THE EFFECT OF WORK SPEED AND TASK PRECISION ON PERCEIVED FATIGUE AND MUSCLE ACTIVATION IN THE ARMS AND SHOULDERS

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ABSTRACT

Work speed and task precision are frequently mentioned as risk factors for work related musculoskeletal disorders but their effect is not clear. This study examines the effect of a combination of 4 task speeds and 2 precision levels on a manual stapling task. Muscle activation in the wrist extensors, wrist flexors, and trapezius musculature using the APDF, perceived task difficulty and fatigue were measured. The results indicate that task speed affects wrist flexor and extensor EMG and task precision effects static wrist flexor EMG, only. There was no effect of speed or precision on trapezius muscle activity, staple force, or subjective fatigue. Both speed and precision affected the difficulty of the task. Changes in static and dynamic EMG characteristics suggest an increased exposure to the injury mechanisms for muscular strain.

INTRODUCTION

Work speed and task precision are frequently mentioned as risk factors for work related musculoskeletal disorders of the upper limb. However, it is not known how changes in task speed or precision influences the risk of developing an upper limb injury. This study examines the effect of altering the speed and precision of a manual stapling task on factors associated with musculoskeletal disorders of the upper limb. The factors are muscle activation of the forearm and shoulder regions, the hand grip force, and the perceptions of fatigue and task difficulty.

METHODS

A laboratory simulation of an industrial task was created to maintain control over intervening factors. The task was to staple *8* rectangles on a target sheet. The rectangles were two different sizes (levels of precision) and they were stapled at four different speeds. Audio signals were used to control the work cycle and speed of stapling. A work cycle was stapling one target sheet, counting errors, and replacing the paper in the holder. A constant period of 22 s was included in the work cycle to allow errors to be counted and the target sheet to be replaced. The conditions were within the skill level of all subjects (≤ 5% error score). The speeds used were 25, 45, 65, and 85 staples per minute or slow, medium, fast and very fast. The precision levels were quantified using the Index of Difficulty (ID) (Fitts, 1954). The ID was 1.7 and 3.9 for the low and high precision levels. Six test conditions were studied. All 4 speeds were studied for the high precision level and the slow and very fast speeds were studied for the low precision level. After a stapling warm-up, subjects were randomly presented with the 6 test trials while resting for 10 minutes between each trial. Six female subjects (mean age 24 years) were given $10.00 to participate in the study and $30.00 was awarded for the lowest error rate.

The stapler was instrumented with two strain gauges to measure the force in the upper grip handle. A marker switch identified when the stapler was half closed or open. The electromyographic (EMG) signals from silver-silver chloride disposable electrodes (Meditrace Pellet) placed over the wrist flexors, wrist extensors, and the upper fibres of the trapezius were collected. The EMG signals were full wave rectified, and low pass filtered at 1.5 Hz. The linear envelope EMG signal (LE EMG) was normalized to 100% maximum voluntary contraction (MVC) and the amplitude probability distribution function (APDF) was calculated. The subjects rated their perceived fatigue and the task difficulty using scales from 1 to 10 (eg. no challenge to maximal) modified from Borg (1982). The stapling portion of the work cycles were concatenated to create one file for each test condition. The dependent measures were analyzed using analyses of variance techniques, alpha level of .05.

RESULTS

Staple Force and EMG

There was not a significant influence of speed on the mean peak force of the staples. The precision level of the task also did not influence the stapling force (Table 1). To minimize errors, the subjects could have used the extra time during the slower speeds to ensure sufficient grip force to close the staple. This goal may have masked any effect due to changes in stapling speed.

Evaluation of the flexor APDF curve indicated a significant main effect of speed at the static ($F(3, 25) = 6.75$, $p = .0017$), median ($F(3, 25) = 3.17$, $p = .0417$), and peak levels ($F(3, 25) = 10.37$, $p = .0001$) (Table 2). In addition to speed, the high precision task produced a larger static load on the wrist flexor muscle then the low precision task, $F(1, 25) = 5.58$, $p = .0262$ (Table 3). As was seen with the wrist flexors, the speed was found to influence all three levels of the APDF curve of the wrist extensors, static ($F(3, 20) = 4.37$, $p = .0161$), median ($F(3, 20) = 4.71$, $p = .0121$), and peak ($F(3,20) = 5.40$, $p = .0069$). The EMG amplitude was greater during the very fast speed then during the slow speed at the static, median, and peak levels, $p < .05$ (Table 2). There was no main effect of precision level for the wrist extensor muscle (Table 3). There was no effect of speed or precision on the trapezius muscle. (Table 1).

As expected, the subjects did not perceive that task speed or task precision influenced their fatigue level ($p > .05$) but they did find that both the task speed and precision influenced the task difficulty, $F(1, 25) = 14.14$, $p = .0048$ (Table 1). The task conditions were developed with the goal that they did not promote subjective fatigue. The very fast speed was chosen so subjects were able to perform the task but found it challenging to reach an error rate of ≤ 5%. The low precision task at the slow and very fast speeds were not found to differ in difficulty ($p > .05$).

DISCUSSION

The stapling task was developed to present different speed and precision conditions within the subjects abilities and without significant fatigue effects, similar to industry. This was supported by the findings that the subjects did not perceive fatigue differences between the conditions but did find that the high precision task was more challenging at the very fast speed than the slow speed. Similar EMG results for the wrist extensor and flexor muscles were expected, since both are active during the power grip (Jonsson and Nilsson, 1979). This was supported by the significant influence of task speed on both wrist flexor and extensor EMG (static, median, and peak level). The influence of task precision on the static level of EMG activity corresponds with Westgaard and Bjorklund's (1987) speculation that a precise task requires more control and stabilization. It would then be expected that both the flexors and extensors would be influenced by precision. However, the precision of the task was found to influence the static level of the wrist flexors, only.

The trapezius muscle was not found to be influenced by the speed or precision of the task. This finding was contrary to the finding of Odenrick (1988) which studied chain saw assembly. A chain saw task may have required more gross shoulder movements then this stapler task which may explain the discrepancies in the findings. In addition, trapezius muscle activity, in response to changes in task demands, is dependent on the individual. Westgaard and Bjorklund (1987) found that EMG amplitude of the trapezius was affected by the increases in the speed of a task only when the subject had a low level of muscle activity at low speeds. It was expected that the increased visual attention required during the high precision task would result in changes in posture and, thus, trapezius muscle activity. The high precision task created in this study may not have required sufficient posture changes to produce an effect.

Table 1. Mean peak staple force (N), difficulty and fatigue ratings for all conditions. Ratings based on the 10 point scale from Borg (1982) (Between subject-standard deviation). Significant relationships identified with *.

Variable	Task Speed -Task Precision					
	Slow High	Med. High	Fast High	V.Fast High	Slow Low	V.Fast Low
Mean Peak Force (N)	105.6 (35.6)	103.5(34.5)	102.5(32.5)	105.3(35.6)	100.4 (29.8)	98.6 (32.8)
Difficulty Rating	1 (.5)*	1.4 (.7)	3 (1.1)	3.8 (1)*	1.2 (1.6)	1.6 (1.4)
Fatigue Rating	1.8 (2.1)	2.1 (1.3)	2.7 (2)	2.4 (1.9)	2.3 (2.5)	1.4 (1.1)
Traps EMG-Static	4.6 (3.4)	5.8 (2.7)	5.3 (2.5)	3.5 (3)	3.9 (3.9)	4.5 (2.8)
Traps EMG-Median	8 (3.4)	9.2 (3.2)	8.5 (3.4)	6.6 (3.1)	6.5 (4.1)	8 (2.6)
Traps EMG-Peak	11.6 (4.9)	13.5 (4.2)	12.6 (4.2)	10 (3.9)	9.9 (4.1)	12.3 (3.4)

CONCLUSIONS

The results of this study indicate that as the speed of the stapling task increases the static and dynamic muscle activity of the wrist and finger flexors increase. Task precision affected the static muscle activity of the wrist flexors. This suggests an increased exposure to the injury mechanisms for muscular strain due to changes in both static and dynamic values of the EMG signal (Moore et al., 1991).

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Table 2. Static, median, and peak wrist flexor and extensor EMG (%MVC) for the slow, medium, fast, and very fast speeds (Between-subject standard deviation). Significant relationships identified with *, •, Δ, ◊, †, and ‡.

Variable	Flexors			Extensors		
	Static	Median	Peak	Static	Median	Peak
Slow	5.5 (3)*	8.8 (4.5)Δ	30.4 (11.3)•	8.9 (4.4)◊	12.7 (5.4)†	25.4 (9.2)‡
Medium	7.5 (4.3)	11.3 (4.5)	42.6 (9.8)	11 (5.3)	14.9 (6.2)	33.5 (12.1)
Fast	7.9 (5.3)	11.9 (5.7)	44.5 (13)•	9.9 (4.8)	13.7 (5.5)	34 (11.5)
Very Fast	8.7 (3.6)*	14.1 (5.1)Δ	48.6 (10.8)•	11.3 (4.4)◊	16.6 (6.1)†	37.4 (13.3)‡

Table 3. Wrist Flexor and Extensor EMG (%MVC) for low and high precision conditions (Between-subject standard deviation). Significant relationships identified with *.

Variable	Flexors			Extensors		
	Static	Median	Peak	Static	Median	Peak
Low Precision	6.3 (3.8)*	10.7 (5.6)	41.4 (12.3)	10.2 (4.8)	15 (6.4)	33.1 (14.2)
High Precision	7.8 (4)*	11.9 (5)	39.8 (15.5)	10.3 (4.5)	14.3 (5.6)	31.8 (12.7)