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Original Article

Relationships between adiposity and postural control in girls during balance tasks of varying difficulty

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ABSTRACT

Objective: This study aimed to examine associations between postural control and body composition in 8–10-year-old girls.
Methods: An observational cross-sectional study was conducted in 47 girls who were healthy-weight/overweight/obese [body mass index (BMI) percentile]. Girls participated in six postural control conditions of varying difficulty (standing with malleoli touching, tandem stance leading with dominant and non-dominant foot, repeated with eyes open and closed). Postural control outcomes included Centre of Pressure (COP) sway area, COP principal and minor axis length and COP maximum velocity. Data were analysed using linear mixed modelling.
Results: BMI percentile was positively associated with COP sway area ($p = 0.034$) and principal axis ($p = 0.030$) during tandem stance non-dominant foot leading with eyes closed and COP principal axis during tandem stance dominant foot leading with eyes open ($p = 0.045$). BMI percentile significantly interacted with postural control conditions of varying difficulty to predict postural control outcomes ($p \leq 0.035$), notable for tandem stance positions [all four COP sway outcomes in tandem stance non-dominant foot leading eyes closed; tandem stance dominant foot leading with eyes open and closed (two COP sway outcomes each)].
Conclusions: Girls with greater adiposity may have impairments in postural control, but only during more challenging postural control conditions. In contrast, BMI has little role to play in girls' postural control in easier postural control conditions (standing with feet together). These findings may suggest potential functional or safety considerations when girls with overweight/obesity are performing demanding postural control tasks (such as during sport or physical activity).

Introduction

Worldwide, childhood overweight and obesity poses a serious and pressing health challenge, impacting more than 340 million children and adolescents globally [1]. While the causes of childhood obesity are complex and multifactorial, low physical activity has been flagged as a key modifiable risk factor [1]. Fundamental motor skills such as running, jumping and ball skills provide a foundation for physical activity engagement [2,3] and longitudinal data suggests that motor skills may be impaired in children with obesity [4]. Integral to the execution of motor skills, is the ability to maintain postural stability or 'postural control' [5]. Based on the Inverted Pendulum Model [6], postural control is the ability to keep the centre of mass (COM) within the body's base of support through corrective body sway or rotation, occurring around a fixed axis (ankle or hip). Obesity has been suggested to have a number of impacts on the developing musculoskeletal system in children [7] which could impact postural control. Firstly, obesity may increase the mass of body segments where there may be relative muscle weakness, meaning children may not be able to produce sufficient internal joint moments to maintain optimal postural control [8,9]. Furthermore, there may be sensory deficits linked with overweight/obesity that could impact postural control (e.g. reduced plantar foot sensation, difficulty with re-weighting

Abbreviations: BMI, body mass index; CI, confidence interval; COP, center of pressure.

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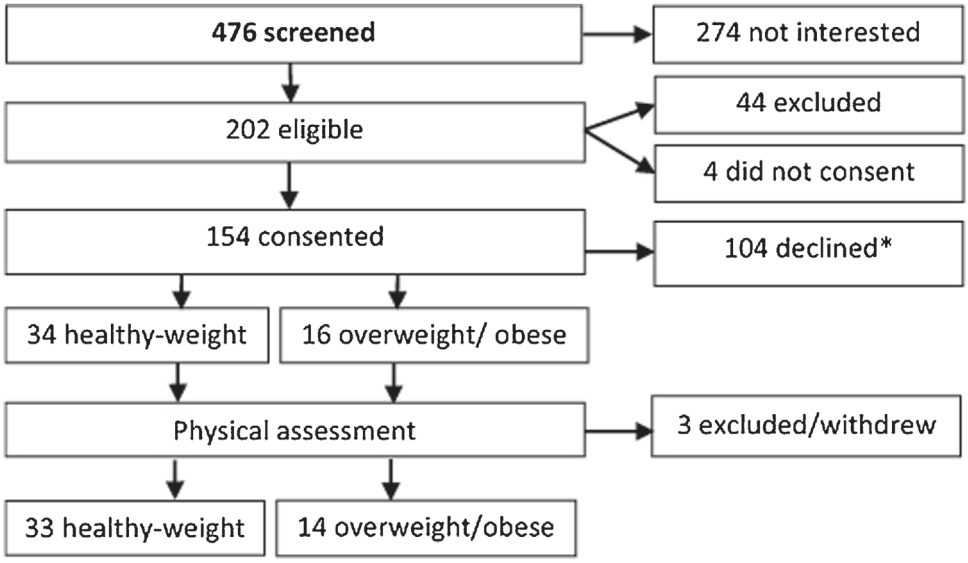

Fig. 1. Summary of volunteer recruitment and participation.
*44 children were excluded for reasons including recent injury, neurological/physical/intellectual disability, outside age range of interest, ear infection/vestibular disturbance, underweight.
**Healthy weight children on wait list that were excluded due to sufficient numbers being met.

Table 1
Demographic and anthropometric descriptive data.

	Healthy-weight (n = 33)	Overweight/obese (n = 14)	*p*
Age (years)	9.5 ± 0.9	9.9 ± 0.8	0.125
Height (m)	1.38 ± 0.1	1.4 ± 0.7	0.277
Mass (kg)	32.1 ± 6.0	44.2 ± 7.3	**<0.001**
BMI (kg/m^2)	16.7 ± 1.4	22.4 ± 2.2	**<0.001**
BMI percentile (%)	50 ± 22.5	92 ± 4.1	**<0.001**
Tanner - count (%)			0.210
Stage 1 (immature)	16 (84.2%)	3 (15.8%)	
Stage 2	13 (59.1%)	9 (40.9%)	
Stage 3	4 (66.7%)	2 (33.3%)	
Stage 4	0	0	
Stage 5 (most mature)	0	0	
Household income - count (%)[a]			**0.027**
$20,001–$40,000 AU	1 (33.3%)	2 (66.7%)	
$40,001–$60,000 AU	0 (0%)	3 (100%)	
$60,001–$80,000 AU	5 (62.5%)	3 (37.5%)	
$80,001–$100,000 AU	11 (91.7%)	1 (8.3%)	
$100,001–$150,000 AU	7 (70%)	3 (30%)	
>$150,001 AU	9 (81.8%)	2 (18.2%)	

Note: Data are presented as mean ± standard deviation, except for categorical variables which are expressed as count (%). Between group differences were analysed using the Student's Independent Samples *t*-test for continuous data and Chi Square Test for ordinal/categorical data. BMI percentile was calculated using Centres for Disease Control criteria, which were also used to classify children as either healthy-weight or overweight/obese. A *p* value of <0.05 was taken as significant and such values are shown in **bold**.

[a] N = 0 participants were in the lowest income category which has been omitted from the table (≤$20,000 AU).

of sensory information when vision is removed etc.) [8,10]. Mass-related decrements in postural control are particularly important, given that links between obesity and falls/fracture risk have been reported [7].

Emerging research exploring relationships between body composition and postural control in children using force plate postural sway assessments [8–16] has suggested deficiencies among children with overweight/obesity compared with their healthy-weight peers [17]; particularly when visual input is removed [8,12,17]. Greater postural sway has been reported in children who are overweight/obese [8,13], with linear velocity measures suggesting more ballistic (i.e. higher velocity) postural corrections [8,12,14]. There have been some conflicting findings showing no differences in postural control when comparing children of a healthy-weight to those with overweight/obesity [10,16]. However, direct comparisons between studies are problematic given inconsistencies in measurement methods (e.g. visual input, stance positions, postural sway measures etc.). Furthermore, there is a distinct under-representation of girls in prior research. Of the studies known to us which report gender, females account for <30% (5/8 studies with ~133 females [8,9,11,13,14] versus ~323 males), with only one study reporting results split by gender [9]. Thus, there is a need for research examining postural control in girls.

Therefore, the aim of this study was to investigate associations between postural control and body composition in 8–10-year-old girls. We hypothesised that associations between increased body composition and postural control would be dependent on the difficulty of the postural control condition.

Table 2
Descriptive data for centre of pressure sway variables (mean ± standard deviation) for each stance condition for the total sample (N = 47).

Sway area (m^2)	
Malleoli touching eyes open	0.0004 ± 0.0002
Tandem dominant eyes open	0.0008 ± 0.0006
Tandem non-dominant eyes open[a]	0.0011 ± 0.0007
Malleoli touching eyes closed	0.0006 ± 0.0003
Tandem dominant eyes closed	0.0031 ± 0.0027
Tandem non-dominant eyes closed[a]	0.0049 ± 0.0062
Principal axis (m)	
Malleoli touching eyes open	0.0140 ± 0.0037
Tandem dominant eyes open	0.0177 ± 0.0058
Tandem non-dominant eyes open[a]	0.0218 ± 0.077
Malleoli touching eyes closed	0.0163 ± 0.0039
Tandem dominant eyes closed	0.0356 ± 0.0159
Tandem non-dominant eyes closed[a]	0.0421 ± 0.0264
Minor axis (m)	
Malleoli touching eyes open	0.0085 ± 0.0022
Tandem dominant eyes open	0.0126 ± 0.0046
Tandem non-dominant eyes open[a]	0.0143 ± 0.0044
Malleoli touching eyes closed	0.0106 ± 0.0030
Tandem dominant eyes closed	0.0235 ± 0.0116
Tandem non-dominant eyes closed[a]	0.0249 ± 0.0126
Maximum velocity (m/s)	
Malleoli touching eyes open	0.0710 ± 0.0222
Tandem dominant eyes open	0.3544 ± 0.4309
Tandem non-dominant eyes open[a]	0.3718 ± 0.3482
Malleoli touching eyes closed	0.1026 ± 0.0454
Tandem dominant eyes closed	0.6983 ± 0.4739
Tandem non-dominant eyes closed[a]	0.6629 ± 0.4073

Note: For descriptive purposes only, participant trials for each postural control condition were averaged. Data shown are not log transformed for interpretability and descriptive purposes only.

[a] 45 participants in the analysis, all others have 46 (no postural control outcomes had complete data for all participants).

Subjects

This observational cross-sectional study was approved by the Human Research Ethics Committee of the University of South Australia (Protocol Number: 0000030898). Recruitment occurred from November 2014 to October 2017 via advertisements on social media, schools and magazines/newspapers. All data were collected at the University of South Australia. Inclusion criteria comprised of girls aged 8–10 years who were either healthy-weight, overweight or obese [18,19]. Exclusion criteria comprised of girls who were classified as underweight or reported acute injury, ear infection/vestibular disturbance, medical cause for their obesity, involvement in a weight loss/obesity treatment program in the previous three months, neurological, physical or intellectual disability or outside the desired age range. Written informed consent was obtained from all participants and their guardians.

Materials and methods

Postural control

Participant's postural control was assessed barefoot in minimal clothing in six different postural control conditions; specifically, three stance positions (medial malleoli touching, tandem with dominant foot leading and tandem with non-dominant foot leading) which were all performed with eyes open and eyes closed. Each condition was 60-s in duration and was repeated twice with a one-minute rest in between trials. Foot dominance was determined by which foot the participant kicked a ball with ≥2 attempts.

Centre of pressure (COP) measures were calculated (using Visual3D™ Version 6, C-Motion Inc., Rockville, USA) from ground reaction forces (GRF) collected with an AMTI force platform (AMTI, BP400600, Advanced Mechanical Technology Inc., MA, USA) set at 2000 Hz. COP data were filtered with a recursive fourth order, low-pass Butterworth filter with a cut-off frequency of 6 Hz. Each 60-s trial was truncated to 30-s by removing the first 20-s, (as this is typically when participants establish steady-state quiet stance [20]) and the final 10-s [21]. The COP along the X-axis and Y-axis were exported from Visual3D to Matlab (MATLAB R2016b, The MathWorks, Inc., Natick, USA) for processing. A 95% confidence interval (CI) ellipse was fitted, allowing the sway area and minor hemi-axes to be calculated as the Eigen vector [22]. Maximum COP velocity was computed from the resultant COP vector magnitude. Postural control outcomes of interest were the 95% CI ellipse of the COP sway area, the length of the principal and minor axes of the ellipse and the maximum velocity of the COP.

Body composition

With participants barefoot and wearing minimal clothing, height was measured using a wall mounted stadiometer (SECA SE206, UK; to the nearest mm) and body mass was measured using portable Tanita UM-051 Body Composition Analyser scales (Tanita Corporation, Tokyo, Japan; to the nearest 0.1Kg). BMI percentiles were calculated using Centres for Disease Control data based on height, body mass, gender and age [23].

Covariates (puberty, socioeconomic status)

Children and parents/guardians were asked to rate the participant's level of pubertal development using the Tanner scale [24]. Parents/guardians completed a questionnaire regarding their gross family annual average household income (seven possible categories ranging from a lowest income category of ≤$20,000 AU to a highest income category of >$150,001 AU). Household income was used as an indicator of socioeconomic status.

Statistical analyses

Descriptive statistics were computed using SPSS version 25 for Windows (IBM Corporation, Atmonk, New York USA). Variables were inspected for normality using histograms, skewness and kurtosis statistics.

Hypothesis testing was undertaken using linear mixed modelling in STATA (version 15 StatCorp, Texas, USA). Postural control conditions and the interaction term (postural control condition × BMI percentile) were treated as fixed effects; ID code was treated as a random effect to account for participants completing two repetitions of each postural control condition. When examining interactions, the standing with malleoli touching eyes open condition was used as the reference/comparator as it was found to be the least challenging condition (see results). The interaction analysis examined whether the effect of BMI percentile on COP sway parameters was different for postural control conditions of varying difficulty when compared with the reference condition (as indicated by a significant interaction term of $p \leq 0.05$). The distribution of residuals were visually inspected for normality – as a result, all postural control data were log-transformed to attain a normal distribution for model residuals.

Covariates were only considered relevant for inclusion in the mixed model analysis if they were theoretically plausible and had a consistent correlation with the postural control outcomes of interest. While Tanner stage and average household income were theorised to potentially influence postural control outcomes, this was not empirically supported. Specifically, Pearson correlations between Tanner stage/household income and the postural control outcomes (repetition 1 data) were not significant (Tanner R = 0.006–0.274, p = 0.97–0.07 respectively; Average household

Table 3
Association between centre of pressure sway outcomes and BMI percentile.

	Coef.	95% Confidence interval		*p*
		Upper	Lower	
Sway area				
Malleoli touching eyes open	−0.003	−0.008	0.002	0.199
Tandem dominant eyes open	0.006	−0.001	0.012	0.097
Tandem non-dominant eyes open[a]	0.001	−0.006	0.008	0.750
Malleoli touching eyes closed	−0.001	−0.006	0.004	0.725
Tandem dominant eyes closed	0.003	−0.006	0.013	0.523
Tandem non-dominant eyes closed[a]	0.011	0.001	0.021	**0.034**
Principal axis				
Malleoli touching eyes open	−0.001	−0.004	0.001	0.356
Tandem dominant eyes open	0.003	0.000	0.006	**0.045**
Tandem non-dominant eyes open[a]	<−0.0001	−0.004	0.004	0.958
Malleoli touching eyes closed	<0.0001	−0.002	0.003	0.900
Tandem dominant eyes closed	0.001	−0.003	0.006	0.533
Tandem non-dominant eyes closed[a]	0.006	0.001	0.011	**0.030**
Minor axis				
Malleoli touching eyes open	−0.002	−0.004	0.001	0.177
Tandem dominant eyes open	0.001	−0.002	0.004	0.574
Tandem non-dominant eyes open[a]	0.001	−0.003	0.004	0.677
Malleoli touching eyes closed	−0.001	−0.004	0.002	0.508
Tandem dominant eyes closed	0.002	−0.003	0.008	0.367
Tandem non-dominant eyes closed[a]	0.004	−0.000	0.009	0.069
Maximum velocity				
Malleoli touching eyes open	−0.002	−0.005	0.001	0.148
Tandem dominant eyes open	−0.002	−0.009	0.005	0.595
Tandem non-dominant eyes open[a]	0.003	−0.003	0.009	0.340
Malleoli touching eyes closed	<−0.0001	−0.005	0.004	0.840
Tandem dominant eyes closed	0.005	−0.002	0.011	0.185
Tandem non-dominant eyes closed[a]	0.005	−0.001	0.012	0.096

Note: All COP variables were log transformed. BMI percentile was defined using Centres for Disease Control definitions. Postural control conditions and BMI percentile were treated as fixed effects, participant ID code was treated as a random effect in all linear mixed models. Unstandardised coefficients and their 95% confidence intervals are presented. $p = 0.05$ indicates significance shown in **bold**.
Abbreviation: BMI; body mass index.
[a] 45 participants in the analysis, all others have 46 (no postural control outcomes had complete data for all participants).

Table 4
Coefficients of interactions between BMI percentile and postural control conditions of varying difficulty to predict centre of pressure sway outcomes.

	Coef.	95% Confidence interval		*p*
		Lower	Upper	
Sway area				
Tandem dominant eyes open	0.009	0.001	0.016	**0.023**
Tandem non-dominant eyes open[a]	0.004	−0.003	0.012	0.271
Malleoli touching eyes closed	0.003	−0.005	0.010	0.455
Tandem dominant eyes closed	0.007	−0.001	0.014	0.086
Tandem non-dominant eyes closed[a]	0.014	0.007	0.022	**<0.001**
Principal axis				
Tandem dominant eyes open	0.004	<0.001	0.008	**0.027**
Tandem non-dominant eyes open[a]	0.001	−0.003	0.005	0.593
Malleoli touching eyes closed	0.002	−0.002	0.006	0.395
Tandem dominant eyes closed	0.003	−0.001	0.007	0.138
Tandem non-dominant eyes closed[a]	0.007	0.003	0.011	**<0.001**
Minor axis				
Tandem dominant eyes open	0.003	−0.001	0.007	0.157
Tandem non-dominant eyes open[a]	0.002	−0.002	0.006	0.233
Malleoli touching eyes closed	0.001	−0.003	0.005	0.628
Tandem dominant eyes closed	0.004	<0.001	0.008	**0.035**
Tandem non-dominant eyes closed[a]	0.006	0.002	0.010	**0.003**
Maximum velocity				
Tandem dominant eyes open	<0.001	0.001	0.008	0.972
Tandem non-dominant eyes open[a]	0.005	−0.003	0.005	0.116
Malleoli touching eyes closed	0.002	−0.002	0.006	0.511
Tandem dominant eyes closed	0.007	−0.001	0.007	**0.032**
Tandem non-dominant eyes closed[a]	0.008	0.003	0.011	**0.016**

Note: All COP variables were log transformed. BMI percentile was defined using Centre for Disease Control definitions. Analysed using linear mixed models **with an α $p = 0.05$ indicating significance**. Postural control condition × BMI percentile (interaction term) was included as a fixed effect and participant ID code as a random effect in all models. Unstandardised coefficients presented represent the interaction terms for each balance condition compared with the comparison condition (malleoli touching with eyes open).
[a] 45 participants in the analysis, all others have 46.

income R = 0.002 to −0.286, p = 0.990–0.054 respectively). Thus, in the interests of model parsimony, Tanner stage and household income were not included as covariates. Age was not included as a covariate as BMI percentile is age-adjusted and the age range of our sample was very narrow. Significance was set at $p \leq 0.05$ for all analyses. We estimated that a sample size of 47 could detect a low to moderate correlation (R = 0.4) between BMI percentile and postural control outcomes at an alpha of 0.05 with 80% power. However, given the presence of repeated measures (two testing repetitions), the actual power of our study is likely to be greater.

Results

The final data set included 47 girls, comprising of 33 of a healthy-weight and 14 who were classified as overweight or obese (10 and 4 girls respectively) (Fig. 1). Descriptive statistics for the sample are displayed in Table 1. In short, girls were aged on average 9.6 ± 0.87 years, were sexually immature (87% were classified at Tanner stages 1 or 2) and were from a range of socioeconomic backgrounds (average household income). The group classified as overweight/obese had a higher mass, BMI and BMI percentile and were from lower income households compared with the healthy-weight group (Table 1). Descriptive characteristics for postural control conditions are shown in Table 2 for the entire sample. By examining mean values for the total sample for COP sway variables, the postural control conditions can be ranked in the following order from easiest to most challenging: malleoli touching eyes open, malleoli touching eyes closed, tandem dominant eyes open, tandem non-dominant eyes open, tandem dominant eyes closed, tandem non-dominant eyes closed. The one exception to this ranking was for maximum velocity whereby the tandem non-dominant eyes closed condition ranked before the tandem dominant eyes closed condition (separated by 0.0354 m/s). Data were missing for some postural control outcomes due to technical difficulties as specified in Tables 2 and 3 (data were missing for 1–2 participants per postural control condition).

As shown in Table 3, BMI percentile showed a significant positive association with sway area (p = 0.034) and principal axis (p = 0.030) for the tandem non-dominant foot leading condition with eyes closed, and also with principal axis in the tandem dominant foot leading condition with eyes open (p = 0.045).

There were significant interactions showing that the effects of BMI percentile on COP sway parameters were different for a number of postural control conditions (Table 4) when compared with the reference condition (standing with malleoli touching eyes open). Significant interactions were observed for the eyes closed tandem non-dominant condition ($p \leq 0.016$) for all COP sway parameters. Eyes open in tandem (dominant foot leading) demonstrated a significant interaction for sway area (p = 0.023) and principal axis (p = 0.027). Eyes closed in tandem (dominant foot leading) demonstrated a significant interaction for maximum velocity (p = 0.032) and minor axis (p = 0.035).

Discussion

The purpose of this study was to explore relationships between postural control and body composition in girls, making this the first study we are aware of that has exclusively examined girls. Postural control is considered fundamental for skilled movement [5], which in turn is important for physical activity [2,3]. Girls have been shown to lag behind boys in their motor skills [2], physical activity [25] and postural stability [26,27] as they transition into adolescence/puberty. Thus, girls may be a vulnerable group, particularly given obesity has been causally linked with reduced motor skills [4] and physical activity [28]. Thus, research focussing on weight-related postural control in pre-adolescent girls is warranted.

We hypothesised that relationships between BMI and postural control would be dependent on the difficulty of the postural control condition. Our findings *partially* support this hypothesis, showing that girls with greater adiposity may have impairments in postural control, but only under more challenging balance conditions. Increasing BMI had little role to play in girls' postural control under easier conditions like standing with feet together. Once postural control tasks were more difficult, challenged by narrowing the base of support in tandem stance, with or without visual input, an association with BMI was evident. Specifically, we found evidence of a larger postural sway area that was more elongated in the anteroposterior direction of movement. We also saw a possible pattern towards more ballistic (i.e. larger velocity) postural control corrections and an elongated sway area in the mediolateral direction, although these did not reach statistical significance and therefore, should be interpreted with care.

Prior research analysing COP force-plate data, suggests that children with greater adiposity may exhibit deficiencies in their postural control [8,11–13,15], with reports of larger postural sway area [8,13] and higher sway velocity [8,12]. We also observed an association with BMI and sway measures but only when girls adopted a challenging and possibly novel stance position (tandem standing, eyes closed, leading with their non-dominant limb). Higher sway velocity may indicate more ballistic postural corrections, although our findings did not support this statistically, as we only observed a non-significant trend for tandem non-dominant eyes closed.

McGraw and colleagues [12] examined similar postural control conditions to our study, finding weight-status related to instability mediolaterally when vision and/or base of support were challenged in boys [12]. Our findings also suggest that increased BMI may be related to a more elongated sway area when base of support was challenged, but this only reached significance in the anteroposterior direction of movement; a difference we think may reflect the varying study populations (i.e. obese boys compared overweight girls). We speculate that our observation of increased anteroposterior sway could reflect a limitation in the use of hip strategies needed to adjust the body's centre of mass (the primary control mechanism thought to be at play when adopting tandem stance [6]).

Consistent with our findings, others have found little evidence of weight-related deficits in children's stability in less-challenging quiet stance positions [9–11]. While Villarrasa-Sapina et al. [8] reported deficits in quiet stance, their sample comprised of children recruited from a tertiary endocrinology clinic and treatment-seeking populations have been found to experience greater functional deficits in other domains (e.g. physical functioning [29]).

Two main theories have been hypothesised to explain postural control deficits in children with obesity [8]. The first relates to the inverted pendulum model of postural control [6]; where an increase in body mass will increase the mass of the pendulum, meaning, greater internal joint moments must be generated to maintain postural equilibrium [8]. For children with obesity, maintaining postural equilibrium may be made more difficult as childhood obesity has been shown to be associated with reduced lower limb strength relative to body mass [17]. Furthermore, King et al. [9] linked reduced lower limb strength (expressed relative to whole body moment of inertia) and decrements in postural control across a range of COP measures in boys and girls of varying weight status (e.g. Pearson correlations −0.27 to −0.35 for sway area). Thus, the idea that obesity-related lower limb weakness could contribute to impairments in postural control seems plausible, yet still largely un-investigated.

The second theory is that sensory impairments may influence balance in children of increased weight status [8]. D'Hondt et al. [10] found that children classified as overweight had reduced plantar cutaneous sensation that was associated with increased COP velocity/excursion mediolaterally in quiet stance. The authors hypothesised reduced plantar sensation to be an outcome of insidious higher foot loading due to increased body mass, combined with other obesity-related decrements in foot structures that have been reported in children from an early age [10]. Other possible sensory decrements that have been discussed include limitations in the re-weighting of sensory information (e.g. when vision is removed) and impairments in ankle proprioception [8,10,11], although few studies have explored this.

The suggestion that weight-related decrements in postural control may be more likely during novel or demanding balance activities may have important functional and safety considerations — for instance during sport or physical activity. Specifically, children with overweight/obesity may be at a greater risk of falls or injuries, which has been reported in this population [16]. While paediatric research is lacking, the link between increased postural sway and fall injuries has been confirmed by longitudinal research in older adults [30]. Thus, it may be sensible for clinicians working in multicomponent obesity management programs to screen girls for possible deficits in postural control, particularly when prescribing physical activity.

The current study has some limitations. Firstly, children with obesity were under-represented in this sample, reflecting difficulties recruiting this population. The sample may also be bias towards parents who were concerned about their child's balance, prompting them to volunteer. Given the cross-sectional design, we cannot draw causative conclusions and longitudinal studies examining weight status and postural control are needed. While our sample size was comparatively larger than many other studies in this field, our sample size was still relatively small, which could have influenced statistical power to detect true effects. Finally, there may be other factors (e.g. lower limb strength) that could influence postural control that were not examined here.

In conclusion, BMI had little role to play in girl's postural control when engaging in 'easy' balance tasks. However, once girls attempted more challenging balance activities by narrowing their base of support in tandem stance or closing their eyes in this position, BMI-related decrements in postural control emerged — we saw greater postural sway, elongated in the anteroposterior direction. Our findings may have functional safety implications when girls with overweight/obesity are performing more demanding postural control tasks such as during sport or physical activity. Thus, clinicians involved in obesity management programs may wish to consider assessing postural control when making recommendations around increasing physical activity in girls. Longitudinal and interventional designs are crucial to establish if adiposity is causatively linked with postural control deficits in girls.

Conflict of interest statement

The authors have no conflict of interest to declare.

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Author contributions

MT and DT contributed to study conception, funding, recruitment, data collection, data interpretation/analysis and manuscript preparation. JB contributed to data collection, data interpretation/analysis and manuscript preparation. SM contributed to study conception, data interpretation and manuscript preparation. All authors had final approval of the submitted and published versions.

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