Muscle Activation and Movement Responses in Youth With and Without Mental Retardation

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The reaction time of individuals with mental retardation has been researched extensively in the past four decades. Consistently, researchers have shown that individuals with mental retardation have longer and more variable reaction times than those without mental retardation (see Anson & Mawston, 2000; Nettlbeck, 1980). Differences in reaction times have often been associated with central and peripheral processing components (Davis, Sparrow, & Ward, 1991; Inui, Yamanishi, & Tada, 1995; LeClair & Elliott, 1995; Un & Erbacecci, 2000) as well as structural alterations within the central nervous system (CNS; LeClair, Pollock, & Elliott, 1995; Saccuzzo & Michael, 1984).

While a plethora of research documents consistently longer and more variable reaction and movement times in individuals with mental retardation, the underlying mechanisms for these differences have not been extensively investigated. Davis (1987) suggested that muscle activation and electromyography (EMG) variability in responses could be the reason for the movement delays observed in this population. He further proposed that there is more trial-to-trial performance variability found in individuals with mental retardation. Although Davis (1987) suggested rationale for movement delays in individuals with mental retardation, to date no research has been conducted to confirm or refute these assertions. Therefore, the primary purpose of this study was to investigate differences in muscle activation and motor unit recruitment in boys with and without mental retardation during a ballistic leg extension movement invoked with a reaction time stimulus. A secondary purpose was to confirm differences in premotor time, motor time, and movement time from previous investigations.

Method

Participants

Ten active boys with mild-to-moderate mental retardation (MR) and 10 active boys without mental retardation (NMR) were recruited from local public schools and summer camp programs. The 10 with MR participating in this study were consistent with the American Association on Mental Retardation definition for intellectual functioning (1992). We considered the participants with mental retardation as active, opposed to sedentary, based on the criteria of participation in youth sports or Special Olympics programs. The Institutional Review Board of the University of Georgia approved methods and procedures, and participants' guardians provided informed consent prior to participation. Based on a t-test, no significant differences were found between groups for the demographic variables of age, height, and weight (p >.05). Table 1 presents demographic data of participants.

Procedures

Participants were required to perform nine single-repetition trials of a leg extension movement using the dominant limb. Participants initiated movement at the prompting of a green light and beeping noise activated after a prewarning signal at varying intervals. The foreperiod range was 1–3 s (Davis, et al. 1991). The University of Georgia Electronics Shop developed and synchronized the program with EMG Recordings (Biopac Systems, Santa Barbara, CA), and participants performed the leg extension movements on a Cybex NORM Isokinetic Dynamom...
eter (Henley Health Care, Sugar Land, TX). Participants performed leg extension movements in the isotonic mode at 30% of their fat free mass to equalize the relative weight moved. Fat-free mass was calculated using the three-point skinfold measurement according to Jackson and Pollock (1978). At the prompt signal, participants moved the limbs as fast as possible through a 90° range of motion.

Participants performed the leg extension movement seated upright and with their backs supported in 80° of hip flexion. Velcro straps were placed across the hips, waist, and chest, with the lower right tibia strapped into the pad of the dynamometer. The lateral epicondyle of the knee was aligned with the rotation axis with the dynamometer, and the tibial pad was placed proximal to the medial malleolus. The contralateral leg was fixed in a position of approximately 110° of knee flexion.

Bipolar surface EMG was used to determine the electrical activity of the vastus lateralis (VL) and vastus medialis (VM) during the isotonic movement. Silver/silver chloride surface electrodes were placed as closely as possible to the estimated motor end plates of the muscles, according to Gram and Kasman (1998). The electrodes were placed 2.5 cm apart from center to center, with a common reference electrode placed over the head of the tibial tuberosity.

The skin was cleaned and abraded to achieve skin impedance of < 5 kOhms. The EMG signal was digitized online with a sampling frequency of 1020 Hz using a data acquisition card and BioPac Acknowledge III software processed through a Macintosh computer with high and low pass filters of 20 and 400 Hz, respectively. The gain was set at 1,000, with a common mode rejection ratio of 90 dB. The raw EMG signal was stored and used to later calculate the median frequency (MDF) and root mean square (rmsEMG) of the EMG. The average rmsEMG was used as a measure of muscular activity according to Basmajian & DeLuca's (1985) recommendation and was normalized with a maximal voluntary contraction. The MDF was processed using a Fast Fourier Transformation with a Hanning window and was used as a measure of motor unit recruitment (Westbury & Shaughnessy, 1987). The window sampled for calculation of EMG measures was based on the following criteria. Similar to the technique used by Cowling and Steele (2001), individual linear envelopes representing each muscle under investigation were first screened for muscle burst onset. Muscle burst onset was considered to occur when 14 consecutive samples of the linear envelope exceeded a threshold of 7% of the maximum amplitude of the linear envelope representing the muscle burst. Initiation of movement was 14 consecutive bursts at 7% of max amplitude. Insofar as all systems were synchronized such that when the participant completed the leg extension movement, data collection was terminated, muscle burst offset was determined by the completion of the leg extension movement.

According to Magill (2001), premotor time (PMT) is the first component of reaction time (RT) and is the “quiet” interval of time between stimulus and muscular activity. Premotor time is believed to represent central processes involved in a motor response (e.g., perception, decisions). Premotor time was operationally defined as the period between the onset of the stimulus (signal) and the beginning of muscle activity (initial change in EMG). Motor time (MT) is the second component of RT and defined as the period from the increase in muscle activity until the actual beginning of the observable movement (Magill, 2001). Motor time was operationally defined as the interval between muscle burst onset and the initiation of action (first movement of the lever arm on the Cybex). The interval of time between initiation and completion of the action (total time from initiation of leg extension to full extension as recorded by the Cybex) was defined as movement time (MVT; Magill, 2001). Data from PMT, MT, and MVT were computed from the synchronized EMG and leg extension movement on the Cybex.

Data Analysis

SPSS version 10.0 statistical software was used to conduct all data analyses. Analyses included descriptive summaries and a one-way analysis of variance (ANOVA). Dependent variables analyzed included rmsEMG, MDF, PMT, MT, and MVT. Inferential testing was conducted at the .05 level, and all variables were calculated as an average of nine total trials. Table 2 represents the means and standard errors of the PMT, MT, and MVT.

<table>
<thead>
<tr>
<th>Variable</th>
<th>MR</th>
<th>SE</th>
<th>M</th>
<th>NMR</th>
<th>SE</th>
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<td>22.45</td>
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</tr>
</tbody>
</table>

Note. MR = mental retardation; NMR = individuals without mental retardation; M = mean; SE = standard error; numbers for height are in inches and cm (in parentheses); weight is in pounds and kg (in parentheses).

Table 1. Age, height, and weight demographics

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Results

Results from the ANOVA revealed statistically significant differences between MR and NMR groups for PMT, $F(1, 18) = 5.56, p = .03$, MT, $F(1, 18) = 6.88, p = .01$, and MVT, $F(1, 18) = 7.51, p = .01$ (see Table 2). Results corroborate previous research findings that individuals with mental retardation take a longer time to respond to a stimulus (Davis et al., 1991). Data indicated that children with mental retardation have elongated PMT, MT, and MVT compared to their age-matched peers.

Group means and standard errors for the MDF of the VL and VM (MDFL, MDFM) muscles are shown in Table 3. The results revealed a similar pattern in spectral density in the NMR and MR groups, indicating that motor unit recruitment in both groups was consistent throughout the test trials. A Levene technique used to test for the homogeneity of variance within and between groups for the MDF of the VL and VM indicated similar patterns of variability across trials ($p > .05$; Kirk, 1990; Levene, 1960). Because the $p$-values exceeded .05 for between-and within-group comparisons, there is no indication that the groups varied significantly, which suggested consistent patterns of motor unit recruitment across trials.

The same pattern of consistency was found in the Trial x Trial comparisons of the normalized rmsEMG for the VL and VM. Tests for the homogeneity of variance indicated no significant differences in the rmsEMG between and within groups across trials ($p > .05$). Normalized rmsEMG amplitudes for the VM were nearly identical for both groups. However, normalized values for the VL were significantly higher for the NMR children, $F(1, 18) = 5.35, p = .03$, indicating that the level by which each muscle is activated differs by group (see Figure 1). Based on our data, it appears that there was a greater activation of the VL than the VM during the leg extension movement in the NMR group but not in the group with MR.

Discussion

This study serves as a starting point in determining muscle activation and motor unit recruitment strategies used by boys with MR during a ballistic leg extension movement. The primary purpose of our study was to examine differences in muscular responses during a simple movement between individuals with and without mental retardation. The differences in movement responses between groups was expected and is consistent with earlier studies (Auson & Mawston, 2000; Davis et al., 1991; Nettlebeck, 1980), which indicated slower reaction and movement times for individuals with MR. In contrast to earlier reports that suggested variability in movement responses and muscle activation were characteristic of individuals with MR (Davis, 1987; Davis et al., 1991), we observed similar patterns of consistency across trials in motor unit recruitment (MDF) and muscle activation (rmsEMG) for participants in both groups.

From the work of Pietti and colleagues, we have ample evidence that muscle responses are similar in children and adults with and without MR (Horvat, Groce,
Muscle responses to training are also similar, while increases in overall functioning are apparent when training interventions are implemented (Horvat & Croce, 1995). While peak torque, power, and work values are generally lower in individuals in MR (Horvat et al., 1999), the muscle responds to training in a similar manner to NMR individuals and implies that other possible explanations must be explored to determine the specific reasons for the lower responses in physical functioning (i.e., peak torque, total work) and movement (i.e., speed, RT).

Movement speed can be increased in two ways: (a) increase the number of motor units and fast motor units recruited, and (b) increase the rate of firing (muscle activation) of each motor unit (Lieber, 1992). In our investigation, the level of muscle activation was similar between groups (see Table 3), and the Trial x Trial comparisons indicated a slight variability in the NMR group, although these differences were not significant. This is in conflict with earlier reports indicating differences in muscle activation and motor responses in individuals with mental retardation (Davis, 1987; Davis et al., 1991). It should be noted that the movement used in our study was similar to kicking a ball and was familiar to all participants who were active in recreational sports activities. Hence, the movement was not unknown or unusual for either group of participants.

More importantly, there were differences in the level of involvement of the VL and VM in the leg extension movement in the two groups. In the NMR group, there was greater muscle activation in the VL than in the VM; in the group with MR, there were similar activation patterns in the VL and VM. It appears that, although there is no significant Trial x Trial variability in amplitude in both the VL and VM, the level by which each muscle is activated differs by group. According to Miller, Croce, and Hutchins (2000), in the case of the quadriceps and hamstrings, a single muscle can use different motor recruitment strategies in accordance with the type of contraction it performs and the task goals. For example, Croce, Miller, Confessore, and Vailas (1998) and Miller, et al. (2000) found that during an isokinetic leg extension movement, both the lateral quadriceps (VL) and the lateral hamstrings (biceps femoris) have greater activation levels than the medial quadriceps (VM) and medial hamstrings (semitendinosus and semimembranosus). The reason given by these authors for this difference was that during open chain movements the freely moving tibia laterally rotates on the relatively fixed femur during the final 30° of knee extension (Norkin & Levangie, 1992). A higher recruitment of the VL during leg extension appears to be the more adaptive response, because this pattern of muscle recruitment better facilitates terminal rotation of the knee and increases stability of the knee joints. It could be that for individuals with MR, a more equal contraction of the VL and VM reflects a tendency to establish a smoother extension movement or possibly implies less knee-joint stability in individuals with MR.

Differences in muscle activation have been observed elsewhere (Aruin, Almeida, & Latash, 1996) and lend credence to the belief that under different contexts, individuals with MR may develop muscle synergies to complete a motor task in a different manner than those without MR. In their study, Aruin et al. (1996) had participants with and without Down syndrome perform a discrete elbow or wrist flexion or extension movement in a sagittal plane, moving the joints as quickly as possible. Participants in the NMR group displayed alternating bursts of activity in the agonist-antagonist muscle pair controlling the nonfocal joint. On the other hand, participants in the MR group displayed simultaneous bursts of activity in the flexor and extensor muscles controlling both joints. The authors postulated that the more universal co-contraction strategy used by participants with Down syndrome may reflect a tendency to trade efficiency for safety. They further suggested that although some of the atypical motor patterns observed in individuals with MR may appear to be clumsy to the casual observer, they may in fact be quite adaptive or even optimal rather than abnormal (Aruin et al., 1996).

The PMT gives us the first indication of a processing delay that may ultimately affect movement, while the pattern in which the muscles are activated demonstrate some differences between groups in how movements are controlled. Although MVT is longer, the consistency of motor unit recruitment and muscle activation were similar, with respect to rmsEMG and MDF, prompting us to look at other reasons for the slower responses in individuals with MR.

The where, how, and why of the delay is unknown, but this information would be the key to understanding the fundamental sensory and motor differences one sees between individuals with and without mental retardation. Simply stating that RT or MVT is slower does not provide the reasons for inefficient movement but simply confirms that individuals with MR are slower. The most noteworthy finding of this study was that the activation level of the medial and lateral quadriceps muscles was different in the two groups. In the group with MR, we saw an atypical recruitment in the VL and VM, which may provide the key to detecting deficient movement patterns or adaptive responses in this population.

It is essential that researchers determine differences not only in reaction and movement times but also in the context of where the movement delays and errors occur to remediate movement difficulties in this population. Future researchers should continue to investigate variations in muscle activation and recruitment, in particular...
differences in neuromuscular control mechanisms, and the ability to select and process sensory information.

References


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