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Whole body organization during a symmetric bimanual pick up task in overweight and obese children

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ABSTRACT

Information on the effects of obesity on the biomechanics of whole body movement control in children is limited. The purpose of the current study is to test the hypothesis that during a simple pick up task, overweight and obese children will organize their whole body movements differently than those in normal weight children. Twelve children who were overweight or obese (5–13 years old) and twelve age matched normal weight children participated in the study. Children picked up an empty box to waist height at a self-selected pace while kinematic and kinetic data were recorded and analyzed using a VICON system and two AMTI force plates. The overweight and obese group showed less knee flexion in both legs, more spine flexion, and less excursion in the height of their center of mass (all Ps < 0.05). However, the overweight and obese group had more anterior movement in their center of mass ($P < 0.05$). For the center of pressure findings, the overweight and obese group had greater anterior excursion with faster average anterior moving speed and spent a longer time with the center of pressure reached forward (all Ps < 0.05). These findings indicate that overweight and obese children organize their whole body movement during a simple pick up task differently with higher and more forward center of mass, quickly shifting their center of pressure anteriorly, and with a longer period of time with the center of pressure remaining forward. Their movement strategy may put them in a less stable condition and thus make them prone to losing balance.

The prevalence of obesity has increased in the past two decades in developed countries. Based on 2009–2010 survey in the U.S., more than 2 in 3 adults and more than one third of children and adolescents ages 6 to 9 years old are considered to be overweight or obese [1,2]. The high prevalence of obesity had led to many studies on obesity-related risks. However, most of these studies have focused on physiological complications related to obesity (e.g. [3,4]). Recently, several studies highlighted that children who are overweight or obese have gross motor and fine motor difficulties. For example, overweight and obese children decrease velocity when walking on a line [5,6], show lower scores in balance and ball skills [7], poor performance during walking backwards and moving sideways [8] and walk heel-first when crossing obstacles [9]. During walking, overweight and obese children have shorter step lengths, slower walking velocities, wider step widths, shorter single limb support times, shorter swing times, and longer double limb support times compared to normal-weight children [10–13]. These aspects of performance in gait and gross motor skills contribute to poor balance and postural control for overweight and obese children [14,15]. Thus, overweight and obese children are at a higher risk for falls and injuries related to falls [9,10]. In addition, obese children have greater joint moments during stair-walking [16]. Such greater joint moments could potentially lead to knee and hip osteoarthritis.

Many daily activities require performing more than one task at a time (e.g. picking up an object requires postural control and body movement to pick up objects). However, studies focusing on detailed whole body movement control especially under dual task constraints for overweight and obese children are scarce. Activities involving dual-task constraints (i.e., completing more than one task simultaneously) are challenging and may increase safety risks, especially for elderly, children, and individuals who are overweight and obese [14,15,17,18]. For example, obese adults decrease postural control and increase their reaction time under dual-task constraints [19]. Hung et al. [20] illustrated that overweight and obese children decrease gait velocity, stride length and increased

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step width, lateral hand, and lateral spine movement, and lateral maximum foot force under a carry a box task (dual task condition) when compared with simple walking. A better understanding of overweight and obese children's movement impairments can help identify potential injury related mechanism and lead to effective injury prevention training.

In the present study, we investigated how overweight and obese children organize their whole body movement during a functional pick up a box task (dual task condition). Although, no previous studies have shown asymmetric performance between dominant and non-dominant sides for overweight and obese children, the nature of the current task involved symmetric movements of both sides. To capture this whole body movement control completely, we used whole body kinematic model and two force plates. Based on previous findings on gait and other gross motor activities, overweight and obese children had slower movement velocity and poor balance and posture control. Thus, we hypothesized that compared to normal weight controls that the overweight and obese children would: 1) increase their movement time, 2) demonstrate different joint movement control and 3) modify their center of pressure and center of mass control during the current pick up a box task.

1. Methods

1.1. Participants

Twenty-four children between 5 and 13 years old participated in this study. School age children who were not considered teenagers were selected based on their ability to follow instructions. To decrease the influence of age on the current findings, age matched paired children were selected. Twelve had body mass index (BMI) scores that were classified as overweight or obese, and twelve age matched children had BMI scores in the normal range. Overweight and obese classifications were based on a comparison between BMI and the CDC weight-for-recumbent length growth charts [21]. Children who were $\geq$ the 85th percentile and <95th percentile were classified as being overweight, and those who were >95th percentile were deemed to be obese. Inclusion criteria for participation included: 1) normal cognitive abilities (mainstreamed in school) and 2) no known physical disabilities or conditions that precluded independent walking. Seven children were classified as obese and 5 were overweight. Descriptive information for each group is shown in Table 1. Informed consent was obtained from all participants and their caregivers, and the study was approved by the University Institutional Review Board.

1.2. Procedure and experimental setup

Children stood quietly with their feet separated about shoulder width and then picked up the empty plastic box (length: 45 cm, width: 29 cm, height: 17 cm) 2.54 cm in front of their toe to waist high without touching their body at a self-selected pace. Two practice trials were given prior to the five collected trials to familiarize participants with the task. If a trial was not collected successfully (e.g., the box touched the body), the participant was asked to perform the trial again. Each trial began with an auditory go signal and ended when children held the box quietly in front of their stomach.

Kinetics and kinematics were collected during pick up movement. Two AMTI OR6-6 force platforms (each 46×50 cm) embedded in the floor under each foot to collect foot ground reaction forces and calculate the location of center of pressure. Three-dimensional kinematic data were collected using the whole body plug-in-gait model with seven infrared cameras using VICON Nexus 1.51. Forty-one reflective markers were placed bilaterally on the anterior and posterior portions of the head, the shoulders (acromion process), the elbows (lateral epicondyle), the wrists (radio and ulnar styloid processes), the hands (index MCP joint), the upper arms, the forearms, the anterior and posterior superior iliac spines, the lateral thighs, the knee joints, each tibia, the ankle joints, the heels and the big toes. Markers were also placed between the clavicles, on the sternum, on C7, on T10, and on the right scapula. All markers were digitized at a rate of 120 Hz and were processed with a low pass digital filter with a cutoff frequency of 6 Hz. Kinetic data from both force plates were processed and synchronized with the kinematic data at a rate of 1200 Hz with VICON Nexus 1.51.

1.3. Analyses

We examined four factors related to whole body organization in obese and overweight children: movement time, joint motion, center of mass control and center of pressure control during a pick up task. For kinematic analyses, the onset of the movement was defined when either hand's velocity reached above threshold (5% of the maximum velocity) and the offset of the movement was when both hand's velocity decreased below the threshold. The whole movement was further divided into three parts: reaching down, grasping, and picking up. Reaching down started with the onset of the trial and ended with the offset of reaching (both hand velocity decreased below threshold). Picking up started when either hand's velocity increased above the threshold. The time period between reaching down and picking up was the grasping time. Temporal variables from kinematic analyses were total movement time, reaching down time, grasping time, and picking up time. The values were averaged and compared between groups. For whole body movement, we measured knee, hip, elbow, shoulder joint and spine excursion on the sagittal plane, and the excursion of center of mass position on all three directions (vertical, anterior-posterior, medial-lateral). To assess how steady was the box, we also evaluate the difference in vertical position (z) between the two hands to assess whether the box was picking up with the top level.

Table 1
Participant Characteristics.

Group	Age (SD m) y,m	Gender	Height (SD) cm	Weight (SD) kg	Leg length (SD) cm	BMI (SD) Kg/m^2
Control group	8,8	Female (n = 6)	139	33	70	17
	(3)	Male (n = 6)	(20.6)	(13.3)	(14.4)	(2.4)
Overweight and obese group	8,2	Female (n = 4)	135	41	69	22
	(3)	Male (n = 8)	(16.8)	(17.4)	(10.9)	(4.6)

Abbreviations: SD, Standard deviation; m, month; y, year.

Table 2
Temporal Findings.

Group	Control	Overweight and obese
Total movement time [s] Mean (SD)	2.06 (0.46)	2.09 (0.52)
Reaching down time [s] Mean (SD)	0.89 (0.27)	0.87 (0.22)
Grasping time [s] Mean (SD)	0.10 (0.09)	0.13 (0.11)
Picking up time [s] Mean (SD)	1.07 (0.28)	1.09 (0.41)

Abbreviations: SD, Standard deviation.

For kinetic analyses, the absolute vertical reaction force differences between the two feet (from two force plates) were calculated and normalized to the total vertical reaction force to evaluate force distribution between the two sides. Net center of pressure data was calculated [22] from both force plates and was used for further analyses. To better understand the detailed postural behavior (anterior-posterior direction), four dependent variables were used: the maximal excursion of the net center of pressure, the average speed of shifting the net center of pressure forward, the average speed of shifting the net center of pressure backward, the time when net center of pressure was shifted anteriorly.

To take into account the effect of body height, all the distance excursion measures of center of pressure and center of mass were normalized with the subjects' height. Two way ANOVAs with one within factor of side (dominant and non-dominant side) and one between factor (group) was performed on parameters with values from both dominant and non-dominant side. T-test for independent samples was used for the other parameters without the effect of dominant and non-dominant side. Statistical significance was set at $p < 0.05$.

2. Results

2.1. Temporal variables

Table 2 shows the average group temporal findings for both groups. There were no significant differences in temporal findings between the two groups for total movement time, reaching down time, grasping time and picking time (all Ps > 0.05).

2.2. Kinematic variables

The average group movement control data is shown in Table 3. The overweight and obese group had similar vertical position differences between the two hands (levelness of the box) when compared to the control group ($p = 0.78$). The overweight and obese group also showed similar elbow and shoulder joint angle at picking up, and hip joint excursion (All Ps > 0.05). However, the overweight and obese group had significantly less knee excursion (group: $p = 0.024$; side: $p = 0.84$) and larger spine flexion excursion ($p = 0.001$). The normalized excursion of center of mass was less vertically ($p = 0.004$) and greater anteriorly ($p = 0.026$) for the overweight and obese group.

2.3. Center of pressure

Fig. 1 illustrates the traces of anterior/posterior center of pressure movement patterns from a paired of represented children. The child in the overweight and obese group (B) showed a more U-shaped pattern while the child of the control group (A) had a more V-shaped pattern. This difference in center of pressure anterior/posterior traces was captured using several dependent

Table 3
Movement Control.

Group	Control		Overweight and obese	
Side	Dom	Non-Dom	Dom	Non-Dom
Elbow at picking up [degrees] Mean (SD)	40.46 (5.43)	39.56 (5.01)	40.89 (6.42)	38.88 (7.56)
Shoulder at picking up [degrees] Mean (SD)	51.41 (11.97)	52.96 (11.98)	51.55 (7.03)	52.83 (14.16)
Maximal vertical hand difference [cm] Mean (SD)	3.53 (2.07)		3.55 (1.18)	
Knee excursion [degrees] Mean (SD)	54.37 (15.82)*	53.32 (14.75)*	39.55 (14.57)*	41.49 (9.95)*
Hip excursion [degrees] Mean (SD)	67.71 (12.27)	70.73 (15.14)	55.30 (16.95)	64.77 (14.94)
Spine excursion [degrees] Mean (SD)	56.46 (16.39)*		90.65 (28.18)*	
Normalized COM anterior-posterior excursion [%] Mean (SD)	6.99 (1.38)*		8.22 (1.08)*	
Normalized COM vertical excursion [%] Mean (SD)	24.03 (2.73)*		20.93 (1.92)*	
Normalized COM lateral excursion [%] Mean (SD)	1.10 (0.34)		0.95 (0.32)	

Abbreviations: SD, Standard deviation; Dom, Dominant; Non-Dom, Non-dominant; COM, center of mass.
* $p < 0.05$.

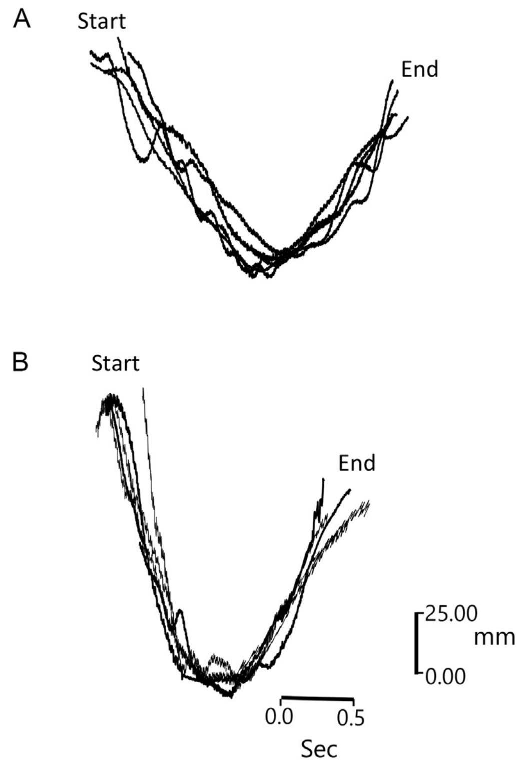

Fig. 1. Kinetic anterior/posterior center of pressure traces of a representative child in the control group (A) and the paired child in the overweight and obese group (B) during the box pickup task. Five traces of each child represent the five trials.

variables: the average speed of shifting the center of pressure forward, the average speed of shifting the center of pressure backward, and the time when center of pressure was shifted anteriorly. Table 4 indicates the group findings for these anterior/posterior center of pressure measurements. For the average speed of shifting the center of pressure forward, the overweight and obese group significantly shifted center of pressure anteriorly faster than the control group ($p = 0.01$). The overweight and obese groups also kept their center of pressure shifted anteriorly for a longer time ($p = 0.001$). No difference was found between the two groups for the average speed of shifting the center of pressure backward ($p = 0.95$). For the normalized excursion of center of pressure anterior/posterior, the overweight and obese group showed greater anterior center of pressure movement ($p = 0.017$). When compared the vertical reaction force between the two force plates, there was no significant difference between the two groups ($p = 0.88$, the average normalized vertical reaction forces differences between the two force plates: Overweight and obese group: 8.7%; Control group: 8.8%).

Table 4
Center of Pressure.

Group	Control	Overweight and obese
Normalized COP Anterior/posterior Excursion [%] Mean (SD)	7.02 (1.35)*	8.51 (1.46)*
Speed of COP Move Anterior [cm/s] Mean (SD)	12.22 (3.52)*	16.69 (4.31)*
COP Kept Anteriorly Time [S] Mean (SD)	0.008 (0.02)*	0.26 (0.07)*
Speed of COP Move Posterior [cm/s] Mean (SD)	13.29 (6.26)	13.15 (6.95)

Abbreviations: SD, Standard deviation; COP, center of pressure.
* $p < 0.05$.

3. Discussion

The primary purpose of the study was to evaluate whole body movement and center of pressure organization in overweight and obese children during a functional dual constraint task. Overweight and obese children were able to perform the task symmetrically (no differences between dominant and non-dominant side) with similar movement time as normal weight children. However, during the current task, overweight and obese children decreased knee flexion and increase spine flexion to pick up the box, thus their center of mass shifted more anteriorly and stayed higher relative to the ground. In contrast, the control group did not shift their center of mass forward as much and kept it lower. The current center of pressure data also showed that overweight and obese children moved their center of pressure more anteriorly faster and did not shift their center of pressure posteriorly immediately after grasping the box.

Previous studies suggest that the dual task condition was more challenging for the overweight and obese group than the normal weight group [19,20]. During a box carrying task (dual task condition), the overweight and obese children decreased their movement velocity even more than their simple walking condition [20]. The findings suggested that decreasing velocity could help compensate for increased attentional demands required for completing activities with dual task constraints. However, in the current study, overweight and obese children were able to maintain movement times that were similar to the normal weight group. This may have been due to the differences between standing and walking; the current task requires standing and may be less demanding than walking (e.g., alternating single and double limb support).

Overweight and obese children increased spine flexion and decreased knee flexion during our task compared to normal weight children. This movement control strategy may cause more stress on the back. In addition, decreased knee flexion results in a higher center of mass (less center of mass vertical excursion), which can decrease posture stability. In contrast, normal weight children showed a lower center of mass (greater center of mass vertical excursion) and thus increased posture stability. These findings are consistent with studies on chronic lower back pain in adults with obesity [23]. During a sit-to-stand task, they increase curving of the spine to decrease knee joint torque, especially when fatigued [23]. Such a decrease in the center of mass vertical excursion can lower the required work for a change in potential energy. Potential energy is positively related to the mass of an object and a change in the height of center of mass. Because overweight and obese children have greater mass, to decrease the required work (to save energy), they may choose to limit the change in the height of their center of mass.

Overweight and obese children also showed poor center of pressure control. Overweight and obese children shifted their center of pressure forward quickly with higher speed, greater excursion of anterior shifting, and remained shifted anteriorly for a longer period of time. Greater and faster center of pressure displacement was also found in obese children in their standing posture control [24]. Greater and faster center of pressure anterior movement could disturb the balance significantly, particularly for those who are overweight or obese. Difficulty controlling the center of pressure may require specific training to minimize increased fall risks.

One could argue about the accuracy of the current kinematic analyses for obese children due to skin motion artifacts from their excess body tissue. Strutzenberger et al. [16] evaluated skin movement artifacts in obese children during stair walking using the same equipment setting and found no significant difference from normal weight children. Hence, it may be assumed that the current findings in biomechanical measures are not caused by the inaccuracy of the measurement technique. Similar biomechanical measures were also reported in many other studies for overweight and obese individuals on various tasks (e.g. [9,16,20,25]).

Conflict of interest

There are no conflicts of interest.

Clinical implications

The current study indicates that overweight and obese children have less stable whole body movement control than normal weight children. Thus, it is important to be aware of movement control difficulties in this population during everyday movements for safety and training. Future studies could evaluate the effects of training movement control for overweight and obese children to reduce safety risks.

Disclosures

The authors have no commercial associations that might be a conflict of interest in relation to this article.

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