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Study on Approaches for Reducing the Vibration Exposure of Hand-Helded Golf Club Heads Grinding †

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Abstract: To control vibration-induced white finger among workers performing the fine grinding of golf club heads, in this study, the influence of different factors on vibration acceleration were verified by adjusting the eccentric mass of different dynamic balance wheels, adjusting the angle of driving wheels and passive wheels, increasing the number of rubber cushions, and using new and old sand belts. This study determined that the eccentric mass of the dynamic balance wheel, the number of rubber pads, and the newness of the sand belt are significant factors affecting the vibration of workers. The vibration hazard posed to workers can be reduced by correcting the dynamic balance of the front wheel, increasing the amount of rubber pads, and replacing the type of sand belt with a newer one.

Keywords: hand-arm vibration; hand-held workpiece vibration; vibration-induced white finger

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1. Introduction

Hand-held workpieces grinding operation is a common hand-arm vibration operation. It is widely used in labor-intensive industries, such as hardware products, sports equipment manufacturing, and household appliance manufacturing. It is an essential link in the production process of enterprises and has a high risk of causing occupational diseases. The typical representative is a hand-held golf ball head polishing operation [1,2]. Previous researchers have reported that up to 30% of workers who perform the grinding of hand-held golf club heads suffered from hand-arm vibration disease [3]. The aims of this study are to explore the effects of various approaches for reducing the vibration exposure of hand-held golf club head grinding by comparing the difference in hand-transmitted vibration acceleration for three typical hand-held golf ball head polishing measures and to provide a basis for the prevention and control strategy of hand-held workpieces polishing operation.

2. Methods

This study consists of 4 experiments. Experiment (1) involves adjusting the balance of the driving wheel of the grinding equipment and analyzing the hand-transmitted vibration acceleration when the grinding driving wheel, weighted at 3.9 kg with different eccentric mass (3 g, 10 g, 15 g, 22 g, 32 g), rotates at 2100 RPM. Experiment (2) involves adjusting the relative position of the driving wheel (front wheel) and the passive wheel (rear wheel) of the grinding equipment and analyzing the hand-transmitted vibration acceleration under different situations wherein the angle between the front and rear wheels is 0 degrees and 5 degrees. Experiment (3) involves adjusting the damping cushion of the grinding equipment and analyzing the vibration acceleration when a single or double damping cushion is placed between the machine stand and the ground. Experiment (4) consists of analyzing and comparing the vibration acceleration using two kinds of sanding belts (WY60#, 3M50#).

For our experiments, we used an XL-168PA belt grinding machine with good performance (Hongweishun Corporation, Zhongshan, China), five kinds of driving wheels with different eccentric qualities (3 g, 10 g, 15 g, 22 g, 32 g), two kinds of rubber pads, two kinds of grind belts (WY60# 3M50#), and lots of golf club heads. An SV106 human vibration analyzer (SVANTEK, Warszawa, Poland) and a SV105B three-axis hand-transmitted vibration sensor (Poland SVANTEK) were used to measure the frequency-weighted accelerations in three orthogonal directions (x, y, and z), according to ISO 5349-1(2001) [4] and the previous research conducted by our research group [1]. The belt grinding machine is a type of classic bench grinding machine composed of a machine stand, motor, rotating shaft, driving wheel, driven wheel, sand belt, safety baffle, etc. The sand belt is fixed to a driving wheel and a driven wheel before operation. After the switch is turned on, the motor powers the driving wheel, sand belt, and driven wheel to rotate through the rotating shaft. The workpiece surface is polished through the rapid rotation of the sand belt.

Several experienced workers participated in this study. The testing grinders were randomly selected from a cohort of experienced grinders who had continuously worked on polishing jobs for more than five years. During experiments (1,2,3), ten club heads were polished. For the purpose of experiment(4), the test continued until the belt could not be polished.

SPSS 25.0 software was used for statistical analysis. A general linear model for the analysis of variance (ANOVA) was used to determine the effectual significance of our approaches. Whenever applicable, independent sample *t*-tests were performed to examine the significance of the vibration differences. Differences were considered significant at the $p < 0.05$ level.

3. Results

Figure 1 shows that five workers performed the same grinding operation by adjusting the eccentric mass of the driving wheel. There is an identifiably significant difference in the hand-transmitted vibration acceleration with different values of eccentric mass for the driving wheel during grinding. The higher the eccentric mass, the greater the hand-transmitted vibration acceleration ($p < 0.05$).

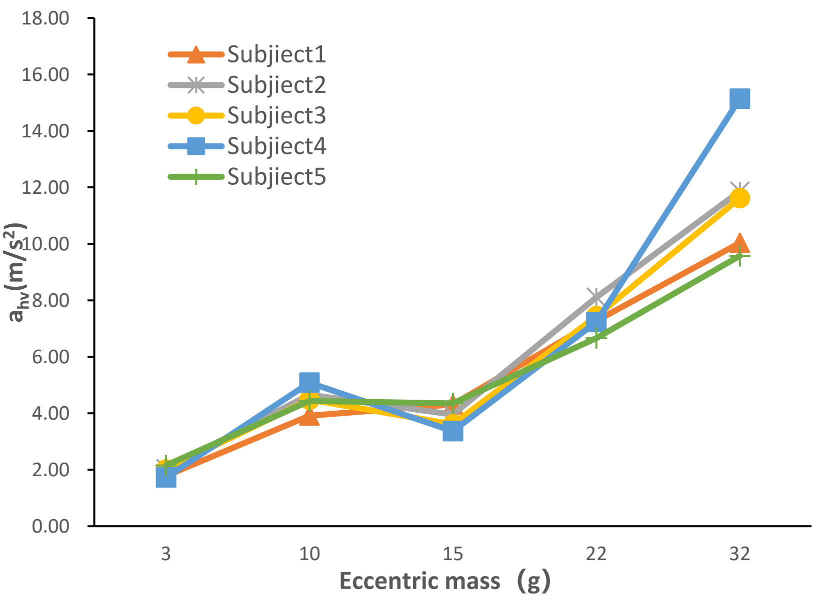

Figure 1. Comparison of results of frequency-weight accelerations in experiment (1), with five kinds of eccentric mass for the driving wheel (one subject but ten trials were performed for grinding with each eccentric mass of the driving wheel).

Table 1 shows that adjusting the angle of the driving wheel and the passive wheel led to no significant difference in the acceleration value of hand-transmitted vibration received by workers during grinding when the angle of driving wheel and passive wheel is 5° and parallel (p = 0.628).

Table 1. Results of the accelerations of hand-transmitted vibration received by workers during grinding when the angle of driving wheel and passive wheel is 5° and parallel.

The Angle of the Driving and Passive Wheels	A_{hv}, Mean ± STD (m/s^2)	t Value	p Value
5°	3.07 ± 0.36	0.491	0.628
<1°	3.01 ± 0.32		

Table 2 lists the results of putting rubber pads on the bottom of the machine. The average value of hand-transmitted vibration after adding double rubber pads is lower than adding a single rubber pad ($p < 0.05$).

Table 2. Comparison of frequency-weighted acceleration values of two kinds of pad.

Number of Rubber Pads	A_{hv}, Mean ± STD (m/s^2)	t Value	p Value
Single rubber pad	7.77 ± 0.56	−2.710	0.012
Double rubber pad	7.22 ± 0.48		

Figure 2 shows that the service life of the two different sand belts is less than that of the same type of a 3M sand belt. Among them, the WY60# sand belt can only grind approximately 19~23 golf club heads, while the 3M50# sand belt can grind approximately 33~37 heads. Moreover, The hand-transmitted vibration acceleration of the new belt (3M50#) was significantly lower than that of the old belt (WY 60#). As the number of grinding workpieces increased, the frequency-weighted acceleration values increased.

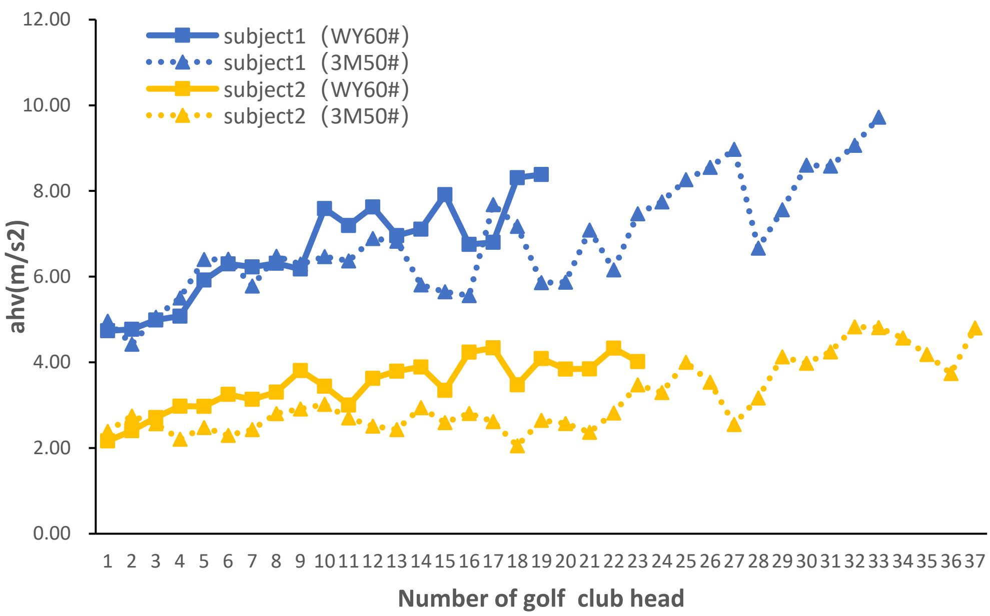

Figure 2. Comparison of the results measured in experiment 4 with two kinds of sand belts.

4. Discussion

We performed some early studies [1,5] to determine the vibration characteristics of golf club heads during the hand-held grinding process to find potential approaches for reducing vibration exposure. However, due to the limitations of our technological process, some possible measures proved difficult to realize, such as adjusting the motor speed, increasing the effective mass of the club head, etc. In this study, we tried to determine the influence of four kinds of practical measures that can be improved. Our research group compared the influence of different values of eccentric mass for the dynamic balance front wheel, the angle of driving wheel and passive wheel, the number of rubber cushions, and the new and old sand belts. The results showed that when the eccentric mass of the front wheel was increased, the vibration exposure level of test workers significantly improved. Adjusting the angle of the driving wheel and the passive wheel did not successfully reduce vibration levels. However, The vibration strength of the grinding workers can be noticeably reduced by adding more rubber pads. The hand-transmitted vibration acceleration of the new type sanding belt (3M 50#) was lower than that of the old type belt (WY 60#), and the service life of 3M in the same type belt is higher than that of the original belt. The above experiments show that, under normal operating conditions, correcting the balance of the front grinding wheel, installing double-layer rubber pads, and making use of the new model 3M sand belt all have a positive effect on reducing vibration hazards—therefore benefitting the workers. It should be noted that for most operations which involve potential exposure to hand-transmitted vibration, it is difficult to control the vibration exposure level and keep it within an acceptable range using a single method. The combination of engineering control and management control may be the best strategy for vibration prevention and control. In practical application, it should be comprehensively considered, along with the feasibility of implementation, cost-effectiveness, and its impact on production efficiency and workplace safety.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Medical Ethics Committee of Guangdong Province Hospital for Occupational Disease Prevention and Treatment (protocol code GDHOD MEC 2021 No.047 and date of approval 23 November 2021) for studies involving humans.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to privacy.

Conflicts of Interest: The authors declare no conflict of interest.

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