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Investigating shoulder muscle loading and exerted forces during wall painting tasks: Influence of gender, work height and paint tool design

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ABSTRACT

The task of wall painting produces considerable risk to the workers, both male and female, primarily in the development of upper extremity musculoskeletal disorders. Insufficient information is currently available regarding the potential benefits of using different paint roller designs or the possible adverse effects of painting at different work heights. The aim of this study was to investigate the influence of gender, work height, and paint tool design on shoulder muscle activity and exerted forces during wall painting. Ten young adults, five male and five female, were recruited to perform simulated wall painting at three different work heights with three different paint roller designs while upper extremity muscle activity and horizontal push force were recorded. Results demonstrated that for female participants, significantly greater total average ($p = 0.007$) and integrated ($p = 0.047$) muscle activity was present while using the conventional and curly flex paint roller designs compared to the proposed design in which the load was distributed between both hands. Additionally, for both genders, the high working height imposed greater muscular demands compared to middle and low heights. These findings suggest that, if possible, avoid painting at extreme heights (low or high) and that for female painters, consider a roller that requires the use of two hands; this will reduce fatigue onset and subsequently mitigate potential musculoskeletal shoulder injury risks.

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1. Introduction

House painters are a sub-group of construction workers with a high reported incidence of shoulder complaints (Stenlund et al., 2002). These shoulder complaints have in turn lead to a high risk of early retirement with disability pensions related to shoulder injuries (Lindbeck et al., 1997). Supraspinatus tendonitis is a common shoulder injury incurred by house painters (Stenlund et al., 2002). According to a research study funded by The Center to Protect Workers' Rights conducted in Washington, D.C. (Hunting et al., 2004), 5% of injured construction workers reporting to emergency rooms over a 7-year period were painters and 4% of all construction workers had shoulder-related injuries. Repetitive strain injuries are the most common and costly occupational health problem according to the U.S. Department of Labour (RSI Statistics, 2007). The cost of a worker compensation claim for a repetitive stress injury is between $20,000 USD and $100,000 USD (RSI Statistics, 2007).

Limited research exists evaluating the effects of painting or sanding techniques on shoulder loading. However, research by Stenlund et al. (2002) has examined this specifically for ceiling work. Researchers described three possible techniques employed by the worker. Of these three techniques, the "pushing technique" produced the least amount of strain on the supraspinatus muscle. This technique required the worker to hold an extension handle with both thumbs pointing upwards while they moved the shaft back and forth in the sagittal plane. The main difference between this technique and others (the "normal grip" and "reversed grip") was the way in which the shaft was moved; with the remaining techniques requiring pivoting and rotating movements. Researchers used a biomechanical model to predict individual supraspinatus muscle forces, which were expressed as relative values proportionate to the respective maximal capacities of the supraspinatus muscle. The average normalized supraspinatus muscle force was 5.19% for the "reversed grip" technique, 5.11% for the "normal technique" and 2.15% for the "pushing technique". Similarly, workers who used the "pushing technique" reported fewer shoulder disorders, suggesting that this technique may reduce the occurrence of shoulder tendonitis. No further research has been presented that examines shoulder loading during vertical

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wall painting. Additionally, the influences of paint tool design on shoulder loading remain unknown; with few attempts made to improve the tool's original design from an ergonomic perspective.

Though the research examining wall painting specifically is limited, other researchers have evaluated tasks that involve comparable upper extremity loading. The design of current paint roller handles require elevated shoulder postures in order to perform horizontal paint strokes. Numerous research studies have documented that arm elevation leads to large increases in shoulder muscular activity levels (Chopp et al., 2010; DeLuca and Forrest, 1973; Walker and Poppen, 1977; Sigholm et al., 1984; Inman et al., 1944; Hagberg, 1981). This increase in muscle activity can subsequently lead to muscle fatigue development (Grieve and Dickerson, 2008) and subsequent pain and discomfort (Wiker et al., 1989). Specifically, occupations that involve elevated arm tasks may lead to "degenerative tendonitis" in the biceps and supraspinatus muscles (Bjelle et al., 1973, 1987; Herberts et al., 1981; Hagberg, 1988). Due to the high incidence of shoulder pain among house painters, it is critical to evaluate the work-related factors that may contribute to excess shoulder load demands and provide recommendations for reducing the risk of upper extremity discomfort.

House painting is a task performed by both genders, which is an important consideration that needs to be addressed. Females are more strength limited than males, with differences greater than 50% in the upper extremity (Miller et al., 1993). As this task has the potential for significant upper extremity loading, it is important to evaluate the possible additional demand experienced by females from executing the same wall painting task.

The purpose of this study was to investigate the influence of gender, work height, and paint tool design on shoulder muscle activity and the horizontal force applied to a vertical paint surface by the paint roller during simulated wall painting. This included testing four specific linked hypotheses:

- Females will demonstrate increased muscle activity compared to men for a given painting task. This is based on the established lower upper limb strength of females, and the consistent paint tool designs used in the study (Miller et al., 1993).
- Work height will influence shoulder muscular activity during simulated wall painting, such that the middle work height produces the lowest muscular loading. This is consistent with other studies that have shown middle or low work heights to have lower mechanical demand for electrical meter installation (Chopp et al., 2011), and lower subjective ratings for a screw-driving task (Ulin et al., 1990) than high work heights.
- The force exerted on a wall will not differ across all work heights as the external task requirements are the same.
- Different paint tool designs will influence the level of shoulder muscular activity associated with simulated wall painting due to their difference in weight, as well as the postures that participants will adopt when using the painting tools.

2. Methods

2.1. Participants

Five male and five female participants took part in this study. Inclusion criteria consisted of right-handed undergraduate students between the ages of 18–25 years with no self-reported history of musculoskeletal symptoms in the past 12 months. Demographic information (height and weight) of study participants were recorded and the mean values were calculated. The mean height and weight of male participants were 178.2 cm (SD = 7.76) and 87.6 kg (SD = 14.77) respectively. Alternately, the mean height and weight of female participants were 161.2 cm (SD = 4.16) and 54.2 kg (SD = 3.31) respectively.

2.2. Experimental design

An experimental counterbalanced design was utilized in this study. All participants completed each of the nine randomized experimental conditions described in Section 2.3. Each trial was coded with a specific number (1–9). Using the website "research randomizer", trial order was randomized. The following parameters were specified to use the program: sets of numbers = 10 (10 participants); number range 1–9 (9 trials); each number in the set was unique. This resulted in 10 sets of randomized numbers ranging from 1 to 9 which were used for trial order.

2.3. Independent variables

Three variables were considered in this study; gender, work height and paint tool design (Table 1). Each gender performed each of nine conditions, which included combinations of three work heights (high, middle, and low) and paint tool design (conventional, curly flex, and a proposed novel design).

2.3.1. Work height

Three wall sections were examined in this study (high, medium and low). Due to anthropometric variations in the participants tested, wall sections were normalized to each subject. The middle of the high, medium and low wall sections were aligned with the participants stature, elbow and knee heights, respectively. A height adjustable frame was developed to ensure the wall sections could be adjusted with ease (Fig. 1). The dimensions of the wall sections were 3 feet long by 2 feet high and the overall height of the adjustable frame was 6 feet 1 inch.

2.3.2. Paint tool design

Currently, there are three major different paint tool designs on the market; two were evaluated in this study (Table 1). The "Conventional Paint Roller" used consisted of a 5-wire roller frame that fits all 240 mm roller covers (Fig. 2a). It has threads for attaching extension poles. The "Curly Flex Paint Roller" by Curly Flex claims that its ergonomic design will require less wrist strength (Fig. 2b). It further claims to create more pressure on the paint surface than traditional paint rollers. Finally, it asserts that applying paint with this tool will be smoother and will require less effort than other rollers. A modified conventional paint tool design was also developed for this study to provide more flexibility in the grip orientation of the paint handle (Fig. 2c); this new design, termed the "Proposed Paint Roller", was the third paint roller tested.

2.4. Dependent variables

Electromyography and horizontal force were collected to identify changes in shoulder loading and force application caused by the manipulated independent variables.

Table 1
Independent Variables (Gender, Work height, Paint tool design).

Gender	Work height	Paint tool design
Female	High work height	Conventional Paint Roller
Male	Medium work height	Curly Flex Paint Roller
	Low work height	Proposed Paint Roller Design

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