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Influence of Metacarpal Gloves on Hand Dexterity and Strength: A Pilot Study

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1. Background

Workers in construction and extraction occupations are often required to wear industrial gloves or metacarpal gloves to protect their hands against cuts, impacts, and other potential sources of severe injuries (Alessa et al., 2020; Sorock et al., 2004). However, when wearing those gloves, workers experience decreased dexterity, less flexibility, and reduced tactile sensitivity as well as functional strength, which may lead to an increased risk of injuries. In addition to protective factors to reduce workplace injuries, glove design and materials must be considered in selecting appropriate gloves to allow optimal dexterity, strength, sensory input, and functionality to complete work tasks efficiently (Heberger et al., 2022; Wong et al., 2020). Although previous research has been conducted regarding glove use in healthcare and manufacturing settings, there is limited research examining the impact of metacarpal gloves on manual hand dexterity within heavy-duty industries such as mining and oil and gas extraction (Woods et al., 2021). This research investigates the effect of metacarpal gloves on hand dexterity, hand strength, and the risk of fatigue.

2. Materials and Methods

Three different styles of metacarpal gloves were selected for this study. These gloves are commercially available and typically used for mining tasks, and oil and gas industries were identified from interactions with industries' safety managers. The impact protection levels of Glove-MM and Glove-SP were evaluated in Sosa and Alessa (2021). For this study, the selected gloves were identified as glove MM, glove RG, and glove SP. Each model included different combinations of natural (i.e., leather, cotton) or synthetic (i.e., nylon, polyester, Kevlar) fabric materials for the primary coverage of the hand palm, as well as different designs of thermoplastic rubber (TPR) protections on the hand's dorsal side. The distribution of TPR reinforcements on the dorsal side of the hand provides different levels of impact or cut protection to the users, but it also affects the hand's flexibility to perform specific tasks. Further details on the characteristics of the selected gloves can be found in Sosa & Alessa (2021) and Woods et al. (2021).

A randomized controlled trial (RCT) pilot study included three types of metacarpal gloves and twenty-four male participants. Approval from the West Virginia University Institutional Review Board (IRB) was given for this research study prior to the recruitment and involvement of participants. Following completion, each participant was compensated for their participation.

Upon arrival, participants' demographics, hand size, and glove size were determined. The participant selected the glove size that was the most comfortable fit around the hands and fingers. Once the participant chose a size for each glove, both hands were measured again to gather the width, length, and circumference of the hands while wearing gloves. Participants were assigned a random test condition (begin with either gloves or bare hand) and glove style. All participants completed grip, pinch, and screwdriver tests on the BTE™ testing machine. Participants also completed the turning and placing tests within the Minnesota Manual Dexterity Test for both test conditions. After completion of each testing condition, participants were asked to measure their perceived level of exertion based on the Borg Rating of Perceived Exertion (RPE) scale. Researchers followed a pre-written procedure script throughout the data collection to maximize inter-rater reliability.

The Minnesota Manual Dexterity Test (MMDT) is an assessment that evaluates dexterity in all populations (Lafayette Instruments, 2019). The test comprises a three-piece blackboard with 60 holes to fit 60 discs. Each disc is colored red and black and measures 3.7 cm in diameter. This research study utilized the MMDT test to assess the impacts of glove use on dexterity. Each participant completed the test, and their trial time was recorded. For the test, participants utilized both

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hands in picking up, turning, and replacing the disk in its original space. In the turning test, the participant picked up the disc in the left hand, flipped it over, translated it into the right hand, and then placed it down. The results of each test were compared to normative data within a participant's age range.

The second assessment used for this study is the Baltimore Therapeutic Equipment work simulator (BTE) which can evaluate grip, pinch, and pronation strength utilizing different tools (BTE Technologies, 2020). The order of the tools used and the gloves were randomized for each participant to reduce the effects of fatigue on the data results. Each tool with each motion was measured four times, once with bare hands and the other trials with the three types of gloves. The trial time was set for 3 seconds with 3 trials for each glove condition, totaling 12 trials for each tool. There was a 30-second rest break between each trial and a 3-minute rest break between each new tool condition. The BTE has been calibrated for consistency and accuracy during the data measurements (BTE Technologies, 2020).

The Borg Rating of Perceived Exertion (BRPE) was used for measuring the exertion in each assessment task. The BRPE scale is a subjective exertion measure with a scale from six to twenty. Six indicate no exertion, and twenty indicate maximal exertion. The BRPE was collected after each glove condition for both the BTE and MMDT assessments. This subjective data accompanies the quantitative numerical data for a holistic view of the participant's performance and perceived level of exertion.

3. Results and Discussion

On average, participants completed the MMDT turning more efficiently with bare hands than with gloves. During the grip, pinch, and screwdriver tests of the BTE™, participants, on average, were more effective with gloves than with bare hands. Participants completing the MMDT and BTE™ tests with gloves had higher perceived exertion levels on the BRPE. Overall results indicate that wearing metacarpal gloves may impact dexterity during tasks requiring precise grasp but may have less effect on dexterity during tasks requiring gross grip and increased hand strength. These results obtained with male participants are consistent with prior findings from Woods et al. (2021), which involved female participants.

The gloves selected for this study were also tested for impact protection, as reported in Sosa & Alessa (2021), who found that thicker gloves offer the highest level of protection when subject to controlled impacts. Conversely, thinner gloves offered a lower degree of mechanical protection (Sosa & Alessa, 2021). Our findings appear to suggest an inverse relationship between impact protection and dexterity. The more protective features the glove has, the less flexible it becomes, and the higher its impact on dexterity. Thicker gloves offer the most mechanical protection but at the expense of reduced flexibility and thus decreased dexterity. Conversely, thinner gloves offer lower mechanical protection but allow much more dexterous function. Safety professionals should consider both aspects: protection and dexterity, in the selection of gloves for tasks to maximize compliance.

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