Fat pattern and its relation to glycated hemoglobin in Egyptian diabetic children

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Received 18 April 2018
Accepted 30 April 2018

Journal of The Arab Society for Medical Research 2018, 13:8–17

Background/aim
Obesity and type 1 diabetes mellitus are the two most common conditions of altered metabolism in children and adolescents. We aimed to assess the fat distribution in diabetic children using different anthropometric measures and indices (mid-upper arm circumference, waist circumference, waist/hip and waist/height ratios) and their correlation with glycated Hb (HbA1c).

Patients and methods
This is a cross-sectional observational study conducted on 100 diabetic children aged 7–18 years, with established type 1 diabetes mellitus. Their mean HbA1c is less than 12.0% during the year before the study visit. Anthropometric measurements (weight, height, BMI, and waist and hip circumferences), BMI, and waist/height and waist/hip ratios were calculated as well as body composition.

Results
The mean age of the whole sample was 10.88±2.55 years, with a mean HbA1c of 8.83±1.61. The mean age at onset was 8.10±3.51 years, with a mean duration of disease of 2.85±2.45 years. According to the BMI percentiles, 10% of children were overweight, 10% were underweight, and 80% were normal weight. Fat% in the uncontrolled group was insignificant higher than those of the controlled group. Waist and hip circumferences showed higher values in the uncontrolled group than those of the controlled group. The waist/height ratio was on the borderline to develop central obesity (waist/height ratio ≥0.5).

Conclusion
Onset at earlier age and longer duration of the disease are considered risk factors to have uncontrolled diabetes with HbA1c greater than 7.5. It is not mandatory to become overweight or obese in diabetic children. Fat% was higher in uncontrolled than controlled group. Waist and hip circumferences as anthropometric tools are better indicators of central obesity than waist/hip ratio in diabetic children.

Keywords:
age at diagnosis, diabetic children, fat pattern, waist circumference, waist/height ratio

J Arab Soc Med Res 13:8–17

1687-4293

Introduction

Type 1 diabetes mellitus (T1DM) is considered one of the most important chronic diseases of children. It affects more than 35 million people worldwide, and its incidence shows significant geographic variability, ranging from less than 1/100 000 to more than 40/100 000 per year. In the Middle East and North Africa, ~129 000 children are affected with T1DM, with Saudi Arabia and Egypt contributing toward nearly half of the region's total. In Saudi Arabia, the incidence is 31.4 per 100 000 population, Kuwait 22.3 per 100 000 population, and Egypt 8.0 per 100 000 population [1].

Obesity and T1DM are the two most common conditions of altered metabolism in children and adolescents.

Obesity is well known to be associated with increased amount of adipose tissue or its disproportionate distribution between central and peripheral body regions, which in turn is related to the development of insulin resistance, dyslipidemia, and coronary artery disease, which increase the susceptibility toward developing T2DM [2].

Body fat distribution is different between diabetics and nondiabetics. It has been recognized for several decades that diabetics have a more centralized or upper body fat pattern than nondiabetics. Recently, attention has focused on fat patterning as possible risk factors for cardiovascular disease, as well.

The importance of body fat distribution as a determinant of various metabolic disorders has been recognized for several decades. Most studies have relied on waist/hip ratio as a single index of fat patterning. It is effective at predicting the metabolic profile as most other commonly used indices [3].

Several studies cited that waist/height ratio and mid-upper arm circumference (MUAC) are anthropometric measurements that showed excellent accuracy in predicting overweight and obesity with high specificity and sensitivity [4,5]. Waist/height ratio is considered a simple marker of central adiposity, which strongly relates to children's trunk fat mass change in dyslipidemia over time in youth with T1DM [6,7].

Given the aforementioned results, the objective of this study is to clarify whether type 1 diabetes mellitus is usually associated with obesity in diabetic children and glycated Hb (HbA1c) is influenced by the percentage of fat in those children or not. We also aimed to assess the fat distribution in diabetic children using different anthropometric measures and indices (MUAC, waist circumference, and waist/hip and waist/height ratios) and their correlation with HbA1c.

Patients and methods

This current study was a cross-sectional one that comprised 100 children with T1DM of both sexes. Their age ranged from 7 to 18 years. They were recruited from the Diabetic Endocrine Metabolic Pediatric Unit outpatient clinic of Abu El-Rish Hospital Cairo University. Diabetic children should be already diagnosed and receiving insulin treatment for at least 1 year. Their mean HbA1c was less than 12.0% (108 mmol/mol) during the year before the study visit, date of examination without any episode of ketoacidosis during the month before the study enrollment. Children with any genetic or chronic diseases that can affect their growth, for example cardiac or renal disease, were excluded. The children were recruited during March–December 2017.

Ethical approval

The study was approved by the National Research Centre Ethical Committee (Approval 16390). The children's parents were encouraged to participate in this study. The study was discussed with them, and written informed consents were taken by the investigator.

Methods

A questionnaire was directed to the parents of each child. It included personal, socioeconomic data, and medical history of the child, with special emphasis on chronic disease or long-term systemic treatment. A complete clinical examination of each child was done to exclude the presence of any organic or genetic disorder that might interfere with normal growth. Then, an anthropometric assessment for each child, including body weight and height, was performed. Body weight was measured using a Seca scale (Seca Balance Beam Scale Model 700, seca deutschland Medical Scales and Measuring Systems; seca GmBH & Co. KG, Hamburg, Germany) approximated to the nearest 0.01 kg, and with minimal clothes on, for which no correction was made, and body height was measured without shoes using a Holtain stadiometer (The Harpenden Portable Stadiometer; Holtain Ltd, Crosswell Pembrokeshire Wales, UK) approximated to the nearest 0.1 cm. They were recorded as the mean of three consecutive readings. Mid-upper arm, waist, and hip circumferences were measured. All measurements followed the recommendations of the International Biological Program [8]. Some indices were calculated as BMI according to the following equation: BMI=weight (kg)/height (m^2), waist/hip ratio, and waist/height ratio. Body composition was measured using body composition analyzer (Computerized Holtain Body Composition Analyzer, Holtain's BCA, Crosswell No.646512; Holtain Ltd, Wales, UK) displaying water content, fat-free mass, fat mass, and fat%. HbA1c was taken from the records of each participant.

Statistical analysis

Data were analyzed using the statistical package for the social sciences (SPSS/Windows version 16; SPSS Inc., Chicago, Illinois, USA). Statistical significance was set at *P* value less than 0.05. Mean and SD were calculated as descriptive measures. Statistical significance was tested by Mann–Whitney test as data were not normally distributed. Correlation was tested by Spearman's correlation. The data for BMI were grouped by age and sex. Means and SD were calculated. The data points at the third, fifth, 10th, 15th, 25th, 50th, 75th, 85th, 90th, 95th, and 97th percentiles were calculated for each sex and age group.

Results

Sample description

Of 100 children diagnosed with type 1 diabetes aged from 7 to 18 years, with a mean age of 6.72±2.08 years, the mean age of males was 6.77±1.99 years, whereas that of females was 6.66±2.17 years. We divide the sample into two groups according to their age (from 7 to <12 and from 12 to 18 years), where 65 children were aged 7 to less than 12 years and 35 children were aged 12 to less than 18 years, and into two subgroups according to their HbA1c (controlled group with HbA1c <7.5 and uncontrolled group with HbA1c >7.5) according to American Diabetes Association Guidelines, where 28 were controlled and 72 were uncontrolled diabetic children [9].

Table 1 showed that 45% of the study population was male; of them, 77.8% were in the age group 7 to less than 12 years and had a mean age of 9.36±1.56 years and 22.2% were in the age group 12 to less than 18 years and had a mean age of 13.62±1.37 years. Moreover, 55% were female children; of them, 54.4% were in the age group 7 to less than 12 years and had a mean age of 9.35±1.54 years, and 45.5% were in the age group 12 to less than 18 years and had mean age of 13.74±1.36 years. We found that the percentage of male in the age group 7 to less than 12 years with uncontrolled HbA1c is more than that of controlled (65.7 vs. 34.3%), and also in the age 12 to less than 18 years (80 vs. 20%); the same was observed in female in the age 7 to less than 12 years (70 vs. 30%) and also in the age group 12 to less than18 years (80 vs. 20%). According to the BMI percentiles, the percentage of normal weight (15th to <85th) children in both age groups was more obvious in the uncontrolled group than the controlled group in both sexes. According to their BMI percentiles, it was found that 10% of children were obese (≥85th to <95th), 10% were underweight (<15th), and 80% were normal weight.

Table 2 showed that the mean age at onset in the age group less than 12 years was 8.09±3.55 years with a mean duration of 2.29±2.31 years and that in the age group greater than 12 years was 8.114±3.50 years with a mean duration of 3.18±2.71 years, whereas in the controlled group less than 12 years was 8.38±4.13 years and that of the uncontrolled group was 7.95±3.28 years, which means that onset at earlier age and longer duration are risk factors to have uncontrolled HbA1c. The mean BMI and fat% in the uncontrolled group were higher than those of the controlled group in both age groups, whereas the weight and height of the uncontrolled group showed higher values in the controlled than the uncontrolled group.

Table 3 showed that the mean hip circumference in the age group 12 to less than 18 years was significantly higher in the uncontrolled group than that of the controlled group. The mean waist/hip ratio in the age group 12 to less than 18 years was significantly lower than that of the controlled group. Waist and hip circumferences showed higher values in the

Table 1 Distribution of the study sample according to sex, age, glycated hemoglobin, and BMI

	Male [45 (45)]				Female [55 (55)]				Total (n=100)
Age [n (%)]	7 to <12 years 35 (77.8)		12 to <18 years 10 (22.2)		7 to <12 years 30 (54.4)		12 to <18 years 25 (45.5)		
HbA1c [n (%)]	<7.5 12 (34.3)	≥7.5 23 (65.7)	<7.5 2 (20)	≥7.5 8 (80)	<7.5 9 (30)	≥7.5 21 (70)	<7.5 5 (20)	≥7.5 20 (80)	
Underweight	2	2		1	1	1	2	1	10
Normal weight	7	21	1	6	8	17	3	17	80
Overweight	3		1	1		3		2	10

HbA1c, glycated hemoglobin.

uncontrolled group than that of the controlled group in both age groups. Regarding the waist/height ratio, their values are borderline to have central obesity (>0.5).

Table 4 revealed that there is a significant positive correlation between the hip circumference and HbA1c. The MUAC had significant positive correlations between waist and hip circumferences, pBMI, waist/height ratio, and fat%.

Table 5 revealed that there is a positive correlation between duration of the disease and both waist/height ratio and fat%. There is significant positive correlation between MUAC and waist and hip circumferences, BMI, waist/height ratio, and fat%. The duration of disease has a significant positive correlation with waist/height ratio and fat%.

Table 6 revealed that here is a significant positive correlation between fat% and MUAC and waist circumference. The MUAC had significant positive correlation with waist circumference.

Table 7 revealed that there is a positive correlation between MUAC and HbA1c, waist and hip

Table 2 Comparison of all parameters between controlled and uncontrolled diabetic children in both age groups

HbA1C	Age 7 to <12 (*n*=65)		*P*	Age 12 to <18 (*n*=35)		*P*
	<7.5 (*n*=21)	≥7.5 (*n*=44)		<7.5 (*n*=7)	≥7.5 (*n*=28)	
Age at onset	8.385±4.134	7.954±3.280	0.432	8.365±3.222	8.051±3.624	0.902
Duration of disease	2.290±2.312	2.875±2.303	0.261	1.487±1.767	3.603±2.763	0.050*
HbA1c	6.5510±1.6137	9.4568±1.2380	0.000*	7.0014±0.5144	9.7929±1.1365	0.000*
z weight	−0.283±0.995	−0.191±0.783	0.340	−0.960±0.657	−0.385±0.762	0.127
z height	−0.592±1.253	−0.498±1.065	0.420	−1.685±1.106	−0.895±1.418	0.050*
zMUAC	−0.301±0.765	−0.193±0.765	0.768	−0.693±0.617	−0.278±0.715	0.099
pBMI	48.388±25.809	53.051±25.313	0.510	38.092±30.763	51.475±24.575	0.257
Fat%	20.424±4.944	21.220±6.241	0.833	21.300±2.426	24.111±7.758	0.155

Data are expressed as mean±SD. HbA1c, glycated hemoglobin; MUAC, mid-upper arm circumference. *Significant difference at $P<0.05$.

Table 3 Comparison of the fat pattern in both age groups

HbA1c	Age 7 to <12 (*n*=65)		*P*	Age 12 to <18 (*n*=35)		*P*
	<7.5 (*n*=21)	≥7.5 (*n*=44)		<7.5 (*n*=7)	≥7.5 (*n*=28)	
Waist circumference	62.64±0.21	62.81±6.75	0.768	71.79±8.89	74.00±6.82	0.099
Hip circumference	70.00±16.50	73.77±9.59	0.658	75.78±9.77	88.42±7.85	0.005
Waist/hip	1.21±1.61	0.85±0.04	0.095	0.95±0.165	0.83±0.06	0.021
Waist/HT	0.47±0.04	0.47±0.03	0.939	0.49±0.05	0.48±0.04	0.536

Data are expressed as mean±SD. HbA1c, glycated hemoglobin.

Table 4 The correlation between some parameters in the controlled group with glycated hemoglobin less than 7.5 for the age group 7 to less than 12 years

	Age at onset	Duration of disease	HbA1C	zMUAC	Waist circumference	Hip circumference	pBMI	Waist/HT	Fat%
Age at onset	1	−0.221 0.335	−0.186 0.420	−0.060 0.797	0.097 0.675	0.084 0.716	0.057 0.806	−0.139 0.548	−0.033 0.887
Duration of disease		1	0.021 0.928	0.176 0.446	0.205 0.372	0.036 0.939	0.308 0.174	0.358 0.111	0.017 0.941
HbA1c			1	0.117 0.614	0.128 0.582	0.587** 0.005	−0.008 0.973	−0.079 0.734	0.031 0.894
zMUAC				1	0.700** 0.000	0.492* 0.023	0.783** 0.000	0.764** 0.000	0.598** 0.004
Waist circumference					1	0.526* 0.014	0.633** 0.002	0.736** 0.000	0.368 0.101
Hip circumference						1	0.375 0.094	0.130 0.574	0.277 0.224
pBMI							1	0.692** 0.001	0.525* 0.015
Waist/HT								1	0.601** 0.004
Fat%									1

HbA1c, glycated hemoglobin; MUAC, mid-upper arm circumference. *Correlation is significant at the 0.05 level (2-tailed). **Correlation is significant at the 0.01 level (2-tailed).

Table 5 The correlation between some parameters in the controlled group with glycated hemoglobin (HbA1c) less than 7.5 for the age group 12 to less than 18 years

	Age at onset	Duration of disease	HbA1c	zMUAC	Waist circumference	Hip circumference	pBMI	Waist/HT	Fat %
Age at onset	1								
Duration of disease	−0.078 0.616	1							
HbA1c	−0.153 0.322	−0.101 0.514	1						
zMUAC	0.115 0.458	0.183 0.234	−0.144 0.350	1					
Waist circumference	0.063 0.683	−0.069 0.655	−0.097 0.531	0.695** 0.000	1				
Hip circumference	0.116 0.452	−0.128 0.409	−0.026 0.865	0.677** 0.000	0.899** 0.000	1			
pBMI	0.073 0.640	0.272 0.074	0.234 0.126	0.891** 0.000	0.618** 0.000	0.615** 0.000	1		
Waist/HT	0.125 0.417	0.315* 0.037	−0.155 0.316	0.712** 0.000	0.503** 0.001	0.338* 0.025	0.772** 0.000	1	
Fat%	0.024 0.878	0.332* 0.028	−0.020 0.896	0.684** 0.000	0.368* 0.014	0.437** 0.003	0.783** 0.000	0.601** 0.000	1

HbA1c, glycated hemoglobin; MUAC, mid-upper arm circumference. *Correlation is significant at the 0.05 level (2-tailed). **Correlation is significant at the 0.01 level (2-tailed).

Table 6 The correlation between some parameters in the controlled group with glycated hemoglobin greater than or equal to 7.5 for the age group 7 to less than 12 years

	Age at onset	Duration of disease	HbA1c	zMUAC	Waist circumference	Hip circumference	pBMI	Waist/Ht	Fat%
Age at onset	1	0.324 0.478	0.342 0.452	0.143 0.760	0.090 0.848	−0.393 0.383	0.107 0.819	0.464 0.294	0.126 0.788
Duration of disease		1	−0.236 0.610	−0.072 0.878	−0.027 0.954	−0.559 0.192	0.703 0.078	0.414 0.355	−0.109 0.816
HbA1c			1	0.018 0.969	−0.191 0.682	0.288 0.531	0.000 1.000	0.018 0.969	0.000 1.000
zMUAC				1	0.775* 0.041	0.679 0.094	0.536 0.215	0.679 0.094	0.991** 0.000
Waist circumference					1	0.342 0.452	0.360 0.427	0.739 0.058	0.836* 0.019
Hip circumference						1	0.179 0.702	0.071 0.879	0.667 0.102
pBMI							1	0.679 0.094	0.487 0.268
Waist/HT								1	0.667 0.102
Fat%									1

HbA1c, glycated hemoglobin; MUAC, mid-upper arm circumference. *Correlation is significant at the 0.05 level (2-tailed). **Correlation is significant at the 0.01 level (2-tailed).

circumferences, BMI, and fat%. The waist circumference is positively correlated with hip circumference, BMI, waist/height ratio, and fat%. The hip circumference is positively correlated with BMI and fat%. Fat% is positively correlated with waist/height ratio. The duration of the disease shows a significant positive correlation with hip circumference.

Figure 1 showed the distribution of the sample according to sex and HbA1c. We found that the percentage of uncontrolled male children was 68.87% whereas that of controlled was 31.13%. However, in female, the percentage of uncontrolled children was 74.55%, whereas that of controlled was 25.45%.

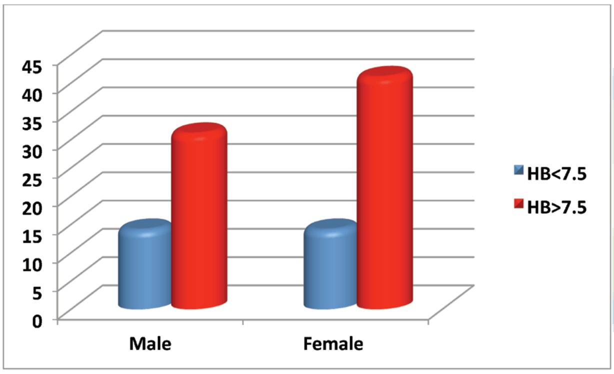
Figure 2 showed that in the age group from 7 to less than 12 years, male had a mean age of onset of 8.37±3.80 years, with a mean duration of the disease of 2.73±2.34 years, whereas female had a mean age of onset of 7.76±3.26 years, with a mean duration of the disease of 2.26±2.28 years. However, in the age group from 12 to less than 18 years, male had a mean age of onset of 6.95±3.88 years, with a mean duration of the disease of 3.24±2.93 years, whereas female had a mean age of onset of 8.57±3.30 years, with a mean duration of the disease of 3.15±2.67 years.

Table 7 The correlation between some parameters in the controlled group with glycated hemoglobin greater than or equal to 7.5 for the age group 12 to less than 18 years

	Age at onset	Duration of disease	HbA1c	zMUAC	Waist circumference	Hip circumference	pBMI	Waist/Ht	Fat%
Age at onset	1								
Duration of disease	0.109 0.581	1							
HbA1c	−0.048 0.806	−0.055 0.782	1						
zMUAC	0.199 0.309	0.022 0.911	−0.383* 0.044	1					
Waist circumference	0.049 0.806	0.202 0.303	0.111 0.575	0.427* 0.024	1				
Hip circumference	0.049 0.806	0.510** 0.006	−0.111 0.573	0.428* 0.023	0.462* 0.013	1			
pBMI	0.203 0.300	0.153 0.437	−0.208 0.289	0.599** 0.001	0.493** 0.008	0.626** 0.000	1		
Waist/HT	0.206 0.293	0.055 0.782	0.275 0.157	0.355 0.064	0.856** 0.000	0.224 0.253	0.512** 0.005	1	
Fat%	0.277 0.154	−0.010 0.960	−0.067 0.736	0.614** 0.001	0.582** 0.001	0.468* 0.012	0.606** 0.001	0.561** 0.002	1

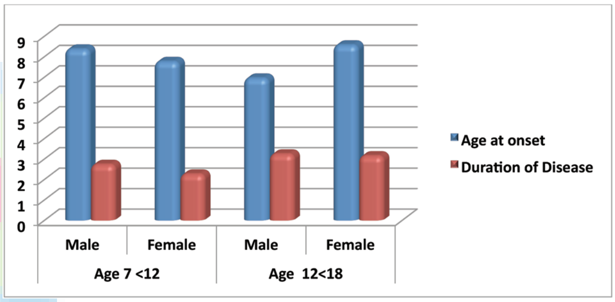
HbA1c, glycated hemoglobin; MUAC, mid-upper arm circumference. *Correlation is significant at the 0.05 level (2-tailed). **Correlation is significant at the 0.01 level (2- tailed).

Figure 1



Distribution of the sample according to sex and glycated hemoglobin.

Figure 2



Comparison of the age of onset and duration of the disease according to sex.

Discussion

The incidence of T1DM and the prevalence of overweight and obesity have been increased during recent decades [10]. The risk for development of T1DM is increased by obesity and may occur at an earlier age among obese individuals with a predisposition [11].

It is known that obesity contributes to immunogenicity and glucose dysregulation. Sex, age at diabetes onset, lower diabetes duration, lower BMI-SD at diabetes onset, intensive insulin therapy, and higher insulin dose were significant predictors of weight gain [12].

Blood glucose control was evaluated by measuring HbA1c. We found that the percentage of uncontrolled group was higher in both age groups (from 7 to <12 years and from 12 to ≤18 years) and both sexes of diabetic children (72%) than the controlled group (28%).

The poor metabolic control is one of many factors that may affect growth of diabetic children. In this study, the mean age of the whole sample was 10.88±2.55, with a mean HbA1c of 8.83±1.61 (in male it was 8.49±1.57 and in female it was 9.11±1.61). This may be owing to the fact that female are heavier than male with different fat distribution and with being less active than male.

In agreement with our results, a Brazil study [13] found that their mean age of patients was 10.6±3.8 years with mean Hb1Ac of 8.07%. Other studies reported higher values of mean HbA1c as that of Saki Shiraz [14] and Khadilkar *et al.* [15], which reported 10.15±2.23 and 9.1±2.0%, respectively. However, a lower value has been reported by Safrida *et al.* [16] where it was 5.6%.

The age at diagnosis is another factor that may affect diabetic children; in this study, we found that the mean age at onset was 8.10±3.51, with a mean duration of disease of 2.85±2.45 years; in both age groups, the age at onset was earlier and the duration of the disease was longer in the uncontrolled group than the controlled group. This means that onset at earlier age and longer duration are risk factors to get uncontrolled HbA1c (>7.5).

Similar to this study regarding the age at onset, Nabil *et al*. [17] found that the mean age at onset of the disease was 7.94±3.39 years, but with higher mean duration of diabetes of 6.36±4.46 years.

Amador-Patarroyo *et al.* [18] cited two peaks of onset, one between ages 5 and 9 years and a second between ages 10 and 14 years, in type 1diabetic children and adolescent. Da Costa *et al*. [13] found that the mean age at onset and the duration of the disease were 5.54 ±2.79 and 5.58±3.37 years, respectively.

However, Jose *et al*. [19]. found an association between disease duration and insulin doses with poor control of T1DM according to the value of HbA1c. Lack of association between disease duration and overweight is justified as patients with longer duration of disease and adolescents know the symptoms and can manage insulin dose better, so they tend to subtract insulin doses and/or meals as measures to prevent undesirable weight gain [13].

According to the BMI percentiles, we found that the percentage of normal weight (15th to <85th) children in both age groups was more obvious in the uncontrolled group than the controlled group in both sexes. From the whole sample, we found that 10% of children were overweight (≥85th to <95th), 10% were underweight (<15th) and 80% were normal weight. The high percentage of normal weight may be explained that uncontrolled diabetic children may miss taking an insulin dose or taking lower doses of insulin needed or low socioeconomic level and illiteracy of parents. The mean BMI in the uncontrolled group were insignificant higher than those of the controlled group in both age groups. However, the weight and height of the uncontrolled group showed higher values in the controlled than the uncontrolled group, which may be to uses of intensive doses of insulin to maintain target level of HbA1c (<7.5) in the controlled group.

Similar to the current study, da Costa *et al*[13] and Saki Shiraz [14] reported higher percentage with normal weight at 59 and 89.7%, respectively. The percentage of overweight was 30.3 and 6.8%, respectively, whereas that of obese was 9.7 and 3.5%, respectively.

On the contrary, many studies found higher percentage of overweight and obesity as that of Safrida *et al.*[16], where 63% were overweight and 37% were obese. Valerio *et al*. [20], Arai *et al*. [21], and Marques *et al*. [22] found 24.5, 17.5, and 16% were overweight, respectively, whereas, 3.9, 2, and 14.1% were obese, respectively [20–22]. Luczyński *et al.* [23] found that 30.2% of patients were overweight, and Saki Shiraz [14] found that abdominal obesity was more obvious in male patients (P=0.01).

Polsky and Ellis [11] revealed that overweight and obesity are highly prevalent among youth (25–35%) and adults (37–80%) with T1DM. The explanation of the tendency to gain weight in T1DM is very complex. This may be referred to the overall trend observed in the general population, from the anabolic effect of insulin treatment, or from a higher caloric intake because of fear of hypoglycemia. The Diabetes Control and Complications Trial Research Group reported that patients treated with intensive insulin therapy gained weight with an average of 4.6 kg more than those on conventional therapy during a 5-year follow-up period [24].

Moreover, insulin itself promotes weight gain by stimulating lipogenesis, inhibiting protein catabolism, and slowing down basal metabolism. These effects are also enhanced by peripheral insulin administration, which is associated with a reduced energy metabolism. In patients with T1DM, insulin therapy induces insulin resistance selective for carbohydrate metabolism. Consequently, insulin doses need to be increased to maintain glycemic control, but as insulin maintains its role in lipogenesis and protein metabolism, intensification of insulin treatment promotes fat mass increases and lean body mass gain [25].

The most important factors for obesity and abdominal obesity are female sex, diabetes duration above 5 years, and poor metabolic control [26].

The study conducted by da Costa *et al*. [13] reported that age greater than or equal to 10 years was protective to be overweight when compared with age less than 10 years, possibly because at the lower age range, there is a greater fear from parents regarding the episodes of hypoglycemia, which leads them to overfeed these children as prevention. However, the greater insulin dose was associated with overweight, which confirms the literature. These results justify further specific actions aimed at younger patients' family members and overweight patients because they have higher risks of overweight and large doses of insulin, respectively, resulting in insulin resistance and increased risk of future complications.

Fat distribution has been widely used for the studies in metabolic disease in many institutes. It is confirmed that the bigger the area with subcutaneous and visceral adipose tissue, the higher the incidence of related diseases, such as intolerant glucose test, diabetes mellitus, insulin resistance, and lipids metabolic disorders [27].

Central obesity is described as excessive fat deposits in the abdominal area, either subcutaneous fatty tissue or visceral adipose tissue rich in free fatty acids [28].

Therefore, cardiovascular diseases and metabolic disorders such as diabetes mellitus are more closely associated with central obesity than peripheral obesity [29]. Central obesity can be determined by waist circumference measurements greater than 90th percentile for age.

Waist circumference alone was significantly more efficient for predicting insulin resistance, increased blood pressure, as well as increased serum cholesterol and triglyceride levels rather than BMI. In children and adolescents, waist circumference greater than 90th percentile was associated with elevated insulin and lipid profiles, which are risk factors for cardiovascular disease and metabolic disorders [30].

Regarding the fat pattern of the diabetic children in the current study, we noticed fat% in the uncontrolled group was insignificant higher than those of the controlled group in both age groups. The mean of the hip circumference in the age group 12 to less than 18 years was significantly higher in the uncontrolled group than that of the controlled group. The mean of the waist/hip ratio in the age group 12 to less than 18 years was significantly lower than that of the controlled group. Waist and hip circumferences showed higher values in the uncontrolled group than that of the controlled group in both age groups. Regarding the waist/height ratio, their values are borderline to develop central obesity (waist/height ratio ≥ 0.5).

The waist/height ratio is an anthropometric index that can be used to easily detect visceral obesity and its association with cardiovascular diseases and metabolic disorders. The ratio is accurate for determining body fat, as it takes into account not only abdominal fat but the percentage of muscle and waist circumference corrected by height, of each individual [31]. Waist circumference and waist circumference-related values (waist/hip ratio and waist/height ratio) have been widely used as a representative indicator of abdominal adiposity, because they are correlated with abdominal fat mass [32]. A prospective cross-sectional study on newly diagnosed children with T1DM evaluated the relationship between adiposity and B-cell autoimmunity. Approximately 30% of individuals were centrally obese, based on a waist/height ratio greater than or equal to 0.5 and were most often young (1–4 years old) or in late adolescence (15–18 years old) [33].

Krishnan *et al.* [34] also found that female adolescents with T1DM had more centrally distributed fat. Dunger *et al.* [35] reported that girls with T1DM had a higher percentage of body fat than the control girls, and they also gained more body fat than their healthy peers during pubertal stages, whereas there was no difference between the T1DM and control boys.

These sex differences may be associated with sexual dimorphism in insulin resistance and growth hormone levels. This is supported by an earlier study that showed a lower glucose disposal rate and higher rates of growth hormone release in females during the hyperinsulinemic-euglycemic clamp [36].

MUAC is a simple measurement which has been used for many years in nutritional evaluation, being an indicator of protein and energy reserves of the individual [37].

In this study, in the controlled group in the age group 7 less than 12 years, the MUAC had significant positive correlations between waist and hip circumferences, pBMI, waist/height ratio and fat%, which means that when we noticed any increase in MUAC or hip or waist circumference, this will be an alarming sign of an increase in the fat% of these children.

In our study, in the controlled group in the age group 7 to less than 12 years, we found a significant positive correlation between the hip circumference and the HbA1c. From this finding, we may use the increase in hip circumference in the age from 7 to 12 years as an indicator of elevated HbA1c.

However, in the uncontrolled group in the age group 7 to less than 12 years, there was a significant positive correlation between fat% and MUAC and waist circumference. The MUAC had significant positive correlation with waist circumference, whereas in the age group 12 to less than 18 years, there is a positive correlation between MUAC and HbA1c, waist and hip circumferences, BMI, and fat%. So the MUAC may be used as an indicator of the HbA1c. The waist circumference is positively correlated with hip circumference, BMI, waist/height ratio, and fat%. The hip circumference is positively correlated with BMI and fat%. Fat% is positively correlated with waist/height ratio. The duration of the disease shows a significant positive correlation with hip circumference.

The waist/height ratio is an anthropometric index that can be used to easily detect visceral obesity and its association with cardiovascular diseases and metabolic disorders. It is considered as an accurate method for determining body fat, as it takes into account not only abdominal fat but the percentage of muscle and waist circumference corrected by height, of each individual [31]. The study by Safrida *et al* [16] found that waist circumference did not have any correlation with HbA1c level (r=0.18; P=0.15). However, waist/height ratio had a weak significant correlation with HbA1c levels (r=0.21; P=0.04). The waist/height ratio was the only variable significantly associated with HbA1c level (P=0.02), whereas age, sex, and nutritional status had no effect on HbA1c levels (P=0.10, 0.34, and 0.45, respectively). In their study, they found that the waist/height ratio was significantly and positively correlated with HbA1c levels in overweight and obese adolescents. However, an earlier study in Yogyakarta stated that patients with central obesity had a 1.21 times (95%CI 0.98–2.94) risk of impaired fasting glucose compared with a noncentral obese group [38]. In contrast, a Malaysian study reported that waist/height ratio was not superior to waist circumference or BMI for predicting glycemic control in patients with diabetes mellitus [39].

In conclusion, the percentage of uncontrolled diabetic in a sample of Egyptian children with wide range of age of 7–18 years is much higher than that of controlled in both sexes, with no sex difference, so we have to emphasis on the importance of maintaining HbA1 less than 7.5 in diabetic children and conducting further researches to clarify the reason to have such high percentage of uncontrolled diabetic Egyptian children. HbA1c, onset at earlier age, and longer duration of the disease in diabetic children are risk factors to get uncontrolled diabetes with HbA1c greater than or equal to 7.5. It is not mandatory to become overweight or obese in diabetic children as they may be within normal weight. Fat percentage was higher in uncontrolled than controlled groups in all ages from 7 to 18 years. Waist and hip circumferences as anthropometric tools are better indicators of central obesity than waist/hip ratio in diabetic children.

Acknowledgements

Financial support and sponsorship was done by National Research Centre, Project Number (11010111) from 2016 to 2019.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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