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Original article

Lifestyle Factors and Anthropometric Obesity Indicators in Libyan Individuals with Down Syndrome

Amani Tayeh

Department of Biomedical Science, Libyan Academy-Aljabal Al-akther Branch, Al-Bayda, Libya.
Email.amaniosama8074@gmail.com

Abstract
Down syndrome (DS) is one of the most common chromosomal disorders and is associated with obesity, reduced physical fitness, and metabolic complications. This study aimed to compare dietary habits, physical activity (PA), and anthropometric obesity indicators between Libyan individuals with DS and healthy controls, and to examine the associations between lifestyle factors and obesity-related anthropometric measures among individuals with DS. A cross-sectional study was conducted at two specialized DS centers in Al-Bayda, Libya. The study included 37 individuals with DS and 42 healthy controls. Anthropometric measurements, including weight, height, waist circumference (WC), and abdominal skinfold thickness (ASFT), were obtained. Body mass index (BMI) and waist-to-height ratio (WHtR) were subsequently calculated. Physical activity levels were assessed, and dietary habits were evaluated using a food frequency questionnaire (FFQ). PA levels differed significantly between groups ($p < 0.001$). Sedentary behavior was more prevalent among individuals with DS (54.1%) than controls (9.5%), whereas moderate and active PA levels were higher among controls. Significant dietary differences were observed for milk, canned juice, and dessert consumption, with higher intake reported among individuals with DS. Among participants with DS, PA was negatively associated with WHtR ($r = -0.363$, $p = 0.027$) and ASFT ($r = -0.372$, $p = 0.023$). In contrast, canned juice and dessert consumption showed positive associations with BMI and WHtR. Lifestyle-related behaviors, particularly low PA and unhealthy dietary habits, may contribute to obesity risk among individuals with DS. Promoting healthier nutrition and increased physical activity may help reduce obesity-related health risks in this population.

Keywords. *Anthropometric Measurements, Dietary Habits, Down Syndrome, Lifestyle, Food Frequency Questionnaire, Physical Activity.*

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Introduction

Down syndrome (DS) is one of the most common chromosomal disorders and is associated with a wide range of health complications, including obesity, reduced physical fitness, and metabolic disturbances [1]. Individuals with DS are particularly vulnerable to excessive weight gain and central adiposity due to multiple contributing factors, such as hypotonia, reduced physical activity, unhealthy dietary habits, endocrine dysfunction, and altered body composition. These factors may negatively affect quality of life and increase the risk of future cardiometabolic complications [2]. Lifestyle-related factors, particularly dietary habits and physical activity (PA), play a crucial role in the development and progression of obesity and related health problems. Previous studies have shown that individuals with DS often exhibit sedentary behaviors and poor dietary patterns, including low intake of fruits and vegetables and increased consumption of calorie-dense foods [3]. Such behaviors may contribute to increased body fat accumulation and unfavorable anthropometric profiles. Anthropometric indicators, including body mass index (BMI), waist circumference (WC), waist-to-height ratio (WHtR), and skinfold thickness, are commonly used to assess general and central obesity [4]. These measurements provide practical and non-invasive tools for identifying obesity-related health risks in clinical and community settings.

Evaluating the relationship between lifestyle factors and anthropometric indices may therefore provide valuable insights into modifiable risk factors among individuals with DS. Despite growing international interest in obesity and lifestyle behaviors in DS populations, limited data are available from developing countries, particularly in North Africa and Libya. Furthermore, few studies have simultaneously evaluated dietary habits, physical activity patterns, and multiple anthropometric obesity indicators in individuals with DS. Addressing this gap may help support early preventive strategies and improve health management in this vulnerable population. Therefore, the present study aimed to compare dietary habits, physical activity patterns, and anthropometric obesity indicators between Libyan individuals with DS and healthy controls, as well as to examine the associations between lifestyle factors and obesity-related anthropometric measures among individuals with DS.

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METHODS

Study design and participants

A cross-sectional study was conducted at two specialized Down Syndrome centers in Al-Bayda/Libya: Al-Ishraqa school and Al-Taqaddum center, over a period of three months, from 1 March to 30 May 2025. The study initially included 47 individuals with DS who were registered at the respective centers. However, parents of 10 subjects declined to provide consent for participation. This resulted in a convenient sample of 37 participants, of whom 21 were males and 16 females, who met the inclusion criteria, aged between 5 and 17 years, with an average of 11.5 ± 3.8 years.
The comparison group (CG), matched for age, sex & BMI (to minimize confounding effects of BMI on metabolic parameters) as a control, was constituted of 42 healthy individuals, with an average age of 12.5 ± 3.8 years without DS, of whom 20 males and 22 females were selected from the local community.

Inclusion criteria:

- Individuals with DS residing in Al Bayda/Libya, who were not participating in other studies.

Exclusion criteria:

- Individuals with DS who have chronic medical conditions and subjects who have taken medication or food supplements.

Anthropometric measurements

Anthropometric measurements were obtained from all participants in the fasting state at Al-Borj Laboratory, Al-Bayda. Body weight (Wt) was measured to the nearest 0.1 kg using a digital electronic scale (InBody 770, InBody Co., Ltd., Seoul, South Korea), with participants wearing light clothing and no shoes. Height (Ht) was measured to the nearest 0.1 cm using a digital stadiometer (BSM series, InBody Co., Ltd., Seoul, South Korea). BMI was calculated according to the standard formula: Wt (kg)/Ht. squared (m^2). WC was measured in cm using a flexible non-stretch measuring tape at the midpoint between the lower margin of the rib cage and the iliac crest. WHtR was subsequently calculated by dividing WC (cm) by Ht (cm). Abdominal skinfold thickness (ASFT) was measured using a calibrated skinfold caliper according to standard anthropometric techniques, and the measurements were recorded in millimeters (mm) as an indicator of subcutaneous fat distribution.

Dietary assessment

Dietary assessment was performed using a culturally adapted and validated Food Frequency Questionnaire (FFQ), specific to the local population [4]. The FFQ was used to evaluate the frequency of consumption of major food groups and commonly consumed food items. Participants (or their caregivers) reported their usual intake frequency for each item based on five categories: (1) never or rarely, (2) once per week or less, (3) twice per week, (4) several times per week, and (5) daily.

Evaluation of physical activity (PA)

PA was assessed and categorized based on participant self-reports (or caregiver reports where applicable). Participants were classified into three levels of physical activity: sedentary, moderate, and active, according to their usual daily activity patterns. Sedentary individuals were defined as those with minimal or no regular physical activity. Moderate activity was defined as engagement in light to moderate physical activities performed on a regular basis, while active individuals were those who participated in frequent or structured physical activity. For analytical purposes, physical activity levels were compared between individuals with Down syndrome and the control group, and the prevalence of each activity category was determined

Statistical analysis

All data were coded prior to entry and analyzed using the Statistical Package for the Social Sciences (SPSS) version 26.0. Continuous variables were first tested for normality using the Shapiro–Wilk test. Based on the distribution of the data, parametric or non-parametric tests were applied accordingly. Normally distributed continuous variables were expressed as mean ± standard deviation (SD), while non-normally distributed variables were presented as median with interquartile range (IQR). Comparisons between individuals with DS and control subjects were performed using an independent samples t-test for normally distributed variables or a Mann–Whitney U test for non-normally distributed variables. Categorical variables, including dietary habits and physical activity levels, were analyzed using the Chi-

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square (χ^2) test and presented as frequencies and percentages. In addition, correlations between lifestyle factors and anthropometric indicators were assessed using Spearman correlation tests. A p-value of less than 0.05 was considered statistically significant.

Results and Discussion

(Table 1) presents the baseline characteristics and anthropometric measurements of the study participants in both the DS and control. No statistically significant differences were observed between the two groups across the evaluated demographic and anthropometric variables. This finding is consistent with the matching criteria applied during participant selection, which included age, gender, and BMI. Although individuals with DS tended to have lower body weight and shorter stature compared with controls, measures of central and peripheral adiposity, including WC, WHtR, and ASFT, were generally comparable between the groups.

Table 1. Baseline characteristics of the study participants with Down Syndrome (DS) and the control group (CG)

Variable	DS (n = 37)	CG (n = 42)	p-value
Age, years	11.54 ± 3.75	12.45 ± 3.73	NS
Sex (male/female)	21/16	20/22	
Weight, kg	40.5 ± 18.98	54.0 ± 25.8	**0.011**
Height, cm	131.5 ± 16.5	148 ± 17.7	**< 0.001**
BMI, kg/m²	20.45 (14.04-45.1)	21.39 (14.12-45.1)	NS
Non-obese	17 (21.5%)	19 (24.1%)	
Overweight/obese	20 (25.3%)	23 (29.1%)	
WC, cm	73.4 ± 18	79.21 ± 20	NS
WHtR	0.51 (0.4-0.87)	0.5 (0.4-0.78)	NS
Pathologic WHtR (≥ 0.5)	19 (24.1%)	19 (24.1%)	
ASFT, mm	20 (2-50)	17 (4-52)	NS

Data are presented as mean ± SD or median (IQR), depending on the distribution or as number (%); n, number of participants; WC, Waist circumference; BMI, body mass index; WHtR, Waist to height ratio; ASFT, Abdominal skin fold thickness; NS, Not significant. Bold p-value indicates statistical significance at P < 0.05

According to (Table 2), physical activity levels differed significantly between individuals with DS and control subjects ($p < 0.001$). Sedentary behavior was markedly more prevalent among the DS group (54.1%) compared with controls (9.5%). In contrast, moderate and active physical activity levels were more common in the control group (57.1% and 33.3%, respectively) than among individuals with DS (32.4% and 13.5%, respectively). Adjusted standardized residual analysis indicated that sedentary behavior contributed most strongly to the observed group difference. Reduced physical activity in individuals with DS has been consistently reported in previous studies [5]. Several physiological and behavioral factors may contribute to this pattern, including hypotonia, lower exercise tolerance, reduced motor coordination, and limited participation in structured physical activities [6]. Social and environmental barriers, including dependence on caregivers and reduced access to recreational opportunities, may also contribute to decreased activity levels in this population [7].

Table 2. Physical activity levels among individuals with Down Syndrome (DS) and the control group (CG)

Physical activity	DS (n = 37)	CG (n = 42)	p-value
Sedentary	20 (54.1%)	4 (9.5%)	**< 0.001**
Moderate	12 (32.4%)	24 (57.1%)	
Active	5 (13.5%)	14 (33.3%)	

Data are presented as numbers (%); n, number of participants. Bold p-value indicates statistical significance at P < 0.05

Table 3 summarizes the comparison of food frequency questionnaire responses between individuals with DS and the CG. Most dietary items showed no statistically significant differences between the two groups. However, significant differences were observed for milk, canned juice, and dessert consumption patterns between the two groups, with a greater proportion of individuals with DS reporting higher consumption of these items compared with controls. These findings may reflect a preference for sweet-tasting and carbohydrate-rich foods, which has been suggested in previous

literature involving individuals with DS [8,9]. Altered appetite regulation, behavioral eating patterns, and caregiver feeding practices may partially explain the increased intake of energy-dense foods in this population [9].

Table 3. Selected dietary behaviors among children and adolescents with Down syndrome (DS) and the control group (CG)

Food item	DS (n = 37)	CG (n = 42)	p-value
Daily fruit intake	18 (48.6%)	10 (23.8%)	**0.021**
Daily vegetable intake	23 (62.2%)	23 (54.8%)	NS
Daily meat/chicken/fish intake	34 (91.9%)	32 (76.2%)	NS
Daily milk/milk products intake	33 (89.2%)	28 (66.7%)	**0.017**
Frequent fast-food consumption	9 (24.3%)	18 (42.9%)	NS
Frequent canned juice intake	28 (75.7%)	20 (47.6%)	**0.011**
Frequent desserts consumption	26 (70.3%)	15 (35.7%)	**0.002**

Data are presented as numbers (%); n, number of participants. Bold p-value indicates statistical significance at P < 0.05

Table 4 presents the associations between anthropometric obesity indicators and lifestyle factors among individuals with DS. PA showed significant negative associations with both WHtr (r = −0.363, p = 0.027) and ASFT (r = −0.372, p = 0.023). In contrast, canned juice consumption was positively associated with BMI (r = 0.496, p = 0.002) and WHtR (r = 0.513, p = 0.001). Additionally, dessert consumption demonstrated significant positive associations with BMI (r = 0.415, p = 0.011) and WHtR (r = 0.350, p = 0.034). These findings support the role of physical inactivity in promoting central and peripheral adiposity in this population and are consistent with previous studies linking sedentary behavior to increased obesity risk among individuals with DS [10].

Since WHtR is considered an important marker of cardiometabolic risk, the observed association may indicate potential long-term metabolic consequences of physical inactivity in DS [11]. Importantly, canned juice and dessert consumption showed positive associations with BMI and WHtR among individuals with DS. These findings suggest that increased intake of sugar-rich foods and beverages may contribute to both general and central adiposity in this population. Similar associations between sugar-sweetened beverage intake and obesity-related indicators have been reported in previous pediatric and DS-related studies [12]. The relationship with WHtR is particularly relevant, as abdominal adiposity is strongly associated with cardiometabolic complications [13].

Table 4. Association between lifestyle factors and obesity indicators in Down Syndrome (n=37)

r (p-value)	BMI	WHtR	ASFT
Physical activity	−0.321 (0.052)	− 0.363 (0.027)	−0.372 (0.023)
Fruits	−0.7 (0.677)	0.166 (0.325)	−0.015 (0.929)
Milk/milk products	0.22 (0.191)	0.288 (0.84)	0.208 (0.216)
Fast food	0.248 (0.139)	0.182 (0.282)	0.308 (0.064)
Canned juice	0.496 (0.002)	0.513 (0.001)	0.272 (0.103)
Desserts	0.415 (0.011)	0.35 (0.034)	0.253(0.131)

r, Correlation coefficient; BMI, body mass index; WHtR, waist-to-height ratio; ASFT, Abdominal skin fold thickness. Bold p-value indicates statistical significance at P < 0.05

Despite the observed differences in physical activity and dietary patterns, no significant differences were found between the DS and control groups regarding anthropometric obesity indicators. This finding may be partially explained by the matching process based on BMI, age, and sex. Nevertheless, individuals with DS tended to exhibit lower body weight and shorter stature, while maintaining comparable indices of adiposity. These findings may suggest that obesity-related risk in DS is influenced not only by overall body size but also by body composition and fat distribution characteristics [14].

Limitations

Some of the limitations should be considered when interpreting the present findings. The relatively small sample size may limit the generalizability of the results. In addition, dietary intake and physical activity data were based on

questionnaire responses, which may be subject to recall and reporting bias. The cross-sectional nature of the study also prevents causal interpretation of the observed associations.

Conclusion

The present findings suggest that obesity risk in individuals with DS may be more closely related to lifestyle-related behavioral patterns than to differences in overall anthropometric status alone. Promoting healthier dietary habits and increasing physical activity may therefore represent important components of obesity prevention strategies in this population.

Conflict of Interest

The author declares no conflict of interest. Funding: This research received no external funding.

Ethical considerations

The study was approved by the Al-Jabal Al-Akhdar Branch Committee for Bioethics, Libyan Academy for Postgraduate Studies/Al-Jabal Al-Akhdar Branch, Libyan National Committee for Biosafety and Bioethics, and Libyan Authority for Scientific Research. The approval reference number is NBC: 004. H. 25. 9. Administrative approval was taken from the directors of both study centers. All participants received information about the study, and their parents signed the free and informed consent.

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