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Association between Physical Activity and Adiposity in Adolescents with Down Syndrome

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Abstract

Purpose—Obesity is highly prevalent among adolescents with Down syndrome (DS); however, reported associations between body composition and moderate-to-vigorous physical activity (MVPA) have been small and non-significant. The purpose of this study to compare group differences between adolescents with and without DS, including dual-energy x-ray absorptiometry (DXA) measured body composition and accelerometer-measured physical activity, and then examine associations within adolescents with DS.

Methods—Thirty-nine adolescents (22 with DS and 17 typically developing controls), aged 12–18 years participated in the study. Groups had similar distributions of age, sex, and Tanner pubertal stage. Body composition was assessed by DXA, BMI, and BMI percentile. MVPA was measured with Actigraph GT3X+ accelerometers.

Results—Adolescents with DS had significantly higher BMI, BMI percentile, and DXA-derived percent body fat (BF%), as well as lower MVPA compared to controls ($p < .05$). Associations between MVPA and BF% in adolescents with DS were moderate ($r = -.39$, $p = .07$), but substantially stronger than BMI ($r = -.19$, $p = .40$). However, linear regression analyses identified Tanner stage ($\beta = -.77$, $p < .001$) and MVPA ($\beta = -.34$, $p = .047$) as significant predictors of BF%. No relevant associations between body composition and MVPA were observed in adolescents with typical development ($p > .05$).

Conclusions—Our findings suggest that MVPA is associated with adiposity when measured with DXA among adolescents with DS.

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Conflict of Interest

The authors have no conflicts of interest to declare.

The results of the present study do not constitute an endorsement by ACSM.

The authors declare that results of the study are presented clearly, honestly, and without fabrication, falsification, or inappropriate data manipulation.

Keywords

Obesity; Intellectual Disability; Youth; Accelerometer; MVPA; Puberty

INTRODUCTION

Childhood obesity in the general pediatric population poses a significant public health problem, with estimated rates continuing to track at epidemic levels (1). Prevalence rates of overweight and obesity are currently estimated at 30% among adolescents in the United States (1). This health condition is likely to continue into adulthood (2), increasing the risks of developing comorbidities and of early mortality (3).

Down syndrome (DS) is the most common genetic form of intellectual disability, with an estimated prevalence rate of 8.27 per 10,000 people (4). Youth with intellectual disabilities experience overweight and obesity with greater frequency than the general population (5). However, overweight and obesity are even more prevalent among youth with DS. Approximately 60% of youth with DS are estimated to be overweight or obese (5–7), rates that far exceed the general population (1). The risk for obesity in youth with DS is 3.00 times greater compared to typically developing peers (5) and 3.21 times greater compared to youth with non-genetic intellectual disabilities (8). In addition to the health risks associated with obesity, decreased community participation, challenges with independent living, and reductions in overall quality of life are also associated with obesity in persons with DS (9). However, the current evidence on obesity in DS is limited by over-reliance upon body mass index (BMI; kg/m²), which may overestimate excess adiposity in this population (6).

Few studies have utilized dual energy x-ray absorptiometry (DXA), an advanced body composition measurement technique, in persons with DS. DXA scans use low levels of radiation to measure fat mass, lean soft tissue, fat-free mass, and bone mineral content, allowing for estimates of total and regional body composition. Limited DXA evidence indicates adolescents and adults with DS have elevated body fat proportions, with greater fat mass and lower lean mass than typically developing controls (6, 10, 11). Greater abdominal obesity has also been identified in adolescents with DS, particularly in girls (10). These findings suggest a unique body fat topology in DS and indicate that DXA-derived fat mass can identify differences that are not available from standard anthropometry. This fat topology pattern is of particular clinical relevance as individuals with abdominal adiposity, especially with greater visceral fat, are at increased risk for type 2 diabetes, dyslipidemia, and cardiovascular disease (12). Research utilizing DXA to study obesity in DS is critical to better understand and account for these systematic differences in body fat distribution.

Despite the high prevalence of overweight and obesity among youth with DS, the factors that contribute to this health condition are not well understood. The objective data available on physical activity among individuals with DS is expanding, but currently inconclusive (13). Reported estimates of youth that meet recommended physical activity guidelines (14) for moderate-to-vigorous physical activity (MVPA) range from 0% to approximately 40% (15–19), suggesting that youth with DS engage in insufficient levels of MVPA. Physical activity appears to be a function of age, with declining physical activity levels observed in

cross-sectional studies of adolescents with DS (17–21) and longitudinally in typically developing adolescents (22). Additional studies in DS have also statistically controlled for age in analyses to address this trend (15, 16). Finally, it appears that individuals with DS engage in less physical activity than typically developing controls (15, 16, 23); however, more studies are needed to confirm these differences.

Researchers contend that low physical activity contributes to the obesity health disparity (7, 24), but this relationship has not been empirically established in DS. MVPA is a well-defined correlate of obesity in the general pediatric population (25). However, studies examining the association between MVPA and BMI in DS have found surprisingly weak and non-statistically significant relationships (18–21, 26). While it is possible that cross-sectional relationships do not exist with these health behaviors, it is equally likely that BMI is an inappropriate index of body composition for use in the DS population. Precise measures of body composition that account for unique regional fat distributions are likely needed to define such a relationship. The association between these health behaviors and adiposity in DS have not been examined using DXA. This relationship is critical as it serves as the foundation for many health promotion practices intended to prevent excess weight gain.

The primary purpose of this study was to measure adiposity using an advanced measurement technique (DXA) capable of examining differences between adolescents with and without DS and the subsequent associations with physical activity behavior. Thus, the study was designed to compare group differences between adolescents with and without DS on body composition and physical activity and examine associations within adolescents with DS. Based on the available literature, we hypothesized that adolescents with DS would have greater BMI and body fatness and lower physical activity levels than would adolescents without DS. We also hypothesized that, when employing DXA to measure fat mass, a significant inverse relationship between physical activity levels and adiposity would be observed among adolescents with DS.

METHODS

Participants

Adolescents with DS and typical development (TD) were between 12 and 18 years old, Tanner pubertal stages III to V (27, 28), and without dual disability diagnosis (e.g., autism), comorbid disease (e.g., diabetes), or contraindication limiting safe engagement in physical activity. All parents signed written informed consent documents while participants completed written or verbal assent prior to initiating the study. Adult participants (e.g., 18 years old) were allowed to independently provide written informed consent. However, parents of adult participants with DS also provided written consent. The study was approved by the Institutional Review Board of the University of Michigan Medical School.

Procedures

Traditional Anthropometry—Height and weight were measured to the nearest 0.1 cm and nearest 0.01 kg, respectively, to derive BMI (kg/m^2). BMI percentiles were determined using sex-specific BMI-for-age growth references from the CDC (29).

Dual-Energy X-Ray Absorptiometry—Each participant completed one whole-body DXA scan (GE Lunar Prodigy Advance [DPX-IQ 240] densitometer; Lunar Radiation Corp, Madison, WI) to measure body composition. Measurement through DXA provides a three-component analysis of body composition (30). Reliability of the GE Lunar Prodigy has been established in pediatric populations for both total and regional estimates of body composition (31). However, reliability evidence specific to populations with DS is not available.

The scanner was calibrated daily according to the manufacturer's instructions using a standardized block by the certified technician. Participants wore light clothing, free of metallic objects, and were positioned in a supine position with hands by the sides in a neutral position. If needed, loose-fitting Velcro around the ankles or a warm blanket were used to assist the participant with maintaining position during the scan. All participants completed a DXA scan suitable for analysis with DXA software (EnCore v.14.10). The DXA scan provided measurements of percent body fat for the total-body and regional segments of arms, legs, and trunk. Ratios of fat mass distribution were then calculated, including trunk-to-total, legs-to-total, arms-to-total, and arms and legs-to-trunk.

Tanner Staging—To account for differences in pubertal development across adolescents, puberty stage was measured using Tanner stages (27, 28). Parents completed a proxy-report questionnaire using schematic line drawings of pubertal development. Ratings on this scale range from I (prepubertal) to V (adult). Questionnaires using line drawings, including via parental report, have been shown to significantly correlate with physician exam (32, 33). Due to the challenges with self-report in adolescents with DS and the invasiveness of a physical exam, the use of parental report was justified in the current study. Tanner stage was operationalized as the average reported stage in pubic hair and genital development for males and pubic hair and breast development for females.

Physical Activity—Each participant wore an Actigraph GT3X+ (Pensacola, FL) triaxial accelerometer at the waist during waking hours for seven days to measure habitual physical activity. Waking hours were determined through a log completed by the parents and participants. All actigraphy data was collected at sampling frequency of 30 Hz with a 10-second epoch to capture intermittent movement. Participants were instructed to wear the monitor for all day-time hours, except during water-based activities (e.g., swimming, bathing). Night-time wear was allowed, but not required. Criteria for minimum wear time included 10 hours per day for at least 4 days of the 7-day period, including at least one weekend day (34). Each accelerometer file was manually cleaned to only include data collected between reported waking and bed times on each day and then assessed for non-wear time using validated algorithms (35) with ActiLife software (v.6.9.5, Actigraph, Pensacola, FL). Data were then reduced into physical activity intensity categories based on

counts per minute (cpm): sedentary (<100 cpm), light physical activity (101–2295 cpm), moderate physical activity (2296–4011 cpm), and vigorous physical activity (>4012 cpm), validated in typically developing youth (36). The Evenson cut-points (36) were selected based on recommendations from a comparative study of cut-points in youth (37) and evidence of moderate MVPA outcomes using this threshold (38).

Data Analysis

Data analyses were performed using SPSS 22.0 (IBM Corp., Armonk, NY) with an α of 0.05. Demographics of the sample were described using independent t-tests and Pearson's Chi-square (χ^2) tests with effect sizes (i.e., Cohen's d and Cramer's V).

Multivariate analysis of covariance analyses (MANCOVA) were conducted to determine if groups with and without DS produced mean differences after adjusting for relevant covariates. Analyses were conducted in two sets: 1) body composition variables controlling for age, sex, and Tanner pubertal stage, and 2) physical activity variables controlling for age, sex, Tanner pubertal stage, and accelerometer wear-time. Effect sizes including eta-squared (η^2) from the adjusted MANCOVA analysis and Cohen's d from unadjusted group means were also calculated. Results were interpreted based on statistical significance of multivariate and univariate F tests and magnitude of effect sizes (39). MANCOVA was used to reduce Type I error rate compared to a series of ANCOVA tests.

Pearson product-moment correlation coefficients and linear regression were used to examine the associations between physical activity and adiposity among adolescents with Down syndrome. Pearson correlations were examined for all possible associations between body composition and physical activity variables. Correlations were interpreted based on statistical significance ($p < .05$) and the magnitude of the association (39). Linear regression analyses examined the association between body composition and sex, age, Tanner pubertal stage, and physical activity (MVPA minutes/day). Linear regression models with dependent variables of BMI percentile and total body fat percentage were employed. Results were interpreted based on the magnitude of standardized coefficients (β), statistical significance ($p < .05$), and effect size (η^2). Semi-partial correlation (sr) and squared (sr^2) coefficients were also calculated to examine the unique contributions of each factor to the total variance explained in the dependent variable.

RESULTS

A total of 39 participants (22 with DS, 17 with TD) participated in the study. Descriptive statistics and demographic information for the participants are presented in Table 1. All participants were between 12 and 18 years old and between Tanner stages III and V. Groups had equivalent distributions for age, sex, race/ethnicity and Tanner pubertal stage ($p > .10$). Adolescents with DS were significantly shorter in stature than adolescents with TD ($p < .001$), but were similar in weight ($p = .612$).

Large differences were observed in body composition between groups (Table 2). Adolescents with DS had significantly higher BMI ($p = .001$, $d = 1.06$) and BMI percentile based on CDC growth charts ($p < .001$, $d = 1.31$). Body fat percentages, measured via DXA,

were also significantly higher among adolescents with DS ($p < .05$); however the magnitude of difference was considerably smaller than was observed for differences in BMI ($d < .80$). Significant differences were observed in body fat percentage for the total body ($p = .011$), as well as fat in regional segments at the arms, legs, and trunk ($p < .020$). To further examine body composition, ratios between regional segments of body fat were calculated. Large and statistically significant differences were observed between groups for body fat ratios of trunk-to-total, legs-to-total, and arms and legs-to-trunk ($p < .001$, $d > 1.15$). No differences were observed in the ratio of arms-to-total body fat ($p = .600$, $d = .264$). Each of these ratios indicated greater fat mass in the abdominal region among adolescents with DS. No significant interactions were observed between sex and metrics of body composition (e.g., total body fat percentage: $F(1,34) = 1.40$, $p = .133$); thus, stratified results were not presented.

Table 3 presents the group differences for each physical activity intensity category. Physical activity levels were very low among most participants. Fewer than 5% of adolescents with DS and fewer than 20% of TD adolescents met physical activity guidelines of 60 minutes of MVPA per day (14). Adolescents with DS averaged 27.83 (SE = 5.43) minutes of MVPA per day compared to 45.76 (SE = 6.21) minutes per day among TD adolescents, while controlling for age, sex, pubertal stage, and wear time. Significant differences between groups were observed for MVPA ($p = .041$, $d = .421$), vigorous physical activity ($p = .011$, $d = .617$), and light physical activity ($p < .001$, $d = 1.10$). No differences were observed in sedentary time or moderate physical activity ($p > .05$). Similar to body composition, there were no significant interactions between sex and physical activity levels (e.g., MVPA: $F(1,34) = 2.22$, $p = .146$); thus, results stratified by sex were not presented.

Correlations between measurements of body composition and physical activity for adolescents with DS and TD are presented in Table 4. For adolescents with DS, bivariate associations between MVPA and BMI ($r = -.187$, $p = .405$) and BMI percentile ($r = -.137$, $p = .542$) were very low. The associations between MVPA and body fat percentages from DXA including total body ($r = -.388$, $p = .075$), arms ($r = -.362$, $p = .098$), legs ($r = -.382$, $p = .079$), and trunk ($r = -.375$, $p = .086$), were substantially stronger, but these associations only trended towards statistical significance ($p < .10$). Statistically significant correlations ($p < .05$) among adolescents with DS were observed between vigorous physical activity and multiple measures of body composition, including total ($r = -.444$, $p = .039$), leg ($r = -.428$, $p = .047$), and trunk ($r = -.440$, $p = .041$) body fat percentages, but not BMI ($r = -.288$, $p = .194$) nor BMI percentile ($r = -.349$, $p = .111$). Among TD adolescents, light physical activity was significantly associated with all metrics of body composition including BMI ($r = -.537$, $p = .026$), BMI percentile ($r = -.502$, $p = .040$), and total ($r = -.633$, $p = .006$), arm ($r = -.565$, $p = .018$), leg ($r = -.506$, $p = .038$), and trunk ($r = -.679$, $p = .003$) body fat percentages. All associations with MVPA or vigorous physical activity were not statistically significant ($p > .05$).

Finally, Table 5 presents a linear regression analysis examining the associations of sex, age, Tanner stage, and MVPA on the dependent variables total body fat percentage and BMI percentile for adolescents with DS and TD. The linear model explained approximately 60% of the variance in total body fat percentage among adolescents with DS, $F(4,21) = 6.28$, $p = .$

003, $R^2 = .596$. Statistically significant predictors of total body fat percentage included Tanner stage and minutes of MVPA ($p < .05$). Semi-partial correlation coefficients (sr^2) suggested that the independent contribution to total variance explained was largest for Tanner stage (43.69%), minutes of MVPA (10.89%), and age (5.06%). Conversely, the linear model with BMI percentile explained less variance, $F(4,21) = 2.16$, $p = .117$, $R^2 = .337$, with no significant predictors ($p > .10$). Among TD adolescents, the same factors explained only 31% of the variance in total body fat percentage, $F(4,16) = 1.37$, $p = .303$, and 23% of the variance in BMI percentile, $F(4,16) = 0.91$, $p = .489$. None of the predictors were statistically significant in either model ($p > .05$).

Discussion

The purpose of this study was to examine associations between body composition and physical activity in adolescents with DS and to identify group differences between adolescents with and without DS. The association between MVPA and body composition was considerably stronger when using body fat percentage from DXA rather than BMI. To our knowledge, this is the first study to report a significant linear relationship between MVPA and body fat percentage ($\beta = -.335$, $p = .047$) and one of the strongest correlations in magnitude ($r = -.388$, $p < .10$) observed in this population. Multiple statistically significant and clinically relevant differences were identified between adolescents with DS and TD, including significantly higher BMI, total and abdominal body fat percentages, and ratios of abdominal adiposity, as well as lower daily levels of moderate and vigorous physical activity among adolescents with DS compared to their TD peers.

The associations presented in this study add to a small, but growing, body of literature examining health behaviors and obesity in youth with DS. In the general population, higher levels of physical activity have been associated with lower levels of body fatness (25). In the current study, strong and significant correlations were observed between vigorous physical activity and body fat percentages ($r = -.428$ to $-.444$, $p < .05$) across multiple body segments (i.e., total body, legs, trunk). Furthermore, associations between MVPA and body fat percentages trended toward statistical significance ($r = -.362$ to $-.388$, $p < .10$). Conversely, the association between MVPA and BMI or BMI percentile ($r = -.187$ and $-.137$, respectively) were weak and non-significant, yet similar to previously reported associations in youth with DS ranging from $r = -.05$ to $-.30$ (18–20). Despite vigorous physical activity being the only classification of physical activity to produce significant correlations with body composition, the associations with MVPA were much stronger with body fat percentage from DXA than traditional BMI metrics.

Given the improved magnitude of association between DXA-measured body fat percentage and MVPA, it was important to examine the relationship between physical activity and body composition in adolescents with DS while controlling for other relevant covariates. A significant association was observed between total body fat percentage and MVPA ($p = .047$). Tanner pubertal stage also exhibited a statistically significant association with total body fat percentage ($p < .001$) and was the strongest predictor. Interestingly, Tanner stage and body fat in adolescents with DS were negatively associated, suggesting lower body fatness at higher Tanner stages. Sexual dimorphisms in body fat during puberty have been

consistently demonstrated in the general population with boys exhibiting a negative association between adiposity and pubertal development while girls exhibit a positive association (40, 41). In addition to differential trajectories in adiposity, sexual dimorphism during puberty is also marked by differences in body fat topology with android fat distribution common among males and gynoid distribution among females (40). Thus, the results presented could be influenced by the larger proportion of male adolescents with DS in the sample. However, the lack of association between body composition and sex or age in our sample of adolescents with DS is also consistent with previous findings in intellectual disability (8). The significant associations of adiposity with MVPA and Tanner stage are novel and have not been previously addressed persons with DS. None of these relationships were seen with BMI percentile, further suggesting that BMI may be an ineffective metric of body composition for adolescents with DS.

To our knowledge, the only other study to examine associations between physical activity and body composition in adolescents with DS using linear regression analyses found no associations (21). Demographics, including age, weight, height, BMI, and body fat, were similar between studies; however, participants in the Izquierdo-Gomez (21) sample engaged in approximately 56 minutes of MVPA per day and had body composition assessed via skinfold measurement. It is possible that the high rates of adiposity and very low rates of physical activity in the current study are inflating the associations reported, but equally possibly that differences between DXA and skinfold measurement are contributing toward differing results. Izquierdo-Gomez (21) posit that physical activity levels may not contribute to fatness in this population, but longitudinal studies of this relationship are needed to make such inferences. However, given that our analysis controlled for multiple relevant factors including sex, age, and Tanner stage, the significant association between body fat percentage and MVPA suggests there is at least a moderate cross-sectional relationship to consider.

A secondary purpose of the study was to compare differences in body composition using traditional anthropometry with BMI and estimates of body fat percentage from DXA. The literature on youth with DS consistently shows greater BMI and higher proportions of overweight and obesity compared to typically developing youth (5–7, 21). The results from DXA measurements tell a similar, but different story. When controlling for sex, age, and Tanner pubertal stage, there were statistically significant differences in BMI and BMI percentile between groups with very large effect sizes. Differences in total body fat percentage from DXA were also statistically significant between groups, but the effect size was only moderate (39). The decrease in magnitude suggests that differences in adiposity between adolescents with and without DS based on the CDC growth charts may be inflated.

The high body fat percentage observed in this sample of adolescents with DS (33.20%) is consistent with previous studies that have measured adiposity with DXA in youth with DS (6, 11). However, Gonzalez-Aguero (10) reported a lower body fat percentage (24.7%) compared to other DXA studies in DS. This was among a sample of youth with DS, ages 10 to 19 years, matched to typically developing controls on BMI. Despite the lack of group matching in the present study, similar differences in regional body fat distribution were observed. Adolescents with DS had significantly higher body fat percentages in the trunk region and both body fat distribution ratios suggest a greater proportion of total body fat is

stored in the abdomen. Gonzalez-Aguero (10) found a similar trend toward abdominal obesity with greater fat mass among adolescents with DS, particularly among girls. Abdominal adiposity is clinically relevant as greater visceral fat mass is associated with higher risk for type 2 diabetes, dyslipidemia and cardiovascular disease (12). This increased risk is evident in adults with DS as higher rates of pulmonary hypertension and diabetes have been reported in this population (42).

The body composition results presented here and in previous studies (10) reflect a unique body fat topology in DS that BMI is not capable of describing. While significant differences in body fat percentage between adolescents with and without DS are evident using both traditional anthropometry and the advanced DXA measurement, the differences seen across regional segments and distribution ratios confirm that more detailed measurements are highly useful in this population. When feasible and cost-effective, the use of DXA to measure body composition in adolescents with DS is suggested.

Finally, this study also adds to the physical activity literature through examining differences in physical activity between adolescents with and without DS. While more research efforts need to be funneled toward understanding correlates of physical activity and designing interventions to increase physical activity behavior in adolescents with DS, there is still insufficient literature to thoroughly describe the physical activity patterns of this population (13). In the current sample, only four of the 39 participants (10%), including one adolescent with DS (4.50%) and three TD adolescents (17.60%), met the guidelines of 60 minutes of MVPA per day (14). Previous studies have also shown a very low proportion of adolescents with DS engaging in adequate physical activity (15–19), including studies that found 0% of the sample with DS met guidelines (15, 16). The average MVPA among the adolescents with DS was approximately 27 minutes per day after controlling for sex, age, Tanner stage, and wear time. The typically developing adolescents also engaged in largely insufficient levels of MVPA as well, averaging only 44 minutes of MVPA per day. Measured MVPA in this sample was consistent with previous reports among adults with DS, ranging from 25 to 30 minutes per day (23, 26), but below previously reported levels for adolescents with DS of approximately 55 minutes per day (17, 21). Age may be relevant in this relationship, as MVPA has been shown to decrease with increasing age both within youth (17–19) and into adulthood (23) in individuals with DS. Interpreting differences in physical activity across studies is challenging due to the variety of accelerometers used to measure physical activity and cut-points employed to categorize time spent in different intensities. Despite these methodological issues, it is clear that increasing levels of physical activity among adolescents with DS continues to be an area of great need.

Limitations

The current study is limited by a number of important factors that should be considered when interpreting the findings presented. First, the study includes a relatively small sample with limited statistical power. While statistically significant results were observed in many analyses, the small sample may have prevented the observation of significant interactions by sex and a more comprehensive, stratified analysis. The data are also cross-sectional in nature, so causal inferences cannot be made.

Second, physical activity was measured using accelerometers with psychometric properties and cut-point procedures from the general population. The use of the Evenson cut-points (36) influences the interpretation of findings, as the time classified in MVPA may have been different using an alternative set of pediatric cut-points (38). Furthermore, the physical activity literature in DS should be viewed cautiously, as psychometric evidence for accelerometer use in this population is limited. Due to differences in energy expenditure (43), the validity of accelerometer cut-points derived from the general population for individuals with DS is highly questionable. Alternative cut-points have been proposed for adults with DS (43), but accelerometer cut-points for youth with DS have not been published to date.

Third, while the use of DXA to measure body composition strengthens the quality of the study compared to traditional anthropometry, the technology is not without limitations. DXA scanning techniques are considered to be inferior compared to more advanced imaging technologies when estimating visceral versus subcutaneous fat (30). Software functions to provide estimates of visceral fat in this pediatric population were not utilized due to limited validity (30). Thus, the results presenting abdominal fat mass are limited by the inability to distinguish between visceral and subcutaneous fat.

Finally, Tanner staging was measured through questionnaires and with parental proxy reporting. These procedures were selected to address issues with self-report among participants with an intellectual disability. While parents have been shown to provide acceptable estimates of Tanner stage using this methodology (33), these validity studies did not include adolescents with disabilities. Given that Tanner stage was an important covariate in the linear regression analysis, a future study with a direct physician exam of Tanner stage is recommended to confirm the current findings.

Conclusions

Despite these limitations, this study demonstrated significantly higher levels of adiposity, unique body fat distributions, pervasively low levels of physical activity, and a significant associative relationship between physical activity and adiposity when properly measured for adolescents with DS. Future research should continue to examine the causes and consequences of greater obesity and limited physical activity in DS and develop novel interventions to address these health disparities.

It is clear that obesity is highly prevalent among adolescents with DS, representing a source of health disparity. Due to unique body fat topology, BMI is an inadequate metric of adiposity. Future studies should utilize DXA or other methodologies capable of capturing abdominal obesity. The results also show a significant association between physical activity and DXA-measured body fat percentage, a relationship not observed with BMI. Though causal nature cannot be inferred, this is the first study to report a significant association between these variables in persons with DS. This finding is important as many health interventions are based on a proposed relationship between this health behavior and health condition. Future studies should continue to create innovative interventions and health promotion programming to increase physical activity levels in adolescents with DS.

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Table 1

Characteristics of participants with and without Down syndrome

	Down syndrome	Typical development	<i>p</i>	ES ^c
<i>n</i>	22	17		
Age (years)	14.96 (1.92)	15.08 (2.12)	.850 ^a	.088
Sex			.163 ^b	.223
Male	14 (63.60%)	7 (41.2%)		
Female	8 (36.40%)	10 (58.8%)		
Race/Ethnicity			.443 ^b	.204
Caucasian	20 (90.90%)	17 (100%)		
African-American	1 (4.55%)	0 (0%)		
Hispanic	1 (4.55%)	0 (0%)		
Tanner stage			.409 ^b	.360
III	7 (31.82%)	5 (29.42%)		
IV	11 (50.00%)	6 (35.29%)		
V	4 (18.18%)	6 (35.29%)		
Height (cm)	145.91 (8.41)	164.68 (11.73)	<.001 ^a	1.379
Weight (kg)	55.69 (10.69)	57.94 (16.76)	.612 ^a	.147

Note: Data are Means (Standard Deviations) or Frequencies, *n* (proportions, %)

^aIndependent samples t-test

^bChi-square test

^cES = effect size (Cohen's *d* for t-tests, Cramer's *V* for X^2 tests)

p < .05, bolded

Group differences in body composition

Table 2

Body Composition ^a	Down syndrome	Typical development	F (1,34)	p	η^2	d ^b
CDC growth reference ^c						
BMI (kg/m ²)	25.84 (.807)	21.32 (.921)	13.26	.001 *	.281	1.06[‡]
BMI %ile	86.47 (4.43)	53.80 (5.05)	23.05	<.001 *	.404	1.31[‡]
DXA (% BF)						
Total %	33.20 (1.80)	25.90 (2.00)	7.26	.011 *	.176	.692
Arms %	33.90 (1.80)	26.30 (2.00)	7.65	.009 *	.184	.603
Legs %	36.10 (1.60)	29.90 (1.80)	6.25	.017 *	.155	.570
Trunk %	32.40 (2.10)	23.30 (2.40)	7.60	.009 *	.183	.772
Body Fat Ratios						
Trunk/Total ratio	.484 (.013)	.402 (.014)	17.66	<.001 *	.342	1.19[‡]
Legs/Total ratio	.357 (.009)	.421 (.010)	23.96	<.001 *	.413	1.32[‡]
Arms/Total ratio	.110 (.004)	.114 (.004)	0.28	.600	.008	.264
Arms & Legs/Trunk ratio	.993 (.056)	1.37 (.064)	18.84	<.001 *	.357	1.23[‡]

MANCOVA controlling for sex, age, and Tanner pubertal stage

 $F(10,25) = 12.43$, $p < .001$, Wilks' $\Lambda = .167$, partial $\eta^2 = .833$;^aAdjusted group means and standard errors (SE);^bCohen's d effect size, (unadjusted),^cCDC growth reference (27);* $p < .05$, **bolded**[‡] $d > .80$, **bolded**

Table 3

Group differences in physical activity

Physical Activity ^a	Down syndrome	Typical development	<i>F</i> (1,34)	<i>p</i>	η^2	<i>d</i> ^b
Sedentary (min/day)	531.74 (9.30)	555.90 (10.64)	2.80	.104	.078	.146
Light (min/day)	200.99 (7.00)	158.89 (8.01)	14.96	< .001 *	.312	1.10[†]
Moderate (min/day)	21.05 (2.42)	25.32 (2.77)	1.29	.264	.038	.098
Vigorous (min/day)	6.78 (3.25)	20.44 (3.72)	7.32	.011 *	.182	.617
MVPA (min/day)	27.83 (5.43)	45.76 (6.21)	4.52	.041 *	.120	.421
60 min/day MVPA, <i>n</i> (%)	1 (4.50%)	3 (17.60%)	3.10	.088	.086	.426

MANCOVA controlling for age, Tanner pubertal stage, and accelerometer wear time

MVPA = moderate-to-vigorous physical activity. All physical activity data are minutes per day.

*R*²(4,30) = 5.18, *p* = .003, Wilks' Λ = .591, partial η^2 = .409;^a Adjusted group means and standard errors (SE)^b Cohen's *d* effect size (unadjusted),* *p* < .05, **bolded**[†] *d* > .80, **bolded**

Table 4

Correlations between body composition and physical activity levels in adolescents with and without Down syndrome

	BMI	BMI percentile	Total %BF	Arms %BF	Legs %BF	Trunk %BF	Down syndrome				
							Sedentary PA	Light PA	Moderate PA	Vigorous PA	MVPA
BMI	–	.723*	.708*	.602*	.583*	.753*	–.354	–.012	–.102	–.288	–.187
BMI percentile	.931*	–	.529*	.469*	.408†	.587*	–.375†	.365†	.020	–.349	–.137
Total %BF	.554*	.557*	–	.964*	.970*	.991*	.063	–.136	–.320	–.444*	–.388†
Arms %BF	.355	.402	.945*	–	.948*	.942*	.078	–.179	–.315	–.391†	–.362†
Legs %BF	.322	.342	.949*	.956*	–	.930*	.205	–.161	–.322	–.428*	–.382†
Trunk % BF	.706*	.684*	.963*	.842*	.834*	–	–.014	–.108	–.302	–.440*	–.375†
Sedentary PA	–.323	–.294	–.074	.017	.045	–.162	–	–.013	–.255	–.234	–.257
Light PA	–.537*	–.502*	–.633*	–.565*	–.506*	–.679*	.240	–	.722*	.332	.587*
Moderate PA	–.090	–.040	–.256	–.255	–.225	–.259	.189	.184	–	.823*	.970*
Vigorous PA	.030	.057	–.215	–.210	–.239	–.187	.20	.017	.937*	–	.937*
MVPA	–.015	.021	–.233	–.230	–.237	–.217	.201	.080	.975*	.991*	–

Note. Pearson product-moment correlations; Correlations within adolescents with Down syndrome are shown above the divide and shaded gray; Correlations within typically developing adolescents are shown below the divide.

BMI = body mass index; % BF = percent body fat; PA = physical activity; MVPA = moderate-to-vigorous physical activity.

* $p < .05$, **bolded**

† $p < .10$, *italicized*

Table 5
Linear regression analyses on total body fat percentage and BMI percentile in adolescents with and without Down syndrome

	Total BF%			BMI Percentile		
	β	<i>p</i>	<i>sr</i>	β	<i>p</i>	<i>sr</i>
Down syndrome						
Sex	.079	.670	.067	-.283	.245	-.238
Age	.298	.163	.225	-.080	.764	-.060
Tanner stage	-.774	<.001*	-.661	-.358	.140	-.306
MVPA (min/day)	-.335	.047*	-.330	-.171	.405	-.169
Typical development						
Sex	.457	.089	.443	-.142	.596	-.138
Age	.105	.858	.044	-.126	.840	-.052
Tanner stage	.122	.230	.055	.568	.331	.256
MVPA (min/day)	-.276	.354	-.230	-.071	.819	-.059

Note: Adolescents with DS ($n = 22$);

BMI Percentile = CDC growth reference (27);

Sex = reference is female;

MVPA = moderate-to-vigorous physical activity;

sr = semipartial (part) correlation;

* $p < .05$, **bolded**