Austin Journal of Clinical Neurology

Open Access

Austin Publishing Group

Original Article

Hand Muscle Strength and Endurance of Individuals with Down Syndrome

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Received: April 28, 2020; **Accepted:** May 14, 2020; **Published:** May 21, 2020

Abstract

Down Syndrome (DS) is a chromosomal disorder. To date, no reports have detailed hand strength and hand endurance of people with DS.

Purpose: To demonstrate strength and endurance characteristics of hand grip and pinch in individuals with DS.

Methods: Forty-eight participants with DS (17.5±4.0 years) and 62 typical peers (17.8±3.7 years) were recruited. A digital dynamometer (MicroFET4) was used to measure voluntary hand force.

Results: The peak grip and pinch strength in DS group were significantly lower than those of the typical group ($p<0.01$). However, no significant differences in dynamic grip and pinch endurance were found between the groups. DS group exhibited lesser strength reduction on the static hold grip test than that of the typical group.

Conclusions: Our findings reveal that individuals with DS exert weaker hand grip and pinch strength; nevertheless, they may have abilities of executing sustained time to the hand movements.

Keywords: Down syndrome; Muscle strength; Endurance; Grip; Pinch

Introduction

Down Syndrome (DS) is the most common chromosomal disorder causing psychomotor disabilities in children, adolescents and adults [1-3]. It is well recognized that individuals with DS exhibit insufficient leg muscle strength [4,5]. In recent studies, grip and pinch strength of individuals with DS were reported [6,7]. In addition to hand strength, hand endurance is also worth studying. In daily living, manual tasks involve the ability of repetitive hand movements (dynamic endurance). Also, using hands to carry or sustain objects involve the ability of hand holding (static endurance). To date, no reports have detailed both the hand muscle strength and endurance in individuals with DS. Studying such hand features in DS is crucial to revealing the physical abilities that are unique to individuals with DS. Moreover, it offers important hand function parameters that would be helpful for any considered physical training intervention. The objective of this study was to demonstrate strength and endurance characteristics of hand grip and pinch in individuals with DS.

Methods

Participants: Participants with DS were recruited via convenience sampling from four local organizations (three special education schools and a local Down syndrome association). The inclusion criteria included participants who had been diagnosed by a pediatrician with DS, had functional visual and hearing abilities, and could follow instructions to participate in our measurements. The exclusion criterion was that participants had had a history of cardiopulmonary or orthopedic surgery in the last year. Forty-eight individuals (DS group, 28 boys & 20 girls) aged between 12.2 and 24.0 years (mean±SD, 17.5±4.0 years) were recruited. Another group of sixty-two participants (typical group, 38 boys & 24 girls, 12.4~24.0 years old) without any clinical neuro-developmental, orthopedic or cardiopulmonary disorders were selected to match the participants with DS on age and gender.

Materials used and three hand tests

A computerized system incorporating a digital hand dynamometer (model TBS-2000 MicroFET-4, Hoggan Scientific, LLC, UT) was used. MicroFET-4 has been reported showing high test-retest reliability and low technical error of measuring hand strength [8,9]. Sensors of the MicroFET-4 include a cylindrical handle for transducing grip strength and a paddle portion for gauging pinch strength. Force output via the sensors is transmitted and recorded by using the computer system software. The device measured in pounds. Measurement precision was in 0.1 pound increments. Three different tests were carried out for all the participants. The order of the tests was: a series of 6-repetition grips, a 15-second static hold grip and a series of 4-repetition pinches. In our pilot testing, performing 6 repetitions of grips and 4 repetitions of pinches were found as appropriate to test individuals with DS without inducing their uncomfortable muscle soreness.

Procedure of hand grip measurement

Participants were instructed to sit in a standardized, stable sitting position in a chair with back support, with hips flexed at approximately 90 degrees, and feet placed flat on the floor. Their elbows were slightly forward of the hips, and were flexed to produce an approximate 90 degrees angle with the forearms in a neutral position. The wrists were positioned between 0 and 30 degrees dorsiflexion. Each participant was instructed to clench the cylindrical handle (cylindrical circumference:

Citation: Wang HY, Tang YT, Long IM. Hand Muscle Strength and Endurance of Individuals with Down Syndrome. Austin J Clin Neurol 2020; 7(1): 1137.

Table 1: Participants' Information: mean (SD), range of minimum ~ maximum.

	Typical			DS		
	All n=62	Boys n=38	Girls n=24	All n=48	Boys n=28	Girls n=20
Age (year)	17.8 (3.7)	18.0 (3.8) 13.4~24.0	17.4 (3.6) 12.4~24.0	17.5 (4.0)	18.1 (4.2) 12.2~24.0	16.6 (3.6) 12.7~24.0
Body height (cm)	165.9 (9.5)*	170.5 (8.2)* 150~188	158.5 (6.5)* 146~173	149.8 (7.8)	152.9 (7.9) 133~166	145.5 (5.1) 138~156
Body weight (kg)	62.4 (13.5)*	63.3 (12.1)* 45.0~98.0	52.8 (9.4) 39.0~76.8	57.0 (11.3)	59.5 (12.7) 31.0~87.1	53.6 (8.3) 41.2~71.0

*indicates a significant difference between the typical and DS participants by groups or by gender, independent t- test, $p<0.05$.

Table 2: Summary of Hand Peak Strength Values: mean (SD).

	Typical			DS		
	All n= 62	Boys n=38	Girls n=24	All n=48	Boys n=28	Girls n=20
Repetitive grip (lb)						
Mean of first 3 repetitions						
D hand	34.7 (14.4)*	41.8 (13.7)*	23.2 (4.8)*	15.0 (6.2)*	16.6 (6.6)*	12.8 (4.9)
ND hand	29.5 (10.7)*	34.5 (10.1)*	21.3 (5.5)*	14.0 (5.2)*	14.4 (5.7)	13.5(4.7)*
Mean of last 3 repetitions						
D hand	28.0 (10.3)	32.8 (9.5)	20.3 (5.9)	13.2 (5.5)	14.1 (5.8)	12.1 (5.1)
ND hand	25.4 (8.9)	29.7 (8.0)	18.6 (5.5)	12.8 (4.7)	13.7 (5.0)	11.2 (4.1
Repetitive pinch (lb)						
Mean of first 2 repetitions						
D hand	16.8 (5.2)*	19.2 (4.7)*	12.9 (3.4)*	10.0 (3.2)	10.0 (2.5)	10.1 (4.3)*
ND hand	15.4 (4.8)*	17.4 (4.4)*	12.1 (3.4)*	9.3 (3.0)	9.3 (2.9)	9.1 (3.3)
Mean of last 2 repetitions						
D hand	15.3 (4.7)	17.5 (4.4)	11.8 (2.8)	9.1 (3.1)	9.5 (3.2)	8.6 (3.1)*
ND hand	14.1 (4.7)	16.4 (3.9)	10.4 (3.2)	8.7 (2.4)	8.6 (2.1)	8.8 (2.9)

D hand: Dominant hand; ND hand: Non-dominant hand; *Using paired t-test for within group data analysis, $p<0.05$: A significant difference between the first 3 and the last 3 repetitive grip of the same side hand; a significant difference between the first 2 and the last 2 repetitive pinch of the same side hand.

14 cm) of the MicroFET-4. Hand grip was performed by consecutive trial alternately on right and left hands to complete 6 trials on each hand. For each trial, participants were verbally encouraged to grip as strong as possible, and held the grip for about 3 seconds in order to generate a peak contraction. A short rest for approximately 5 seconds was given between trials. The peak of each contraction was recorded. For static hold grips, participants clenched the dynamometer handle to conduct a 15-second grip. Participants were verbally encouraged to sustain maximal contraction. Each hand performed once. By using the computer software of the MicroFET-4 system, the value of fatigue slope after each hold grip was displayed. Fatigue slope indicates the degree to which muscle strength leans downward during muscle contraction. A larger negative value of the fatigue slope represents a poorer static hand endurance.

Procedure of hand pinch measurement

Participants were instructed to sit in the chair with shoulders abducted between 30 and 45 degrees. Their elbows were flexed in an approximate 90 degrees with the forearms in a pronated position. They pinched the paddle transducer of the dynamometer by using the pads of thumb and index finger, and were verbally encouraged to maintain this for about 3 seconds to generate peak contraction. The testing was performed alternately on both hands until 4 trials completed on each side. A peak value of each contraction was recorded.

Data analysis

Statistical analyses were conducted using IBM SPSS V19. Descriptive statistics were applied to all analyzed variables. Independent sample t-test was applied to compare variables between the two groups. In order to understand any significant change of peak value during the period of repetitive contraction, paired t-test was used to examine the mean peak strength of the first half of the repetitive contractions (i.e. the first 3 grips, the first 2 pinches) and that of the second half (i.e. the last 3 grips, the last 2 pinches). To estimate the dynamic grip and pinch endurance, a fatigue index was used as a measure of endurance flowing the method of Nicolay, et

al. [10] and White et al. [11] This index is the percentage of [peak strength of the first repetition minus the last repetition] relative to the peak strength of the first repetition. A larger fatigue index indicates a greater dynamic fatigue. A significance level of p <0.05 was used for all analyses.

Results

Table 1 displays the data of participants' age, body height and body weight by groups and also by gender.

Grip and pinch peak muscle strength

In Table 2, for the DS group, the mean peak strength of the first 3 repetitive grips on the dominant hand (15.0±6.2 lb) and the non-dominant hand (14.0±5.2 lb) were correspondingly lower than the mean peak strength of the dominant hand (34.7±14.4 lb) and non-dominant hand (29.5±10.7 lb) in the typical group ($p<0.01$). Regarding the repetitive pinch strength, the mean strength of the first 2 pinches in DS group was 10.0±3.2 lb on the dominant hand and 9.3±3.0 lb on the non-dominant hand, which were significantly lower than those of the typical group (16.8±5.2 lb for the dominant hand, 15.4±4.8 lb for the non-dominant hand) ($p<0.01$, the results of independent t-test analysis was not shown in Table 2.

Table 2 also displays the results of within group data analysis. In the typical group, the mean grip and mean pinch strength of the second half repetitive contractions were significantly reduced compared to their mean of the first half contractions, using either combined gender or by gender analysis ($p<0.05$). For the DS group, the mean strength of repetitive grips in the second half was significantly reduced ($p<0.05$). However, there was no significant strength reduction in the second half repetitive pinches compared to their first half contractions.

Grip and pinch muscle endurance

In Table 3, a larger fatigue index value indicated a poorer dynamic endurance. There were no significant difference in grip and pinch fatigue index between the two groups (using combined gender and by gender analysis). Regarding fatigue slope, larger negative values indicated poorer static endurance. In the DS group, the negative value of the fatigue slopes were significantly lesser than those of the typical group ($p<0.05$) (using combined gender and by gender analysis).

Discussion

The results of this study demonstrated both strength and endurance characteristics of hand grip and pinch in individuals with DS.

Grip and pinch muscle strength

The peak grip and pinch strength values of the typical group in this study were similar to the hand muscle strength reported in previous studies [12-14]. For the repetitive strength of the DS group, our data demonstrated that the DS group produced on average about 45% of the peak grip strength and 60% of the peak pinch strength of the typical group. When showing the extent of differences in hand strength between the two groups, it is necessary to understand certain body structural variations found in DS. Normally, muscles recruited for griping and pinching are located in the forearm and hand [15]. Individuals with DS have small hands and short fingers [16]. In addition, they may have absences of some musculature. Two of these absences are lack of palmaris longus (a forearm muscle involved in motion of wrist flexion) and the tendons of flexor digitorum superficialis (a forearm muscle that provides flexion of wrist and fingers) [17,18]. This would suggest a possible link between such specific anatomical variations and lower hand strength in individuals with Down syndrome.

In regard to the results of repetitive grip and pinch measurements, in the DS group, the mean peak strength of the second half repetitions was about 10% less for the mean of their first half repetitions; while such a strength decrease in pinch movements was about 8% (calculated according data in Table 2. The corresponding data of strength decrease in the typical group were about 17% and 9% respectively (calculated according data in Table 2). These findings illustrate that the hand strength reduction in the DS group was similar or even lesser compared to the typical group. That is, although individuals with DS have weaker hand strength, they have a relatively small decrease in strength during repetitive movements.

Grip and pinch muscle endurance

Regarding the static grip endurance, our result showed that the

Table 3: Summary of Hand Endurance Values: mean (SD).

	Typical			DS		
	All n= 62	Boys n=38	Girls n=24	All n=48	Boys n=28	Girls n=20
Fatigue index of Dynamic grip						
D hand	20.0 (18.5)	23.6 (17.9)	17.9 (13.9)	17.0 (26.2)	17.3 (26.9)	18.4 (18.1)
ND hand	19.5 (17.0)	22.9 (17.1)	17.4 (13.6)	15.3 (20.9)	13.1 (22.7)	17.8 (15.9)
Fatigue index of Dynamic pinch						
D hand	9.5 (22.5)	10.4 (11.5)	9.0 (26.5)	8.7 (13.0)	9.2 (20.7)	6.4 (14.5)
ND hand	9.2 (14.3)	9.5 (12.8)	9.0 (15.0)	7.8 (22.0)	7.7 (25.0)	7.8 (18.1)
Fatigue slope of Static hold grip						
D hand	-0.41(0.3)*	-0.47 (0.2)*	-0.31 (0.3)*	-0.20 (0.2)	-0.25 (0.2)	-0.17 (0.2)
ND hand	-0.38(0.3)*	-0.42 (0.3)*	-0.30 (0.2)*	-0.20 (0.2)	-0.22 (0.3)	-0.16 (0.2)

D hand: Dominant hand; ND hand: Non-dominant hand; *A significant difference between the typical and DS participants by groups or by genders, independent t-test, $p<0.05$.

DS group maintained the contraction force and had less fatigue than the typical group. Cole et al. found the subjects with DS had the ability to generate substantive great grip forces but failed to adapt the force to lift objects [19]. The authors suggested this was due to the lack of using sufficient somatosensory information for controlling movements. Masumoto et al. found that subjects with DS exhibited a systematic delayed force controlled onset in finger movements [20], and suggested that this phenomenon could be attributed to a neuro-physiological difference in motor unit recruitment. In our study, the endurance measurements provided time to output muscle strength. One possible neuromuscular mechanism is that the participants with DS could gradually build up more somatosensory information and accumulate newly recruited motor units to continue their grip and pinch movements.

In this study, there were no data comparisons between genders. However, the differences in hand data between the typical group and the DS group were analyzed using gender combinations and by gender, and the statistical results were similar. It may indicate that gender did not mainly affect hand strength and endurance differences between the two groups. In future studies of children and youth with DS, the gender effects on hand strength characteristics can be further investigated. Muscle strength and muscle endurance are two basic body function parameters and are often utilized as important outcomes for reflecting the effectiveness of intervention programs in clinical trainings. It is worthwhile for therapists to know how the characteristics of hand strength and endurance (i.e. isometric strength, dynamic endurance, and static endurance) in individuals with DS are related to their functional performances. Individuals with DS may exert weaker hand strength in daily manual tasks. However, at the same time, they may have the physical ability to perform repetitive and sustained tasks. In future research, the relationship between hand force and functional manual performances can be further studied in order to provide reference data for designing appropriate therapeutic programs for children and youth with DS.

About the limitations, the results of this study may not be transferable to DS populations with different age ranges. Furthermore, in this study, standardized positioning during the measurement process prevented the participants from choosing their preferred positioning. This introduces the possibility of limiting their hand performance. Therapist should be aware of this possible limitation when conducting clinical measurements.

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