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Original article

Relationship between Down Syndrome (DS) and Obesity in Children and Adolescents and its Relation to Dietary and Lifestyle Factors.

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Abstract. Down syndrome (DS) and obesity in youngsters have attracted the attention of researchers due to the higher risk of overweight and obesity among DS children and adolescents versus the general young population. This study, was conducted in two Riyadh disability centers, which aimed to determine overweight and obesity status in Saudi DS children and adolescents and relate it to dietary and lifestyle factors. The 28 children, 20 adolescents with DS and 17 children, 10 adolescent healthy siblings (control) were assessed for obesity using anthropometric indicators and body composition analysis. Nutritional status and physical activity were determined using questionnaires. Results indicated that DS adolescents were shorter and had higher BMI ($P < 0.05$) while DS children and siblings were comparable in height and BMI. Using weight-for-age curves, the prevalence of overweight and obesity in DS children was at 25% and 29% respectively whereas DS adolescents had 50% and 10% respectively. Using BMI-for age curves, obesity was higher in DS adolescents versus siblings, while the children had comparable rates. No difference in nutritional status was observed between DS groups and their siblings, except for a few differences in meals, food groups frequency or dietary habits. Adolescents had few significant correlations between anthropometric indices and meals intake. The study confirms higher risk of overweight and obesity in DS adolescents and children, therefore research linking obesity to pre-disposing factors is necessary.

Key words: Obesity, Down syndrome, Children, Adolescents.

Introduction

Obesity is the most common variety of malnutrition, spreading widely and rapidly throughout the developing world. Due to its increasing prevalence, obesity is significantly considered as a major health threat (1). Several reviews have indicated a higher risk of obesity in youth with mental and growth disabilities (2, 3). Available evidence points to a greater tendency toward obesity in Down Syndrome (DS) subjects (4, 5). In DS, overweight frequently begins in late infancy, remaining evident throughout their growth years (6, 7). A literature review estimated the combined prevalence of overweight and obesity in DS youngsters to range anywhere from 23 to 70 percent (4). The development of obesity in DS youngsters is possibly related to syndrome-specific physiological features. Clinically, subjects with the syndrome demonstrate smaller head circumference, lack of muscle tone, shortness of the upper and lower extremities, and evident slowness in growth rate; occurring between the ages of 3 to 36 months (8-10). Therefore, youngsters with DS have a different growth pattern than that of the general young population.

Metabolic disorders are common with DS and may predispose affected subjects to obesity. For

example, a low basal metabolic rate (BMR), which accompanies hypothyroidism, was evident in DS children versus their siblings, and the difference was significant even when accounting for lean body mass (11, 12). Moreover, DS subjects manifest leptin resistance, resulting from an over-expression of leptin hormone, and this was linked to obesity (13). Indeed, obesity has been connected to these metabolic disturbances in the general population, and their effect on satiety and energy expenditure is well-established, hence they may also be pertinent to obesity in children and adolescents with Down Syndrome.

Studies have observed the impact of environmental factors on the obesity risk for DS youngsters. Diet, dietary habits, behavioral aspects and physical activity are recognized factors impacting on body composition and can promote the development of obesity in youth. One study reported that DS subjects participated in less vigorous physical activity as compared to their siblings (14). A low level of physical activity (PA) is conjectured to be attributed to physical difficulties, leading to poor motor development. Another study reported that DS adolescents, aged 14 to 15 years, are the most sedentary, spending the least amount of time in light or moderate-to-vigorous PA (15). The study noticed a decrease in PA as children get older (15). However, research linking high body mass index (BMI) to PA in DS youngsters is inconsistent. One cross-sectional study reported a weak association between BMI and PA, yet another study has reported the absence of such an association, suggesting the need for additional studies (16, 17). Regarding diet, inappropriate dietary patterns such as snacking, skipping meals, irregular meals and low consumption of fruits and vegetables are common among adolescents (18). Such patterns may contribute to the development of macro and micronutrient malnutrition (19). In DS, the evidence linking dietary patterns to obesity is scarce (4).

In conclusion, studies suggest a higher prevalence of overweight and obesity among Down Syndrome youth. Syndrome-specific growth retardation, low PA level, low BMR and poor dietary choices are among the contributing factors to obesity development. However, metabolic alterations, namely hypothyroidism and leptin insensitivity, may explain their higher risk. Because of the health threats associated with obesity, prevention and early dietary intervention should be a health priority, avoiding and tackling the risk of malnutrition-associated conditions in DS youth. Studies in Saudi Arabia that examine obesity status and its relation to dietary and PA factors in DS youth are limited (20, 21). In addition, no studies were done on DS adolescents in Riyadh, the central region of the kingdom of Saudi Arabia. This case-control study aims to assess overweight and obesity status in children and adolescents enrolled in two Down Syndrome specialized centers located in Riyadh, and compare them to healthy, age-group matched siblings. Anthropometric indices were assessed, then related to PA level, food craving, meals and common foods and beverages intake frequency.

Methods

Subjects

Participants in this cross-sectional study were recruited from two specialized centers of DS in Riyadh, Saudi Arabia: The Voice of Down Syndrome Society (SAUT) and Down Syndrome Charitable Association (DSCA). Parents and caregivers of DS subjects were provided with information sheets regarding the study, and written informed consent was obtained from all participants. According to the study design, 60 DS subjects and 60 sibling controls aged (3-18 years old) were targeted to enroll. Sample size was calculated on the basis of a significant difference between DS and siblings in BMI, reported in a previous study, with a two-sided significance level of 5% and a power of 80% (Samarkandy, et al, 2013). However, due to the limited number of DS students in the centers and the shortage in submitting complete questionnaires and in collecting anthropometric data, fewer cases and controls were available for analysis. In this study, complete data was available for 48 subjects in the DS group (28 children and 20 adolescent), and 27 subjects in the sibling groups (17 children and 10 adolescent). DS children and adolescents were compared to their healthy, age-matched, sibling. The rationale for using siblings as a control was to ensure similar dietary, lifestyle and environmental factors. All the DS children and adolescents

included were living with their parents and had at least one sibling; all siblings of DS children and adolescents were living in the same house. Ethical approval was obtained from the relevant ethics committee of the College of Applied Medical Sciences in King Saud University, Riyadh, Saudi Arabia.

Following parental/caregiver approval, DS children (2-12 years old), DS adolescents (13-20 years) and their controls (healthy age-matched siblings) were assessed for study variables, including anthropometric (weight and height, BMI) measurement, body composition analysis (lean mass, fat mass and fat percentage), food craving questionnaire, comprehensive fully validated meals and common foods and beverages frequency questionnaire, as well as a PA questionnaire. The food craving questionnaire was specifically designed to ask questions regarding meals and snacks consumption frequency, quantities, habits and related emotions. It was validated using test-retest on a pilot group of DS children. Parents were provided with written guidelines to assist them in filling out the questionnaires. A Stadiometer was used to measure the height. Weight and lean body mass, fat mass and body fat percentage were measured using a bioelectrical impedance scale (Inbody 770®, Inbody Co., Ltd., Seoul, Korea). BMI was calculated by dividing weight in kilos by height in meters. Weight and stature for age and BMI-for-age (in percentiles), and age-specific ideal weight cutoff were obtained using suitable growth charts (Centers for Disease Control and Prevention (CDC) growth charts for DS and non-DS growth charts for controls (7, 22). Classification of weight-for-age percentiles using curves for age and gender was presented as follows: underweight; <5thpercentile, normal weight; ≥5th–<85th percentile, overweight; ≥85th–<95th percentile, obese; ≥95th percentile (23). Classification of BMI-for-age percentiles using curves for age and gender was done as follows: underweight; <5th percentile, normal weight; ≥5th–<85th percentile, overweight; ≥85th–<95th percentile, obese; ≥95th percentile (23, 24).

Statistics

For data entry and analysis, the SPSS22 software package was used (SPSS Inc., Chicago, IL, USA). Results are presented as mean values ± standard deviation (Std). Subjects were divided into four groups; children with DS (n = 28), adolescents with DS (n = 20), as case groups, and compared to age-appropriate healthy siblings; children (n = 17) and adolescents (n = 10). After normally distributed quantitative variables verification, a student *t*-test was used. A paired sample *t*-test was used to compare actual to ideal weight, and actual to ideal fat percentage. An independent sample *t*-test was employed to compare variables between cases and controls. Significance was set at $P < 0.05$. For categorical variables, output was presented as frequencies (percentages). A non-parametric test (Chi-squared test) was applied to examine the difference in questionnaire output between DS subjects and their siblings. Significance was set at $P < 0.05$. The anthropometric indices were correlated with outputs collected from the questionnaires using the Spearman coefficient test. A *P*-value of <0.05 was considered significant.

Results

Anthropometrics

Data was analyzed for 48 DS cases: 28 children and 20 adolescents, and 27 sibling controls: 17 children and 10 adolescents. The cases and controls characteristics and anthropometric values are reported in Table 1. There was no difference within age groups (DS vs non-DS controls) in age or gender distribution ($P > 0.05$).

With regard to weight, there was no difference between the DS youth and their respective siblings, for either children or adolescents. The average height was not statistically different between children DS cases and siblings; however, DS adolescents were significantly shorter than their siblings (Table 1, $P < 0.01$). In addition, the average BMI of DS adolescents was higher than their siblings, 27.9 kg/m^2 and 22.6 kg/m^2 respectively ($P < 0.05$). Whereas there was no difference in BMI between DS children and their controls (P = 0.54).

Comparison of weight-for-age percentiles, using recommended cutoff for overweight and obesity between DS and control groups is presented in Table 1.

There were significantly higher overweight and obesity rates in DS children as compared to their siblings; and a higher overweight rate in DS adolescents as compared to their siblings (*Chi*-square test, $P < 0.05$ for both children and adolescents, Table 1).

Standard BMI-for-age growth curves were used to compare DS youth and their siblings with respect to rate of overweight and obesity (Table 1). There was no difference between DS children and siblings in overweight and obesity rate distribution, however, there was a higher rate of obesity in DS adolescents as compared to their corresponding siblings, where more than half were obese (55%), versus only 10 percent of siblings. In adolescents, fat mass and fat percentages correlated positively with obesity distribution according to BMI -for- age curves (Spearman coefficient; Fat percentage R = 0.743, P < 0.0001; FM: R = 0.823, P < 0.0001).

For DS youth and their siblings, actual weights were compared to ideal body weights, as displayed in Table 2. Both DS children and adolescents had higher actual weight as compared to recommended ideal body weights ($P < 0.001$, $P < 0.002$, respectively). Notably, there was no difference between actual and ideal weights within the sibling groups.

Results for the body composition analysis for DS children and adolescents are presented in Table 3. Average fat percentages computed from BIA scale for the DS groups were evaluated against ideal values. Both children and adolescents with DS possess a higher body fat percentage as compared to the ideal estimated levels (**Table 3**, Paired sample t-test $P < 0.005$).

Table 1. Anthropometrics of DS children and adolescents compared with siblings.

Parameters DS		Children		*Sig (2-sided)* DS	Adolescents		*Sig (2-sided)*
		Sibling			Sibling		
		Mean± Std	Mean± Std		Mean± Std	Mean± Std	
n		28	17		20	10	
Gender (male/female)		(11/17)	(7/10)	*0.900*	(11/9)	(5/5)	*0.893*
Age (y)		7±2	8±3	*0.167*	15±2	17±3	*0.188*
Weight (kg)		26.3±10	27.6±10.6	*0.676*	59.02±13	55.80±9.2	*0.494*
Height (cm)		114.8±11.3	116.6±27‡	*0.841*	145±8.3*	161.1±22	*0.009*
BMI (kg/m2)		19.3±4	19.7±3.5‡	*0.783*	27.9±5.5*	22.6±5.8	*0.029*
weight/age Percentiles (n/%)	≥95th %	8 (29) **	1 (6)	*0.018*	2 (10)	1 (10)	*0.007*
	≥85th <95th %	7 (25)	1(6)		10 (50) **	0 (0)	
	≥5th -<85th %	13 (46)	13 (76)		8 (40)	8 (80)	
	<5th %	0 (0)	2 (12)		0 (0)	1 (10)	
BMI/age Percentiles (n/%)	≥95th %	13 (46)	4 (33) ‡	*0.775*	11(55) **	1 (10)	*0.038*
	≥85th <95th %	6 (21)	4(33)		4(20)	3 (30)	
	≥5th -<85th %	8 (29)	4 (33)		5 (25)	4(40)	
	<5th %	1 (4)	0 (0)		0 (0)	2 (20)	

* Denotes significance versus siblings at the $P < 0.05$ (2-tailed) using Independent sample *t*-test. ** Denotes significance versus siblings at the $P < 0.05$ (2-tailed) using Fisher Exact test (cells count is < 5).
‡ Height information was not available for 5 healthy siblings, therefore, BMI and BMI-for -age for sibling is calculated for n=12.
Std: standard deviation; Sig: significance: DS: Down syndrome

Table 2. Actual weights and ideal body weights in DS and control groups.

Age groups Mean± Std Mean± Std		Weight	Ideal body weight	*Sig*	Paired Differences (Weight – Ideal weight)	*Sig*
			Mean± Std			
Children	DS	26.26±10 [a]	20.60±5.1	*0.001*	5.65±8.1 [b]	*0.001*
	Siblings	27.58±10.6	27.58±8.3	*1.00*	0.00±5.2	
Adolescent	DS	59.02±13 [a]	49.57±5.9	*0.002*	9.44±11.2 [b]	*0.044*
	Siblings	55.80±9.2	54.80±6.98	*0.790*	1.00±11.4	

[a] Denotes significance versus ideal body weight at the $P < 0.05$ (2-tailed) by paired sample *t*-test.[b] Denotes significance versus siblings at the $P < 0.05$ (2-tailed) by independent sample t-test between DS and control.
Std: standard deviation; DS: Down syndrome

Table 3. Body composition analysis for DS children and adolescents (Mean± Std).

Age groups	Lean body mass (Kg)	Fat mass (Kg)	Fat %	Ideal fat%	Differences (Fat% – Ideal fat%)
Children DS	10.5±5.7	22.3±8.3	38.89±13.8*	15.88±1.4	23.01±14.1
Adolescent DS	14.4±5.1	34.7±6.6	35.30±11.6*	20.05±5.8	15.24±10.57

* Denotes significance versus ideal fat percentage at $P < 0.0001$ by Paired sample t-test.
Std: standard deviation; DS: Down syndrome

Physical Activity

Analysis of output from the PA questionnaire for cases and controls are shown in Table 4. There was no difference between DS children or adolescents and their respective controls in PA ($P > 0.05$, Table 4). However, a significantly lower frequency of walking was observed in the DS children as compared to DS adolescents ($P < 0.05$, Table 5). A positive correlation was found in children; reporting more frequent regular exercise was associated with a higher BMI, fat mass and lean body mass (Spearman coefficient; BMI: R = 0.403, P < 0.05; FM: R = 0.489, P < 0.05; LBM: R = 0.632, P < 0.02). No such association was significant in adolescents.

Dietary Analysis

The output of meals and common foods frequency questionnaire is presented in Tables 6 and **7**. DS children reported less frequent red meat intake, and less vegetables/salad intake, compared to their siblings (P < 0.05 for both). There were no other significant differences in frequency of intake of other foods or any significant correlations between anthropometric indices and dietary output in children.

The adolescent siblings reported less frequent lunch consumption as compared to the DS adolescents, where 95 percent reported a daily lunch intake ($P < 0.05$, Table **7**). In addition, DS adolescents reported less frequency of fast-food intake when compared to siblings ($P < 0.02$, Table **7**). No significant differences in the intake frequency of other foods were found. There were significant correlations between anthropometrics and dietary output in adolescents; BMI was associated positively with frequency of breakfast, lunch and dairy consumption (Breakfast: R = 0.462, P < 0.02; Lunch: R = 0.400, P < 0.05, Dairy: R = 0.437, P < 0.02), Fat mass (Kg) was associated positively with frequency of sweets and dessert intake (R = 0.480, P < 0.05), lean body mass (Kg) was associated positively with frequency of breakfast intake (R = 0.474, P < 0.05).

Output for beverage frequency for children and adolescents is presented in Table 8. Analysis indicates no differences in beverage intake, save for a statistically higher frequency of carbonated beverage intake in siblings as compared to DS adolescents (P < 0.02, Table 8). Beverage frequency did not correlate with anthropometric indices in any of the age groups.

The Output of Food Craving Questionnaire is displayed in Table 9**.** Output was comparable for DS

Table 4.

%	Children DS n= 23				Children Sibling n=19				*Sig*
	Always	Sometimes	Rarely	Never	Always	Sometimes	Rarely	Never	
Walking	13	26	22	39	22	37	22	18	*0.348*
Climbing stairs	43	35	13	9	67	26	0	7	*0.157*
Regular exercise	30	22	35	13	41	33	19	7	*0.424*
Play football	13	44	13	30	26	26	22	26	*0.287*
Swimming	0	13	35	52	0	33	34	33	*0.467*
Domestic activity	13	52	18	17	19	26	22	33	*0.303*
	Adolescent DS n= 7				**Adolescent Sibling n=8**				***Sig***
	Always	Sometimes	Rarely	Never	Always	Sometimes	Rarely	Never	
Walking	43	14	43	0	40	20	40	0	*0.328*
Climbing stairs	57	15	14	14	52	24	12	12	*0.621*
Regular exercise	43	29	28	0	48	14	38	0	*0.474*
Play football	43	29	28	0	25	25	50	0	*0.267*
Swimming	17	0	33	50	0	50	25	25	*0.056*
Domestic activity	0	43	43	14	0	48	24	28	*0.554*

Note: Categorical variables were expressed as percentages. *Chi*-square test (2 -sided) was used to compare the groups (cells count is > 5). Children and adolescents with missing data were excluded (n=5 for DS children and n=13 for DS adolescents, n=1 child sibling, n=2 for adolescent sibling). Sig: significance:DS:Down Syndrome

Table 5. Physical activity questionnaire output for DS children and DS adolescent.

%	DS children n= 23				DS adolescent n=7				*Sig*
	Always	Sometimes	Rarely	Never	Always	Sometimes	Rarely	Never	
Walking	13	26	22	39	43	14	43	0	*0.047**
Climbing stairs	43	35	13	9	57	15	14	14	*0.71*
Exercise regularly	30	22	35	13	43	29	28	0	*0.57*
Play football	13	44	13	30	43	29	28	0	*0.08*
Swimming	0	13	35	52	17	0	33	50	*0.21*
Domestic activity	13	52	18	17	0	43	43	14	*0.39*

Note: Categorical variables were expressed as percentages. *Chi square* test (2 -sided) was used to compare the groups (cells count is > 5). Children and adolescents with missing data were excluded (n=5 for children and n=13 for adolescents). *Denotes significance using Chi square test, significant at $P<0.05$. Sig: significance:DS:Down Syndrome

children and their siblings. However, DS adolescents and their siblings had fewer significant differences; more siblings reported ignoring breakfast and sleeping less as compared to DS adolescents ($P < 0.01$ and $P < 0.05$ prospectively). More DS adolescents reported eating with their families as compared to their siblings ($P < 0.05$). There was a significant negative correlation between BMI and sleeping duration; adolescents who reported sleeping less had a higher BMI ($R = -0.448$, $P < 0.02$).

Discussion

Literature assessing anthropometrical differences, particularly height and BMI, between DS youngsters

Table 6. Summary of meals and common foods frequency questionnaire output for DS children and their siblings (n=34).

(%) weekly	DS children n= 17					Sibling children n=17					*Sig*
	7	4-5	2-3	1	None	7	4-5	2-3	1	None	
Breakfast	82	6	6	6	0	59	17	18	6	0	*0.43*
Lunch	82	12	6	0	0	82	12	6	0	0	*1.00*
Dinner	59	29	12	0	0	76	12	12	0	0	*0.42*
Fast food	0	0	12	35	53	0	0	12	41	47	*0.93*
Dairy Products	59	12	23	0	6	59	18	23	0	0	*0.66*
Seafood	0	0	29	18	53	0	0	24	35	41	*0.50*
Red Meat	35	24	29	6	6	53	41	0	0	6	*0.04**
Fruits	6	17	59	6	12	17	18	47	12	6	*0.74*
Vegetables/salad	12	18	29	6	35	35	18	29	18	0	*0.02**
Rice	35	30	29	6	0	35	35	18	6	6	*0.74*
Dessert/Sweets	18	59	23	0	0	18	35	35	0	12	*0.24*

Note: Categorical variables were expressed as percentages. *Chi square* test (2 -sided) was used to compare the groups (cells count is > 5) at a significance level of $P<0.05$. Children and with missing data were excluded (n=11 for DS children). *Denotes significance using Chi square test, significance set at $P<0.05$. Sig: significance:DS:Down Syndrome

Table 7. Summary of meals and common foods frequency questionnaire output for DS adolescence and their siblings.

%	DS adolescents n= 20					Sibling adolescents n=10					*Sig*
	7	4-5	2-3	1	None	7	4-5	2-3	1	None	
Breakfast	90	5	5	0	0	64	18	18	0	0	*0.22*
Lunch	95	5	0	0	0	64	36	0	0	0	*0.02**
Dinner	80	15	5	0	0	55	36	9	0	0	*0.33*
Fast food	5	0	30	40	25	0	27	46	27	0	*0.01**
Dairy Products	80	15	5	0	0	46	27	18	9	0	*0.16*
Seafood	0	0	32	47	21	0	0	9	64	27	*0.33*
Red Meat	69	16	10	5	0	55	18	27	0	0	*0.55*
Fruits	20	20	40	15	5	9	18	28	27	18	*0.61*
Vegetables/salad	45	15	20	10	10	10	10	30	50	0	*0.06*
Rice	40	30	25	5	0	20	40	20	0	20	*0.17*
Dessert/Sweets	5	20	30	35	10	0	60	20	10	10	*0.20*

Note: Categorical variables were expressed as percentages. *Chi square* test (2 -sided) was used to compare the groups (cells count is > 5) at a significance level of $P<0.05$. *Denotes significance using Chi square test, significance set at $P<0.05$. Sig: significance:DS:Down Syndrome

and their siblings, report mixed results. Studies often compare DS subjects to siblings, in order to limit potential economical and lifestyle differences, such as family eating habits (11, 21, 25). Several studies report a significantly higher BMI in DS youngsters than for their siblings (13, 20, 21, 26, 27). However, other studies found no differences between DS children and siblings, similar to our study (28-30). Yet, the current study agrees with studies that report significantly shorter stature and greater BMI in DS adolescents as compared to corresponding siblings (4, 31). The failure in reporting difference in BMI among children groups is potentially related to age (4). Studies involving adolescents alone consistently reported a higher BMI for

Table 8. Beverage Frequency Questionnaire (BFQ) results for DS children and their siblings

% weekly	DS children n=17					Sibling children n=17					Sig
	1	2	3	≥4	None	1	2	3	≥4	None	
Carbonated beverages	12	12	0	00	76	35	6	0	6	53	*0.20*
Caffeinated beverages	12	0	6	0	82	29	0	0	0	77	*0.23*
	DS adolescents n=20					**Sibling adolescents n=10**					***Sig***
	1	2	3	≥4	None	1	2	3	≥4	None	
Carbonated beverages	5	5	0	0	90	18	9	9	27	37	*0.01**
Caffeinated beverages	15	10	0	0	75	27	9	9	18	37	*0.07*

Note: Categorical variables were expressed as percentages. *Chi square* test (2 -sided) was used to compare the groups (cells count is > 5) at a significance level of $P<0.05$. Children and with missing data were excluded (n=11 for DS children). *Denotes significance using Chi square test, significant at $P<0.05$. Sig: significance:DS:Down Syndrome

Table 9. Food Craving Questionnaire results for DS children and their siblings.

(%)	DS children n=17			Sibling n=17			*Sig*	DS adolescence n= 20			Sibling n=10			*Sig*
	Yes	**Often**	**No**	**Yes**	**Often**	**No**		**Yes**	**Often**	**No**	**Yes**	**Often**	**No**	
3 main meals	59	35	6	50	50	0	*0.39*	70	30	0	40	56	4	*0.09*
Ignore breakfast	18	18	64	25	31	44	*0.47*	5	5	90	18	46	36	*0.01**
Wants more particular food	59	18	23	44	18	38	*0.64*	42	37	21	44	19	37	*0.08*
Loss control when start eating	18	12	70	7	6	87	*0.52*	16	16	68	10	0	90	*0.21*
Desire to eat increases at certain times	29	24	47	38	6	56	*0.36*	21	16	63	0	20	80	*0.16*
Feeling affect the amount of food	24	29	47	38	6.3	56	*0.19*	25	15	60	27	18	55	*0.95*
Similar quantities/times to family	35	41	24	65	25	10	*0.06*	84	16	0	46	36	18	*0.03**
Difficult to resist attractive foods	31	19	50	37	25	38	*0.77*	26	16	58	0	27	73	*0.07*
Fried food	12	41	47	8	46	46	*0.92*	10	15	75	18	27	55	*0.51*
Short period of sleep	6	6	88	6	19	75	*0.51*	5	0	95	9	27	64	*0.02**
DS child weigh more than sibling	19	0	81	33	0	67	*0.11*	65	0	35	33	0	67	*0.35*
Eating while watching TV	65	0	35	65	0	35	*0.64*	55	0	45	44	0	56	*0.45*
The child snacks	94	0	6	100	0	0	*0.23*	58	0	42	89	0	11	*0.08*

Note: Categorical variables were expressed as percentages. *Chi square* test (2 -sided) was used to compare the groups (cells count is > 5) at a significance level of $P<0.05$. Children and with missing data were excluded (n=11 for DS children). *Denotes significance using Chi square test, significant at $P<0.05$. Sig: significance:DS:Down Syndrome

DS than non-DS subjects (5, 32), whereas studies involving children usually report mixed results (26, 29, 33, 34). Furthermore, variation in BMI found between DS adolescents and corresponding siblings may in part be related to short stature being more pronounced in adolescence than in children with DS. In addition, the use of standard growth charts, rather than DS-specific charts, may lead to overestimation of short stature for DS subjects (21).

Inconsistent with our study, Samarkandy, et al. (2012) reported that Saudi DS children were shorter and had higher BMI, as compared to their sibling. Such inconsistency is attributed to differences in sample size, and reference curves used; the study used standard CDC growth charts to estimate weight and height for age for DS children, whereas in our study, DS-specific CDC growth charts were used, thus accounting for the growth retardation associated with the syndrome. Moreover, consistent with our study, a report on Saudi DS children living in Jeddah found comparable BMIs among DS children and their siblings (20).

This study used both weight-for-age (DS-specific for DS and standard for sibling) and BMI-for age (standard) curves to assess overweight and obesity distribution in DS and siblings. The rationale for using BMI-for age curves is to account for stature when classifying youngsters. The rate of overweight and obesity was significantly higher in DS children than siblings when weight-for-age curves were utilized. However, there was no difference between DS children and siblings in overweight and obesity rates when BMI-for-age curves were used. This is expected, since no difference in heights or BMI were found. Body composition analysis for DS children indicate higher weight and body fat percentages than the age-specific normal cutoffs. Analysis of questionnaire for food and beverage frequency, food cravings and PA shows similar patterns for DS children and siblings, except for less frequency of red meat, vegetable and salad consumption in DS children. In adolescents, using weight-for-age curves, one half of the DS adolescents were overweight; this was significantly higher than their siblings, and comparable to prevalence rates reported by other studies (4). Body composition analysis revealed statistically higher weights and fat percentage than recommended, flagging an approximating obesity. Indeed, BMI-for-age reference curves, which account for stature, indicated a higher obesity rate in DS adolescents compared to their siblings.

Certainly, the effect of the syndrome on body composition appears more visibly in DS adolescents, when compared to unaffected peers, implying a greater risk as age increases (4, 35). Such a difference may be driven by a variation in dietary or behavioral factors, as well as level of PA. For example, parents and caregivers might be excessively carrying and overfeeding youngsters with DS. In older children, negative behavior may occur when the parent attempts to encourage healthy food choices, or attempts to involve the child in PA. The present study found a comparable level of engagement of physical activity between DS groups and siblings, discordant with studies reporting a significantly lower PA level in DS children and adolescents compared to healthy control groups (36, 37) or siblings (5, 21, 34). In addition, no age difference in PA between DS children and DS adolescents was found, except for a higher frequency of walking in DS adolescents. To the contrary, one study reported a higher sedentary rate in DS adolescents as compared to DS children (17). In addition, another study reported lower amounts of activity were associated with older children (38). However, studies on individuals with intellectual disabilities in general reported that no individuals with intellectual disabilities met the current PA recommendations (36). A greater effort must be made to promote PA participation among DS youth, in order to reduce potential health risks associated with poor fitness and sedentary behavior.

Dietary factors can greatly contribute to overweight and obesity in DS youngsters. In the present study, DS adolescents had higher BMIs and fat percentages, despite the common meals and daily habits shared with siblings. Interestingly, a disperse intake behavior between DS adolescents and their siblings was observed, which may be attribute to the observed difference in BMI. Eating behaviors, such as infrequent lunch intake, ignoring breakfast, sleeping less, and frequent consumption of fast food and carbonated beverages, was higher in the non-DS adolescent siblings as compared to the DS adolescents. Indeed, we found a positive association between BMI and the frequency of breakfast, lunch, and dairy intake among

adolescents. Likewise, one study did find that skipping breakfast was associated with weight loss (39). Moreover, BMI was lower in adolescents experience shorter sleep duration, hence, explaining the higher BMI in DS adolescents, where the majority reported no to short sleeping duration. Noticeably, DS adolescents demonstrated greater commitment to eating with their families as compared to their non-DS siblings, which may impact on appetite and amount of food consumed at a meal. The current study found no difference in television viewing between DS children and their siblings, in line with a previous study (21). Nevertheless, several physiological and metabolic factors were implicated in the development of obesity in DS such as low gastrointestinal motility, low basal metabolic rate, and leptin resistance (11-13).

metabolic disorders are common in DS and may predispose affected subjects to obesity

In the current study, we acknowledged the limitations of BMI; its inability to distinguish body fat from fat free mass; or the location and type of adiposity, as well as the inability to account for gender differences in body composition, or syndrome difference in stature (40). Hence, BMI results should be interpreted with caution, and the present study used bioelectrical impedance analysis scale in combination with BMI to more accurately assess body composition. Moreover, in this study design, adolescents were included as a separate group, in order to overcome the limitations of some studies that combined adolescents and children without controlling for age (26, 29, 33), as well as other studies which included adolescents within the adult cohort (5, 30). Combining different age groups are not recommended, due to the variability in body composition, including lean muscle mass, associated with puberty. In the current study, DS children and DS adolescents were compared to their age- and gender-matched siblings, thus decreasing a potential confounding factor, such as environmental and genetic factors, and recruitment bias of healthy controls. Moreover, this study used specific growth charts for Down Syndrome (CDC), and used BMI- for- age curves to account for stature in classifying youngsters according to their body mass.

In spite of the strengths listed above, we acknowledge the following limitations in the study design: lower number of DS and siblings as compared to target, due to limited number of suitable cases in the centers, as well as exclusion of incomplete questionnaires; missing body composition analysis for siblings using BIA, due to an inability to attend the centers during school hours. Finally, the questionnaires were self-administered by parents and guardians, and therefore subject to reporting bias. Yet, written guidelines were provided in order to facilitate guided completion.

Conclusion

The present study affirms the higher risk of overweight or obesity in DS children and adolescents versus siblings sharing their households. Obesity may contribute to an elevated risk of developing various complications, such as high blood pressure, obstructive sleep apnea, hyperlipidemia and insulin resistance (8), which increases the burden on families, guardians, and the health care system. If diagnosed sufficiently early, obesity can be corrected and reversed, via developing simple lifestyle and dietary changes, such as, lowering portion sizes, minimizing high calories snacks, and introducing a daily exercise routine. Therefore, youth with DS may be targeted in dietary and physical fitness initiatives and campaigns in order to reduce their obesity risk. Perhaps, with motivation to be active, and an increase in PA, enhancement in dietary choices and balanced nutritious meals, optimum weights can be achieved, and malnutrition and obesity-related morbidities can be avoided. In addition, national-based studies that include all age groups, and comprehensively assess pre-disposing factors that link obesity in the DS youngsters, are warranted.

Abbreviations: BIA: Bioelectrical Impedance Analysis, BMI: Body Mass Index, BMR: Basal Metabolic Rate, CDC: Centers for Disease Control and Prevention, DS: Down Syndrome, DSCA: Down Syndrome Charitable Association, FM: Fat Mass, LBM: Lean Body Mass, SAUT: The Voice of Down Syndrome Society, Std: Standard Deviation, PA: Physical Activity.

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