Evaluation of speed-accuracy trade-off in a computer task to identify motor difficulties in individuals with Duchenne Muscular Dystrophy: A cross-sectional study

AUTHORS

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ABSTRACT

Introduction: Individuals with Duchenne Muscular Dystrophy (DMD) present with progressive loss of motor function which can impair both control of speed and accuracy of movement. **Aim:** to evaluate movement time during a task at various levels of difficulty and to verify whether the level of difficulty affects the speed and/ or accuracy during the task. **Methods:** the DMD group comprised of 17 individuals age matched with 17 individuals with typical development (TD group). The task evaluates the relationship between speed and accuracy, consisting of the execution of manual movements (using the mouse of the computer) aimed at a target at three different levels of difficulty (ID). **Results:** A MANOVA demonstrated statistically significant differences in dispersion data and intercept values between the groups with greater movement time in the DMD group. An ANOVA indicated differences between groups for ID, except for when there was a higher accuracy demand (higher ID). In the other IDs that required lower accuracy demand, individuals in the DMD group had significantly longer movement time when compared to the TD group. **Conclusion:** These results show that the TD and DMD did not differ in the higher ID, therefore it can be concluded that for those with DMD, motor performance is more affected by speed than accuracy of movement.

What this paper adds?

It is known that individuals with DMD have considerable motor deficits, however this paper shows that when the task involves higher accuracy compared with speed, people with DMD have performance similar to typically developed peers. This insight is a novel finding and can inform the rehabilitation team, to focus on training of speed, whilst maintaining accuracy for better execution of daily life tasks.

Keywords: Fitts' law; Relative speed and accuracy of movement; Duchenne muscular dystrophy; Movement time; Motor control.

1. INTRODUCTION

Duchenne muscular dystrophy (DMD) is a severe, progressive disease affecting 1 in 3600–6000 males worldwide (K. Bushby & Connor, 2011; Katharine Bushby et al., 2010; Flanigan, 2014). DMD is characterized by the absence of dystrophin in muscle biopsies (although residual dystrophin can be present) (Arechavala-Gomeza et al., 2010). Dystrophin is essential in maintaining the structural integrity of muscle membranes during contraction; its absence results in irreversible progressive muscle weakness and manifests itself in the first decade of life, in a symmetrical way initially in the proximal region of the body with evolution to distal regions. Weakness of the skeletal, respiratory and cardiac muscle produces severe physical incapacity and a reduced life expectancy (Snow, Anderson, & Jakobson, 2013).

Over the last five decades, the lifespan of men with DMD has increased from 20 to 35 years due to improvements in health services and the introduction of home care technology, such as artificial ventilators (Lobo-Prat et al., 2017). As a result, there is

currently a considerable group of adults with DMD living with severe physical impairments and a strong dependency on health resources (Snow et al., 2013).

In the last few years there has been increasing focus on the assessment of upper limbs (Bartels et al., 2011; Berard, Payan, Hodgkinson, & Fermanian, 2005; Mattar & Sobreira, 2008b; Mayhew et al., 2013; Mazzone, Vasco, Palermo, Bianco, Galluccio, Ricotti, Castronovo, Di Mauro, et al., 2012; Servais et al., 2013), especially considering that upper limb weakness in DMD generally occurs at a later stage compared to the lower limb (M. Janssen, A. Bergsma, A. C. H. Geurts, & I. J. M. de Groot, 2014; Mattar & Sobreira, 2008b; Wagner, Lechtzin, & Judge, 2007a, 2007b). Although the distal performance is preserved, the prevalent muscular deficits that characterize the clinical profile of DMD may significantly affect performance of fine movements, particularly in those requiring motor execution such as writing tasks (Vuillerot et al., 2012; Wagner et al., 2007a). Therefore, in advanced stages of the disease upper limb activities, although limited are especially significant in daily life and require specific attention in rehabilitation programs and research with the aim of prolonging independence and functionality (Bartels et al., 2011; Mattar & Sobreira, 2008b; Wagner et al., 2007a).

An important factor that should be investigated when considering upper limb functional tasks is the relation between speed and accuracy of movement in order to plan and develop optimal assistive technology interfaces (Fernani et al., 2017). In typically developed (TD) individuals, movement speed and accuracy and their relationship are inversely proportional (Beamish et al., 2009; Boyd, Vidoni, Siengsukon, & Wessel, 2009a, 2009b). However, considering individuals with motor disability the mechanisms underlying the speed-accuracy tradeoff can be different, with individuals being able to utilize a speed-energy-accuracy trade-off for goal-directed movements as an alternative strategy to compensate for muscle contraction difficulties (Fernani et al., 2017).

Under this paradigm, skill improvement is concerned with improving the accuracy rate, or productivity in achieving a spatial task (Ashworth-Beaumont & Nowicky, 2013). In relation to human performance, Fitts and Radford (Fitts & Radford, 1966) considered the effect of movement rate on spatial variability with respect to a manual target for the upper limb. In general terms, for a standardized target of index of difficulty (ID) in an aiming task, a person must on average successfully commit sensorimotor control resources matching or exceeding the ID to achieve reliable targeting accuracy (Ashworth-Beaumont & Nowicky, 2013).

The relationship between speed and accuracy can be described by a mathematical equation, such that there is a log-linear relationship between movement time and task difficulty, with targets of smaller sizes requiring more time to reach due to the increase in accuracy requirements (Boyd et al., 2009a; Lam, Hodges, Virji-Babul, & Latash, 2009). Due to the intrinsic information between the target size (W) and the distance between targets (D), the equation log2 (2D / W) provides an ID where by the higher the difficulty the slower the movement (Fitts, 1954).

Due to the motor alterations present in DMD, the evaluation of the relationship between speed and accuracy can be useful for the analysis of the motor control in pre-defined tasks, manipulating difficulty through the size and distance of the target. Thus, it is important to verify the relation between the execution time of the movement considering distance and size of the targets. These data can boost future research and enable better planning of interventions for individuals with DMD.

Considering the above deliberations, individuals with DMD and TD were engaged in a movement time task with different indices of difficulty (IDs) in the present study. The same ID was performed in different ways (considering the relation between widths and distances) similar to the proposal of Fernani et al., (2017), where tasks were

performed with thicker sidebars and longer distances between them and thinner sidebars with shorter distances.

Thus, this study aimed to evaluate whether difficulty in movement performance in those with DMD was still present when there is a demand for speed (due to a greater distance between targets with larger sidebars) or accuracy (thinner sidebars with a small distance between targets). The aim was to also verify the differences in speed and accuracy performance between individuals with DMD and TD.

Hence, we can hypothesize that, due to muscle weakness and slowness of movement (i.e. more time required to perform motor activities) (Kinali et al., 2009; Smith, Dainoff, & Smith, 2006), individuals with DMD will present greater difficulty when the task demands speed (which requires a larger range of motion and more muscle strength) when compared with a task requiring accuracy. Also, when compared with their TD peers, individuals with DMD would require more time to complete the proposed movement activities.

2. METHODS

This study was approved by the Ethics Committee for review of research projects in the School of Medicine, University of São Paulo under protocol number CAAE: 12689513.3.0000.0065 and was conducted in accordance to the declaration of Helsinki. The legal guardian of each participant signed a free and informed consent.

2.1. Participants

Between March and September of 2014, a total of 28 males with DMD, were invited (convenience sample) and after 11 exclusion (in which 6 were unable to use the

computer's mouse, 3 did not finish the trial, and 2 participants older than 21 years old took too long to 'move' when performing the tasks and were therefore considered outliers and excluded during data analysis), 17 participated. Participants with DMD were recruited during treatment at the Brazilian Association of Muscular Dystrophy (Associação Brasileira de Distrofia Muscular – ABDIM), with a mean age of 15±2.2 years old. TD participants were eligible males without any neuromuscular alteration and were age-matched to the participants of the DMD-group (n=17).

The participants in the DMD group were considered eligible if they had a diagnosis of DMD confirmed by molecular method and/or protein expression, if they were between 11 and 25 years old, and had capacity to understand the task proposed. Exclusion criteria for participants in both groups were: presence of associated comorbidities such as contractures, deformities of upper limb that impeded the accomplishment of the task; non-acceptance of participation in research by the participant and/or legal guardian through the non-signing of the consent form, and/or assent form for minors.

2.2. Functional evaluation

To evaluate functionality and performance on the task for people with DMD, we applied the Motor Function Measure scale (MFM) which is a validated tool developed specifically for muscular dystrophies (Berard et al., 2005; Iwabe, Miranda-Pfeilsticker, & Nucci, 2008). The Portuguese version of the MFM has been used in several studies (Mazzone, Vasco, Palermo, Bianco, Galluccio, Ricotti, Castronovo, Mauro, et al., 2012; Vuillerot et al., 2010; Vuillerot et al., 2012) and shows high reliability (Iwabe et al., 2008).

The MFM is composed of 32 items (tasks) divided into three sub sections expressed as a percentage of the maximum possible score which provides a detailed profile of disability: (D1) transfers and standing posture, (D2) and proximal axial motor capacity, and (D3) distal motor capacity. The lower the total score, the more severe the impairment (Berard et al., 2005; Iwabe et al., 2008; Vuillerot et al., 2012).

2.3. Instruments

The software used to simulate the task according to Fitts'law was the "Fitts' Reciprocal Aiming Task v.1.0 (Horizontal)" (Okazaki VHA. Discrete Aiming Task (v.2.0). 2007. http://okazaki.webs.com/ softwaresdownloads.htm#297051518. Accessed 1 March 2013). We used the version 1.0 as this was the version available during data collection. However, now the software comes in version 2.0, which presents additional features such as subject number and trial number, yet the features used in this study remain the same. The software presents the task proposed by Fitts' law on a computer and establishes a relationship between speed and accuracy (Figure 1). Another important aspect is the record of movement time and the number of touches (hits and misses). To highlight the difference between speed and accuracy, we used three increasing indices of difficulty (IDs) by modifying the width and distance of the bars (ID2, ID4 and ID6). Moreover, ID4 was applied in two ways (ID4a and ID4b): in ID4a the distance between the bars and the width of each were smaller and in ID4b the distance between the bars and their width were larger, but the ID remained the same (a detailed explanation can be found below in the legend of Figure 1). This approach regarding ID4a and ID4b was used to evaluate if individuals with DMD show more difficulty in performance when the bars are smaller, but closer (requiring more accuracy) or larger, but more distant (requiring more speed). We did not split the ID6 and ID2 as the protocol

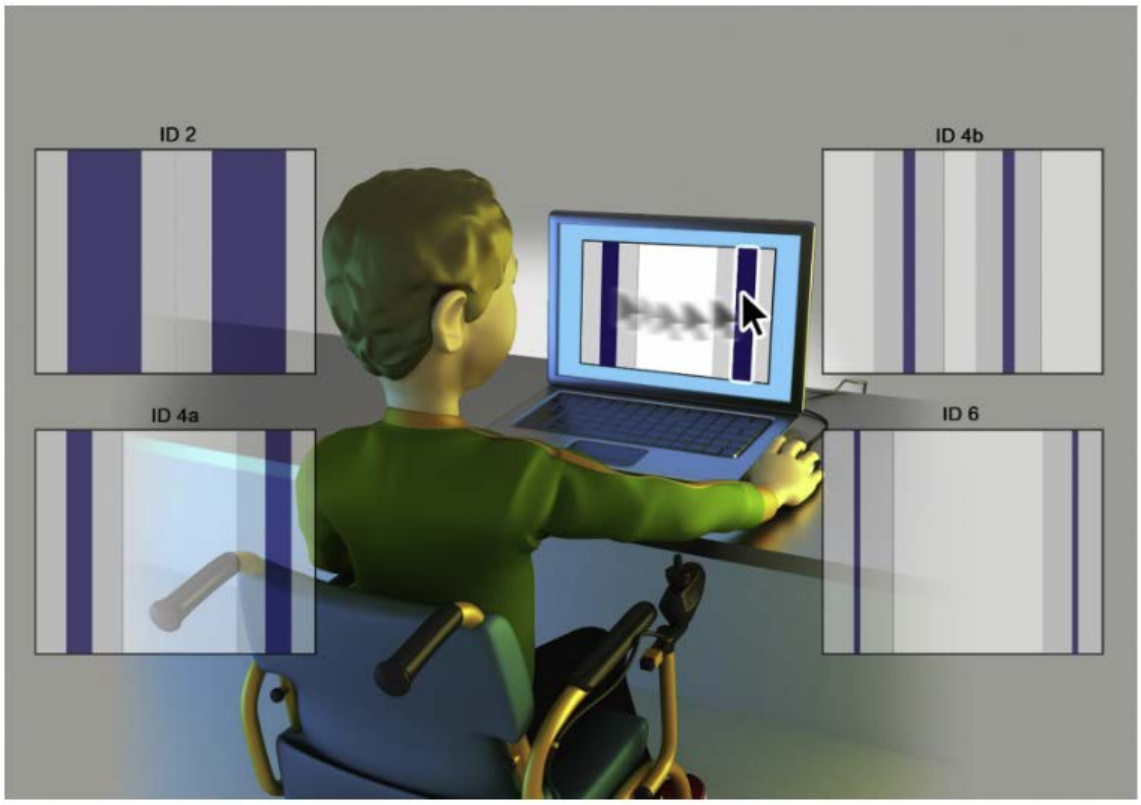
would be timely which could result in fatigue, and this can have a negative influence on results in the DMD. Thus, only ID in the medium difficulty (ID4a and ID4b) were split.

2.4. Procedure

The individuals were seated at a height-adjustable table, with a front mounted computer. The best position was considered the one that each person identified as the most functional when using their own personal computer. Thus, the chair was adjusted according to the size and needs of the individual, so that it was positioned comfortably throughout the task. Before starting the task, the procedure was explained verbally: the subject was instructed to place their hand on the mouse with the cursor at an intermediate point between the two targets (sidebars), and the participant was instructed to make contact with the targets by moving the mouse cursor and "clicking" on the alternate targets as quickly as possible. The targets were two bars which were vertically arranged in parallel with dimensions and distance determined in accordance with each ID (Figure 1). The participant was able to start the movement with the dominant hand after hearing an audible alarm triggered by the computer.

After 10 seconds, a second beep indicated the end of the current attempt after which the time was recorded. Total movement time was obtained by dividing the seconds pre-set for the task (10) by the number of "clicks" on the targets, or 10 by the number of clicks. If more than two clicks were wrong, the subject had to repeat the task, which of three attempts at each of the three different levels of difficulty.

Figure 1: Illustration of the task at the respective index of difficulty.



Legend: ID2= the target sidebars are thicker (5.08cm), with little distance between them (10.16cm) – Log2 [(2x6)/3] = Log2 4 = 2; ID4a= the target sidebars are thinner (2.54cm), with a greater distance between them (20.32cm) – Log2 [(2x24)/3] = Log2 16 = 4; ID4b= the target sidebars are thinner than used in ID4a (1.27cm), however the distance between them is smaller (10.16cm) – Log2 [(2x12)/1.5] = Log2 16 = 4; ID6= the target sidebars are the thinnest (0.635cm), with the greatest distance between targets (20.32cm) – Log2 [(2x48)/1.5] = Log2 64 = 6.

The procedure took approximately 10 minutes, however the individuals had a rest between each trial, while researchers adjusted the parameters of the software. Therefore, they performed the trial for 10 seconds followed by a rest for around 30 seconds, for 12 trials. During this procedure none of the participants felt tired or fatigued.

2.5. Data analysis

Data normality was assessed by histogram analysis. An ANOVA with two factors (Groups: DMD and TD) by two (ID) with repeated measures on the last factor, and Movement Time as the dependent variable. For the factor 'ID', separate comparisons were made: ID2 *versus* ID4a, ID4a *versus* ID4b, ID4b *versus* ID6. Partial eta-squared

(η_p^2) was reported to measure effect size and interpreted as small (effect size >0.01), medium (effect size >0.06), or large (effect size >0.14) (Silva-Filho et al., 2018). Multiple regression analysis was used to determine which factors influenced movement time in the DMD group.

In order to establish whether there was a relation between accuracy and speed, as used by Fernani et al, (2017) a linear regression analysis was performed on the movement time data (dependent variable) and the index of difficulty (independent variable), using curve estimation and obtaining the values of: b0 (intercept, i.e. is the value of Y if the value of X = 0), b1 (slope, i.e. this is the amount that the Y variable will change for each 1 unit change in the X variable) and r^2 (coefficient of determination, evaluates the degree of agreement between model predictions and the dependent variable, ranging from 0 to 1). Thus, this analysis was done for each participant considering the three trials in each index of difficulty (ID2, ID4a, ID4b and ID6). Moreover, Y was the MT (in milliseconds) and X the index of difficulty (ID2, ID4a, ID4b and ID6). The value of r^2 was used in order to show the dispersion of data as used for Fernani et al., (2017) and Meira Jr, (2018).

A one-way MANOVA was used to compare group means for the three variables of interest (b0, b1 and r2). To examine associations between performance and the slope of the line (b1), Pearson correlation coefficient was used. The data was described using mean and standard deviation. The software package used was SPSS, 20.0. Findings were significant at $p<0.05$.

3. RESULTS

Characterization of our sample including age, weight, height, BMI, functional scales and use of corticoids is presented on Table 1. For the TD we only collected data regarding age.

Table 1
Characterization of the groups.

Variable	TD-group Mean ± SD [min – max]	DMD-group Mean ± SD [min – max]
Age (years)	15.4 ± 2.3 [12–20]	15.4 ± 2.3 [12–20]
Weight	–	52.9 ± 13.6 [32.8–84.6]
Height	–	1.55 ± 0.12 [1.29–1.73]
BMI	–	22.0 ± 4.5 [12.8 – 28-6]
MFM-total (%)	–	46.6 ± 22.1 [19.8–86.5]
MFM-D3 (%)	–	78.7 ± 16.2 [52.4–100.0]
EK	–	11 ± 5 [2–20]
Vignos	–	6 ± 2 [1–8]
Corticoid		n (%)
Deflazacort	–	9 (53)
Prednisolone	–	7 (41)
None	–	1 (6)

TD-group: group with Typical Development; DMD-group: group with Duchenne Muscular Dystrophy; SD: Standard Deviation; BMI: Body Mass Index; MFM-total: total score of the Motor Function Measure scale; MFM-D3: third domain score of the Motor Function Measure scale; EK: Egen Klassifikation scale; n: sample size.

Effect of ID on Movement Time

ID2 – ID4a

There was a statistically significant difference between IDs [F (1,32)=113.7; p <0.001; ŋ2=0.78], with movement time increasing significantly from ID2 (M=572 ms, SD=22) to ID4a (M=873 ms, SD=40). However, no interaction was found.

A main effect for groups [F (1,32)=14.0; p=0.001; ŋ2=0.31] was found. Individuals with DMD (M=832 ms, SD=40) were 219 ms (26%) slower than the TD group (M=613 ms, SD=40).

ID4a – ID4b

There was no main effect or interaction between IDs.

However, a main effect was found between groups [F (1,32)=6.38; p=0.017; ŋ2=0.17]. Individuals with DMD (M=1013 ms, SD=70) were 249 ms (25%) slower than the TD group (M=764 ms, SD=70).

ID4b – ID6

There was a statistically significant difference between IDs [F (1,32)=39.9; p <0.001; ŋ2=0.55], with movement time increasing significantly from ID4b (M=904 ms, SD=64) to ID6 (M=1295 ms, SD=84). Nevertheless, no interaction was found.

There were no statistically significant differences between the DMD group (M=1219 ms, SD=10) and TD group (M=981 ms, SD=10), although the DMD group was 238 ms (20%) slower than the TD group.

In terms of the difference between IDs 2 and 6, the DMD group increased movement time from 674 ms to 1402 ms and the TD group increased from 471 ms to 1188 ms respectively. The DMD group showed a difference of 728 ms (52%) from ID6 to ID2, while the TD group showed a difference of 717 ms (60%).

Figure 2: Graph representing the linear regression analysis with dispersion data and indexes of difficulties (ID), using values of b0, b1 and r^2.

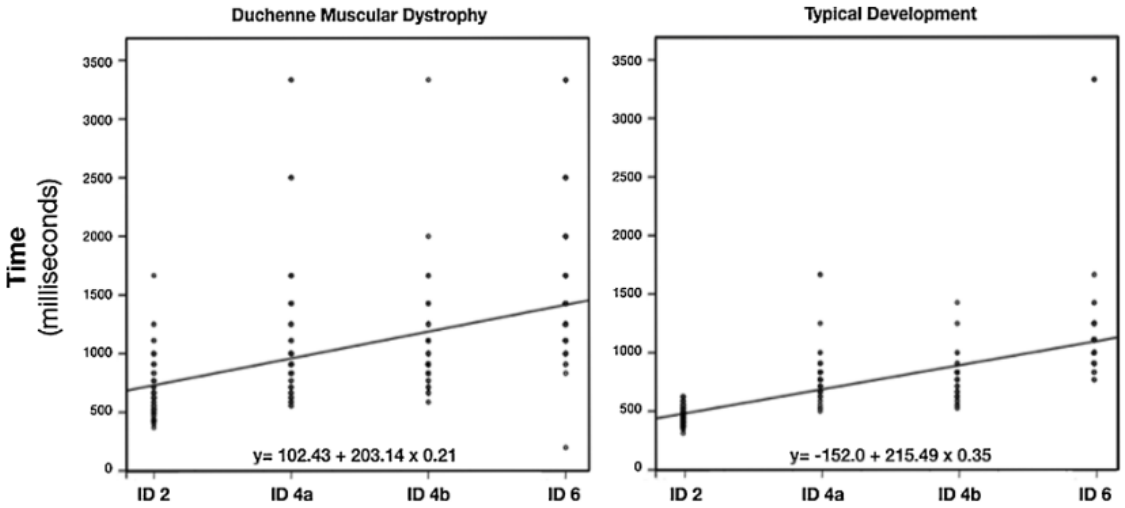


Fig. 2. Graph representing the linear regression analysis with dispersion data and indexes of difficulties (ID), using values of b0, b1 and r^2.
Legend: DMD: Duchenne Muscular Dystrophy; TD: Typical Development.

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Pearson correlation coefficient

Significant correlations were found between the values of r^2 and MFM-D3 scale (Table 2).

Table 2
Pearson correlation between the values of b0, b1 and r^2, score of the MFM-D3 and -total scale.

Variables	MFM-D3	
	r	*p*
b0	−0.285	0.267
b1	−0.169	0.517
r^2	0.500*	0.041*

* statistically significant difference; MFM-D3: motor function scale Motor Function Measure to third domain; b0 (intercept), b1 (slope) and r^2 (determination index).

In order to find out which factors (age, Vignos, MFM-D1, MFM-D2, MFM-D3 and MFM-total) could influence the increase in movement time (MT) from ID2 to ID6 (Δ ID6 – ID2) among individuals in DMD individuals, the multiple regression analysis

revealed a significant regression model with F (4,12)=7.19, p=0.003, r^2=.71, resulting in the following equation: increase in movement time = - .096 * age and - .013 * MFM-total. Therefore, only age and performance in terms of the total score on the MFM scale can predict the increase in movement time, which implies that with increasing age, there is a greater increase in movement time. Also, the higher the score on MFM-total, the lower the increase in MT.

Comparison of the regression variables (b0, b1 and r^2)

Due to violation of the assumption of compound symmetry, it was necessary to adjust the F statistic for the Hotelling's Trace procedure. A MANOVA was used to test for differences in the slope of the regression line and no significant difference was found between groups (p>0.05). However, a statistically significant difference was found in the dispersion (r^2) data between the DMD (r^2: M=0.70, SD=0.04) and the TD group (r^2: M=0.85, SD=0.04) [F (1.32)=5.93; p=0.021; ŋ2=0.16].

The intercept values (b0) differed significantly [F (1,32)=5.16; p=0.030; ŋ2=0.14], with longer movement time in the DMD group (M=321 ms, SD=73 ms) compared to the TD group (M=86 ms, SD=73), as represented in Figure 2.

4. DISCUSSION

This study was designed to determine how different levels of difficulty related to speed and accuracy, influence the motor performance of with DMD. We found that young men with DMD had difficulty achieving fast movements with no difficulty in accuracy, and that moving fast was problematic at all accuracy levels equally. As such we propose that augmenting technology device interfaces to utilize smaller more accurate

approaches will better enable those with DMD to engage and communicate as the disease progresses. We further suggest rehabilitation strategies to increase movement distance and speed may prolong and maintain functioning and increase participation in daily life activities over a longer period in this group.

Among the factors studied in the area of motor control in DMD, speed and accuracy of movement are drawing much attention due to the fact that the majority of manual directional skills require fast and accurate performance (Huys, Fernandez, Bootsma, & Jirsa, 2010). In the current study, the behavior exhibited by both groups with respect to the relationship between speed, accuracy and movement time correlated linearly with overall difficulty indicating a close match to Fitts' behavior, as seen in Figure 2. In other words, both groups showed greater mean movement time when the task required more accuracy. If the relationship with speed and accuracy does apply to these individuals, this would indicate that this relationship is extremely robust and that even the performance of people with damaged central nervous systems can adhere to it despite their motor difficulties (Smits-Engelsman, Rameckers, & Duysens, 2007).

One of the initial hypotheses was that individuals with DMD would present greater movement time than their healthy peers – at all levels of difficulty – as a consequence of the limitations that characterize the disease. This hypothesis was partially confirmed in this study, as there was a statistical difference in ID2 movement time compared to ID4a in both groups and the DMD group showed an increase of 219 ms in movement time when compared to the TD group. There was no statistical difference in movement time between ID4a and ID4b for both DMD and TD groups and this data is consistent if we consider that the difficulty was maintained by the ratio of distance/width of the bars; however, again the group with DMD took longer movement time to execute the same task (increase of 249 ms).

The greater MT observed in IDs 2 and 4 in the DMD group may be related to difficulties in muscle contraction, weakness and joint stiffness that limit functional activities (M. M. Janssen, A. Bergsma, A. C. Geurts, & I. J. de Groot, 2014; Mathur et al., 2010; Mayhew et al., 2013), or due to the changes in the central nervous system that characterize the disease. Gao et al. (1996) and Cyrulnik et al. (2008) reported that the cerebellum, a region that is affected by the absence of dystrophin, is involved in the control of motor actions and discrimination of sensory information. Its action is often associated with motor tasks requiring speed and accuracy, and therefore may contribute to changes in motor performance in these individuals. Winstein, Grafton & Pohl (1997) and Witney et al. (2004) (Winstein et al., 1997; Witney, Wing, Thonnard, & Smith, 2004)(Winstein et al., 1997; Witney, Wing, Thonnard, & Smith, 2004)(Winstein et al., 1997; Witney, Wing, Thonnard, & Smith, 2004)(Winstein et al., 1997; Witney, Wing, Thonnard, & Smith, 2004)(Winstein et al., 1997; Witney, Wing, Thonnard, & Smith, 2004)(Winstein et al., 1997; Witney et al., 2004b)suggest that the motor cortex, an area that appears to be activated during the task used in the current study is essential for fast and accurate manipulation of objects. Evidence has shown that individuals with DMD have reduced motor cortex excitability and impaired bilateral manual dexterity (Di Lazzaro et al., 1998; Lee et al., 2002).

Despite the worse performance of the DMD group, there was a significant difference in MT for both groups when comparing ID4b to ID6, such that ID4b was carried out with greater speed and accuracy. However, there was no difference between the DMD and TD groups. In other words, the TD group showed superior performance to the DMD group in the other IDs (ID2, ID4a and ID4b) but not in ID6. This result seems to confirm our general observation that the DMD group experiences more difficulty in performing the task when there is an emphasis on speed (in ID2 and ID4 – where the

targets were wider and easier to hit). In ID6 the target was narrower and both groups needed to reduce their movement time, as the emphasis on task accomplishment was accuracy.

Some assumptions could explain the greater difficulty in speed than accuracy for the group with DMD: (1) studies point to a positive correlation between muscle weakness and function loss with a progressive increase in the time required to perform motor skills in individuals with DMD (Caromano, Niitsuma, Vainzof, & Zatz, 2003; Scott, Hyde, Goddard, & Dubowitz, 1982; Sienko Thomas et al., 2010); (2) another related assumption is that DMD selectively affects the subset of skeletal muscle fibers (Type IIB) specialized for fast contraction, high force rapid movements, and the number of type 2 fibers is severely reduced in individuals with DMD (Li et al., 2014; Webster, Silberstein, Hays, & Blau, 1988); (3) another point to be considered is the changes in muscle fibers in DMD that alter the muscle fiber conduction velocity (MFCV), that is the velocity at which muscle fibers transmit action potentials prior to muscle contraction. The motor control and contraction characteristics of muscle fibers suggest that changes in MFCV affect reaction time; therefore a decrease in MFCV slows the propagation of excitation and delaying muscle contraction time (when MFCV decreases, muscle dynamic characteristics deteriorate), which is thought to be followed by a decline in speed of movement (Murakami, Fujisawa, Onobe, & Sato, 2014). Cruz Martinez & Lopes Terradas (1990) and Al Ani et al. (2001) reported that conduction velocity was significantly slower in individuals with DMD compared to unaffected individuals of the same age.

Additional findings from the current study found significant correlations between values of r^2 and the MFM-D3 scale, indicating that the higher the distal functioning of the upper limbs, the lower the variability of the movement time between the touches made.

It is known that better performance is highly related to a decrease in variability (Cohen & Sternad, 2009), which is associated with dispersion. Berard et al.(2005) reported that good performance in "Dimension 3" of the MFM reflects a high level of distal motor function of the upper limbs. Wagner et al.(2007a) emphasized that most adults with DMD have limited motor skills, but that some muscles of the upper limbs, especially the finger flexors, may be preserved and provide important skills to control the joystick of a wheelchair, play video games and to use a computer.

Finally, multiple regression analysis indicated that age and motor performance on the MFM-total scale can predict the increase in movement time from one ID to another. Distal motor function, although limited from early stages of the disease, worsens with age (Mattar & Sobreira, 2008a, 2008b; Wagner et al., 2007a, 2007b). Sienko Thomas et al. (2010) evaluated motor function by means of timed motor performance tests and found a negative correlation between MFM and motor performance, indicating that the higher the gross motor function, the lower the time required to complete the motor tasks.

Mattar & Sobreira (2008b) reported that the strength of the hands in individuals with DMD declines with age and Bartels et al. (Bartels et al., 2011) reported a relationship between age and reduced distal motor function of the upper extremities, predominantly between 20 and 30 years of age. Therefore, overall motor function is severely impaired and great variability can be found in distal motor function, muscle strength and range of motion of the upper limbs.

In clinical practice, individuals with neurological deficits present slowness of movement and changes in muscle strength that may influence the control of movement as their primary functional deficiency (Kim, Wininger, & Craelius, 2010; Smith et al., 2006). Although individuals with DMD have motor skills of the upper limbs with

relatively good functional ability, limitations of movement and slowness of precise reach constitute considerable disadvantages in this population. Based on the present findings, we can only speculate that focusing on direct treatment for tasks that influence speed of movement could be more important than those related to improving accuracy, as the results showed that in the task that required more accuracy they presented good performance, similar to those with TD, but in the task that required more speed they presented worse performance. The possibility of adjusting the difficulties of tasks according to the capacity of the individual (Zimmerli et al., 2012) and the development of practical day-to-day activities based on the distance and size of the target are factors that should be investigated in future studies and may constitute an additional possibility in the rehabilitation of individuals with DMD.

5. CONCLUSION

Individuals with DMD had significantly longer movement time when compared to the TD group and this was particularly evident in activities that required faster speeds of movement. In ID6 in which there was a greater demand for accuracy of movement, individuals with DMD performed similarly to those with TD. It can be inferred that the difficulty experienced by those with DMD was higher when the task required more speed versus accuracy. This suggests that individuals with DMD show higher ability in tasks that require accuracy, and therefore these kinds of tasks should predominately be used in their daily activities in order to keep them engaged in social participation. However, as a purpose of rehabilitation, tasks that demand speed should be a focus of training to improve their abilities and to increase their independence.

AUTHORS' CONTRIBUTIONS

All authors participated in the acquisition of data and revision of the manuscript. All authors determined the design, interpreted the data and drafted the manuscript. All authors read and gave final approval for the version submitted for publication.

DECLARATION OF INTEREST

All authors report no conflict of interest. All authors were responsible for the content and writing of this paper.

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