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DESIGN INTERVENTION TO REDUCE MUSCULAR STRENGTH FOR USING STONE POLISHING MACHINE

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Abstract: *Stone polishing work is an integral part of the construction sector. Hand-held polishing machine often results in excessive hand-arm vibration (HAV) and manual effort. To overcome these problems, a new design was conceptualised, developed, and validated. This study aims to evaluate the effect of a new handle on the transmissibility of HAV and muscle activities during polishing activity. 13 experienced participants involved in polishing activities were selected in this interventional field experiment. Tool handles (existing and modified) were taken as the independent variables, while electromyography and HAV values were considered as dependent variables. The vibration level was measured at the handle and wrist for both existing and modified stone polishing machine. The result showed that the muscle strength for operating the modified stone polishing machine was less than the existing stone polishing machine.*

Keywords: *Hand Vibration, Electromyography, Muscle fatigue, Design Intervention*

1. INTRODUCTION:

Many occupations in the unorganized sector use non-ergonomic hand tools for doing their regular activities. Some of the construction, mining, forestry, and agricultural occupations also comes in such category where vibrating hand-held tools are commonly used [1, 2]. The users of those hand-held power tools often exposed to hand-arm vibration (HAV). Furthermore, prolonged use of such tools leads to physical, physiological and musculoskeletal disorders among the workers [2, 3, 4, 5, 6,]. Construction industry which is the second largest industry in India after agriculture. It makes a significant contribution to the national economy and accounts for about 11% of India as GDP [7] employing a large number of people. Stone polishing work is an integral part of the construction sector, where a hand-held polishing machine is used to control the surface finish and quality of the intended surface of the stone/mosaic. Excessive exposure to vibration is one of the significant drawbacks of the hand-held stone polishing machine. The pressure is applied to the handle of the polishing machine by the palm, thumb, and rest of the fingers to conduct polishing activities. The salient drawback of the existing polishing machines in the market is the extensive vibration at the grip. The vibration from the handle of the polishing machine gets transmitted to the hands, arms, and shoulders of the operator. It causes discomfort to the operator and results in early fatigue [2]. When such fatigue prevails over months and years, they may cause physical, physiological, and, musculoskeletal disorders. The existing machine also gives an external shock to a great extent, along with vibration. Due to external shock, the polishing machine moves away from the surface, more force required for smooth movement on the surface.

Previous studies suggested that the exposure to the hand-transmitted vibration as well as cumulative trauma disorders depends on the magnitude of the hand-force imparted on the handle of the vibrating equipment [8, 9]. The studies related to the biodynamic response to HAV have shown that the increase in hand force (either grip force or push force) leads to increase in the magnitude of the vibration [9, 10]. Exposure to high pressure on the surface of the hand due to grasping and controlling the handle of the power tool can lead to discomfort and tissue damage. There is also excessive flexion and extension at the wrist while operating the stone polishing machine. Excessive flexion and extension of the wrist were associated with the high chance of carpal tunnel syndrome (CTS) [11, 12,]. CTS is specified by pain or burning in the thumb, long and index fingers of the hand with the reduction of median nerve conduction at the wrist due to the entailment of the median nerve in the carpal tunnel [13]. Although the prevalence of CTS has reported for vibration-exposed workers, the mechanism is still not known [14]. It is believed that exposure to vibrations in amalgamation with ergonomic factors (power grip, hand posture, static load) is considered to increase the risk of CTS [14, 15, 16]. Other factors such as working posture, tool weight, grip/ push forces, hand-handle interface and individual's work habit, duration of exposure also contribute to the transmissibility of vibration to the hand-arm system [17].

Hand-arm mechanical properties are responsible for transmissibility of vibration caused by externally powered tools maintained with hand. These powered tools induce vibration to a great extent, and the operators of powered tools exposed to a high level of vibration. During use of vibrating tool high level of coupling, forces are required, which results in an increase of transmission of vibration to the hand [18]. The increase in vibration exposure causes the muscle to voluntarily, involuntarily and reflexively contract (known as the Tonic Vibration Reflex); which promotes muscles fatigue and stress [19] and are also known to decrease productivity through compromising hand dexterity, making manual handling tasks harder to perform [20, 21]. Muscular fatigue happens when motor units are no longer able to maintain an established force level. Muscle fatigue is a complicated situation encompassing various causes, mechanisms, and forms of exposition. It develops due to a chain of metabolic, structural and energetic changes in muscles due to insufficient oxygen and nutritive substances supply through blood circulation, as well as a result of changes in the efficiency of the nervous system. According to Merletti et al., 2004 [22] the potential sites of neuromuscular fatigue can be grouped under three headings: (1) central fatigue (2) fatigue of the neuromuscular junction and (3) muscle fatigue. In the neuromuscular condition in which muscles fail to generate the required force.

The continuous monitoring of local muscle fatigue during the performance of specific work is possible by measuring the myoelectric activity of particular muscles by the method of surface electromyography (EMG) [23]. The determination of localized muscle fatigue is one of the critical parameters in the industrial application of ergonomics. Surface electromyography (EMG) records bioelectric signals caused by neuromuscular activity with the help of surfaces electrodes (also known as topical or cutaneous electrodes).it has broad areas of application like posture analysis, gait, product certification, motion analysis, ergonomic design, etc.

Therefore, to overcome the problem of the existing polishing machine, a new design was conceptualized and developed. Based on market survey and field observation, some limitations found out, which made the ways for redesigning the existing polishing machine. Then the functional diagram was made on the need statement and solid structure of the polishing machine. The sub-functions that considers everything of the product created from the functional diagram. The feasible subcomponents were identified through various sub-functions, and a morphological chart made. Then new concepts were developed, combining each product sub-function of the sub-component from the morphological chart. Then the criteria chosen for the screening of the concepts of the polishing machine was smooth functioning of the machine, stability of the stone, less jerk and reduction of vibration of transmission to the hands and arm of the operator and thus the concept was developed.

The existing polishing machine has standard compound gear, which is suitable for vertical drilling. The existing system gives an external shock to a great extent, along with vibration. Due to external shock, the polishing machine moves away from the surface; as a result, more force required for smooth movement on the surface. To solve this, issue the rotation of the motor is transferred to the output shaft using a planetary gear arrangement. Supporting handles of stainless steel alloy was attached along with spherical wheels on it for smooth movement of the machine on the surface. Rubber coating was used for coating on handles because coating material can reduce vibration transmission by 59% [2]. The present research carried out to check the superiority/effectiveness of the new design in comparison to the existing one. Also, also to compare the muscular strength required to operate the existing and modified machine and vibration transmission to the hand-arm system during polishing activities using existing and newly developed polishing machine.

2. METHODOLOGY

2.1 Participants

Thirteen (13) male stone polishing workers purposively selected for this experimental study. These skilled polishers were working in construction located within the urban/ rural area of Guwahati. The workers selected for the study had no history of vascular or neuromuscular disorders having right-hand dominance Participants were informed briefly about the experiment, and consent for participation obtained from each of them before the experiment. Detailed demographic characteristics and job profile have been mentioned in Table 1

Table 1. Demographic characteristics and job profile of the participants (n=45)

Characteristics	Mean (±SD)
Age (years)	25.64 (5.4)
Height (cm)	156.16 (6.6)
Weight (Kg)	49.87 (4.7)
Work experience (years)	3.42 (1.6)
Working hours per day	4.64 (0.9)
Working days per week	4.96 (0.2)
Number of breaks in a day	3.16 (1.1)
Duration of total breaks in a day	2.20 (1.2)

2.2 Equipment

EMG signals were recorded using DELSYS Trigno Wireless EMG (4.1.5) system. DelSys EMG collected EMG raw data works 4.1.5 acquisition software platform at a frequency of 2000Hz. The magnitude of transmitted vibration (from the handle of a polishing machine) was measured using hand-arm vibration meter (Make Manfred Weber, Model: VM31-HA) following the measurement techniques as described in European Occupational Health Directive 2002/ 44/EC and ISO 5349-1.

2.3 Electromyography study

2.3.1 Muscle Selection:

The polishing activities mainly involve repetitive activities that are prone to higher chances of injuries and accidents. The polishing work involves manual effort in lifting the machine and frequent repetitive movements, with maximum shoulder extension, forearm flexion, and wrist flexion and flexion. In the present study, EMG activities of Deltoid, Biceps, Extensor Carpi Radialis (ECR) and Flexor Digitorium Superficialis (FDS) muscles were considered to investigate the force requirement for polishing operation. Bano et al. (2012) [24] considered Flexor Carpi Radialis (FCR) and FDS for recording EMG activities for screw driving task. Again Garapati, 2007, [25] considered Bicep muscles and Deltoid muscles to examine the effect of overhead drilling on the muscular activity of the shoulder. Mogk and Keir, 2003 [26] considered FCR, FDS, Extensor Carpi Radialis (ECR) muscles for recording EMG activities during gripping activities. The surface EMG electrodes recorded the activities of four muscles. The electrodes were attached parallel to the muscle fibers. The electrodes were placed on the anatomical landmark done based on dominant bone areas when the participant was sitting and standing with arms resting and extended along sides and palm facing upward [27]. The identification of muscles for the location of the electrodes was made with the help of physiologist and previous studies [24, 28]. The electrodes on deltoid muscle were located at the point halfway between the lateral aspect of the acromion process and insertion of the deltoid on the deltoid tubercle. The location of surface electrodes on Bicep muscles was positioned on the lateral epicondyle of the humerus. The electrode for ECR was located within 10-20 mm after lateral epicondyle, which was close to the origin of the muscle and far from the tendon zone at a distance of 20mm. The electrode for FDS muscles was placed over the belly of the muscle, parallel to the assumed longitudinal axis of the muscles [29]

2.3.2 Experimental protocol

The EMG signals during maximum voluntary isometric contractions (MVC) test for stone polishing activity were collected. The testing sequence of each participant was randomized and they were introduced to the procedures used during the experiment. They were asked to stand still with relaxed arms along sides and palm facing upward. The skin (at muscle location) was cleaned with alcohol and electrolyte gel to improve the electrical conductivity and mechanical contact of electrodes. Afterward, the surface electrodes were attached to the belly of DT, BB, FDS and ECR muscles [30 ,31] (Delsys Inc., Natlick, Massachusetts, USA) as shown in Fig. 1. This phase of the experiment was carried out in two parts. The first part of the experiment included recording of MVC data and EMG normalization, while the second part examined the comparative data of normalized EMG (NEMG) of existing and modified polishing machine

2.3.2.1 MVC recording

Following the placement of the electrodes on the skin and signal quality verified, a small warm-up session (2 min) for the preparation of the next step of MVC (maximum voluntary contraction) data collection. MVC was carried out to standardize the muscle activation level to the percent of maximum voluntary contraction (%MVC). As the EMG signal depends on various factors like muscle contraction, muscle crosstalk, sensor characteristics, electrode placement, etc., the best way to minimize the effects of these factors is to normalize the muscle activities using the MVC test. The participants were asked to perform posture specific MVC for each muscle group to collect the individual muscles MVC value. The participants were asked to exert their maximum force (isometric contraction) and hold their maximum effort for 5 seconds. They were provided with a recovery break of 60 seconds, and the experiment was repeated thrice to collect the best MVC data. The same procedure was adopted to collect the MVC data each muscle. The participant was given a rest break of 15 minutes' rest between each exercise to remove any muscle fatigue.

2.3.2.2 EMG recording and Normalization:

After completion of MVC tests, the second part of the EMG study was acquiring data during the polishing task. The participants were instructed to perform polishing activities for 15 minutes with the existing and modified stone polishing machine on the floor (mosaic) of area 6.25 ft^2. The raw EMG signals collected during the last 3 minutes of the polishing work. The participants were asked to take rest for 15 minutes between polishing with the existing and modified machine. After collection of raw EMG signals of 3 minutes, middle 30 seconds data were trimmed for analysis. Each trimmed signal was band-pass filtered (20-500 Hz) and was full-wave rectified [32].

Fig 1: Placements of electrodes on muscles

2.4 Measurement of HAV during polishing activity

2.4.1 Position of accelerometer:

The accelerometer was attached to the wrist and handle by a plastic cable strap to measure the vibration transmission of the existing and modified polishing machine as shown in Fig 2.

2.4.2 Vibration exposure in existing and modified polishing machine:

The vibration level was measured at both the tool handle and wrist of the operator. The magnitude (acceleration) of the hand-transmitted vibration for all the three axes (x, y, and z) and their vector sum (as mentioned in ISO 5349: 2001) was recorded for the last 30 s (after 1 min. of polishing activity) while performing the polishing at the floor.

Fig. 2. Hand-arm vibration meter connected with the tri-axial accelerometer (left-image) and tri-axial accelerometer on the wrist of the operator during use of a polishing machine (right-image)

2.5 Statistical Analysis

The subjected were examined for data recording starting from 09:00 AM to 05:00 PM. The acquired EMG and HAV data of each participant were further downloaded into the spreadsheets for further analysis. Eventually, the data was statistically analysed using Statistical Package for the Social Science (SPSS v.22.0.0, IBM Corporation, USA).
All data analyses were carried out using commercially available statistical software, IBM SPSS Statistics for Windows (version 22; SPSS Inc., Chicago, IL, USA). Wilcoxon test was conducted to compare the muscle strength between the two data set of existing and modified stone polishing machine. A paired-sample t-test was conducted to compare the difference between the vibration transmission at the wrsit of the existing and modified stone polishing machine.

3. RESULTS

The EMG signals showed that the muscles had different levels of activity. The FDS muscle had maximum involvement out of the four selected muscles, followed by consistently decreasing of involvement of bicep muscles.
After collection of raw EMG signals for the duration of last 5 min of polishing activities with the existing and modified stone polishing machine, middle 30-sec data processed and analyzed to obtain the percentage of Maximum Voluntary Contraction (% MVC).
The values of the muscle of the existing and modified stone polishing machine were expressed as % of MVC (Table-2). It is noticeable from table 2. that there was a massive difference in %MVC of EMG data between the existing and modified stone polishing machine. In the field, survey data (related to body parts discomfort while operating stone polishing machine) also showed a similar mode of observations like the workers reported for wrist and finger pain, which could be due to the active involvement of FDS muscles.
For the old machine, mean EMG (MV, expressed as % equivalent of mean MVC) fig 8 of Deltoid, Bicep, FDS, and ECR muscle was 7.3%, 3.55%, 5.17% and 14.93% whereas for the modified machine was 2.72%,0.72%,5.83%, and 2.65%. The strength required for the modified machine was lower than the old machine was by 62.73%, 79.72%, 12.77%, and 82.25%.

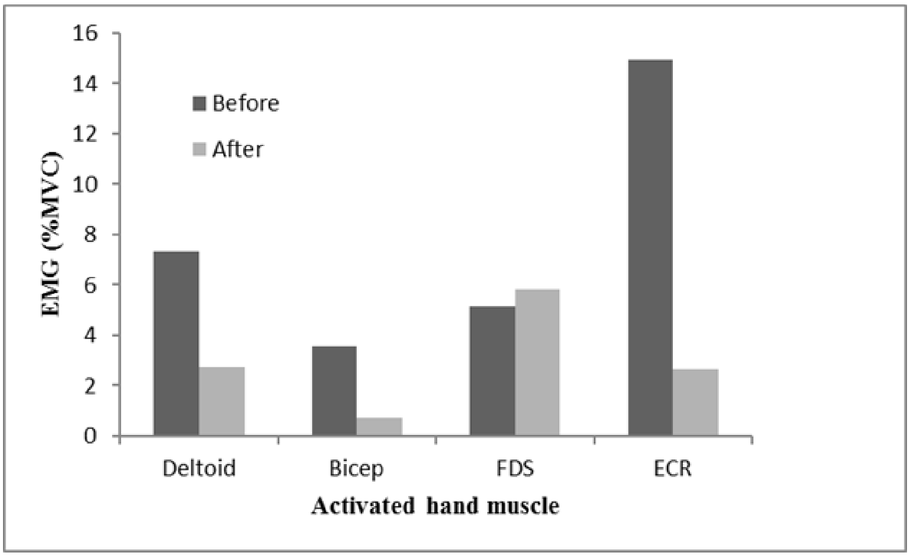

Fig 3: The RMS% MVC graph plot for Deltoid muscles, Bicep muscles, Flexor Digitorium Superficialis muscles (FDS) and Extensor Carpi Radialis muscles (ECR) for existing and modified stone polishing machine

There was a massive difference in muscle strength required for operating the existing polishing machine and modified stone polishing machine, comparatively the requirement of force is quite less in the operating the existing polishing machine than the modified stone polishing machine

Muscles	Mean		Std. Deviation		Range		Minimum		Maximum	
	Before	After	Before	After	Before	After	Before	After	Before	After
Deltoid	7.30	2.72	6.08	3.21	18.30	11.68	1.11	0.49	7.34	2.72
Bicep	3.54	0.72	3.48	0.45	12.10	1.39	0.47	0.27	3.54	0.72
FDS	5.11	5.82	6.29	4.64	23.08	16.59	0.86	0.72	5.11	5.82
ECR	14.92	2.65	13.83	1.69	53.0	4.97	3.35	0.11	14.92	2.65

Table 2. The %MVC values of the muscle for the existing and modified polishing machine

Wilcoxon signed ranks test was performed to compare the muscle fatigue between the existing and modified stone polishing machine. Wilcoxon signed-test showed that all four muscle elicits a statistically significant change for Deltoid muscle (Z = - 3.180, p<0.001), Bicep muscle (Z= - 3.180, p< 0.001), ECR (Z= -3.180, p<0.001) in muscle strength levels while operating old and modified stone polishing machine. For FDS muscle, the %MVC was higher in the developed polishing machine compared to the old polishing machine. Therefore, it is evident from the results (Table 2) that there was a decrease in %MVC while the EMG data with the new machine compared to the old machine.

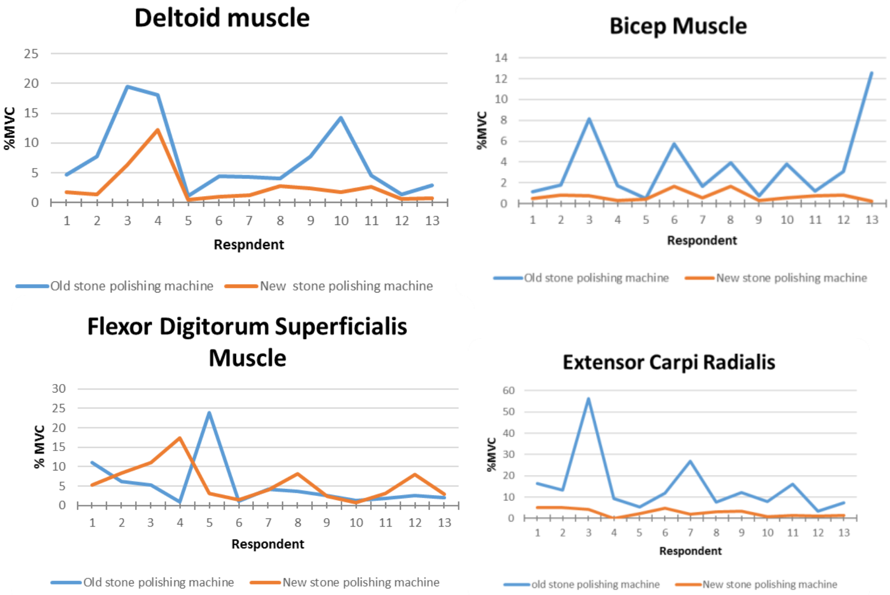

Figure 4: Muscular effort (%MVC) required for polishing activities with the existing polishing machine (before) vs. modified polishing machine (after)

HAV values were collected while the workers were doing stone polishing work. Vibrations are transmitted to hand from the polishing machine. The RMS frequency-weighted acceleration magnitudes recorded in the right hand was dominant in z-direction followed by x-direction. Vibration magnitude was measured at the wrist and handled of the polishing workers as shown in fig in terms of frequency weighted RMS acceleration (*aw* in m/s^2) which is the main feature to determine the health risk for any equipment along with the duration of the exposure. The data collected using hand-arm vibration meter revealed that the eight-hour energy equivalent frequency-weighted acceleration magnitude [A (8)] for each of the participant was more than the recommended daily average vibrational exposure (action value = 2.5 m/s^2 and exposure limit = 5 m/s^2) for the existing machine. Whereas for redesign machine, it was below the exposure value was found below the exposure for the modified one. The daily exposure of A (8) in m/s^2 from mean daily time of operation vary from 2.02 to 3.12 m/s^2 for handle and 2.7 to 3.43 for wrist m/s^2.

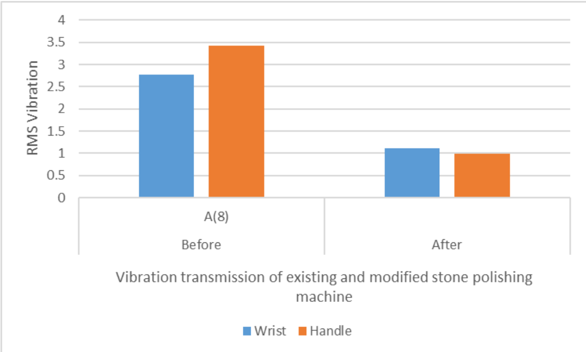

Figure 5: Vibration transmission at the wrist and handle of the existing and modified stone polishing machine.

Table 3. Descriptive statistics for vibration transmission at the handle of the existing and modified stone-polishing machine

Handle	ahwy (m/s^2)		MTVV (m/s^2)		A(8) hrs	
	Before	After	Before	After	Before	After
Mean	11.91	3.08	15.77	3.06	2.78	0.95
Median	11.70	3.98	11.41	2.71	2.84	0.92
Std.Deviation	1.65	1.24	12.50	0.73	0.94	0.31
Percentiles(5)	9.41	2.51	4.83	2.31	0.20	0.63
25	10.37	2.79	9.82	2.40	2.45	0.70
50	11.70	3.98	11.41	2.71	2.84	0.92
75	13.37	4.11	14.62	3.94	3.47	1.03

The comparison between the two data set (before and after) would be made through Paired-t-test. However, the data were not normally distributed so the alternative of Paired-t-test, Wilcoxon test was conducted. A Wilcoxon signed- rank test showed (table 3.) that after design intervention, elicit a demographic change in vibration transmission in the wrist of the operators of the stone polishing machine. Indeed, the median rating of frequency-weighted acceleration [ahwy (m/s^2)] was 3.98, was 2.71 and A (8) was 0.92.

Table 4. Descriptive statistics for vibration transmission at the wrist of the existing and modified stone-polishing machine

Wrist	ahwy (m/s^2)		MTVV (m/s^2)		A(8) hrs	
	Before	After	Before	After	Before	After
Mean	10.89	4.22	9.58	3.31	2.62	1.08
Median	10.10	4.16	10.28	3.16	2.92	1.04
Std.Deviation	1.68	1.27	3.11	0.77	0.87	0.31
Percentiles (5)	9.07	2.51	3.63	2.31	0.86	0.63
25	9.46	2.95	8.50	2.67	2.33	0.85
50	10.10	4.16	10.28	3.16	2.92	1.04
75	12.16	5.15	10.98	4.03	3.12	1.32

A paired-sample t-test was conducted to compare vibration transmission at the wrist of the existing stone polishing machine and redesigned stone polishing machine. There was an essential difference in the scores of daily exposure value A (8) in m/s ² transmission of vibration of existing and redesigned stone polishing machine (M= 1.53, SD= 0.86) at the handles; (t (12) = 6.45, p= .000). These results suggest there was a difference in vibration transmission at the handle while operating the existing and modified stone polishing machine. Specifically, the results say that there was less vibration transmission at the handles while using the modified stone polishing machine.

4. DISCUSSION

The main reason for discomfort during their working hours was the extensive vibration transmitted to the hand-arm system of the polishing workers. As reported by the workers, there was a tingling sensation felt by them while performing stone polishing activities. All these factors mentioned above can be accepted broadly as a sign of improper workstation design and inappropriate working equipment [33]. In the modified stone polishing machine, a supportive frame is developed to withstand the load of the whole machine and to minimize the vibration occurs due to the friction between the stone and floor. Earlier the weight of the machine borne by hand sustained load holding, but in the existing machine, the weight of the machine borne by the supportive structure on the ground. Studies had mentioned that the sense of discomfort and fatigue is associated with absorption of localized forces at the handle interface [10, 9]. The gear system is changed to planetary gear trains from compound gear trains to reduce the external shock which makes the machine moves away from the surface; as a result, less force required for smooth movement on the surface.

To record the muscle activity EMG was used, mainly four groups of muscles, Deltoid muscles, Bicep muscles, FDS muscles, and ECR muscles were evaluated. The results experiment showed that there was a significant decrease in %MVC for the modified polishing machine, then the existing polishing machine for Deltoid, Bicep, and ECR muscles. The strength required for the modified machine was lower than the old machine was by 62.73% (Deltoid), 79.72% (Bicep), 12.77% (FDS), and 82.25%(ECR). The %MVC of the existing polishing machine was higher for Extension Carpi Radialis (14.93%) while performing polishing activities on the floor. It is one of the muscles in the lower arm which control the movements at the wrist) [28]. Many studies had mentioned that while gripping on the handle of a vibrating tool, the hand muscles adjacent to the base of the thumb were most affected [34]. Also, the lower arm is more affected compared to the other parts of the arm, which causes muscle fatigue (Radwin et al.,1987). The %MVC for the deltoid muscle of the existing and modified polishing machine was 7.3% and 2. 65%). The deltoid muscle originates from the scapula and clavicle and attaches to the lateral surface of the humerus which helps in moving the arm away from the body to reach out to the side while performing polishing activities (Konrad,2005). It is named after the Greek letter delta, which is shaped like an equilateral triangle. The deltoid has three distinct functions that correspond to the three bands of muscle fibers. The anterior region assists the pectoralis major during transverse flexion of the shoulder and acts weakly in strict transverse flexion. The lateral region assists in shoulder flexion when the shoulder is rotating, although it also assists the transverse abduction of the shoulder. The posterior region is the hyper extensor of the shoulder, contributing to the transverse extension (Konrad,2005).

The %MVC of ECR for existing and modified polishing machine was 14.93% and 2.65%. In the existing polishing machine, there is having improper grip diameter (35mm) for holding which hinder muscle activities. With the extension of proper grip (42mm) and length as per Indian hand male population, the muscle activity was more compared to the existing polishing machine [35]. Polishing activities involve wrist extension motion, so this muscle is gets highly activated. ECR is a pair of muscles located on the side of the forearm, allowing them to control extension and abduction of the wrist. Both originate from the humerus and attach to the base of the hand (Konrad,2005).

The %MVC for FDS was less in the existing stone polishing machine (3.55%) compared to the modified machine (5.83%). It is the critical muscle that controls the wrist and finger flex, which lies below the superficial region and splits into four tendons at the wrist which travels through the carpal tunnel and attach to the fingers (Konrad,2005). Earlier there were restrictions in finger movements due to the improper grip of the handle of the stone polishing machine and after the design intervention space for proper grip to the handle was provided. With the proper grip, there was an improvement of fingers, so there was an increase in %MCV for FDS muscle.

The lowest % MVC was for Bicep muscle (5.17% existing and 0.72% modified), which means it is not the prime muscle in pushing the polishing machine. The biceps brachii is a two-headed muscle. Majority of the muscle mass is located anteriorly to the humerus, but it has no attachment to the bone itself originate from the scapula and attach via the bicipital aponeurosis to the fascia of the forearm and it helps in supination of the forearm also with flexion of the arm at the elbow and the shoulder (Konrad,2005).

The surface electromyography method is well-established for the assessment of muscle activities related with force exertion, muscle fatigue while performing a task [36,]. The amplitude of the EMG signal assesses the muscle activity [37 , 38 , 39] and has been used in studies of various purpose to evaluate muscle loads in job involving upper limbs [40, 39 , 41] Bano et al., 2012 examined the effect of grip force, stroke rotation, and on EMG activities of forearm muscles. The findings revealed that extensor muscles were more fatigued in a torquing and gripping task. Farooq et al., 2012 [42] examined the effects of upper limb postures on discomfort score for repetitive gripping task and EMG activities. Again The force that the muscle expend as well as muscle tension is shown by the amplitude of the EMG signal depend on muscle strength (Danuta and Tomasz,2002). Again, the differentiation in EMG signal amplitude in the flexor carpi radialis muscle must happen according to wrist flexion and extension [43] and the activity of the biceps brachii depends

on the arm adduction and arm rotation [43]. Kong et al., 2012 [44]examined the handle diameters and orientations for evaluating maximum torque, muscle activity, perceived comfort for a torquing task Similarly, Domizio and Keir,2010 [45] investigated the shoulder and forearm muscle activity while performing hand grip efforts in the push and pull exertions in different forearm postures. Similarly, Chang et al., 1999 [46] evaluated hand-arm stress on finger force and EMG activity of the flexor digitorium muscle while operating an electric screwdriver. In this study, the difference in muscle strength between the existing machine and the modified machine were studied.
The EMG data shows between the requirement of less force while moving the existing and modified polishing machine. Literature tells that deltoid, bicep, ECR, and FDS are those muscles exposed to vibration while operating any vibrating equipment [47]. Moreover, many researchers had mentioned that there was also increase in muscle activity in the shoulder muscles and forearm muscles (extensor carpi radialis and biceps) during exposure to local vibration [48]. Studies had mentioned that there is a positive correlation between %MVC and vibration level. Exposure to hand-arm vibration significantly affects the muscles and grip strength of the operators. The decrease in grip strength increases vibration level (NIOSH,1989). The magnitude of vibration transmitted from a vibrating handle to the wrist increases with increasing grip and push forces (Singh and Khan,2012), which increases the electrical activity of finger-flexor muscles.
The measured vibration intensity of the modified polishing machine existing polishing machine was, which is evident from the accelerometer (hand-arm vibration) data. In an earlier case, the vibration intensity was beyond the exposure action value (2.5m/s2) and exposure limit (5m/s2) and exposure limit (5m/s2). If the exposure action value is exceeded, then it indicates that the employer shall initiate and execute a program of technical and organizational measures intended to reduce to minimum exposure to mechanical vibration, taking into account in particular. Also, if the exposure limit is exceeded, it indicates that the employer shall take rapid action to reduce exposure below the exposure limit value (ISO 5349).

5. CONCLUSION:

The EMG (%MVC) of the Deltoid, Bicep, ECR decreased with the modified stone polishing machine. For FDS muscles, the EMG (%MVC) was more in the existing machine compared to the existing machine due to proper grip diameter (42mm) and length provided on the new stone polishing machine. The vibration generation and transmission were below the exposure limit and exposure action value in the modified polishing machine. Hence it can be concluded that the requirement of force (as evident from EMG data) and vibration transmission was less (accelerometer data) during polishing activities using a newly developed polishing machine**.**

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