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Impact of tactile function on upper limb motor function in children with Developmental Coordination Disorder

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ABSTRACT

This study investigated the presence of, and relationship between tactile dysfunction and upper limb motor function in children with Developmental Coordination Disorder (DCD) compared to typical developing (TD) children. Participants were 36 children aged 6–12 years. Presence of DCD ($n = 20$) or TD ($n = 16$) was confirmed using the Movement Assessment Battery for Children, second edition. All children participated in a comprehensive assessment of tactile registration (Semmes Weinstein Monofilaments); tactile spatial perception (Single Point Localisation (SPL) and two-point discrimination (2PD)); haptic perception (Stereognosis); speed of simple everyday manual tasks (Jebsen–Taylor Test of Hand Function (JTTHF)); and handwriting speed and accuracy (Evaluation Tool of Children's Handwriting (ETCH)). Compared to TD children, children with DCD demonstrated poorer localisation of touch in the non-dominant hand ($p = 0.04$), slower speed of alphabet writing ($p < 0.05$) and less legible handwriting ($p < 0.01$), but no difference in speed of simple everyday manual tasks (JTTHF: $p > 0.05$). Regression analysis showed that spatial tactile perception (SPL) predicted handwriting legibility (ETCH: $r = 0.11$) and speed of functional tasks (JTTHF: $r = 0.33$). These results suggest that tactile function, specifically single point localisation, should be a primary tactile assessment employed to determine reasons for upper limb motor difficulties experienced by children with DCD.

1. Introduction

Developmental Coordination Disorder (DCD) is a neurodevelopmental condition characterised by disordered motor coordination (American Psychiatric Association, 2013). It is the most common motor disorder in childhood, affecting 5–6% of children internationally (APA, 2013; Bair, Barela, Whitall, Jeka, & Clark, 2011). Males predominate with ratios ranging from 2:1 to 7:1 (APA, 2013; Miller, Missiuna, Macnab, Malloy-Miller, & Polatajko, 2001). Poor fine motor skills are one of the most common coordination issues experienced, collectively causing significant functional impact at home, school and in recreational environments (Miller et al., 2001; Polatajko & Cantin, 2006). In particular, parents and teachers frequently identify poor handwriting in children with DCD (Chang & Yu, 2010; Miller et al., 2001; Smits-Engelsman, Niemeijer, & Van Galen, 2001). This is a significant problem because 30–60% of the school day involves handwriting (McHale & Cermak, 1992) and handwriting proficiency has been correlated with effective communication, self esteem and everyday function (Chang & Yu, 2010; Feder & Majnemer, 2007). In order to produce accurate and coordinated upper limb movements for handwriting

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and dexterity tasks, integration of multisensory inputs is required (Elbasan, Kayihan, & Duzgun, 2012; Schoemaker et al., 2001). Deficits in visual recognition (Sigmundsson, Hansen, & Talcott, 2003), visual perception (Maeland, 1992; Schoemaker et al., 2001; Tsai, Wilson, & Wu, 2008) and proprioception (Laszlo, Bairstow, Bartrip, & Rolfe, 1988; Smyth, 1994) have been well documented in children with DCD. However, although early literature has highlighted the importance of assessing tactile function in the hands of children with DCD who have fine motor difficulties (Watter, 1996), only preliminary research examining this relationship has been conducted. Tactile function is essential because it provides information regarding the physical properties of an object which guides selection of magnitude, direction and timing of hand movements (Johansson & Flanagan, 2009; Maeland, 1992). Therefore, the purpose of this study is to determine the characteristics of tactile function in the hands of children with DCD and the potential influence on upper limb motor performance.

The paucity of literature investigating tactile function in children with DCD makes it difficult to determine the presence and patterns of tactile deficits in the hands of children in this population. Tactile function is comprised of two phases – registration and perception (Auld, Boyd, Moseley, & Johnston, 2011). Registration is the initial and basic detection of a tactile stimulus and is the precursor to perception. Tactile perception encompasses the spatial, temporal and modality specific components of a stimulus. In this phase the individual interprets and gives meaning to the sensory input based on where, when and the quality of the stimulus (Auld, Boyd, Moseley, Ware, & Johnston, 2012; Auld, Ware, Boyd, Moseley, & Johnston, 2012). Both phases must be assessed to ascertain the level and severity of tactile impairment (Auld et al., 2011). In one available study to date, no differences in registration were found between children with and without DCD when assessed using Semmes Weinstein Monofilaments (Law, Lo, Chow, & Cheing, 2011). However two additional studies of spatial tactile perception have demonstrated that children with DCD perform significantly worse on localisation of single and double simultaneous stimuli, graphesthesia (Elbasan et al., 2012), identification of the fingers (Malloy-Miller, 1995) and two point discrimination under both moving and static conditions (Law et al., 2011). This useful preliminary research suggests that children with DCD experience predominately perceptual issues however further detail is required. For example, dermatomal locations utilised for single and double simultaneous localisation were not specified in the Elbasan et al. (2012) study and Malloy-Miller (1995) utilised a tactile assessment that was intended for a younger population (4–8 years-old) than the participants of their study (7–12 years-old), leaving the possibility that tactile difficulties may be worse than measured. These methodological factors require refining to improve valid and reliable representation of tactile function in children with DCD.

Early research also suggests that children with DCD have difficulties with stereognosis compared to children with typical development (TD). Stereognosis, otherwise known as haptic perception, is the ability to identify unseen objects with the hand and is a motor-enhanced form of tactile perception involving tactile and proprioceptive inputs (Auld et al., 2011). Deficits have been demonstrated using the Manual Form Perception (MFP) subscale of the Southern California Sensory Integration Test (Elbasan et al., 2012) and during posting tasks with a stereognosis element (Schoemaker et al., 2001). However, further work is required to determine the specific degree of haptic deficits that eliminate or control slow reaction time, a common concomitant deficit identified in children with DCD (Mon-Williams et al., 2005; Wilmut, Byrne, & Barnett, 2013) and other efferent deficits in motor coordination.

Use of heterogeneous tactile assessments in studies of children with DCD makes it somewhat difficult to develop an accurate understanding of tactile dysfunction in this population. A clinimetric review addressing this same issue for children with cerebral palsy recommends a multi-dimensional assessment framework and test battery including tactile registration, as well as spatial, temporal and stereognosis to comprehensively profile tactile function (Auld et al., 2011). Research using this model is warranted for children with DCD, to determine the true nature and frequency of upper limb tactile deficits in this population. Comprehensive tactile assessment also needs to be paired with assessment of upper limb motor function to establish a clear relationship between these two elements.

Understanding the role of tactile function during motor tasks is critical to understanding deficits experienced by children with DCD. It has been shown in typical populations that tactile afferents override visual cues after initial contact emphasising their importance in manipulative tasks (Johansson & Cole, 1992; Johansson & Flanagan, 2009) and handwriting (Feder & Majnemer, 2007; Yu, Hinojosa, Howe, & Voelbel, 2012). This data supports research in other paediatric populations with motor disorders where tactile dysfunction has been shown to be a critical contributor to upper limb motor dysfunction (Auld, Boyd, et al., 2012; Auld, Ware, et al., 2012; Sakzewski, Ziviani, & Boyd, 2010). However, with the current studies available it is difficult to establish a clear relationship between tactile function and upper limb function in the DCD population. Law et al. (2011) assessed tactile registration and two-point discrimination alongside a motor task involving picking up a cup, however the article appeared not to report the statistical relationship between sensory and motor performance. A relationship between poor finger identification and handwriting execution was also found in children with DCD (Malloy-Miller, 1995), however finger identification is potentially not the most discriminative tactile assessment (Auld et al., 2011). Elbasan et al. (2012) found a relationship between graphesthesia and self-care on the WeeFIM® ($p < 0.01$). However, the WeeFIM® describes global functional independence via a parent questionnaire and does not directly measure quality (accuracy and speed) of upper limb function. Thus, further investigation is required to determine the relationship between upper limb tactile and motor function in children with DCD.

This review has indicated a need for a more comprehensive examination of tactile function alongside motor function of the hand in children with DCD. The primary aims of this study were therefore to investigate the characteristics of tactile function in children with DCD compared to children with typical development (TD), and whether tactile function correlates with upper limb motor function. Based on the current literature, it was hypothesised that (i) compared to children with TD,