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Biomechanical analyses of prolonged handwriting in subjects with and without perceived discomfort

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ABSTRACT

Since wrist-joint position affects finger muscle length and grip strength, we studied its biomechanical relevance in prolonged handwriting. We recruited participants from young adults, aged 18–24, and separated them into control ($n = 22$) and in-pain ($n = 18$) groups, based whether or not they experience pain while handwriting. The participants then performed a writing task for 30 min on a computerized system which measured their wrist-joint angle and documented their handwriting kinematics. The in-pain group perceived more soreness and had a less-extended wrist joint, longer on-paper time, and slower stroke velocity compared to control group. There was no significant difference in handwriting speed and quality between the two groups. The wrist extension angle significantly correlated with perceived soreness. Ergonomic and biomechanical analyses provide important information about the handwriting process. Knowledge of pen tip movement kinematics and wrist-joint position can help occupational therapists plan treatment for individuals with handwriting induced pain.

1. Introduction

Handwriting is a fundamental skill needed for everyday activities that can be performed with many different hand positions and pen-holding styles. It is an essential, fine motor skill directly related to most school activities. The ability to produce fluent and legible script is important for expressing, communicating, and recording ideas, as well as for educational development, achievement in school, and self-esteem (Phelps, Stemple, & Speck, 1985).

With the gradual substitution of handwriting for its digital forms, such as computer keyboards and tablets in daily life situations, the instruction and monitoring of handwriting development can be overlooked at younger ages (de Almeida, da Cruz, Magna, & Ferrigno, 2013). However, handwriting is still an important means for taking notes, writing reports, and taking examinations in school. Difficulty in handwriting could result in problems in situations that demand intense handwriting use in class, such as the inability to properly perform written exams due to significant discomfort.

Over the past decades, studies have been carried out to investigate the role handwriting plays in composition writing in children (e.g., Jones & Christensen, 1999; Medwell, Strand, & Wray, 2007; Wagner et al., 2011; Yan et al., 2012) and university students (e.g., Connelly, Campbell, MacLean, & Barnes, 2006). For example, Yan et al. (2012) demonstrated that speed and fluency measures were strongly predictive of overall writing quality. For both children and adults, faster handwriting

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speed is related to higher-quality essay writing; for adults, handwriting speed is also related to higher-quality lecture notes (Peverly, 2006). Especially in a written examination, handwriting fluency requires the writer to maintain sufficient speed with a certain level of legibility. The ability to demonstrate knowledge by producing a sufficient amount of information in a set time period becomes a concern in secondary and tertiary education. Interventions for handwriting difficulty are often required to support students' requests for extra writing time during examinations.

Since there is an increase in the demands for speed and production of written information during the progression in academic life, monitoring the handwriting process through classroom notes and especially through evaluations could enhance the performance of students in written assignments, ensuring greater comfort and productivity and reducing the risk of cumulative trauma and injuries. Parush, Levanon-Erez, and Weintraub (1998) assessed quality, speed and ergonomic factors prior to writing and after writing for 10 consecutive minutes. They demonstrated that children with both poor and good handwriting were influenced by fatigue. Especially, the children with poor handwriting had inferior pencil, paper and body positioning, stabilization of paper and consistency of pressure, compared to children with good handwriting.

The proximal stability, believed to be a prerequisite for manipulative hand use, is widely accepted among clinical therapists (Kurtz, 1994; Naider-Steinhart & Katz-Leurer, 2007). The forearm muscles play an active role in stabilizing the hand posture while keeping a fixed wrist angle (Van Galen, Müller, Meulenbroek, & Van Gemmert, 2002). In an EMG analysis of two handwriting grasp patterns in young adults, de Almeida et al. (2013) monitored the surface EMG activity of muscles of the upper arm and forearm during a handwriting task. They found that people who used the static tripod grasp showed statistically significant changes in the EMG activity of the trapezius and biceps brachii muscles during handwriting when compared to the dynamic tripod group's subjects. Their findings suggested an increased activity of the proximal muscles among subjects using transitional grasps, such as the static tripod grasp, indicating potential higher energy expenditure and muscular harm with the maintenance of this motor pattern in handwriting tasks, especially during progression in academic life.

The handwriting apparatus can actually be described in terms of three degrees of freedom; one corresponding to the wrist-joint movement, and the other two to the finger-joint movements (Teulings, Thomassen, & Maarse, 1989). As stated by Valls-Solé and Hallett (1995), the coordinated function of the wrist flexor and wrist extensor muscles is important for performing fine and accurate hand movements. The lateral progression of western handwriting is an important coordination task where wrist extension has a separate degree of freedom for motor control. Their results indicated the importance of wrist control in handwriting. Therefore, this study focused on the wrist position, which is important to the proximal stability in handwriting.

Since wrist-joint position affects the length of the finger muscles and then the grip force, its influence on the handwriting process, product quality and efficiency was studied in this research. To examine the effect of the wrist angle on the perceived discomfort in long lasting handwriting tasks, we conducted a pilot study (Yu, Chang, & Chang, 2011) of participants from a university Chinese literature class. According their self perceived soreness, subjects were classified into "effortless" and "hard" groups. Wrist joint angles were found to be significantly different between the two groups. In this study, we recruited control and in-pain groups and performed a repeated-measures experiment to test whether the angle of wrist extension had a significant influence on the kinematic characteristics, handwriting quality and the perceived soreness of the writing hand.

2. Methods

2.1. Participants recruitment

Forty participants were recruited from the university where this study was conducted. Table 1 shows the demographic data of the recruited participants. Participants who reported having a painful experience while performing the task were placed in the in-pain group. Those who completed the task without experiencing pain were placed in the control group. None of the participants had any neuromuscular disorders, nor had they undergone any treatments or surgeries for musculoskeletal disorders in their upper limbs. There was no significant difference between the two groups in terms of age (independent *t* test) or their dominant hand (Fisher's exact test) and gender proportions (Chi-square test). Ethical approval for the study was obtained from Institutional review board (IRB) of E-Da Hospital, Kaohsiung, Taiwan.

2.2. Handwriting task

The participants in this study performed a prolonged handwriting task in which they continuously wrote Chinese characters for a fixed time (30 min). The writing material given to them was sufficient enough so that every participant would be able to write continuously for the whole time without running out of characters. For the purpose of simulating the heavy

Table 1
Demographic data of participants.

Group	Age, mean (SD)	Gender, male (female)	Dominant hand, right (left)
Control ($n = 22$)	20.45 (.77)	12 (10)	19 (3)
In-pain ($n = 18$)	20.61 (1.19)	6 (12)	16 (2)
Comparison between the two groups	$t_{38} = .515$	$\chi^2_{\text{def}=1} = 1.045$	
	$p = .609$	$p = .307$	$p = .617$