The Egyptian Journal of Hospital Medicine (October 2025) Vol. 101, Page 5102-5110

Assessment of Muscle Status among Children and Adolescents with Type 1 Diabetes Mellitus

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ABSTRACT

Background: Hand grip strength **(**HGS) is a non-invasive approach for the assessment of muscle strength in diabetic patients, and it is a good tool in differentiating diabetic patients with good control and those with poor glycaemic control.
Objective: to evaluate the muscle status including (skeletal muscle mass and muscle force) among children and adolescents with T1DM using non-invasive HGS and BCM in relation to diabetes-related parameters, which include age at onset, duration of T1DM, average total daily dose of insulin, level of glycaemic control (average HbA1c % level), and lipid profile.
Patients and methods: This is a cross-sectional controlled study with an analytical component that was carried out on 200 children in the period between October 2022 to October 2023. All children in this study were subjected to medical history, complete general examination, anthropometric measures, body composition measurement, and HGS measurement. The patients' group was subjected additionally to detailed medical history related to diabetes, full neurological examination, and biochemical laboratory tests.
Results: There were significant higher median values of HGS and HGS Z-score among diabetes than the control group ($p<0.001$). There was a significant positive correlation between HGS and HGS z-score with diabetes duration and a significant negative correlation between HGS and HGS z-score with HbA1c.
Conclusion: HGS values were higher in T1DM children compared to controls and higher values were detected with long duration compared to others with shorter duration of disease. HGS was good in differentiating between diabetic cases with good control and those with poor glycaemic control.
Keywords: T1DM; Muscle strength; HGS; BCM.

INTRODUCTION

Type 1 diabetes mellitus (T1DM) is a chronic endocrine and metabolic disease among children and adolescents but can have its onset at any age. The incidence of children diagnosed with DM is rising annually [1]. long-term vascular complications of DM comprise nephropathy, retinopathy, neuropathy and macrovascular diseases including cardiac diseases, peripheral vascular disease, and stroke. It has been demonstrated that diabetes-related vascular complications are uncommon among children. On the other hand, early functional and structural changes could be present a few years following DM onset [2].

Longer duration of DM, older age, puberty, and higher body mass index (BMI) are predisposing factors for the long-term vascular complications of DM [2]. In addition, the possibility of acquiring complications could be increased by poor glycaemic control, hypertension, and hyperlipidemia together with genetic factors [3]. Skeletal muscle represents about 80% of glucose disposal and muscle mass play a significant role in metabolic regulation**.** It is the most abundant insulin-sensitive tissue in the body [4].

Diabetic skeletal muscle disorder is a frequent symptom noticed in diabetic subjects. The patient presents by diminished muscle mass, generalised weakness, and diminished physical capacity [5].

Impairment of muscle strength has been recorded in adults with DM as a late complication of extensive diabetic peripheral neuropathy (DPN) with motor nerve affection [6]. In contrast, other studies conducted in adults with T1DM displayed that diminished muscle strength could happen in the initial stages of DM regardless of DPN and may affect the upper extremities [7].

Precise description of the muscle status of chronic kidney disease (CKD) cases could be achieved by detecting muscle function by the handgrip strength tool and by offering a proper evaluation of the muscle mass by the body composition monitor (BCM) device [8]. HGS is a measurement of the maximal voluntary force of the hand/arm, which is defined as a helpful modality in evaluating muscle function as it is a noninvasive, fast, and cheap approach [9]. Another important tool is the BCM device using bioelectrical impedance analysis (BIA), which is noninvasive, simple, fast and highly reproducible. BCM is a very useful tool in measuring lean tissue mass (mainly muscle mass) and fat tissue in the human body [10].

To the best of our knowledge, assessment of muscle status among children and adolescents with T1DM using HGS was rarely evaluated in previous studies. Hence, this study aimed to evaluate the muscle status including (skeletal muscle mass and muscle force) among children and adolescents with T1DM using non-invasive HGS and BCM in relation to diabetes-related parameters, which include age at onset, duration of T1DM, average total daily dose of insulin, level of glycaemic control (average HbA1c % level), and lipid profile.

PATIENTS AND METHODS

This is a cross-sectional controlled study with an analytical component that was carried out on 200 children in the period between October 2022 to October 2023 and was conducted at the Pediatric

Received: 07/05/2025
Accepted: 09/07/2025

Endocrinology Unit of Mansoura University Children's Hospital (MUCH).

Subjects were divided into two main groups:

1- **Patients group:** This included 100 patients recruited from the Endocrinology Unit–Mansoura University Children's Hospital (MUCH) with confirmed diagnosis of T1DM according to WHO criteria**.** Then patients were classified into 4 groups (n=25 in each group) based on disease duration. Also, they were subclassified according to glycaemic control into 3 groups based on HbA1c.
2- **Control group:** this included 100 healthy children of matched age and sex recruited from the general outpatient clinic MUCH.

Inclusion criteria:

1. Age 6-18 years.
2. patients with a confirmed diagnosis of T1DM with different durations.

Exclusion criteria:

1. Cases with T2DM or 2^{ry} DM.
2. Cases with cachexia secondary to any underlying otherwise chronic illness such as chronic hepatic diseases, malignant tumor and so on.
3. Cases with upper limb malformation.
4. Cases with neuromuscular diseases.
5. Cases who had short stature (Height Z-score < -2 SD).
6. Athlete children with T1DM including any child engaged in any sport rather than regular daily physical activity.
7. Thyroid disease and positive serological tests of celiac disease.

METHODS

All children in this study were subjected to medical history, complete general examination, anthropometric measures, body composition measurement, and HGS measurement. The patients' group was subjected additionally to detailed medical history related to diabetes, full neurological examination, and biochemical laboratory tests.

1) Detailed medical history: comprising name, age, sex, age of onset and duration of DM, insulin regimen, total daily insulin dose, associated comorbidities, symptoms of neuropathy as tingling, numbness, pain, burning or paresthesia of hand and foot, family history of DM, and frequency of hospital admissions for uncontrolled hyperglycemia or DKA.

2) Examination: Full medical examination including:

A) Complete general examination: To exclude any deformity or manifestations of chronic systemic disorders.

B) Neurologic examination: Including metal condition, coordination, cranial nerves, motor system (muscle state, tone, power, and reflexes), sensory system, and gait.

C) Anthropometric measures: Measurements comprised height, weight, and BMI. Height and weight were measured by standard techniques. BMI was calculated body weight divided by stature squared (kg/m^2). Mid upper arm circumference measurement (MUAC) was reported using a plastic measuring tape at the midpoint between the tip of the shoulder and the tip of the elbow. Age and sex-specific Z scores of both BMI and Height [standard-deviation scores (SDS)] using Egyptian children and adolescents reference data are estimated by the next equation:

Z-score (or SD-score) = (noticed value - mean value of the reference population) / standard deviation value of reference population.

D) Body composition measurement:

Body composition was estimated through the evaluation of body fat and muscle mass by BIA approach, using the body composition analyzer "Tanita BC-418 MA" (Tanita coop, Tokyo, Japan) **[11].** Measurements were obtained on the morning of the study after an overnight fast and after the subject had voided. The subject stood on the two-foot plates with legs apart catching the two hand electrodes for 60 seconds. It offers measurements for total and segmental body composition. BIA data included total body fat percentage (TB-fat %), total body fat mass (TB-FM; Kg), total body muscle mass (TB-SMM; Kg), and appendicular FM and SMM obtained as a summation of the results of segmental analysis (right leg, left leg, right arm, left arm) **[12].**

E) Measurement of handgrip strength (HGS): Muscle strength was assessed by maximal isometric grip force using a standard calibrated adjustable-handle Jamar mechanical dynamometer (Fabrication Enterprises INC White Plains, NY 10602, U.S.A) with a precision of 0.5 kg **[2].** To acquire the best results, subjects were told to self-adjust the dynamometer such that it comfortably suits their hand size. Subjects were told to grip the dynamometer using the dominant hand with full strength in response to the voice command where the child remains in the seat with adducted shoulder, elbow flexed ninety degree and forearm in a neutral position. Three trials were conducted with a minimum one-minute rest period between each, and the greatest HGS value in kilograms was recorded to be analyzed**.**

F) Biochemical data: Mean hemoglobin A1c (HbA1C) and metabolic control were considered good, moderate and poor when HbA1C levels were 6.5%-7.5%, 7.6%-9% and >9% correspondingly, Baseline laboratory investigations (Complete blood count (CBC), renal function tests, liver function tests. Recorded results of thyroid profile, celiac antibodies and lipid profile.

Statistical analysis

Data analysis was conducted by SPSS software, version 25 (PASW Statistics. Chicago: SPSS Inc., USA). Qualitative data were defined using numbers and percentages. The Kolmogrov-Smirnov test was used to

test for normality, and the median for non-normally distributed data and mean±SD for normally distributed data were used to assess quantitative data. The significance of the results was set at the (≤0.05) level.

Ethical Considerations

The study was conducted after obtaining approval from the Research Ethics Committee of the Faculty of Medicine, Mansoura University (IRB no. MS.22.07.2060). Written informed consent was obtained from the parents or legal guardians of all participating children prior to enrolment. The consent form explicitly documented voluntary participation and permission for publication of anonymized data, with strict safeguards to maintain confidentiality and privacy. All procedures complied with institutional and national research ethics standards and adhered to the principles of the Declaration of Helsinki for research involving human subjects.

RESULTS

This table (1) illustrates significant higher median values of TB-FM, TB-SMM, TK-FM, appendicular-SMM and appendicular-FM among studied diabetes than the control group **(P<0.05).**

Table (1): Comparison of body composition parameters of the studied groups by BIA

	Diabetes group	Control group	Test of significance
	N=100	N=100	
TB-F%	20.25(16.3-27.68)	18.35(14.6-24.38)	Z =1.93 P=0.053
TB-FM (kg)	7.85(4.9-14.05)	6.1(4.2-8.75)	Z=2.73 P=0.006*
TB-SMM (kg)	31.3(23.45-39.65)	24.4(20.63-33.85)	Z =3.27 P=0.001*
TK-FM (kg)	3.15(1.90-5.95)	2.6(1.53-3.78)	Z=2.14 P=0.03*
Appendicular-SMM (kg)	13(9.1-16.9)	10(7.63-14.88)	Z=3.24 P=0.001*
Appendicular-FM (kg)	4.75(2.83-7.88)	3.5(2.5-5.18)	Z=2.96 P=0.003*

n: number, BIA: Bioelectrical Impedance Analysis, TB-F%: Total Body Fat Percentage, TB-FM: Total Body Fat Mass, TB-SMM: Total Body Skeletal Muscle Mass, TK-FM: Trunk Fat Mass, Appendicular-SMM: Appendicular Skeletal Muscle Mass, Appendicular-FM: Appendicular Fat Mass, kg: kilogram, Z: Mann-Whitney test, *: Significant p-value.

This table (2) demonstrates significant higher median values of HGS and HGS Z-score among diabetes compared with the control group (p<0.001). In addition, a significant higher frequency of HGS Z-score more than +2 SD among diabetes than the control group and a higher frequency of HGS Z-score < -2SD were detected among control than diabetic patients **(p<0.001).**

Table (2): Comparison of HGS and HGS Z-score among studied groups

	Diabetes group	Control group	Test of significance
	N=100	N=100	
HGS (kg)	35(30-45)	21(20-39.5)	Z=5.17 P<0.001*
HGS z-score	3.4(2.4-5.2)	2.25(1.40-3.1)	Z=5.48 P<0.001*
HGS z-score status < -2 SD Between -2 & +2 SD +2 SD	 8(8.0) 68(68.0) 24(24.0)	 24(24.0) 67(67.0) 9(9.0)	 χ^2=14.82 P<0.001*

n: number, HGS: Hand Grip Strength, SD: Standard Deviation, Z: Mann-Whitney test, χ^2: chi-square test statistic, *: Significant p-value.

This table (3) illustrates a significant higher TB-F%, TB-FM and appendicular-FM values in diabetic children with diabetes duration > 5 years and 3-5 years compared to T1DM <1 year duration. Also, significant higher TB-SMM, TK-FM and appendicular-SMM values in diabetic children with diabetes duration > 5 years compared to the other 3 studied groups.

Table (3): Body composition parameters of T1DM patients based on duration of diabetes

	T1DM < 1year	T1DM 1-3 years	T1DM 3-5 years	T1DM > 5 years	Test of significance	Within group
	N=25	N=25	N=25	N=25		
TB-F%	17.6(16.05-22.2)	18.5(15.2-27.15)	21.5(18.7-29.3)	24.5(17.55-31.05)	Kw=8.71 P=0.03*	P1=0.154 P2=0.012* P3=0.007* P4=0.258 P5=0.182 P6=0.836
TB-FM (kg)	5(3.85-8.8)	6.4(4.6-9.85)	7.2(5.55-15.5)	11.6(8.95-17.1)	Kw=18.89 P<0.001*	P1=0.231 P2=0.014* P3=0.003* P4=0.200 P5=.073 P6=0.602
TB-SMM (kg)	27.2(19.7-34.25)	27.4(21.7-36.1)	31.1(23.15-40.15)	37.8(34.85-43.15)	Kw=17.93 P<0.001*	P1=0.526 P2=0.141 P3=0.001* P4=0.398 P5=0.001* P6=0.01*
TK-FM (kg)	2(1.45-4.3)	2.4(1.8-4.8)	2.9(2.05-5.45)	4.6(3.85-8.1)	Kw=15.43 P=0.001*	P1=0.268 P2=0.032* P3=0.005* P4=0.398 P5=0.041* P6=0.033*
Appendicular-SMM (kg)	11(7.3-13.6)	10.9(8.0-15.8)	13.1(9-18.4)	16(13.45-18.6)	Kw=4.26 P=0.007*	P1=0.625 P2=0.04* P3=0.0002* P4=0.116 P5=0.009* P6=0.027*
Appendicular-FM (kg)	3.1(2.4-5.0)	3.9(2.7-6.0)	4.8(3.25-8.65)	7.3(5.25-9.3)	Kw=3.65 P=0.015*	P1=0.245 P2=0.008* P3=0.005* P4=0.131 P5=0.096 P6=0.875

n: number, T1DM: Type 1 Diabetes Mellitus, TB-F%: Total Body Fat Percentage, TB-FM: Total Body Fat Mass, TB-SMM: Total Body Skeletal Muscle Mass, TK-FM: Trunk Fat Mass, Appendicular-SMM: Appendicular Skeletal Muscle Mass, Appendicular-FM: Appendicular Fat Mass, Kw: Kruskal–Wallis test statistic, *: Significant p-value.

This table (4) illustrates a significant higher TB-F%, TB-FM and appendicular-FM values in diabetic children with diabetes duration > 5 years and 3-5 years compared to T1DM <1 year duration. Also, significant higher TB-SMM, TK-FM and appendicular-SMM values in diabetic children with diabetes duration > 5 years compared to the other 3 studied groups.

Table (4): HGS and HGS Z-score between T1DM patients based on duration of diabetes

	T1DM < 1 year	T1DM 1-3 years	T1DM 3-5 years	T1DM > 5 years	Test of significance	Within group
	N=25	N=25	N=25	N=25		
HGS	25(20-42.5)	35(20-42.5)	35(30-40)	40(39-55)	Kw=12.07 P=0.001*	P1=0.011* P2=0.013* P3=0.001* P4=0.089 P5=0.007* P6=0.046*
HGS Z-score	2.25(2.05-3.3)	3.3(2.6-5.85)	3.7(2.2-5.45)	4.3(2.51-4.95)	Kw=7.66 P=0.001*	P1=0.014* P2=0.001* P3=0.001* P4=0.103 P5=0.041* P6=0.063
< -2 SD Between -2 & +2 SD +2 SD	14(56.0) 5(20.0) 6(24.0)	3(12.0) 15(60.0) 7(28.0)	2(8.0) 17(68.0) 6(24.0)	1(4.0) 19(76.0) 5(20.0)	MC=1.17 P=0.003*	P1=0.005* P2=0.002* P3=0.013* P4=0.013* P5=0.046* P6=0.071

n: number, T1DM: Type 1 Diabetes Mellitus, HGS: Hand Grip Strength, SD: Standard Deviation, Kw: Kruskal–Wallis test statistic, MC: Monte Carlo exact test, *: Significant p-value.

This table (5) shows no significant difference between good, moderate and poor glycemic control groups as regards HGS z-score; but there is a significant higher frequency of diabetic children with HGS Z-score > +2SD detected among cases with good glycemic control compared to cases with poor glycemic control. Also, a higher frequency of diabetic children with HGS Z-score < -2SD was detected among those with poor glycemic control compared to cases with moderate and good glycemic control.

Table (5): HGS Z-score values and distribution of children with T1DM according to HGS Z-scores based on their glycaemic control levels

	Hba1c			Test of significance	Within group
	Good <7.5	Moderate 7.6-9	Poor >9		
	N=23	N=24	N=53		
HGS z-score	3.3(1.92-5.33)	3.50(2.25-5.13)	2.23(2.11-3.3)	KW=0.235 P=0.889	P1=0.960 P2=0.633 P3=0.587
< -2 SD Between -2 & +2 SD +2 SD	1(4.3) 16(69.6) 6(26.1)	3(12.5) 16(66.7) 5(20.8)	36(67.9) 13(24.5) 4(7.5)	MC=4.37 P=0.018*	P1=0.586 P2=0.037* P3=0.0.016*

n: number, HbA1c: Glycated Hemoglobin A1c, HGS: Hand Grip Strength, SD: Standard Deviation, KW: Kruskal–Wallis test statistic, MC: Monte Carlo exact test, *: Significant p-value.

This table (6) shows a significant positive correlation between HGS and total dose of insulin(P=0.001).
There was a positive correlation between HGS and HGS Z-score with diabetes duration (P=0.001). Also, significant negative correlation between HGS and HGS Z-score with HbA1c (P=0.014, P=0.008 correspondingly). There was no significant correlation between HGS, HGS Z-score and lipid profile (p >0.05).

Table (6): Correlation between both the absolute value of HGS and HGS Z-scores and diabetes treatment, duration and lab finding

	HGS		HGS Z score	
	r	p	r	p
Total daily dose of insulin (U/kg/d)	0.324	0.001*	-0.043	0.669
Diabetes duration	0.261	0.001*	0.340	0.001*
HbA1c	-0.216	0.014*	-0.312	0.008*
Cholesterol	0.012	0.902	-0.009	0.932
TG	0.155	0.125	0.138	0.172
HDL	0.105	0.298	0.075	0.459
LDL	-0.196	0.051	0.795	0.100

HGS: Hand Grip Strength, HbA1c: Glycated Hemoglobin A1c, TG: Triglycerides, HDL: High-Density Lipoprotein, LDL: Low-Density Lipoprotein, U/kg/d: Units per kilogram per day, r: correlation coefficient, *: Significant p-value.

This table (7) shows that among significant factors assessed by univariate analysis; longer duration of diabetes was a significant predictor of an increase in HGS value. Also, a higher HbA1c value was a significant predictor for low HGS values.

Table (7): Multiple linear regression for predictors of HGS among studied cases

	β	P value	t
Total daily dose of insulin (U/kg/d)	11,19.	0.056	1.93
Diabetes duration	11,15	0,032*	2.18
Hb A1c	-11.10	0.017*	-2.20

HGS: Hand Grip Strength, HbA1c: Glycated Hemoglobin A1c, U/kg/d: Units per kilogram per day, β: regression coefficient (beta), t: t-statistic, p: p-value, *: Significant p-value.

This table (8) demonstrates that the area under the curve for HGS and HGS Z-score was good in differentiating diabetic cases with good control and those with poor glycaemic control.

Table (8): Validity of HGS Z-score in differentiating between good and poor glycaemic control groups among diabetic children

	AUC (95% CI)	P value	Cut off point	Sensitivity %	Specificity %
HGS	0.709 (0.637-0.780)	<0.001*	≥27.50	76.0	60.0
HGS Z-score	0.724 (0.655-0.794)	<0.001*	≥2.41	74.0	56.0

AUC: Area Under the Curve, CI: Confidence Interval, HGS: Hand Grip Strength, *: Significant p-value.

DISCUSSION

The impact of T1DM on skeletal muscle function is believed to arise from multiple factors, primarily due to hormonal changes and hyperglycemia [5]. HGS has been widely used in the adult diabetic population as a tool to evaluate muscle function but rare in children with T1DM. To our knowledge, this study uniquely made use of the HGS device to assess muscle function in children and adolescents with T1DM compared with healthy children; also, in relation to different durations of diabetes and different levels of glycaemic control. This study shows a significant higher median value of BCM among diabetes than the control group. T1DM significantly alters the body composition of children and adolescents, often leading to an excess of fat mass. There was a study that noticed a significant reduction in FM% and lean mass in children with T1DM at the time of diagnosis compared with the non-diabetic group [13].

Also, significant higher BCM values were detected in diabetic children with DM duration > 5 years and 3-5 years compared to T1DM < 1-year. This difference in BCM may be explained by the following, when diabetes is diagnosed a primary period of glucosuria, osmotic diuresis, and lipolytic catabolic condition is brought on by insulin deprivation and after six weeks of treatment body composition returns to normal as there is marked increases in fat mass and minor loss of lean body mass (LBM) [13].

Insulin causes anabolic effects on adipose and muscle tissues [8]. Insulin-mediated body composition alterations have been especially well-assessed in T1DM cases and the majority of studies assessing body composition changes recommended that this weight gain is made of fat and this may be explained by the

intrinsic actions of insulin on LBM, the reduction of glycosuria, sedentary lifestyle [14], unbalanced nutrition, which mostly emphasized on carbohydrate counting instead of appropriate fat consumption [15] or leptin resistance, especially in girls. According to a study done on children and adolescents with T1DM; larger daily insulin dosage and earlier diabetes onset were accompanied by 9% higher body fat in diabetic children compared with their typically developing peers with no difference in LBM between them. Another study reported neither a significant difference in FM nor FM% in children and teenagers with recently diagnosed T1DM compared with the controls, though there was a significantly lower muscle mass nor no significant changes in body composition throughout the follow-up [16].

The current study shows that there were significant higher median HGS and HGS Z-score values among diabetic children than in the control group. In the same line, there was a study that has assessed the effect of T1DM on bone and muscle development and recorded a significant increase in HGS among diabetic children compared with healthy populations reference [12]. The findings of the study aren't consistent with most of the research, which revealed that there was a significant decrease in muscle strength in diabetic patients. Reduction in HGS and impairment of muscle functions among adults were recorded by a lot of studies to be a complication of DM, whatever their type, in particular among cases with diabetic polyneuropathy and carpal tunnel syndrome [17,18]. The inconsistency in the results may be secondary to changes in age group, type of DM medications used for diabetes control, level of glycaemic control, physical activity, and different types of dynamometers that may provide different HGS values [19].

As regards the comparison of HGS and HGS Z-scores between T1DM groups based on disease duration, significant lower median values of HGS and HGS Z-score in children with T1DM < 1 year duration compared to other 3 groups. The significant difference in the values of HGS and HGS Z-score among T1DM patients based on different disease durations may be explained partially by the significant older age and higher frequency of pubertal patients observed in the group with longer diabetes duration (> 5 years) with known significant changes in body anthropometric and body composition parameters result from rapid growth rate and effect of sex steroid during puberty. For example, a study showed a significant positive linear relationship between age and HGS among diabetic children [20]. Also, metabolic and muscular adaptation over time as prolonged exposure to insulin therapy can lead to improved glucose uptake in muscle tissue, supporting muscle maintenance, which contributes to greater HGS in those with longer disease duration. Moreover, consistent insulin therapy promotes anabolic effects in muscle as it raises blood flow and amino acid delivery to the muscle tissue leading to enhanced protein synthesis and possibly increased muscle mass and strength [21].

About relation between HGS Z-score and diabetic control, this current study displayed that there was insignificant difference between good, moderate, and poor glycaemic control groups as regards HGS z-score; but there was a significant higher frequency of diabetic children with HGS Z-score who were detected among those with good glycaemic control compared to those with poor glycaemic control. In contrast to this study, a study reported significant greater HGS values in children with an HbA1C beyond 8.5% compared with those with lower values of HbA1C and revealed that body weight was the strongest predictor of maximal muscle force [22].

Uncontrolled T1DM has adverse impacts on bone and muscle (LBM); in addition, it could impair their functions [23]. This may be explained by the following, skeletal muscle protein glycation occurs in a long-standing hyperglycaemic state, a process by which proteins undergo chemical modification due to sugar reduction [5]. Initially, myosin motility demonstrated a significant reduction [17]. Additional oxidation reactions cause the development of advanced glycation end-products (AGEs), which are confirmed to participate in T1DM-related complications [5]. The deposition of AGE in skeletal muscle was proposed by numerous studies to be accompanied by a reduction in muscle function in adult cases with T1DM and T2DM [24]. In addition, good glycaemic control improves insulin sensitivity, allowing muscles to efficiently take up glucose and respond to the anabolic effects of insulin and this enhances muscle protein synthesis leading to stronger and potentially hypertrophic muscles. Another study performed on 150 Saudi diabetic children showed that no significant differences in HGS were noticed between cases of poorly controlled and those with fairly or well-controlled T1DM [20].

Regarding the Correlation between both HGS and HGS Z-scores with diabetes treatment, this present study displayed that there was a significant positive correlation between HGS and the total dose of insulin. This may be due to the protein anabolic effect of insulin on muscle. In contrast, there was a significant positive correlation that was detected between HGS and HGS Z-score with diabetes duration. This may be explained by the following; bodies of children with longer diabetes duration may adapt to manage blood glucose fluctuations more effectively and this metabolic adaptation can help maintain or enhance muscle function. Moreover; as children grow, they naturally gain muscle mass and strength. In contrast, another study found no relationship between HGS and the duration of the condition in children with diabetes who

had it for longer than five years as opposed to those who had it for shorter periods of time [11].

A significant negative correlation between HGS and HGS Z-score with HbA1c was detected. This may be due to muscle damage by oxidative processes, AGE accumulation, chronic inflammation, neuromuscular impact, and reduced insulin sensitivity that interfere with the anabolic effect of insulin on muscle tissue. Consistent with our findings, a study performed on adults with T1DM recorded a significant negative relationship between HGS and HbA1c [13].

The present study revealed that among significant factors assessed, a longer duration of diabetes was a significant predictor of an increase in HGS values. Also, a higher HbA1c value was a significant predictor for low HGS values. Moreover, HGS and HGS Z-scores were good in differentiating diabetic cases with good control and those with poor glycaemic control.

This study had some limitations worth considering in understanding the study findings. First, this study is a cross-sectional with relatively small sample size and deals with a single medical center in the country. Second, the lack of pediatric reference for BCM devices and thus inaccurate interpretation of lean tissue mass results. Finally, HGS and BCM were all assessed at a single time point and as a result don't reflect changes over time.

CONCLUSION

HGS values are higher in T1DM children compared to controls. It is good in differentiating between diabetic cases with good control and those with poor glycaemic control. HGS is a non-invasive and reliable tool for the evaluation of muscle strength and nutritional status in diabetic children. Finally, higher body composition parameters are detected among diabetic children compared to control and higher values are detected with long duration compared to others with shorter duration of disease.

RECOMMENDATIONS

HGS may be used as an index for glycaemic control of diabetic patients and further multi-centric prospective studies with large sample size and serial measurements of HGS are needed to confirm our results.

Conflict of interest: None.
Fund: None.

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