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Manual Dexterity and Hand Strength in Children with Type 1 Diabetes Mellitus and Their Healthy Peers

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Abstract:Background: Type 1 diabetes mellitus represents a prevalent chronic endocrine and metabolic disorder affecting a significant proportion of pediatric and adolescent populations, with a rising incidence of diagnoses annually. Myopathy, or diabetic skeletal muscle disease, is a prevalent clinical manifestation in type 1 diabetic persons. This study was conducted to compare manual dexterity and hand strength between diabetic children and their healthy peers.

Methods

An observational cross-sectional study of one hundred-twenty children from both sexes who were divided into two groups: the study group including sixty diabetic children (29 girls and 31 boys) and the control group including sixty non-diabetic children (31 girls and 29 boys). A laboratory investigation of the standardized hemoglobin A1c (HbA1c) test was conducted on the children in all groups. The Bruininks-Oseretsky Test of Motor Proficiency, second edition, was utilized to measure manual dexterity, the Baseline Mechanical Pinch Gauge was utilized to assess pinch strength (tip, tripod, and key strength), and the JAMAR hand-held dynamometer was utilized to evaluate hand grip.

Results: There were significant decreases in hand grip, tip to tip, tripod, and key strength and manual dexterity of the diabetic group compared with that of the non-diabetic group.

Conclusion: Type 1 diabetes has an effect on hand grip, tip to tip, tripod, and key strength and manual dexterity in children aged from 6 to 8 years.

Keywords:*Diabetes, Hand Grip, Pinch grip, Manual dexterity.*

I. Introduction

Diabetes Mellitus (DM) is a multifaceted condition encompassing a range of disorders marked by elevated blood sugar levels, resulting from the body's impaired glucose metabolism [1]. Type 1 diabetes mellitus (T1DM) develops due to an intricate interplay between genetic susceptibilities and environmental triggers [2].

The clinical presentation of T1DM can be affected by diverse nutritional and viral factors worldwide [3]. Significant progress has been made in T1DM management over recent decades. Glycosylated hemoglobin A1C (HbA1c) continues to be a crucial indicator for diagnosing, managing, controlling, and predicting complications in individuals with diabetes [4]. Nevertheless, individuals with poorly controlled T1DM will likely experience long-term effects from complications affecting both small and large blood vessels, including vision loss, renal disease, and cardiovascular disorders. Additionally, the musculoskeletal system is frequently impacted by T1DM, and inadequate disease control can lead to adverse outcomes in this system as well [5].

Diabetic skeletal muscle disease is frequently seen in type 1 diabetic patients [6]. This condition manifests as reduced muscle mass, general and functional weakness, and a comprehensive decline in physical function [7]. In diabetic children, muscle weakness increases physical disability risk [8]. Reduced muscular strength has been observed in diabetic individuals as an end-stage consequence of severe diabetic peripheral neuropathy (DPN) affecting motor nerves [9]. Nevertheless, other research indicates that upper-body muscle weakness may develop earlier in diabetes, regardless of DPN [10].

The American Society of Hand Therapists (ASHT) indicates that assessing grip and pinch strength reflects the total upper limb strength [11]. Hand grip strength (HGS) represents the collective force exerted by the flexor muscles against the palmar surface, serving as an indicator of the maximum static force that can be generated by the hand [12]. Handheld dynamometry (HHD) offers an easy-to-use, cost-effective, and versatile alternative for muscular strength assessment [13].

Pinch strength is the manual motor function most commonly used in daily tasks, and is a key component of hand function. Good pressing force helps fine motor movements of the hands [14]. Dexterity, which includes both manual and fine dexterity, is vital for evaluating hand function comprehensively [15]. Manual dexterity describes the capability to manipulate objects using the hands, while fine dexterity involves in-hand manipulations distinct from the gross motor skills of grasping and releasing [16]. Additionally, tests of dexterity can evaluate the task execution speed, in-hand manipulation skills, and/or the control of dynamic force [15].

Evidence from studies suggests that diabetes has implications for brain structures, with variables like hypoglycemia frequency and the timing of disease initiation impacting its progression. The brain in humans constantly depends on simple sugar as a vital fuel source, and when hypoglycemia arises in diabetes, it results in diminished cognitive and motor functions [17]. In evaluating upper limb function among both diabetic and non-diabetic individuals, findings revealed that 75% exhibited conditions impacting their mobility. Previous research has identified prevalent hand and shoulder impairments among diabetics; however, limited investigation has been conducted on the manual dexterity of T1DM children [18, 19]. So this study was conducted to assess hand grip, pinch grip, and manual dexterity in type 1 diabetic children and compare them with their healthy peers.

II- Participants & Methods

2.1. Study design and Ethical consideration

An observational cross-sectional study was carried out to compare grip and pinch strength and manual dexterity between diabetic and non-diabetic children. The study was carried out with approval of Cairo University's Faculty of Physical Therapy's ethical review board (No: P.T.REC/012/005206). For this study to begin, we received written approval from the participants' legal representatives, either parents or guardians.

2.2. Participants

One hundred and twenty children from both sexes (60 girls and 60 boys) aged between 6 and 8 years participated in this study. They were allocated into two groups; the diabetic study group (n=60) and the non-diabetic control group (n=60). The children with diabetes were selected from Tanta Student Health Insurance Hospital and the healthy normal developed children were selected from the primary schools.

The diabetic children were included if they were diagnosed with type I diabetes for ≥ 6 months and received their medical treatment regularly. All included children were able to follow the instructions. Children with hyper/hypoglycemia during the test evaluation or uncontrolled diabetes, those with structured deformity on the upper limbs, major musculoskeletal and neurological disorders, and complications as loss of body parts, hemiplegia or ataxia, myopathy or neuropathy due to medical causes other than diabetes, cheiroarthropathy, and also who had visual or auditory problems, epilepsy, mental retardation, or autistic features were excluded from this study.

2.3. Procedures

This study was conducted at Tanta Student Health Insurance Hospital.

2.3.1. Evaluation procedures for both groups

2.3.1.1. ***The standardized hemoglobin A1C (HbA1c) test***

For children with T1DM, a glycated hemoglobin (HbA1c) level of higher than 7% is a diagnostic requirement, ascertained using an assay approved by the National Glycohemoglobin Standardization Program 226 [21].

2.3.1.2. ***Measurement of hand grip strength***

Adhering to the guidelines set forth by the ASHT [22], the grip strength of the participant's dominant hand was evaluated utilizing the Jamar Hand Held Dynamometer (Serial No: 30402264). Hand grip strength represents a benchmark for evaluating hand function. It can be evaluated by using a dynamometer to measure the isometric force that the hand produces [23, 24]. When techniques are standardized and calibrated equipment is used, hand dynamometry can be a reliable measurement method even when testing is carried out by many assessors [25].

2.3.1.3. ***Measurement of pinch grip strength***

For all participants, the baseline mechanical pinch gauge of 0, 60 lb. was used to evaluate tip to tip, tripod, and lateral key grip strength on dominant hands. Compared to similar instruments, it provides a more precise and excellent interrater reliability of pinch (r =0.98 to 0.99) measure of strength [26].

2.3.1.4. ***Measurement of manual dexterity***

The Bruininks-Oseretsky Test of Motor Proficiency, Second Edition (BOT-2) was utilized to measure the manual dexterity of the dominant hand in all participants. Physical and occupational therapists are commonly using this standardized and norm-referenced assessment tool in clinical or training environments. It is intended to be used by both practitioners and researchers for the purposes of identifying and assessing motor performance, emphasizing fine manual control, coordination of movements, total body alignment, as well as strength and agility [27].

Manual dexterity includes targeted activities requiring both hands to reach and grasp small objects in a coordinated way, which is part of the manual coordination composite. The assessment consists of five tasks: 1), to pick up plastic pennies and put them in a box, 2) to create a series of connected small blocks, 3) to organize cards, 4) to insert pegs into pegboards. 5) Inserting dots into circular shapes. Attention is paid to both the correctness and rapid implementation of tasks to encourage children to do what they can as quickly as possible. The addition of the speed element allows for a more precise distinction in skill levels [28].

2.4. Sample size calculation

Based on the finding of the previous study ofAtay et al.[20], who compared hand grip strength between children with T1DM and their non-diabetic counterparts, sample size calculation was done utilizing the G*POWER statistical software (version 3.1.9.2; Universitat Kiel, Germany). The analysis indicated that each group necessitated 60 subjects. The calculations were conducted with an effect size of 0.52, a statistical power of 80%, and a significance level (α) of 0.05.

2.5. Statistical analysis

To compare the participant's characteristics between the groups, an unpaired t-test was implemented, while the Chi-squared test was utilized to evaluate the distribution of sex across the groups. The data normality was assessed utilizing the Shapiro-Wilk test. To ensure homogeneity between groups, Levene's test for homogeneity of variances was utilized. Grip strength and manual dexterity between groups were compared using another unpaired t-test. The significance level for all statistical analyses was set at $p < 0.05$. All statistical analyses were performed utilizing the Statistical Package for the Social Sciences (SPSS) version 25 for Windows.

III. Results

***Subject characteristics*:**

Subjects' characteristics of both groups were demonstrated in Table 1. There was an insignificant difference among groups in age and sex distribution ($p > 0.05$). The diabetic group demonstrated a significant increase in HbA1c compared to the non-diabetics ($p < 0.001$).

Table 1. Participants' basic characteristics.

	Non-diabetic group	Diabetic group	p-value
	Mean ± SD	Mean ± SD	
Age (years)	7.05 ± 0.78	6.99 ± 0.81	0.69
HbA1c	4.69 ± 0.44	8.03 ± 0.63	0.001
Sex, n (%)			
Girls	29 (48.3)	31 (51.7%)	0.72
Boys	31 (51.7%)	29 (48.3%)	

SD, standard deviation; p-value, level of significance

Comparison of grip strength and manual dexterity between non-diabetic and diabetic groups:

The diabetic group revealed a significant reduction in hand grip, tip to tip, tripod, and key strength compared to the non-diabetics ($p < 0.001$). Also, the diabetic group showed a significant decrease in manual dexterity compared to the non-diabetics ($p < 0.001$) **(Table 2).**

Table 2. Mean grip strength and manual dexterity of non-diabetic and diabetic groups:

	Non-diabetic group	Diabetic group	MD	t- value	p value
	Mean ± SD	Mean ± SD			
Grip strength (lb)					
Hand grip	8.98 ± 1.43	3.12 ± 1.29	5.86	23.57	0.001
Tip to tip	3.50 ± 0.85	1.24 ± 0.87	2.26	14.34	0.001
Tripod	5.57 ± 1.06	2.54 ± 0.96	3.03	16.33	0.001
Key	7.10 ± 1.09	2.40 ± 1.23	4.7	22.12	0.001
Manual dexterity	13.48 ± 1.59	7.18 ± 1.41	6.3	22.98	0.001

SD, standard deviation; MD, mean difference; p-value, probability value

IV- Discussion

In this study, the hand functions (strength and dexterity) were examined in children with T1DM and compared to age-matching non-diabetics. We found that diabetic children have lower hand grip, tip to tip, tripod, and key grip strength than non-diabetic children. Also, non-diabetic children have better manual dexterity than diabetic children.

Functional manipulation of objects is an essential motor action for independent life daily activities. By using proper grip force amount, the objects can be manipulated effectively. Actually, information utilized from skin mechanoreceptors regarding an object's weight, along with friction force, enables an accurate rapid estimation of the required grip force [29].

Examining hand function in children is primarily focused on neurological and orthopedic conditions in existing literature. Numerous studies examining the association between DM and hand function in adults have demonstrated that suboptimal metabolic regulation impairs hand function, especially in later stages of life [30, 31].

While the relationship between HGS and T1DM remains unclear with varying results, chronic diseases are frequently linked to muscle function decline. Multiple studies have documented HGS reduction in children and adults with chronic conditions [26, 32, 33]. In this study, decreased grip and pinch strength were reported in type 1 diabetic children (diabetic group) compared to the non-diabetics.

Krause et al. [34] observed a decline in the maximum contraction power of muscles in individuals with T1DM. They suggested that this muscle strength loss resulted from decreased growth of glycolytic muscle fibers and atrophy, despite the potential contribution of various other factors. That is reinforced by the retrospective research conducted by Balducci et al. [35], who intended to examine the correlation between muscular strength and diabetes, and assessed factors affecting muscle and bone strength abnormalities.

Fricke et al. [36] demonstrated that type 1 diabetic children exhibited significantly diminished maximal isometric force across all age groups when compared to age-matched reference individuals, a finding that is partially consistent with the present study's observations. Likewise, DongareBhor et al. [37] revealed that type 1 diabetic children had significantly lower HGS than their control counterparts. Wallymahmed et al. [38] also found a significant inverse correlation between HGS and HbA1C.

A Nigerian study on diabetic patients, consistent with our findings, showed that the dominant hand grip strength was lower in diabetic patients (males 19.56 kg, females 12.17 kg) than in non-diabetic controls (males 21.94 kg, females 14.06 kg) [39].

On the other hand, Bechtold et al. [40] examined T1DM effects on skeletal and muscular development, noting a significantly superior HGS in diabetic children relative to control individuals. This difference was related to the profound motivational levels displayed by participants during the assessment phase. Also, Fricke et al. [36] observed a considerably greater HGS among pediatric individuals exhibiting an HbA1c surpassing 8.5% when contrasted with those displaying lower HbA1c readings, a finding that contradicts the observations of the present study. Dongare-Bhor et al. [37] observed an absence of correlation between grip strength and HbA1c levels in T1DM.

Zhang et al. [14] reported decreased pinch force (fingertip type) measurement in both hands in diabetic people who have distal peripheral neuropathy which may be due to skeletal muscle atrophy.

This study's results demonstrated a further reduction in manual dexterity scores in type 1 diabetic children than in non-diabetic ones. Adequate manual dexterity is essential for the successful execution of different daily living tasks. Pfützner et al [41] previously published similar results, which indicate that insulin-dependent individuals with type 1 and type 2 DM had worse hand dexterity than healthy controls. Also, diabetic persons needed a longer duration to accomplish the dexterity assessment (407.5 ± 29.1 seconds for males and 396.4 ± 22.9 seconds for females) when contrasted with normative data obtained (313 seconds for males and 308.33 seconds for females) [42].

Our results aligned with a meta-analysis conducted by Naguibet al [43] which examined 24 research that investigated the neurocognitive abilities and visual-motor coordination of type 1 diabetic children and they had poor performance in dexterity test.Even though the differences between T1DM children with optimal versus suboptimal glycemic regulation were not statistically significant, suboptimal glycemic control seemed to have a more detrimental effect on hand functioning in children with T1DM, in line with the study's outcomes [44].

Limitations:

The study was limited by extraneous factors that may have interfered with the study's findings. These factors are associated with challenges faced by the normal child sample because of regular school schedules. A further limitation was the children's psychological state during the study's implementation period.

V- Conclusion:

It was concluded that type 1 DM has a significant impact on children aged between 6 and 8 years old who are affected by diabetes.

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Conflict of interest

Authors state no conflict of interest.

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