THE INFLUENCE OF WALL PAINTING ON SHOULDER MUSCLE ACTIVITY AND HORIZONTAL PUSH FORCE

Patricia M. Rosati and Clark R. Dickerson
Department of Kinesiology, University of Waterloo, Waterloo, ON N2L 3G1

Background:

House painters are a group of construction workers that commonly develop shoulder musculoskeletal disorders (Stenlund et. al., 2002). A specific disorder typically incurred by these tradesmen is supraspinatus tendonitis. Information regarding shoulder loading during ceiling painting is available. However, no comparable data sets exist for wall painting. Even less information is available on the benefits of using different paint roller styles or the consequences of wall painting at different heights.

Purpose:

The purpose of this study was to investigate the influence of paint roller design, wall height and gender on shoulder muscle activity and force applied during standard wall painting. This study tested four specific hypotheses:

1. Females will experience greater muscular loading for a given task.
2. The middle wall height will produce the lowest muscular loading.
3. The force applied to the wall will be consistent among the tested wall heights.
4. The conventional design will have the greatest muscular loading amongst rollers.

Methods:

Subjects: Five male (stature 178.2 ± 7.8 cm; body weight: 87.6 ± 14.8 kg) and five female (stature 161.2 ± 4.1 cm; body weight: 54.2 ± 3.3 kg) healthy, right-handed undergraduate students participated in this study.

Independent Variables: Three variables were modified; gender (2 levels), wall painting height (3 levels: high, medium, and low) and paint roller design (3 levels: conventional, Curly Flex, ergonomic design).

a) Conventional b) Curly Flex c) Ergonomic Design

Figure 1: Paint Roller Designs

Dependent Variables: Electromyography, optoelectronic motion analysis and horizontal push force were collected to identify changes caused by the independent variables.

Electromyography: The electrical activity of six right upper arm and shoulder muscles were collected using surface electrodes. These muscles included: anterior deltoid, middle deltoid, posterior deltoid, pectoralis major (clavicular insertion), biceps brachii and upper trapezius.

Optoelectronic Motion Analysis: Body movement was monitored using the Vicon MX20, optoelectronic motion analysis system, equipped with eight 2.0 mega pixel cameras. Nineteen sites were tracked with reflective markers.

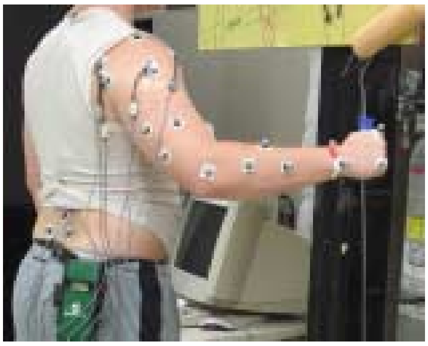

Figure 2: Surface Electrode and Reflective Marker Placements

Push Force: A MC3A-500 force transducer measured the force exerted by subjects while painting. The transducer was mounted to the back of the painting surface.

Figure 3: Paint Surface With Force Transducer Attached

<u>Experimental Considerations</u>

Painting Technique: The "zigzag" technique was identified as the most effective method of painting with a roller (Curtis, 2007). One cycle of the technique was completed per experimental trial. The steps to perform this technique are as follows:

1. First, a zigzag pattern is painted with the first stroke moving away from the participant.
2. Without lifting the roller, horizontal strokes are performed to further spread the paint.
3. Last, light vertical strokes ensure evenly spread paint

To ensure all subjects followed this technique, directional lines were marked on the paint surface and subjects were asked to follow the markings when performing their painting trial. To follow the markings subjects were instructed to start at the red line located in the bottom right corner, proceed to the green line, and finish with the black line.

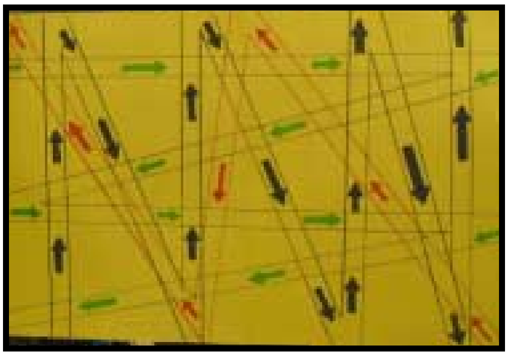

Figure 4: Paint Surface Directional Lines

Painting Height: Three wall sections were examined in this study (high, medium and low). 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.

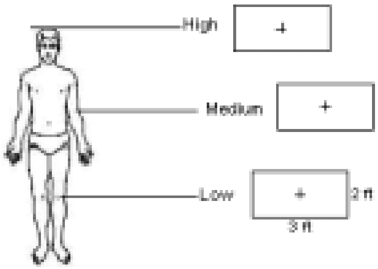

Figure 5: Painting Heights
(High, Medium, Low)

Tool Handling: Subjects were restricted to use their right hand when using the traditional paint roller and the curly flex plaint roller. The proposed ergonomic design required subjects to use two hands. For up and down strokes the paint roller was held as shown in Figure 6 (A) and side to side strokes were performed as shown in Figure 6 (B).

A – Up and down

B – Side to side

Figure 6: Proposed roller design tool handling

Experimental Protocol: At the start of each testing session, participants read an information letter and signed a consent form. Participant characteristics (age, height, gender and dominant hand) were documented and electrodes and body markers were attached to the subject. Next, two maximal exertions were collected for each muscle, separated by 2 minutes of rest (12 total; 6 muscles x 2 exertions).

Participants were familiarized with the zigzag painting technique by performing three practice trials at the medium wall height. Next, the participant executed all experimental trials (9 total; 3 paint roller designs x 3 wall heights) in a randomized order. One experimental trial consisted of performing one cycle of the zigzag painting technique at a specified height.

Results/Discussion:

Gender, wall height and roller type were found to affect both specific and average muscular activity, as well as the amount of horizontal force applied during wall painting.

Gender: Our findings support the hypothesis that females would have higher muscular demands than males. However, the average force and peak force of females was lower then males, suggesting that females use a greater percentage of muscular effort to complete the painting tasks. This difference may be attributable to physiological upper extremity gender differences. Documented differences exist in upper extremity strength and muscle fiber characteristics for males and females. Miller et al. (1993) found that females are between 52% and 66% as strong as men in the upper extremity and have 45% less cross-sectional area in the biceps brachii muscle then males.

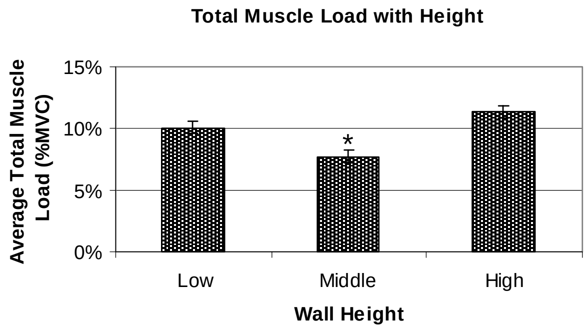

Figure 7: Average Total Muscle Load (%MVC) vs Wall Height

Wall Height: Shoulder muscular activity was expected to be the greatest at the high wall height, and a trend, though not significant, to this situation existed. Muscle activity was, however significantly lower at the middle wall height than the other two heights (low and high). Ulin et al. (1990) found similar results for a screw-driving task using psychosocial scales, as subjects preferred driving screws between 114 and 139 cm above the standing surface (comparable to the middle wall height in the current study), regardless of anthropometry. Arm abduction is known to cause increases in shoulder muscle activity levels (DeLuca and Forrest, 1973). It is probable that the lower muscle activity at the middle height was due to the minimization of arm abduction at this level.

The force applied to the wall during wall painting was consistent among the tested wall heights, implying that while using a given paint roller, the average and peak forces remain the same at any work height. Despite consistent force at all heights, muscle activity was affected, which supports the contention that arm posture causes the differences.

Roller Design: Total average EMG for the conventional roller and the curly flex roller were both significantly higher compared to the ergonomic paint roller design. Most muscles were not affected by roller design, except for middle deltoid and biceps brachii, for which the ergonomic design significantly reduced muscular activity. This roller may have successfully reduced muscular loading for the right shoulder by distributing the weight between both hands, or, it is possible that subjects took longer to complete the trial while using ergonomic roller and therefore resulting in lower average EMG.

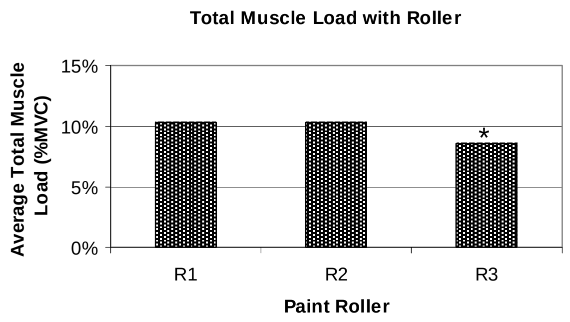

Figure 8: Average Total Muscle Load (%MVC) vs Paint Roller (R1 – conventional, R2 – Curly Flex, R3 – Ergonomic Design)

Implications for muscular fatigue: Previous research has documented that prolonged static elevated arm tasks at 10% MVC is adequate to cause muscular fatigue, including for repetitive arm loading (Jonsson, 1988). In our study, the average muscular activity of females was above the 10% threshold, while males were below. The average %MVC for wall height showed a similar trend such that the middle wall height was below the 10% threshold and the other two heights were above. Paint roller design also displayed similar results whereby the proposed design was below the 10% MVC threshold and the other two rollers were above. This suggests that the proposed design is least likely to cause muscular fatigue. These lead to conclusions regarding preferred painting conditions and possibly personnel.

Conclusion:

In general, males working at the middle wall height, with the proposed ergonomic roller design are least likely to become fatigued while painting. Painting should be completed primarily at the middle wall height where possible. When painting at a high wall height, it is recommended that painters stand on a platform/ladder to simulate painting at the middle wall height.

The amount of force applied to the wall does not change with respect to wall height. However, amount of force applied to the wall varied with paint roller design; the proposed design resulting in the highest average and peak force. Future research should investigate the bilateral effect of the proposed ergonomic roller design in addition to the effect of alternative tool handling.

REFERENCES

Curtis, W. (2007). How To Paint A room. June 19, 2007; http://home.howstuffworks.com/how-to-paint-room.htm

DeLuca, C. J. and Forrest, W. J. (1973). Force Analysis of Individual Muscles Acting Simultaneously on the Shoulder Joint during Isometric Abduction. J. Biomech., 6, 385-393.

Jonsson B. (1988) The static load component in muscle work, EJAP 57:305-310.

Lindbeck, L. (1997) A method to determine joint moments and force distributions in the shoulders during ceiling work –a study on house painters. Clin Biomech. 12:452-460.

Miller A., MacDougall J., Tarnopolsky M, and Sale D., (1993). Gender differences in strength and muscle fiber characteristics, EJAP 66:254-262.

Stenlund, B., Lindbeck, L. and Karlsson, D. (2002) Significance of house painter's work techniques on shoulder muscle strain during overhead work. Ergonomics. 45, 455-468.

Ulin, S., Armstrong, T., Snook, S. and Keyserling M. (1993). Perceived exertion and discomfort associated with driving screws at various work locations and at different work frequencies. Ergonomics, 36(7), 833 – 846