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Handwriting movement analyses comparing first and second graders with normal or dysgraphic characteristics

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A B S T R A C T

Dysgraphia of sufficient severity to interfere with the school work has been recognized as representing a distinct deficit; characterization of its movement problem is a necessary step toward offering improved intervention. From among children aged 6–8, 69 children with dysgraphic characteristics (study group) and 69 matched proficient hand-writers (control group) were recruited into this study. Four copying tests of differing complexity levels were administered using a digital tablet. The acquired data included direct measure (axial pen tip force) and derived parameters (stroke velocity, pause time, number of velocity peaks and ratio of In Air to On Paper measures). The major finding is that children with dysgraphic characteristics had increased pause time per stroke and an increased number of directional changes in velocity. Significant differences were also found between students in two different grades, especially in the control group. The parameters extracted and observed in this study can further differentiate and characterize the handwriting problems originating from fine motor deficits.

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1. Introduction

Handwriting is an essential fine motor skill in school-aged children. Children's 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; Weil & Amundson, 1994). This skill is directly related to most school activities. From a survey of the activities in an elementary school classroom, 30–60% of the time is spent in fine motor activities, with handwriting predominating over other tasks (McHale & Cermak, 1992). From surveys on occupational therapy service in elementary schools, the most common referrals were for handwriting problems (Tseng & Cermak, 1993).

Handwriting is actually a very complicated skill. Neat and smooth handwriting requires the maturity and integration of cognition, visual perception and fine motor skills (Tseng & Murray, 1994; Volman, Van Schendel, & Jongmans, 2006; Weil & Amundson, 1994). Handwriting studies of typical children in primary school have found that the quality of handwriting develops quickly during grade one (ages 6–7) and reaches a plateau by grade two (ages 7–8). By Grade 3 (ages 8–9), handwriting becomes automatic, organized, and is available as a tool to facilitate the development of ideas (Overvelde & Hulstijn, 2011). Therefore, it is important to find out if a defect in handwriting exists and its characteristics during the developmental age, especially early on in Grades 1 and 2.

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Poor fine motor control, such as the lack of coordination of muscle contractions and irregularities in stroke speed and force may lead to laborious or even illegible handwriting. Assessment of fine motor control in handwriting movement is thus important in any comprehensive evaluation of handwriting dysfunction. Handwriting is a dynamic yet fluent process. Clinical observations and performance tests can be made and are traditionally part of a handwriting evaluation. For deeper insight into the handwriting process, advanced computerized evaluation has been applied for temporal, kinematic and kinetic analysis (Di Brina, Niels, Overvelde, Levi, & Hulstijn, 2008; Lam, Au, Leung, & Li-Tsang, 2011; Marquardt & Mai, 1994; Mergl, Tigges, Schroter, Moller, & Hegerl, 1999; Rosenblum, Parush, & Weiss, 2003). According to temporal and kinematical measures, the frequency or duration of pauses was usually measured for the proficiency of handwriting movement. The frequency of pauses made by non-proficient handwriters was found significantly more than the proficient handwriters (Plamondon, 1995; Wann & Jones, 1986). Lam et al. (2011) found that dyslexic children with difficulties in writing showed longer total writing time, pause time, on paper time, and average time to write an individual character when compared to the typical group. In addition to pauses of handwriting movement on paper, the time spent holding the writing instrument above the paper was thought to correspond to the time needed to initiate the handwriting movement to execute the character. Rosenblum et al. (2003) used the time or trajectory of "in air" movements to characterize handwriting deficit in psychomotor control. They found that compared to the proficient handwriters, both the "in air" time and the path length of non-proficient handwriters were conspicuously longer.

From the aspect of motor control theory, the slowness in handwriting is associated with the degrees of automation of the hand movement. The kinematic model of Plamondon (1995) defines rapid human movements in an open-loop movement, with less reliance on the feedback information. The movement is attained in a manner of automation which is kinematically well characterized by smooth velocity and acceleration curves (Plamondon & Alimi, 1997). To describe the degree of automation, Mergl et al. (1999) employed the number of velocity peaks per stroke to characterize the automation of handwriting movement. Higher values reflect a disturbance in the execution of open-loop movements. This concept has been applied to the comparison of handwriting automation between children with DCD and children without DCD. The results revealed that the attainment of automated handwriting was markedly slower in children with a combination of handwriting deficits and DCD (Chang & Yu, 2010). It also showed promising results for using this parameter to characterize motor control problems in children with handwriting difficulties.

In the kinetic analysis of handwriting movement, poor writers have been observed to have higher pressure exerted on the writing surface during their writing tasks (Di Brina, Niels, Overvelde, Levi, & Hulstijn, 2008). The pen pressure of the poor writers was more than twice that of the good writers. However, different results were reported by Rosenblum and Livneh-Zirinski (2008) in both the name writing and the paragraph copying tasks, the children with DCD exerted significantly lower mean pressure in comparison to the control children. Our past work showed no significant difference in mean pressure between DCD and control groups in simple character tasks. However, the changes in mean pressure during the transition from simple to complex character tasks differed between the groups. This change was significantly larger in the children with DCD than in the comparison group. A significant difference was found for the mean pressure applied in complex character tasks, with the DCD children exerting less pressure when writing (Chang & Yu, 2010).

Through the above reviews and deliberations from previous studies, three questions have been raised: What are major differences in kinematic and kinetic characteristics between children with or without dysgraphia? What are the important factors in using computerized handwriting in a clinical setting. Finally, are these parameters and their variances different between the first two grades in early school years? The aim of this study was to compare the handwriting process in children with non-proficient characteristics to those of typical children in Grades 1 and 2. Based on literature reviews and our past research experience (Chang & Yu, 2010), parameters of paramount significance in graphomotor function were adopted to evaluate the children with non-proficient characteristics. The performance evaluation in regard to these parameters was measured and compared with those of typical children.

2. Methods

2.1. Participants

The subject recruitment consisted of a two-step process. The first step was to screen children with dysgraphic characteristics by the referral of teachers in three public elementary schools in the Kaohsiung area, using the Chinese Handwriting Evaluation Form (CHEF) (Chang & Yu, 2012). Children were excluded from this study when they reported a history of any medical, neurological or pervasive developmental disorders, intellectual disability, oncological, musculoskeletal, sensory (hearing, vision, etc.) or skin disorders. From 594 first and 718 second graders, 82 children met the screening criteria. This was followed by the administration of an Elementary Reading/Writing Test; 69 children with dysgraphic characteristics were identified and then recruited into this study as the study group. Their ages ranged from 6 yr 3 mo to 8 yr 2 mo; 30 children (23 boys and 7 girls) were in Grade 1 and 39 children (27 boys and 12 girls) in Grade 2. For recruiting matched children as the control group, 69 typically developing children without poor penmanship were recruited. In regard to their matching the study group, they were recruited randomly from the same classes as the children who were in the study group. In addition, they were matched with the study group in regard to factors such as: gender, age and preferred hand. The ages of children in the control group also ranged from 6 yr, 3 mo to 8 yr, 2 mo. Since all of the participants came