TIMING ERROR BY CHILDREN IDENTIFIED WITH DCD LEADS TO INEFFICIENT JUMP PERFORMANCE

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The aim of this study was to identify outcome and response differences in vertical jumping between children typically developing (TD) and those identified with Developmental Coordination Disorder (DCD). Efficient vertical jumping is essential to physical activity in children. The TD group jumped higher as a result of a faster vertical velocity of the centre of mass (VCOM) at take-off. Peak VCOM was greater and occurred closer to take-off in TD when compared to DCD. Earlier occurrence of peak VCOM observed in DCD caused a noticeable loss of VCOM at take-off compared to TD. The timing of the peak VCOM before take-off resulted in large group variation for DCD (CV = 50%) compared to the stereotyped TD (CV = 6%). The difference between groups emphasises coordination difficulties of DCD during vertical jumping.

KEY WORDS: DCD, vertical jumping, timing of peak, velocity of the centre of mass

INTRODUCTION: Generally, children develop physical fitness whilst performing fundamental movements (Hands & Larkin, 2002). One such fundamental movement is vertical jumping which occurs in most sports (Gallahue & Ozmun, 2002). Children identified with Developmental Coordination Disorder (DCD) have difficulties performing fundamental movement patterns and for many reasons choose to avoid sports and physical activity, leading to more sedentary lives (Bouffard et al., 1996; Mandich et al., 2003). Defined as the "activity deficit hypothesis" (Bouffard et al., 1996), over time the avoidance or withdrawal from sports and physical activity can lead to obesity (Dewey & Wilson, 2001) and a reduction in physical fitness, which can eventuate in poor health (Parker & Larkin, 2003). For children identified with DCD, a vicious cycle of motor activity avoidance, depression, social isolation and decreased participation in physical activity and sport emerges (Rasmussen & Gillberg, 2000). Understanding the differences between those children identified with DCD and those typically developing whilst performing fundamental movement patterns may help reduce the avoidance of sports and physical activities observed in this population.

This study aimed to identify the differences in jumping response and outcome measures between typically developing children (TD) compared to children identified with DCD. Usually, a coordinated effort resembling jumping is not apparent until after the age of three years (Clark et al., 1989; Jensen et al., 1994) with a mature pattern evident around the age of six years (Gallahue & Ozmun, 2002). The appearance of the mature jumping pattern coincides with a noticeable increase in strength (Malina et al., 2004). A mature jumping pattern provides the most favourable conditions for the neuromuscular system to coordinate jumping (Bobbert & van Ingen Schenau, 1988). This robust stereotyped movement pattern of jumping therefore offers a model platform for the study of development in children.

METHOD: Following approval by the Australian Catholic University human research ethics committee, participants were invited to volunteer from a local primary school. All participants (n=162) were healthy and provided parental or guardian informed consent. To determine motor proficiency, all participants completed the Movement-ABC (Henderson & Sugden, 1992). Following a standardised warm-up, dressed in dark tight-fitting clothing and wearing sports shoes, each participant attempted three self-selected countermovement maximal vertical jumps. Data was collected using a forceplate (VUPLATE) sampling at 700Hz. From vertical acceleration, displacement and velocity of the centre of mass was calculated by integration. Vertical jump height was calculated between quiet standing height and peak vertical displacement of the centre of mass. Only the best attempt determined by the highest jump was used for analysis. Those participants with a total score below the 15^{th} percentile on the Movement-ABC were identified with DCD (male = 32 and female = 30; age = 8.7 ± 2.1 years; stature = 132.2 ± 13.8 cm; mass = 33.3 ± 11.9 kg). The TD group (male = 31 and female = 31; age = 8.7 ± 2.0 years; stature= 131.3 ± 12.5 cm; mass = 31.9 ± 10.8 kg) was established by matching age, stature and mass to their DCD counterparts. No significant differences for age, stature and mass were found. Those participants who were not matched were removed from the analysis. The coefficient of variation (CV) was calculated from: CV=(SD/mean)x100 where SD was the standard deviation of the measure. Independent t-tests were used to test for differences between groups for age, stature and mass. MANOVA was used to establish differences between groups for the selected variables. To test the relationship between two variables Pearson's product moment correlation was used (SPSS 12.0).

RESULTS AND DISCUSSION: From quiet stance, the TD group jumped significantly higher (p= .014) than the DCD group. Mean jump height for the TD group was 31.1 ± 7.7 cm compared 28.1 ± 5.4 cm for the DCD group. Ultimately, these findings support previous work that children identified with DCD are unable to perform explosive movements at a level of competence equal to typically developing age-matched peers (Larkin & Hoare, 1991; Raynor, 1998).However, the difference in jump height between the groups was comparatively small, which reflects the mild effects upon movement patterns experienced by children with DCD compared to those with neurological problems such as spina bifida (Mandich et al., 2003).

Slow reaction and movement times have been associated with children identified with DCD, which adversely affect movements such as jumping. The slower movement rates and difficulties caused by reflexive and volitional processing restrict the child's ability to control their movements to an expected level for their age (Henderson et al., 1992). When jumping for height, the response measure of Vertical Velocity of the Centre of Mass (VCOM) at take-off is essential to jump performance outcome (Bobbert & Van Soest, 1994; 2001).Therefore, a faster take-off VCOM will augment performance. This was confirmed by the significant relationship between VCOM at take-off and jump height for all participants (r_{xy}= .69; p< .01; r^2 = .471). However, consistent with previous research, VCOM was not the sole contributing factor to jump height and other influences were present (Aragón-Vargas & Gross, 1997;Bobbert & van Ingen Schenau, 1988). Considering this relationship between VCOM at take-off and jump height performance, it follows that a significant difference (p= .003) between the DCD group and TD group was found for mean VCOM at take-off. VCOM at take-off for the TD group was 1.77 ± 0.23 $m \cdot s^{-1}$ whereas the group identified with DCD was generally slower with a VCOM of 1.64 ± 0.26 $m \cdot s^{-1}$. The common goal for the motor task uses organisation of the individual segments to maximise VCOM at take-off and that requires appropriate timing. Peak VCOM does not occur at the instant of take-off, but before (Figure 1). This is due to the geometric problem that is inherent for the transformation from rotation of segments to vertical translation of VCOM (Bobbert & van Soest, 2001).
The magnitude of peak VCOM was significantly higher (p= .004) for the TD group than the DCD group which is consistent with the findings of VCOM at take-off. Peak VCOM for the TD group was 1.97 ± 0.21 $m \cdot s^{-1}$ compared to 1.86 ± 0.21 $m \cdot s^{-1}$ for DCD group. However, the timing of peak VCOM occurred significantly closer (p= .036) to take-off in the TD group. Peak VCOM occurred at 0.030 ± 0.005 s before take off in the TD group, whereas peak VCOM for the DCD group occurred earlier at 0.036 ±0.018 s. This earlier occurrence coincided with a loss in VCOM that was noticeably greater for the DCD group (12.07 ± 6.99%) when compared to the TD group (10.11 ± 4.54%). However, the difference for drop in VCOM from the instant of peak VCOM to take-off between groups was not significantly different (p= .067). Therefore, as a consequence and in addition to a lower peak VCOM and a lower VCOM at take-off, jump performance was further reduced in the DCD group by the earlier timing of peak VCOM.

Of particular interest, the DCD group displayed greater variation (CV%) in the timing of peak VCOM than the TD group. In any typically developing group of children, of the same age, intra-task variation during the learning of motor skills is expected (Henderson & Barnett, 1998) yet the intra-group variation (CV) displayed by the TD group was 6% compared to 50% for the DCD group.

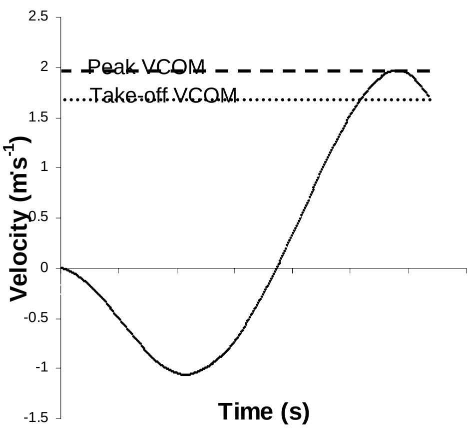

Figure 1: An example of a participant's timing of peak VCOM in relation to the instant of take-off.

Within subject variability of response and outcome measures is considered as noise of the sensorimotor system when repeated measures are used (Newell & Corcos, 1993). In jumping, attaining peak VCOM close to take-off is an important response for performance outcome and has been shown in the present findings by reducing the VCOM loss from the instant of peak VCOM to take-off in the TD group. Therefore, the small intra-group variation observed for the duration between the instant of take-off and the occurrence of peak VCOM displayed by the TD group appears to be stable or invariant. This level of stability within the TD group is consistent with a stereotypical movement and the notion that an optimal coordination solution exists to achieve a common goal. The comparatively greater variation observed in the DCD group for the occurrence of peak VCOM may reflect coordination difficulties that caused error in timing. Timing error equates to the over or undershooting timing of peak VCOM in relation to take-off. The earlier timing of mean VCOM for the DCD group would suggest a bias to under-shooting when compared to the TD group. The observation of over or undershooting can be attributed to neuromotor noise which is reported consistently throughout the DCD literature (Geuze & Kalverboer, 1987; Piek & Skinner, 1999).

CONCLUSION: Basic measures of jump performance such as jump height have been commonly used to differentiate the coordination of TD children from DCD children (Larkin & Hoare, 1991; Raynor, 1998). Jump height, however, is known to improve as a child ages and therefore is not a sensitive or stable measure of coordination. This study found, however, a measure of peak VCOM timing readily differentiates the jump performance of TD children from DCD children. The stability of this measure in the TD children also reflects the robust stereotyped coordination pattern of the whole body that continues through to adulthood. Knowledge of an earlier occurrence of peak VCOM in DCD children may provide researchers with a useful marker for identifying children who experience coordination difficulties when jumping. Furthermore, the measure is stable and unaffected by ageing, therefore useful in quantitatively evaluating the effectiveness of intervention programs administered over extended periods of time to improve coordination in children.

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