.

The majority of subjects never used to have major accident were 90% of the study group and 100% of the control group.

Past histories of bone and muscle injury of the grinding workers were found that 100.0% of the subjects had no serious history of bone and muscle illness during the part three months.

The majority of the study group had numbness symptoms (56.7%), pain (20.0%) and combination numbness and pain (23.3%).While, the control group had no serious symptoms 100.0%.

Assessment of hand strength and hand dexterity

The hand muscle strength's assessments were measured by the pinch strength test (PS) and the hand grip strength (HGS), while hand dexterity were measured by the maximum tapping ability in 10 seconds. The study group was measured for 8 time intervals as following: initial time at (1)08.00, before morning rest break at (2)10.00 a.m., after morning rest break at (3)10.10 a.m., (4) before lunch at 12.00 a.m., (5) after lunch at13.00 p.m., (6) before afternoon rest break at 15.00 p.m., and (7) after afternoon rest break at 15.10 p.m. and (8) end of work at 17.00 p.m.. In contrast, the control group was measured only at before work at 08.00 a.m.

One way ANOVA was applied to compare mean of maximum tapping ability/10 sec, pinch strength and hand grip strength in each time intervals.

The comparison of maximum tapping ability /10 sec (MTA) between dominant hand (DH) and non-dominant hand (NDH).

All time intervals, the maximum tapping ability /10 sec of dominant and non-dominant hands were determined by paired t-test. The result showed that the mean values of maximum tapping ability /10 sec of dominant hand significant higher than non-dominant hand at all time intervals (p-value < 0.05). In thumb finger, the mean values of maximum tapping ability /10 sec were not significantly between dominant and non-dominant among time intervals except the initial time at 08.00 a.m. and before lunch at 12.00 a.m. were significant different between dominant and non-dominant hands. Furthermore, maximum tapping ability /10 sec of index finger of dominant hand significantly faster than non-dominant hand at before rest break time at 10.00 am. (p-value <0.001). The data were showed in Figure1.

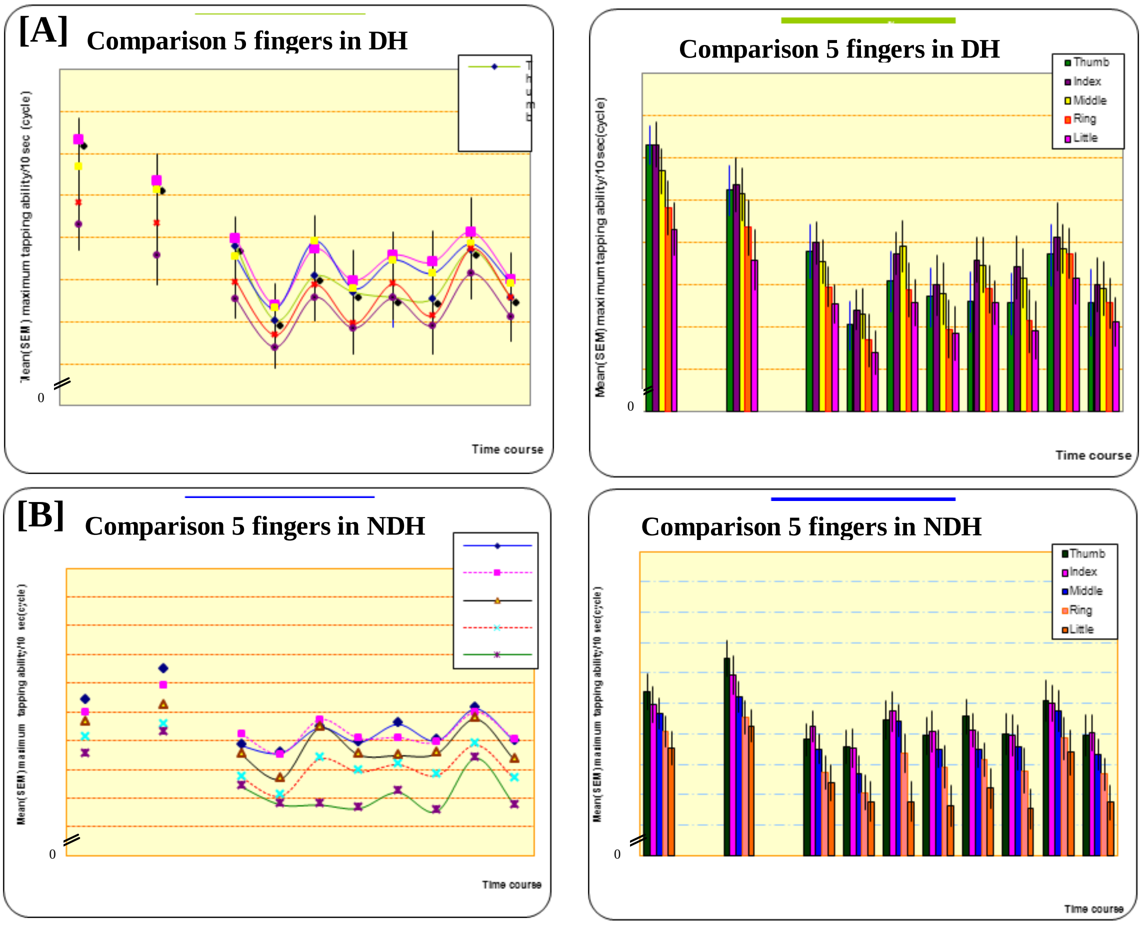


Figure 1 The means (± SEM) of maximum tapping ability in 5 fingers of dominant (DH): [A] and non-dominant hand (NDH): [B] in 8 time interval. *, **, *** *signifies significance level at p <0.05, p < 0.01 and p < 0.001 respectively. R = right hand, t= left hand.*

The comparison of pinch strength between dominant and non-dominant hand of the study group and the control group in 8 time intervals.

Figure 2 showesthe mean of pinch strength (tip, palmar and key) values. The data were analyzed by paired t-test. The dominant hand of the study group performed by tip pinch strength test was significantly higher than that of the non-dominant hand in time intervals at the initial time at 08.00, before rest break morning (10.00 am.), after lunch (13.00 am.) and after work (17.00 am.)(p-value <0.05). Furthermore, all time intervals of tip pinch strength test performed by the dominant hand were significantly higher than that of non-dominant hand (p-value < 0.001). (Figure2).

All time intervals of the study group, the mean palmar pinch strength of dominant hand were significantly more than the non-dominant hand (p-value <0.05) except palmar pinch strength time intervals at before lunch (12.00 am.) and before rest break afternoon (15.00 am.).In addition, all time intervals of the dominant hand performed palmar pinch strength test by were significantly higher than that of non-dominant hand in the control group (p-value < 0.001).The data were shown in Figure 2.

The dominant hand of the study group performed key pinch by strength test was significantly higher than that of the non-dominant hand in all time intervals except before rest break morning (10.00 am.) and after rest break afternoon(15.10 am.)(p-value<0.001). Furthermore, the dominant hand performed key pinch strength test by was significantly higher than that of non-dominant hand in the control group (p-value < 0.001).(Figure 2).

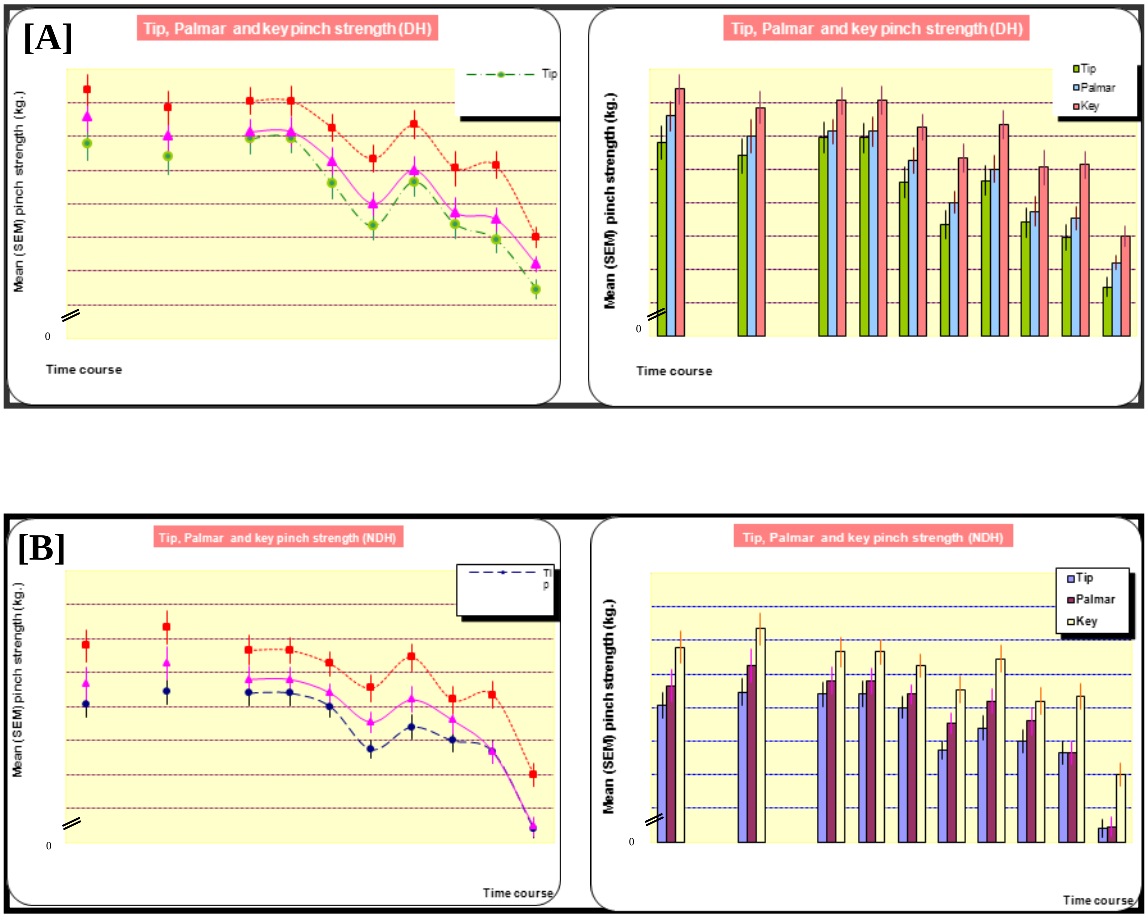


Figure 2The comparison means (± SEM) pinch strength of dominant (DH): [A] and non-dominant hand (NDH): [B] in 8 time intervals. *, **, *** *signifies significance level at p <0.05, p < 0.01 and p < 0.001 respectively. R = right hand, L= left hand.*

The dominant and non-dominant hands were determined by paired t-test. The hand grip strength of the dominant hand were significantly stronger than that of the non-dominant hand (p-value <0.05). The result was showedin Figure5.

The comparison of maximum tapping ability, pinch strength hand grip strength between the study and the control groups before work at 08.00 am.

The comparison of maximum tapping ability/10 sec at 08.00 am between the study group and the control group. Figure 1 showed the mean value of maximum tapping ability (cycles/10sec) of all subjects. The mean value all fingers of a dominant hand and left hand of the study group was significantly lower than the control group's (p-value < 0.05).Insignificant difference of the mean value all fingers of non-dominant and right hand maximum tapping ability (p-value >0.05).

Mean values of pinch strengths (tip, palmar and key pinch) are illustrated in Figure 2.The pinch strength (tip, palmar and key pinch) between the study group and the controls group were determined by t-test. The results of pinch strengths (tip, palmar and key) were not significantly different between the study group and the control group (p-value >0.05).

The hand strength (Figure 5)and hand dexterity in right and left hands (Figure 1) after exposed hand arm vibration from grinding were measured at the initial time (08. 00 a.m.) and after grinding (10.00 am., 10.10 am., 12.00 am, 13.00 pm., 15.00 pm., 15.10 pm. and 17.00 p.m.).Hand strength was tested from pinch and hand grip strength. The pinch and hand grip strength were measured at the initial time (08.00 a.m.) compared with after grinding. Hand dexterity was determined by maximum tapping ability (cycles/10 sec) in each finger. Maximum tapping ability (cycles/10 sec) was compared to initial time at 08.00 a.m. The means of these tests were statistically compared by One-Way ANOVA.

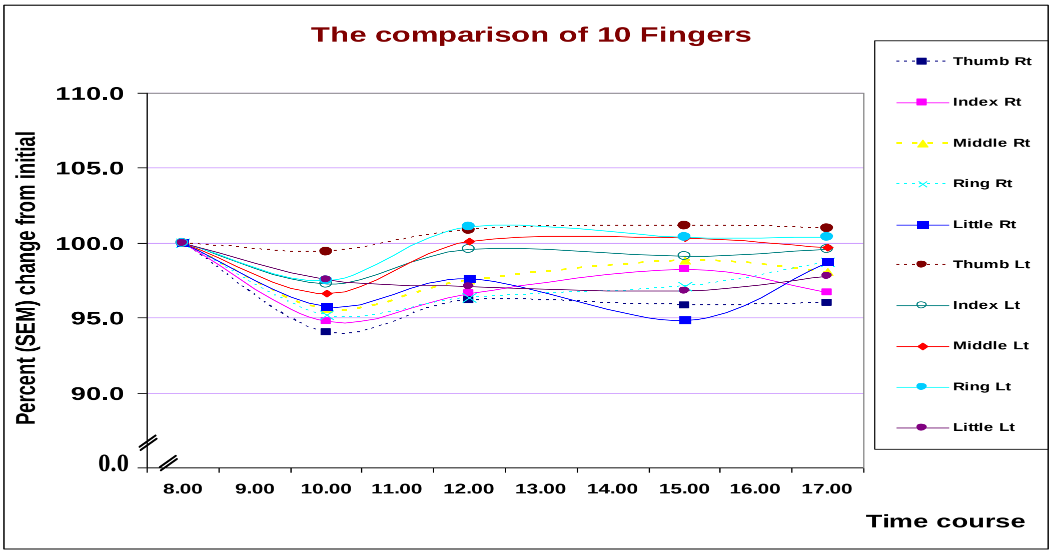


Figure 3 Percent changes (%) from initial time (08.00 a.m.) of maximum tapping ability /10 sec among fingers. Line graphs of hands omitted resting time. *, **, *** *signifies significance level at p <0.05, p < 0.01 and p < 0.001 respectively. Rt = right hand, Lt= left hand.*

Figure 5 shows that the percent changes from initial time at 08.00 am. of maximum tapping ability in 10 second in every time intervals were not different from the initial time (before work) except the middle finger of left hand in after rest break afternoon (15. 10 pm.) and ring finger of the right hand in before rest break morning (10.00 am.) showed statistically significant different from the initial time at 08.00 am.

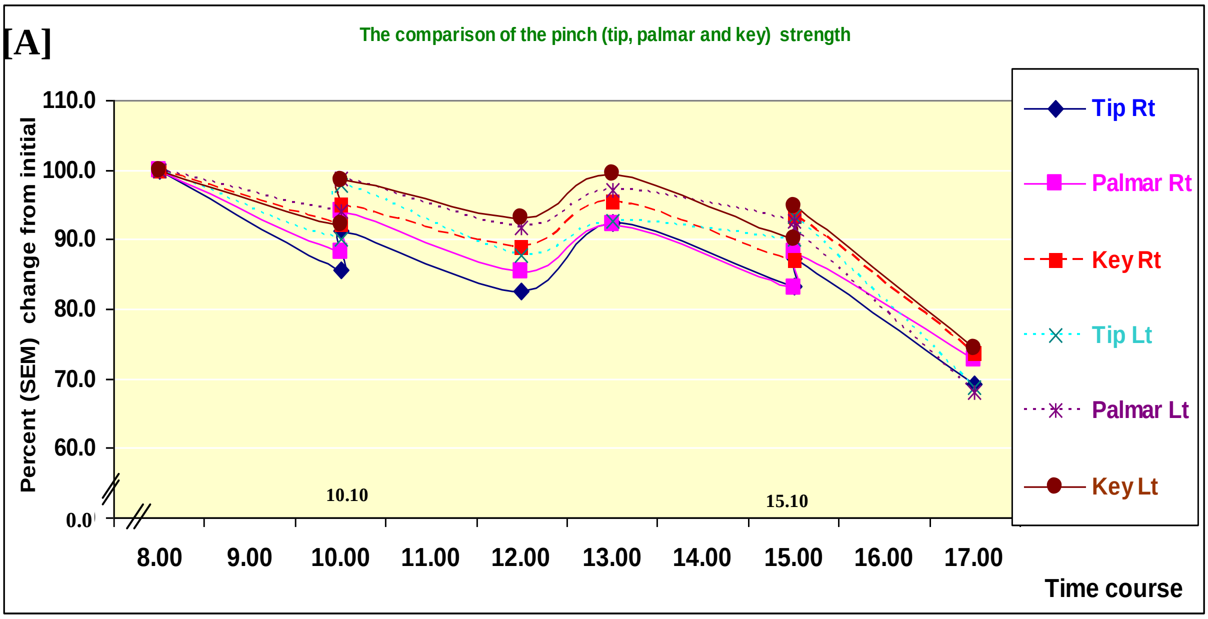
Thumb finger of both hands in time interval at 10. 00 am., 10.10 am., 12.00 am., 13.00 pm.,15.00 pm., ring finger of time interval at 15.10 pm and ring finger at 12.00 am. were statistically significant different between right and left hands (p-value 0.015 and 0.034).

The performance of tip pinch strength in the right hand changed at (2)10.00 a.m., (3)10. 10 a.m., (4)12.00 a.m., (5)13.00 p.m., (6)15.00 p.m., (7)15.10 p.m. and (8)17.00 p.m. as compared to initial time at (1)08.00 a.m with significantly different (p – value < 0.001). Tip pinch strength in left hand and palmar pinch strength in right hand were apparently seen at 10.00 am., 12.00 am., 13.00 p.m.., 15.00 p.m., 15.10 p.m. and 17.00 p.m. could show scientifically different (p – value < 0.001) as compared to initial time (08.00 a.m.) The palmar pinch of the right hand showed significant different (p – value < 0.01) at 12.00 am., 15.00 p.m., 15.10 pm. and 17.00 p.m. compared to initial time (08.00 a.m.). On the other hand the key pinch strength in both hands showed significant different(p – value < 0.01) at 10.00 a.m., 12.00 a.m., 15.00 p.m. and15.10 p.m. compared to initial time (08.00 a.m.)(Figure 2).

TheFigure 2 shows that the tip pinch strength of both hands in almost time intervals were different from the initial time (before work) except left hand at 10.10 am. showed no significant difference from the initial time.Tip pinch strength of right and left hands in almost time intervals were significant different from the initial time except left hand at 10.10 am. Palmar pinch strength in almost time intervals were statistically significant different from the initial time except left hand at end of work (17.00 pm.)Key pinch strength in almost time intervals of right hand were statistically significant different from the initial time, while key pinch of left hand were significant different from initial at 10.00 a.m. , 12.00 a.m., 15.00 p.m. and 17.00 p.m., respectively.

In the Figure 2 shows that thepalmar pinch at 12.00 a.m. significantly different between right and left hand.

Thepinch strength in almost time intervals were statistically significant different from the initial time. The percent maximum reduction was found in before work (17.00 p.m.). In addition, % pinch strength of right hand (tip,palmar and key)change from initial time were higher than left hand.(Figure 4).



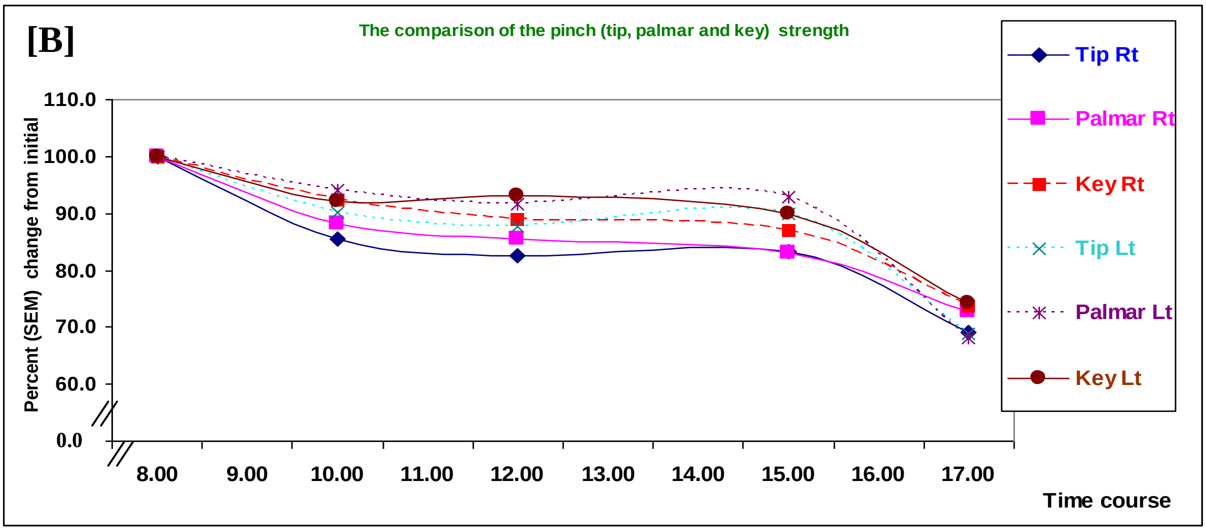


Figure 4Percent change (%) from initial time (08.00 a.m.) of pinch strength (tip, palmar and key) between right and left hands: [A], pinch strength (tip, palmar and key) between right and left hands omitted resting time: [B]. *Rt = right hand, Lt= left hand*

The hand grip strength in right and left hands are presented in Figure 5. Hand grip strength in right and left hands at (2)10.00 a.m., (3)10.10 a.m.., (4)12.00 a.m., (5)13.00 p.m., (6)15.00 p.m., (7)15.10 p.m. and (8)17.00 p.m. compared to initial time at (1) 08.00 a.m. was not significant different (p - value = 0.310 and 0.776 respectively).

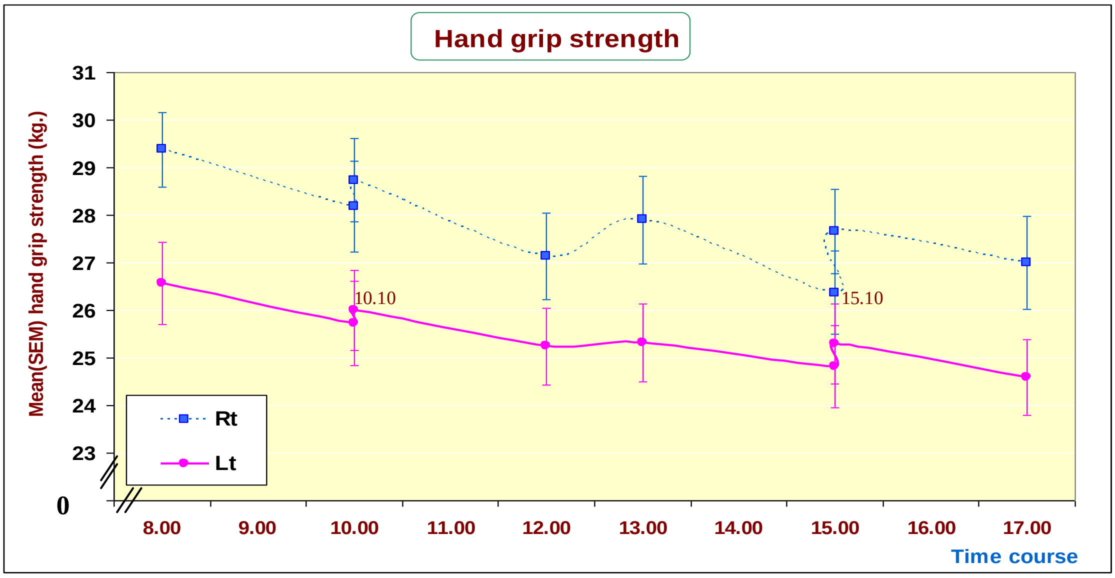
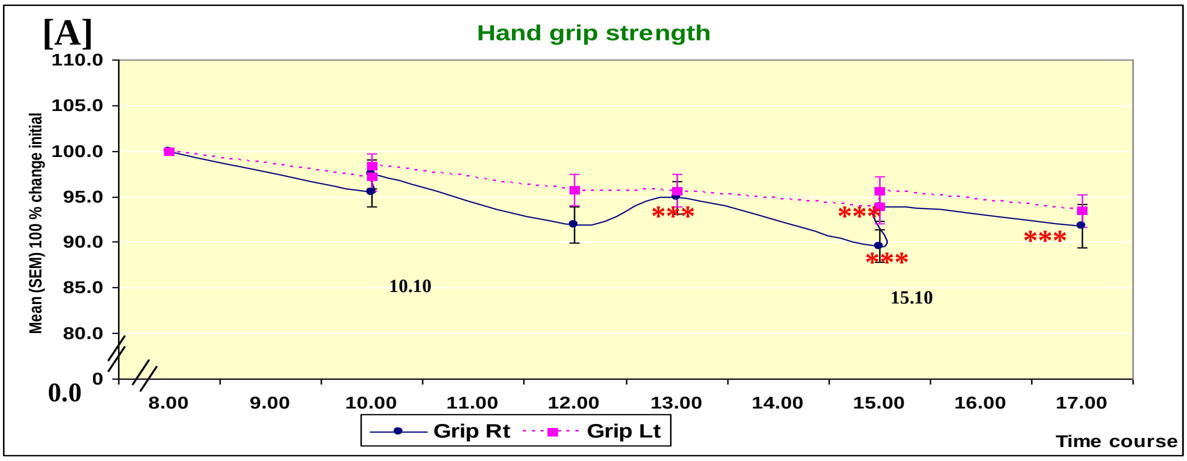


Figure 5.The means (+SEM of hand grip strength(HGS) throughout 8 hour of working day ofright (RT) and left (LT)hands after work and resting of each period were include in this graphy.

Percent changes (%) of hand grip strength of right hand were significant different from initial time at 12.00 am. , 13.00 p.m., 15.00 p.m., 15.10 p.m. and 17.00 p.m.. While the percent changes (%) of hand grip strength of left hand were statistically different at 13.00 p.m., 15.00 p.m. , 15.10 p.m. and 17.00 p.m. Comparison among time intervals of right and left hands showed that almost time intervals were not statistically significantly different from initial time. (Figure6)

Figure 7 The percent maximum changes from the initial of all the parameters in this study (without after resting data are shown here) was found that the strength of tip pinch of right hand is the most sensitive parameter to 8 hour grinding work exposure.



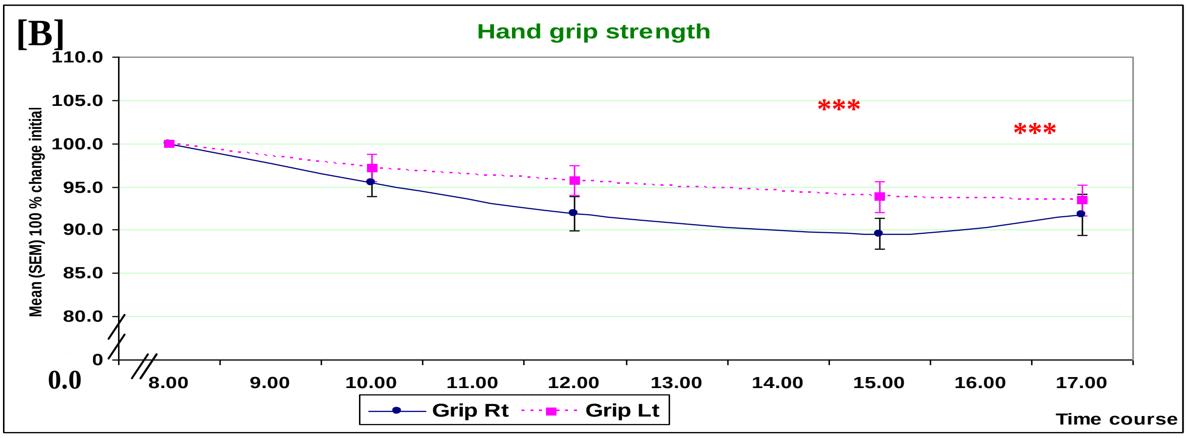


Figure 6 The percent change (%) from initial time (08.00 a.m.) of hand grip strength between right and left hanc |, hand grip strength between right and left hands omitted resting time: [B], respectively. *, **, *** *signifies significant different from initial time (08.00 a.m.) level at p <0.05, p < 0.01 and p < 0.001 respectively. a, b ,c signifies significant different between right and left hands level at p <0.05, p < 0.01 and p < 0.001 respectively. Rt = right hand , Lt= left hand.*

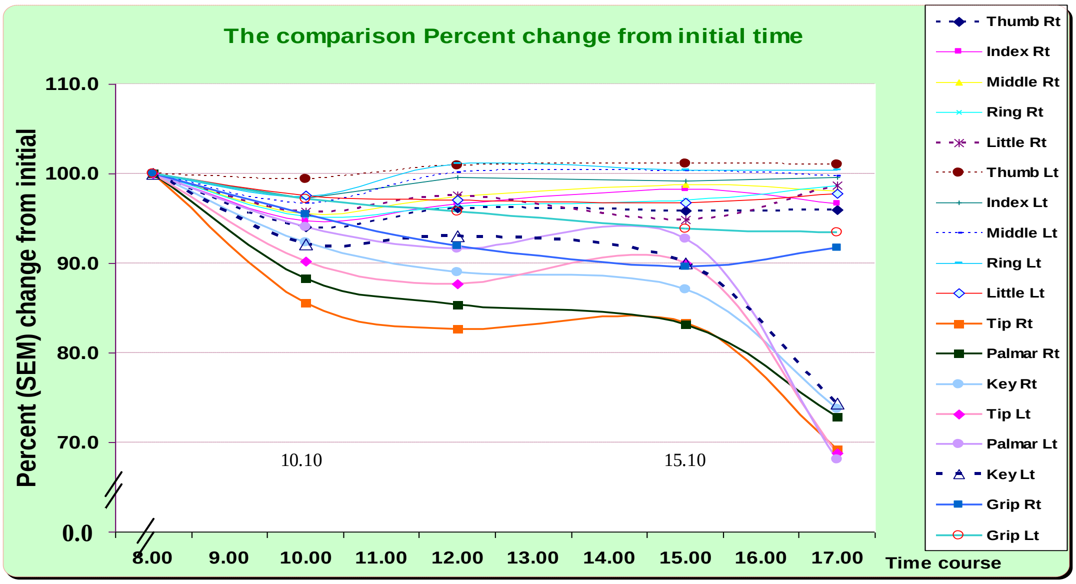


Figure 7Percent change (%) from initial time (08.00 a.m.) among maximum tapping ability in 10 sec, pinch strength and hand grip strength withomitted resting time.

*, **, *** signifies significance level at p <0.05, p < 0.01 and p < 0.001 respectively. *Rt = right hand, Lt= left hand.*

DISCUSSION

This study was concentrated on changes in hand strength and hand dexterity after exposing hand and arm vibration in the workers which consisted of maximum tapping ability/10sec, pinch strength and hand grip strength bias.

In order to decrease bias from selecting of the study group and the control group in the same factory. Reduction of selection bias was done by determining a strict criterion for the study group and the control group. This study included the study group and the control group with age of workers were more than 20 years old, experience of working at least six months, healthy and strong, no personal serious disease such as liver disease, bladder disease, cardiovascular disease, renal disease, diabetes disease and had no history of serious hand and finger injury and there was no menstruation in the experimental day.

There were varies of instruments that were used in this study such as denominator for maximum tapping ability test, pinch test, dynamometer and vibration meter (HAV Pro).To prevent error from using the instrument, the researcher studied and tried to train to use it before starting the experiment and conducted follow up as instructed in the hand book of using this instrument. In addition, those instruments were carefully checked such as, set zero and calibrated every time by researcher before starting the experiment.

Hand grip strength, pinch strength, maximum tapping ability between the study group and the control group.Female workers are often involved in occupation and job tasks characterization by a combined exposure to hand transmitted vibration and physical stress such as forceful and repetitive movements and awkward postures. Vibration can produce both and long lasting effects when it is transmitted to the fingers, hands and arms of an operator by a tool or work piece. The major long lasting effects of vibration exposure are vasospastic disorders, neurological disorders either in the form of a nerve entrapment at the wrist, or as a peripheral nerve and bone or joint disorders. Functional tests for the evaluation of peripheral circulatory, peripheral nerve, and motor function were applied to the hands of all workers. Motor functions used in this project were evaluated by grasping power, pinching power and tapping ability of the finger for 10 sec.This study showed that the hand dexterity by using maximum tapping ability (MTA) in 10 second. The MTA of dominant hand in the control group were significantly higher than in the study workers group (p-value < 0.05).This finding is consistent with those reported by otherresearchers who found impairment to manual dexterity in groups of hand transmitted vibration workers.(10-12). Sakakibara et al. (11) observed an impaired manual dexterity tested by measuring the performance time in a transferring task in a group of 29 patients affected with the hand arm vibration syndrome (HAVS) compared with 30 male controls. Toibara et al (12) reported significantly prolonged performance times of buttoning-unbuttoning a work jacket and transferring beans from a plate to another one in 30 patient with HAVS compared with 50 controls (30 office workers and 20 manual workers). In cross-sectional study of 111 vibration- exposed workers, Cederlund et al, (10) studied twenty male workers (aged 28 to 65 years) subjected to vibration by hand-held tools were assessed with a battery of objective tests for dexterity. The test results were compared with normative data. He concludes that vibration-exposed patients present considerable impairment in hand function. Rui et.al(13) was investigated on 115 hand transmitted vibration (HTV) workers (82 forestry workers and 33 stone workers) and 64 control men over 1 year follow up period. The Purdure pegboard method was used to test manipulative dexterity. Purdue pegboard scores were significantly lower in the HTV worker than in the controls (p value < 0.05). Moreover, Mirbod et al. (14) found that diminution of tapping ability during the 4-year follow-up course. Furthermore, both of the study group and the control group were not statistically significant difference of hand grip and pinch strength of both right and left hands (p-value >0.05). The results were inconsistent with previous study by Necking et al (5-6), grip and pinch strength was significantly reduced in the vibration-exposed group. They postulated that the reduced manipulative skill and impaired dexterity of the hand. may be due to the vibrating tools cause direct damage to muscle fibres as well as nerves. Beside, they compared hand muscle strength between workers regularly exposed to hand-held vibrating tools (n=81) and a non-exposed control group (n=45). Maximal voluntary strengths of hand grip, thumb pinch, thumb palmar abduction and index and little finger abduction were measured. The exposed workers had significantly weaker muscles than the controls. During a 2 years- follow-up period, lumberjacks with HAVS symptoms lost 21% of their hand grip strength while lumberjacks without HAVS symptoms only lost 5% (15). In comparing the grip strength of non- vibration and vibration exposure workers, Miyashita et al (4) observed that grip strength progressively decreased as the total vibration exposure time increased: 52.5 kg grip strength in controls; 46.5 kg (-11.5%) in workers with up to 2,500 hr of total vibration exposure time; 40.1 kg (-24%) in workers with more than 7,500 hour of total vibration exposure time. McGeoch and Gilmour (16) confirmed the association between grip strength loss and prolonged vibration exposure.

Pinch and grip strength were not significantly different between the study and the control group may be due to the average age of was 31.43 years and total operational time was only 35.32 month (3 years) in the study group. This result found no clear evidence of exposed to vibration from grinding affecting the hand strength and dexterity between study and control group. There may be two major factors; firstly most of workers were younger or secondly less total operating time of work. This might be explained by most of the workers were younger and less total operating time of work. This result is similar to Futatsuka M, et al. (17)focused on the health effects of vibrating tools on workers in the tropical area. They found no clear evidence of vibration-induced white finger (VWF) may be several reasons such as they were younger and less experienced workers and healthier. However, Mathiowetz et al. (18) found highest grip strength scores occurred in the 25 to 39 age groups. For tip, key, and palmar pinch the average scores were relatively stable from 20 to 59 years.Over more, Josty et al (19) measured grip and pinch strengths in non-manual, light manual and heavy manual workers using a Jamar dynamometer and a pinch measuring device. Heavy manual workers had the strongest grips while the office workers had the weakest grips. They concluded that occupational was an important factor when grip strength was being measured. Maximum tapping ability /10 sec (MTA), pinch (PG) and hand grip strength (HGS) in the study group throughout 8 hours of working day. The result found here showed that the percent changes from initial time at 08.00 a.m. of maximum tapping ability in 10 second in most time intervals were not statistically significant different from the initial time (before work). This study participants were asked to perform the tests at (1) initial time at 08.00 a.m., (2) before morning rest break at 10.00 a.m., (3) after morning rest break at 10.10, (4) before lunch at 12.00 a.m., (5) after lunch at13.00 p.m., (6) before afternoon rest break at 15.00 p.m., (7) after afternoon rest break at 15.10 p.m. and (8) end of work at 17.00 p.m.. The result showed that the MTA, PA and HGS had highest values in the initial time (before work: 08.00 a.m.), but the MTA, PA and HGS was decreased when after work such as 10.00a.m. , 12.00 a.m., 15.00 p.m.and 17.00 p.m. MTA, PA and HGS. During an 8 hour work shift, we found patterns of change in the values of MTS, PS, and HGS. Measured values were reduced after exposure to vibration, but increased again after rest break. This result confirms the importance of rest break to change hand strength and hand dexterity in vibration-exposed workers. The MTA, PS, and HGS of study subjects in all time intervals were lower than the initial measurement done before work began at 8:00 a.m. Measured MTA of the right hand (grasping grinder) were higher than the initial time. The thumb and index fingers of the right hand were weakened significantly after the initial measurement (-6% and -3%, respectively). Workers use the right thumb to hold the machine "on button" down while also using it to guide the machine. The left hand is used to hold the work piece. We compared the grip strength in 3 positions (tip, palmar, key) in both hands at intervals of every hour starting 8.00 a.m until 18.00 p.m. At every time the right hand was weaker than the left hand. For the right hand Tip pinch decreased more from the initial time than did palmar or key pinch (Right hand tip pinch decreased 30% from the initial measurement). Moreover, all three grip strengths were lowest at the end of work (5:00 p.m.). At almost every time interval the grip strength of both hands was lower than the initial measurement. We found that the hand that holds the equipment was less strong than the left hand. The lowest values were measured at 12:00 and at 5:00 p.m. Tip pinch of the right hand was decreased mostly in the thumb strength. There may be due to the thumb of right hand was used to grasp handle of grinder most of the time during working. This result followed the report of Malchoire et al, 1998 (20) who found that vibration can produce both acute and long-lasting effects when it is transmitted to the fingers, hands and arms of an operator by a tool or work piece. Acute sensory impairment was recently demonstrated after an exposure of only 30 min to vibration, in that the vibration perception thresholds increased and paraesthesia and numbness developed. This finding was consistent when compared to the previous studies by Kihlberg, et al. (21) which found that when the hand was exposed to vibration from a grinder, the subjective ratings in the hand and temporal shift in vibratory sense threshold were more affected than the static condition, or even higher than the chipping hammer exposure. The increase in electromyography activity when exposed to acute vibration reflects the well known tonic vibration reflex of a muscle, and possibly other mechanisms dependent on neuromuscular vibration. The electromyographic activity found in forearm flexor and triceps muscle could be explained. Subjective rating in the hand and shift in vibration perception threshold were effected more in using grinder than the hammer exposure. The fingers exposed to the most vibration are affected first, but all the fingers may gradually become affected later. The thumb is usually not affected in the earlier stages. Luo et al. (22) measured finger blood flow (FBF) over three 5 min periods of vibration separated by 5 min rests. They reported a downward trend in the finger blood flow (FBF) over the three periods of vibration in the unexposed hand but not the exposed hand. There is overwhelming evidence that long-term exposure to vibration may cause muscular dysfunction, as evidenced by both reduced muscle force and endurance (23). Most researchers agree that the intrinsic muscles are affected much earlier than the forearm muscles. This means that grip-strength tests may be an inadequate tool for the assessment of muscular dysfunction, at least in the early stages of HAVS. Necking et al. (5-6) have demonstrated morphological evidence of muscle fibre necrosis and regeneration in several animal studies. The observed degenerative-regenerative activity implies that the muscle lesions have occurred early and indicates that even the short-term vibration stress applied directly to muscle tissue may exceed the critical limit for maintenance of structural integrity. These researchers concluded that the level of tissue displacement is a crucial factor for development of vibration-induced muscle injury.Furthermore, the handle of the equipment had the highest vibration level, compared to other parts of the machine. Vibration in the handle was highest on the Z axis (2.96 m/s^2). The value compared to the threshold limit values (TLVs) of The American Conference of Government Industrial Hygienist (ACGIH) is less than the limit of 4 m/s^2. Howerer, when the level of vibration of this study is compared to the the Commission of the European Communities (EU) standard indlicate that it is also not over the limit (5 m/s^2), but is more than the action level of EU (2.5 m/s^2) (24-25). EU has suggested that, to decrease risk, workers need information, training, technical measures and health surveillance. The information is that when using the equipment they will experience vibration from the handle in their fingers. The force of holding the machine tightly will cause numbness in the fingers, then the muscles may cramp. Because of muscle cramps may eause the to may become painful. These symptoms came from information from the EU and ACGIH, and are the same as found in this study in 94.4% of the subjects(24,25). This is the evidence that confirms that exposure to vibration of equipment will cause not only numbness and pain in the hand that can develop into chronic pain. The method to reduce risk of these symptoms is to reduce the time exposed to vibration by increasing the number of rest breaks.

Recommendation from the finding of this study may be summariged as follows

1. The employer should provide a health monitoring program such as the base line data, medical examination for all workers occupationally exposed to hand- arm vibration from the use of vibrating tools.

2. The employer should be supplemented anti-vibration devices for reducing vibration at the grinder such as the use of anti-vibration gloves, grinding handheld wraps.

3.Reducing the number of hours and a worker uses a vibrating tool during the work day. Furthermore, grinding workers should have appropriate work duration to time to rest break for grinding workers.

REFERENCES

1. วิทยา อยู่สุข. อาชีวอนามัย ความปลอดภัย และสิ่งแวดล้อมกรุงเทพฯ: โรงพิมพ์นำอักษรการพิมพ์2542.
2. Bovenzi M, Franzinelli A, Scattoni L, Vannuccini L. Hand-arm vibration syndrome among travertine workers: a follow up study. *OccupEnvironMed* 1994; 51: 361-365.
3. Färkkilä M, Pyykkö I, Heininen E. Vibration stress and the autonomic nervous system. Kurama Med J 1990; 37: 53-60.
4. Miyashita K, Shiomi S, Itoh N, Kasamatsu T, Iwata H. Epidemiology study of vibration syndrome in response to total hand- tool operating time. *BrJIndMed* 1983; 40: 92-98.
5. Necking LE, Lundborg G, Fridén J. Hand muscle weakness in long-term vibration exposure. *JHandSurg* 2002; 6 : 520-522.
6. Necking LE, Fridén J, Lundborg G. Reduced muscle strength in abduction of the index finger: an important clinical sign in hand-arm vibration syndrome. *ScandJPlastReconstrSurgHandSurg* 2003; 37: 365-370.
7. Necking LE, Lundbörg G, Lundström R, Thornell LE and Fridén J. Hand muscle pathology after long-term vibration exposure. *JHandSurg*2004; 5: 431-437.
8. กรมควบคุมมลพิษ.โครงการศึกษาผลกระทบมลพิษทางเสียง และความสั่นสะเทือนต่อสุขภาพ. กรุงเทพ2541.
9. Kaewboonchoo O, Yamamoto H, Miyai N, Mirbod SM, Moriokai I, Miyashita K. The standardized nordic questionnaire applied to workers exposed to hand-arm vibration. *JOccupHealth*1998; 40: 218-222.
10. Cederlund R, Isacsson A, Lundborg G. Hand function in workers with hand-arm vibration syndrome. *JHandTher*1999; 12: 16-24.
11. Sakakibara H, Hirata M, Toibana N. Impaired manual dexterity and neuromuscular dysfunction in patients with hand-arm vibration syndrome. *IndHealth* 2005; 43: 542-547.

12. Toibana N, Ishikawa N, Sakakibara H. Measurement of manipulative dexterity in patients with hand arm vibration syndrome. *IntArchOccupEnvironHealth* 2002; 75: 106-110.
13. Rui F, Agostin F, Negro C, Bovenzi M. A prospective cohort study of manipulative dexterity in vibration-exposed workers. *IntArchOccup* Environ Health 2008; 81: 545-551.
14. Mirbod SM, Akbar-Khanzadeh F, Onozuka M, Jamali M, Watanabe K, Inabai R, et.al. A four-year follow-up study on subjective symptoms and functional capacities in workers using hand-held grinders. *IndHealth* 1999; 37: 415-425.
15. Färkkilä M, Aatola S, Starck J, Korhonen O, Pyykkö I. Hand-grip force in lumberjacks: two-year follow-up. IntArch*OccupEnvironHealth*. 1986;58(3):203-208.
16. McGeochkl and Gilmour WH. Cross sectional study of a workforce exposed to hand-arm vibration: with objective tests and the Stockholm workshop scales . *OccupEnvironMed* 2000;57:35-42
17. Futatsuka M, Shono M, Sakakibara H, Quan PQ. Hand arm vibration syndrome among quarry workers in Vietnam. *JOccupHealth* 2005; 47: 165-170.
18. Mathiowetz V, Wiemer DM, Federman SM. Grip and pinch strength: norm for 6 to19 year-olds. *AmJOccupTher* 1986; 401: 705-711.
19. Josty IC, Tyler MP, Shewell PC, Roberts AH. Grip and pinch strength variation in different types of workers.*JHandSurg* 1997; 22: 266-269.
20. Malchaire J, Piette A, Rodriguez Diaz LS, Amaral FG, Schaetzen. Neurological and functional effects of short-term exposure to hand-arm vibration. *IntArchOccupEnvironHealth* 1998; 71: 270-276.
21. Kihlberg S,Attebrant M, Gemne G, Kjellberg A. Acute effects of vibration from a chipping hammer and a grinder on the hand-arm system. *OccupEnvironMed* 1995; 52: 731-737.
22. Luo J, Sakakibara H, Zhu S, Kondo T, Toyoshima H. Effect of vibration magnitude and repetitive exposure on finger blood flow in healthy subjects. *IntArchOccupEnvironHealth* 2000; 73: 281-284.
23. Pyykkö I, Strack J, Färkkilä M, Hoikkala M, Korhonen O, Nurminen M. Hand arm vibration in the etiology of hearing loss in lumberjacks. *BrJIndMed* 1981; 38: 281-289.
24. วันทนี พันธุ์ประสิทธิ์. มาตรฐานสารเคมีในอากาศและดัชนีชี้วัดทางชีวภาพ. กรุงเทพฯ: นำอักษรการพิมพ์, 2543.
25. The European Parliament and the Council of the European Union. On the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (vibration). Directive 2002/44/EC. *OfficialJournaloftheEuropeanCommunities*, 6 July 2002, L177/13- 19, Brussels, 2002.