Effect of Working Position on the Perceived Fatigue while Drilling on the Ceiling

Jangwhon Yoon

Department of Physical Therapy, Dongshin University, Naju, Jeonnam, 520-714

ABSTRACT

Objective: The purpose of this study is to compare the performance of drilling on the ceiling in three different positions (standing, standing on ladder and lying on the floor) and the subjective responses of perceived fatigue after the drilling.

Background: Drilling on the ceiling is harmful for construction workers due to the awkward posture and prolonged static nature of task. Method: Ten young participants (20-45 years of age) without any recent pain during the past month or any history of neuromuscular disorders in the neck and upper extremities drilled 20 holes at the pre-marked places on the ceiling in supine, standing and standing on the ladder. Perceived fatigue at neck, shoulder, elbow, hand and overall body was asked separately at the end of each task. One-way ANOVA and Tukey post-hoc test were used to test the effect of test condition on dependent variables. Results: Perceived fatigue in the neck decreased in supine, while there was no statistically significant difference in the shoulder, elbow, hand and overall body. Conclusion: The perceived fatigue on the overall body while drilling on the ceiling was worst in ladder standing and best in supine position. Application: The result of this study suggests a better way of drilling on the ceiling with less perceived fatigue in the neck.

Keywords: Drilling, Perceived fatigue, Neck, Posture

1. Introduction

Overhead work has been identified as a major occupational risk factor and has been a main research subject. Epidemiologic, physiological and biomechanical studies (Bjelle, Hagberg, & Michaelson 1981;Punnett et al. 2000;Sakakibara et al. 1995;Svendsen et al. 2004) found evidences to relate the overhead work and the prevalence of work-related musculoskeletal disorders, especially in the neck and shoulder joint. A dose-response relationship was discovered (Bjelle, Hagberg, & Michaelson 1981;Hagberg & Wegman 1987;Holmstrom, Lindell, & Moritz 1992;Svendsen, Bonde, Mathiassen, Stengaard-Pedersen, & Frich 2004). Mechanical impingement of the bicipital and supraspinatus tendons in the subacromial region may occur, especially if shoulder elevation is in the 60 to 120 range or at the end range of motion (Flatow et al. 1994). Since the tendons in these regions have atypical vascularity (Lohr & Uhthoff 1990;Seiler, III et al. 1989), repetitive shoulder motion and prolonged static task in these ranges can lead to tendonitis or rupture of the rotator cuff. Increasing hours of overhead work is strongly associated with shoulder pain and disorders (Holmstrom, Lindell, & Moritz 1992;Welch, Hunting, & Kellogg 1995). The mechanism of injury is commonly explained by decreased blood supply due to increased gravity and intramuscular pressure (Hagberg & Wegman 1987;Jarvholm et al. 1991) and mechanical impingement under the acromion (Flatow, Soslowsky, Ticker, Pawluk, Hepler, Ark, Mow, & Bigliani 1994).

In the construction industry, overhead drilling into concrete ceiling is one of the most physically demanding tasks (National Institute for Occupational Safety and Health(NIOSH). 2002). Rosecrance and his colleagues (Rosecrance et al. 2001) reported that 41% of a sample of construction workers in the pipe trades with high demand for ceiling drilling complained of work-related shoulder pain, with tasks performed in differing postures including directly overhead.
Drilling on the ceiling is hazardous for construction workers due to the awkward posture and prolonged static nature of task and it is typically performed in standing on a ladder or scaffold. However, identification of its relationship to work-related musculoskeletal disorders does not solve the problem. Working in overhead posture is unavoidable at the construction sites. Oftentimes, the extra-weight and vibration of the hand tools make the situation worse. Rempel and his colleagues (Rempel D et al, 2008) attempted to develop and evaluate different ways for overhead drilling. An inverted drill press and a lever design could avoid the awkward posture of upper extremity and improve the worker's usability rating and the perception of fatigue during drilling (Rempel et al. 2009). However, the new interventions had minimal effect on the awkward neck posture because the workers still had to look up at the ceiling while standing on the floor instead of on the ladder. In addition, the productivity of drilling was decreased by affecting the working speed and accuracy. When the distance between tool and body increased, it obviously takes more time and effort.

Working on a motorized lifting platform is common at construction sites. By lying down on the lifted platform, a worker may be able to perform better in drilling on the ceiling with less discomfort and risk of injury. In this way, the distance between tool and body can be maintained minimal and the worker can avoid the awkward position in neck and shoulders. The influences on the worker’s body fatigue of drilling in supine position have not been tested yet, as far as I know. The purpose of this study is to suggest a better way for overhead drilling with less perceived discomfort in the neck and upper extremity.

2. Method

2.1 Subject Recruitment

Ten young voluntary participants (20-45 years of age) without any recent pain during the past month or any history of neuromuscular disorders in the neck and upper extremities were recruited. All participants were asked to read and sign the consent form approved by the Office of Institutional Board of Research Associates of New York University School of Medicine.

2.2 Testing Procedure

Upon arrival, participants were informed of the study procedure and the height and weight were measured. Participants were provided with the safety goggles and a disposable mask for protection. Upon request, a lab gown and a shower cap were provided to avoid the wood dust from their clothes and hair. Sufficient (5 to 10 holes) drilling practice period was provided with demonstration prior to data collection. Condition 1 was drilling 20 holes on the height adjusted wooden board at the subject’s wrist level with the arm fully elevated in standing position (Figure 1). Condition 2 was drilling 20 holes on the board placed on the ceiling using a type IA ladder (Figure 2). Condition 3 was drilling 20 holes on the height adjusted board at the subject’s wrist level with the arm vertically elevated in the supine position (Figure 3). 20 drilling targets were pre-marked by spraying over a punctured cardboard. The order of the testing conditions was randomized. There was a 2-minute break before each trial. Participants were asked to drill as fast as they can and to hold the drill with both hands.
2.3 Instruments

A 2.27 kg cordless drill (DeWalt 3/8” VSR Cordless DW991, Hampstead, MD, USA) was used. An oval-shaped drill, with the handle circumference of 14.5 cm (4.8 cm front to back, 3.7 cm wide), hard plastic near the trigger, and a rubber anti-slip grip was used throughout. A battery pack is attached at the bottom of the handle, which balances the drill in the palm when positioned vertically. A 2.4 m long, type IA step ladder (136 kg load capacity, Werner 6208, Greenville, PA, USA) was used for Condition 1 and 2. A custom-maid moving platform will be used for Condition 3.

2.4 Data Collection

Perceived discomfort (0: comfort and 10: most
discomfort) at neck, shoulder, elbow, hand and overall body was separately asked at the end of each task. Rating of perceived discomfort was found to be more reliable than the fatigue measure based on electromyography in overhead activity (Sood, Nussbaum, & Hager 2007).

2.5 Data Analysis

One-way analysis of variance tested the effect of working posture on the perceived discomfort. When there was a statistically significant ($p < 0.05$) effect of working posture, Tukey post-hoc analysis was followed for pair-wise comparison. SPSS version 13 was used for statistical analysis.

3. Results

The levels of reported discomfort on the overall body, shoulder, elbow, and hand were not statistically significant different ($p = 0.130$ for overall body, $p = 0.192$ for shoulder, $p = 0.844$ for elbow, and $p = 0.868$ for hand) between drilling positions (Figure 4). However, the levels of reported discomfort on the neck was significantly ($p = 0.034$) affected by drilling positions. Drilling in supine position had significantly ($p = 0.040$) lower neck discomfort than drilling on the ladder. There was no significant difference in the neck discomfort level between supine and standing ($p = 0.096$) and between standing on the ladder and standing positions ($p = 0.911$).

The perceived discomfort in the neck after the drilling was lower in supine position than in standing on the ladder. It was fail to find statistical significance in the perceived discomfort in the other part of the body. Most of the participants reported no perceived discomfort in the neck and much improvement in shoulder and overall body in supine position. Some of the participants reported increased discomfort in the elbow in supine position. On a study with electromyography (Anton et al. 2001), the farther away from the head (far reach and low step), the more muscle recruitment and shoulder joint moment were observed while drilling on the ceiling on the ladder. Sood and his colleagues (Anton, Shibley, Fethke, Hess, Cook, & Rosecrance 2001) found a non-linear relationship between drilling height and perceived discomfort, with the highest rates observed at the most extreme reaches.

Couple of participants suggested raising the head side for more comfort. It may worthy to consider a reclined long sitting position for shorter distance between head and the drill, avoiding the wood dust from face, and less load on the elbow muscles. Drilling in supine or reclined long sitting position can be an alternating working position for some workers who have problem in the neck and when there is increased workload of drilling on the ceiling.

Limitation of this study was, firstly, the samples size was small. That may be why failing to show the statistical significance on the perceived fatigue on the shoulder and overall body. Secondly, even the participants had some experiences in drilling, they were not professionals. The relationship between working posture and perceived discomfort in professionals can be different. Thirdly, drilling 20 holes, which took about 2 minutes, seems to be far less than what the workers do at real construction site.

4. Conclusion

The purpose of this study was to compare the performance of drilling on the ceiling in three different positions (standing, standing on ladder and lying on the floor) and the subjective responses of perceived fatigue after
the drilling. Ten young participants drilled 20 holes at the pre-marked places in each position. Perceived fatigue in the neck decreased in supine position. The result of this study suggests another way of drilling on the ceiling with less perceived fatigue in the neck.

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References


Author listings

Jangwhon Yoon: yoon@dsu.ac.kr

Highest degree: PhD, Graduate Program in Ergonomics and Biomechanics, NYU

Position title: Assistant Professor, Department of Physical Therapy, Dongshin University

Areas of interest: Ergonomics, Work-related Musculoskeletal Disorders, Lower Back Pain, Injury Prevention and Management, Product Design