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Influence of Dual-Task Constraints on Whole-Body Organization During Walking in Children Who Are Overweight and Obese

ABSTRACT

Hung Y-C, Gill SV, Meredith GS: Influence of dual-task constraints on whole-body organization during walking in children who are overweight and obese. Am J Phys Med Rehabil 2013;92:461–471.

Objective: The aim of this study was to examine the influence of dual-task constraints on movement and force control in children who are overweight and obese.

Design: Twelve children who are overweight and obese (4–12 yrs old) and 12 age-matched children with normal weight participated. The children walked along a path at a self-selected pace under two conditions: walking carrying nothing (baseline condition) and walking while carrying a box (dual-task condition).

Results: The overweight/obese group showed less normalized hand vertical motion and shoulder range of motion compared with the control group (all P's < 0.05). However, in comparison with the baseline condition, the overweight/obese group decreased gait velocity and stride length and increased step width, lateral hand movement, lateral spine movement, and medial/lateral ground reaction force during the dual-task condition (all P's < 0.05).

Conclusions: These findings indicate that children who are overweight and obese modify lateral movements and force organization when faced with dual-task constraints, which may influence their ability to maintain safety when dual tasking is required.

Key Words: Obesity, Children, Gait, Force Control

CME Objectives:

Upon completion of this article, the reader should be able to: (1) describe general gait and postural control differences between overweight / obese children and normal-weight children, (2) understand the challenge that dual-task constraints pose for functional movement, and (3) discuss the potential impact of dual-task constraints on overweight and obese children.

Level: Advanced

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The prevalence of childhood obesity is growing, with 10% of 2- to 5-yr-olds, 20% of 6- to 11-yr-olds, and 18% of 12- to 19-yr-olds in the United States classified as obese.[1] These high rates of obesity have prompted an examination of obesity-related risks. Children who are obese are more likely to sustain lower extremity injuries such as fractures and sprains compared with children who are not obese.[2] For example, differences in walking, postural control, and gross motor skills in children who are overweight and obese may be behind the slight increase in falls and injuries in this population.[3–7]

During overground walking, individuals who are overweight and obese 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 with their counterparts with normal weight; these characteristics of walking are true for both children[8–10] and adults.[11–13] Gait patterns of children who overweight and obese are also different from those of children with normal weight during functional gross motor tasks; they decrease velocity when walking on a line[10] and land heel-first when crossing obstacles.[3] Postural control is also compromised in children with obesity. Differences in gait and gross motor skills contribute to poor balance and postural control for children who are overweight and obese.[10] Compared with children with normal weight, children who are overweight and obese also demonstrate poorer dynamic and static postural stability with increased sway[9] especially without visual input[12,13] when performing dynamic tasks (such as sit to stand).[13]

Many daily activities performed by children not only involve the use of walking, postural, and gross motor skills but also require the ability to perform more than one task at a time (i.e., dual tasking) such as walking while carrying objects. Movements that require dual-task constraints are more challenging and may therefore increase safety risks.[14–16] For example, adults with obesity have been found to decrease postural control and increase reaction time while performing activities with dual-task constraints.[16] Although differences in gait and postural control in children with obesity have been interpreted as a way to compensate for instability,[11] these changes, although intending to improve balance, may actually jeopardize the ability to recover when a loss of balance occurs in individuals with obesity.[17] Despite the challenges that dual-task constraints pose on many everyday tasks, it is unknown how such constraints would affect movement organization and gait in children who are overweight and obese.

Differences in walking and postural control between children with obesity and children with normal weight suggest that children with obesity need more than weight loss interventions. Children's motor skills are related to health outcomes.[18] Motor skill abilities have been shown to predict children's physical competence,[19] body mass index (BMI) scores,[20] and amount of physical activity.[21] Motor skill training can be used in conjunction with weight loss interventions to improve children's ability to safely participate in the amount and the intensity of physical activity needed to lose weight.[22] Therefore, there is a need to examine the impairments in motor skills for children who are obese to support the best practice in creating interventions that incorporate motor skills training. Identifying deficits in motor skills for children with obesity can help work toward conducting randomized controlled trials to systematically test the effects of motor skills training used in conjunction with traditional obesity interventions.

Although previous studies have documented impairments in walking, postural control, and gross motor skills in children who are obese, the authors have limited information about their ability to perform functional tasks with dual-task requirements. This study is unique because it provides kinematic and kinetic analyses while children perform a movement with dual-task requirements related to their everyday movements: walking while carrying a box. In the present study, the authors investigated how weight classification affects whole-body control during walking (baseline condition) and walking while holding a box (dual-task condition). Specifically, three factors related to changes in motor skills were examined in children who are obese and overweight: gait, upper body motion, and force control during walking. It was hypothesized that, compared with the controls with normal weight, during the dual-task condition, the children who are overweight and obese would (1) modify their gait patterns by decreasing velocity, stride length, and step width to accommodate the dual-task constraints, (2) alter ground reaction forces to reflect these changes in gait and postural demands, and (3) demonstrate different upper extremity and trunk control than the children with normal weight because of higher task demands under the dual-task condition.

METHODS

Participants

Twenty-four children between 4 and 12 yrs old participated in this study. Twelve had BMI scores that were classified as overweight or obese, and 12 age-matched children had BMI scores in the reference range. Overweight and obese classifications were based on a comparison between BMI and the Centers for Disease Control and Prevention weight-for-recumbent length growth charts.[23] The children who were between the 85th and the 95th percentile were classified as being overweight, those who were higher than the 95th percentile were deemed to be obese, and those between the 5th and the 85th percentile were considered to have normal weight. The inclusion criteria for participation included (1) normal cognitive abilities (mainstreamed in school) and (2) no known physical disabilities or conditions that precluded independent walking. Descriptive information for each child 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.

Procedure and Experimental Setup

The children walked along a flat 406-cm–long path under two conditions at a self-selected pace: walking while carrying nothing (baseline condition) and walking while carrying an empty plastic box (length, 45 cm; width, 29 cm; height, 17 cm) with two hands (dual-task condition). During the dual-task condition, the children were instructed to carry the box steadily with their elbows flexed at right angles without touching the body. The experimenter completed one demonstration trial to ensure that the participants understood the task. Three practice trials were given before the five collected trials to familiarize the participants with the task. The baseline condition was performed before the dual-task condition to avoid possible residual effects from walking with the box. If a trial was not collected successfully (e.g., the box touched the body), the participant was asked to perform the trial again. The participants walked for a total of ten trials: five trials in each condition. Each trial began with an auditory go signal and ended when the children reached a line taped to the floor at the end of the path.

Kinetics and kinematics were collected during the trials. Two AMTI OR6-6 force platforms (each 46 × 50 cm) embedded in the floor in the middle of the walking path collected foot ground reaction forces in the anterior/posterior, medial/lateral, and vertical directions. 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 (radial and ulnar styloid processes), the hands (index metacarpophalangeal 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.

Analyses

For kinematic analyses, the gait cycle was defined from heel strike to heel strike of the same foot and began with the foot strike on the first force plate. The dependent variables for gait parameters were stride length, step width, velocity, and the percentage of the stance phase during the gait cycle for each trial. The values were averaged and compared between the groups. For upper extremity movement, the authors measured the difference in vertical position (z) between the two hands to assess whether the box was carried with the top level and the amount of vertical (z) and lateral (y) hand range of motion to assess the steadiness of the box. Both elbow and shoulder joint excursions in the sagittal plane were measured.

TABLE 1 Participant characteristics

Group	Age, Mean (SD)	Sex	Height, Mean (SD), cm	Weight, Mean (SD), kg	Leg Length, Mean (SD), cm	BMI, Mean (SD), kg/m^2	Min and Max Percentiles, %
Control	8 yrs 7 mos (3)	F (*n* = 6) M (*n* = 6)	140 (20.7)	33 (13.1)	71 (13.7)	17 (2.1)	Min = 5th Max = 84th
Overweight/obese	8 yrs 9 mos (3)	F (*n* = 5) M (*n* = 7)	138 (18.6)	43 (17.9)	72 (12.2)	22 (4.7)	Min = 85th Max = 95th

F indicates female; M, male; Max, maximum; Min, minimum.

Trunk control was assessed via measurements of movement at C7: flexion and range of motion of the lateral (y) and vertical (z) movements of C7. Vertical (z) movement was indicative of spine rotation. The peak anterior/posterior, medial/lateral, and vertical ground reaction forces at the terminal stance phase were evaluated to measure force control of the foot in both conditions. The peak vertical and anterior/posterior ground reaction forces at the terminal stance phase were used to measure the generation of propulsion at push-off. The peak medial/lateral ground reaction force provided information on how body weight was distributed on the contralateral leg. To account for anthropometric differences among the children because of the large age range, stride length, step width, velocity, hand range of motion, and C7 movement were normalized to the children's height, and the peak ground reaction forces were normalized to their weight.

Repeated-measures analyses of variance with one between factor (two groups) and one within factor (two tasks) were performed on all gait, force control, and trunk control parameters. Repeated-measures analyses of variance were done on upper extremity measures during the dual-task condition, with one group factor. Post hoc comparisons were carried out using the Tukey procedure. Statistical significance was set at $P < 0.05$.

RESULTS

Gait Parameters

Table 2 shows the average normalized walking velocity for the two groups under the baseline and dual-task conditions. The overweight and obese group walked with a slower velocity than did the group with normal weight and walked even more slowly when walking with a box (group, $F_{1,22} = 5.19$, $\eta^2 = 0.19$, $P = 0.03$; group × task, $F_{1,22} = 6.93$, $\eta^2 = 0.24$, $P = 0.015$). The post hoc comparisons showed that the overweight and obese group significantly decreased their velocity during the dual-task condition, whereas the group with normal weight maintained their velocity between the two conditions. The overweight and obese group increased their normalized step width under the dual-task condition compared with the baseline walking condition, whereas the control group maintained similar step width (Table 2; group × task, $F_{1,22} = 5.24$, $\eta^2 = 0.19$, $P = 0.034$). The overweight and obese group had shorter normalized stride lengths than did the control group and decreased their normalized stride lengths under the dual-task condition compared with the baseline walking condition (group, $F_{1,22} = 5.09$, $\eta^2 = 0.19$, $P = 0.03$; group × task, $F_{1,22} = 5.70$, $\eta^2 = 0.21$, $P = 0.026$). No differences were found between the groups and the tasks for the percentage of the stance phase (group, $F_{1,22} = 2.25$, $\eta^2 = 0.10$, $P = 0.15$; task, $F_{1,22} = 0.002$, $\eta^2 = 0.001$, $P = 0.96$).

Upper Extremity Movement Control

The average dominant and nondominant hand normalized vertical and lateral range of motion during the dual-task condition for the two groups is shown in Table 3. The overweight and obese group had significantly less normalized vertical hand motion than did the group with normal weight for both hands (dominant hand, $F_{1,11} = 12.15$, $\eta^2 = 0.53$, $P = 0.005$; nondominant hand, $F_{1,11} = 7.46$, $\eta^2 = 0.40$, $P = 0.02$). The normalized vertical position differences between the two hands were not significantly different between the two groups (group, $F_{1,11} = 2.20$, $\eta^2 = 0.17$, $P = 0.17$). The overweight and obese group had significantly greater normalized lateral hand range of motion than did the group with normal weight for both hands (dominant hand,

TABLE 2 Gait parameters

	Control Group		Overweight and Obese Group	
	Baseline Condition	Dual-Task Condition	Baseline Condition	Dual-Task Condition
Normalized velocity (1/sec), mean (SD)	0.90 (0.12)[a]	0.92 (0.10)[a]	0.84 (0.12)[a,b]	0.78 (0.10)[a,b]
Normalized step width, mean (SD), cm/cm	0.08 (0.03)	0.08 (0.03)	0.09 (0.02)[b]	0.10 (0.03)[b]
Normalized stride length, mean (SD), cm/cm	0.88 (0.08)[a]	0.88 (0.07)[a]	0.84 (0.07)[a,b]	0.79 (0.08)[a,b]
% Stance phase (% gait cycle), mean (SD)	52.7 (6.8)	53.1 (5.6)	55.4 (5.6)	54.5 (5.0)

[a] $P < 0.05$, the overweight and obese group compared with the control group.
[b] $P < 0.05$, the baseline condition compared with the dual-task condition.

$F_{1,11} = 21.50$, $\eta^2 = 0.66$, $P = 0.001$; nondominant hand, $F_{1,11} = 15.42$, $\eta^2 = 0.58$, $P = 0.002$). The average dominant and nondominant elbow flexion/extension and shoulder flexion/extension joint excursion during the dual-task constraint is also shown in Table 3. The overweight and obese group had significantly smaller joint excursion of the dominant and nondominant shoulder joint than did the control group (Table 3; dominant side, group, $F_{1,11} = 5.67$, $\eta^2 = 0.036$, $P = 0.34$; nondominant side, group, $F_{1,11} = 5.28$, $\eta^2 = 0.35$, $P = 0.044$). There was no significant difference between the two groups in elbow joint excursion (dominant elbow, group, $F_{1,11} = 1.91$, $\eta^2 = 0.16$, $P = 0.20$; nondominant elbow, group, $F_{1,11} = 3.43$, $\eta^2 = 0.24$, $P = 0.09$).

Trunk Movement Control

Normalized C7 and spine motion are shown in Table 4. The overweight and obese group showed significantly larger normalized lateral C7 motion than did the control group and even greater lateral motion when holding the box (group, $F_{1,22} = 6.87$, $\eta^2 = 0.24$, $P = 0.016$; task $\times$ group, $F_{1,22} = 4.88$, $\eta^2 = 0.18$, $P = 0.038$). For spine movement, spine rotation significantly increased from the baseline to the dual-task condition for the overweight and obese group, whereas the control group showed no difference in spine rotation between the tasks (group $\times$ task, $F_{1,22} = 4.86$, $\eta^2 = 0.18$, $P = 0.038$).

Force Control

Table 4 also indicates the maximum normalized peak foot ground reaction force in the vertical, medial/lateral, and anterior/posterior directions at the terminal stance phase for both groups in both conditions. The overweight and obese group had significantly smaller normalized peak anterior/posterior force than did the control group (group, $F_{1,22} = 4.38$, $\eta^2 = 0.17$, $P = 0.048$). There was no significant finding for peak normalized foot vertical force. For normalized peak foot medial/lateral force, the overweight and obese group increased normalized medial/lateral force during the dual-task condition, whereas the control group maintained similar medial/lateral force (group, $F_{2,21} = 86.83$, $\eta^2 = 0.81$, $P = 0.001$; task, $F_{2,21} = 9.54$, $\eta^2 = 0.31$, $P = 0.006$; group $\times$ task, $F_{1,21} = 10.43$, $\eta^2 = 0.33$, $P = 0.004$).

DISCUSSION

The primary purpose of this study was to evaluate the effects of dual-task constraints on gait, upper extremity and trunk, and force control in children who are overweight and obese. Performing a task with dual-task constraints affected the children who are overweight and obese. Under the dual-task condition, the children who are overweight and obese decreased walking velocity, stride length, box vertical motion, and shoulder joint excursion but increased the box's lateral motion, body trunk rotation, lateral C7 motion, and medial/lateral normalized peak ground reaction foot force at the terminal stance phase. In contrast, the dual-task constraints did not change the performance of the control group.

The findings of this study suggest that the dual-task condition was more challenging for the overweight and obese group but not for the group with normal weight. First, this study's baseline results support previous findings on differences in gait in children who are overweight and obese. At baseline, the children who are overweight and obese had slower velocities and shorter stride lengths compared with the children with normal weight, which can serve to

TABLE 3 Upper extremity movement control

	Control Group		Overweight and Obese Group	
	Dom	Nondom	Dom	Nondom
Normalized vertical hand ROM, mean (SD), cm/cm	0.052 (0.015)	0.052 (0.009)	0.046 (0.013)[a]	0.047 (0.010)[a]
Normalized lateral hand ROM, mean (SD), cm/cm	0.072 (0.021)	0.069 (0.020)	0.114 (0.036)[a]	0.104 (0.033)[a]
Normalized vertical hand difference, mean (SD), cm/cm	0.030 (0.012)		0.026 (0.010)	
Elbow excursion, mean (SD), degrees	5.58 (2.50)	5.85 (2.89)	4.04 (1.73)	4.54 (2.29)
Shoulder excursion, mean (SD), degrees	9.75 (3.97)	9.38 (3.51)	6.65 (1.80)[a]	6.62 (1.30)[a]

[a] $P < 0.05$, the overweight and obese group compared with the control group.

Dom indicates dominant hand; Nondom, nondominant hand; ROM, range of motion.

TABLE 4 Trunk and force control

	Control Group		Overweight and Obese Group	
	Baseline Condition	Dual-Task Condition	Baseline Condition	Dual-Task Condition
Normalized C7 y motion, mean (SD), cm/cm	0.09 (0.02)	0.09 (0.03)[a]	0.09 (0.02)[b]	0.12 (0.03)[a,b]
Spine rotation, mean (SD), degrees	15.09 (6.48)	16.70 (5.24)	13.05 (4.16)[b]	19.01 (5.48)[b]
Normalized peak vertical GRF, mean (SD), N/kg	12.55 (2.35)	12.79 (2.20)	11.77 (1.30)	12.69 (2.12)
Normalized peak medial/lateral GRF, mean (SD), N/kg	0.83 (0.28)	0.89 (0.19)[a]	0.83 (0.19)[b]	0.97 (0.22)[a,b]
Normalized peak anterior/posterior GRF, mean (SD), N/kg	2.61 (0.81)[a]	2.49 (0.55)[a]	2.07 (0.36)[a]	2.14 (0.34)[a]

[a] $P < 0.05$, the overweight and obese group compared with the control group.
[b] $P < 0.05$, the baseline condition compared with the dual-task condition.
GRF indicates ground reaction force.

increase balance control and stability.[8–11] Slower preferred walking speeds have also been purported to minimize energy cost per distance during walking for individuals with obesity.[12] During the dual-task condition, the overweight and obese group further decreased their velocity and stride lengths in comparison with the baseline condition. This may be caused by the increased attentional demands required to achieve the goal (i.e., to carry the box level and away from the body with elbows flexed) and to maintain postural control at the same time. Walking more slowly with shorter stride lengths could help compensate for a decreased ability to perform multiple tasks at once successfully and safely.[14,15] Second, the children who are overweight and obese increased their step width under the dual-task condition, whereas the control group did not. Individuals who are obese and overweight tend to increase their step width, which could serve to increase stability and postural control during walking.[12,24–27] However, a wider step width may increase their metabolic rate.[12] Third, the children who are overweight and obese limited their range of motion during the dual-task condition. In limiting their range of motion, they were freezing their degrees of freedom: holding some joints rigid while performing a skill.[28] Freezing degrees of freedom has been associated with early skill acquisition during motor learning because of increased task difficulty.[28] These findings warrant creating rehabilitative techniques focused on decreasing the challenge of performing multiple tasks at once for the overweight and obese population, namely, creating targeted motor skills training to use in conjuction with obesity interventions.

The results of this study showed that the children who are overweight and obese increased lateral hand and trunk movements and increased medial/lateral peak ground reaction force during the dual-task condition. Children who are overweight and obese tend to increase their lateral movements during walking.[9] A larger peak medial/lateral ground reaction force has been thought to contribute to the wider step width related to obesity.[29] Presumably, both increasing step width and lateral movements could serve to increase postural control and decrease the risk for falling. However, previous work shows that increasing lateral movements during walking actually increases the risk for falling; adults with obesity demonstrate higher transversal (lateral) frictional force compared with their lean counterparts, which increases their fall risks in the transverse (lateral) direction.[29] Therefore, modifying postural control by increasing lateral movements may have deleterious effects for maintaining safety. More research needs to be done to investigate whether larger samples of children who are overweight and obese consistently increase lateral movements when attempting to meet dual-task constraints.

Clinical Implications

The current study suggests a need to improve the ability of children who are overweight and obese to perform everyday movements requiring dual-task constraints successfully and safely. Health professionals can create training that targets motor skills of children with obesity to be used in collaboration with current obesity interventions. Supporting improvements in motor skills with specific training may help to increase the motivation and the ability of children with obesity to safely participate in obesity interventions.

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1. In this study, which of the following dual-task constraints was used to evaluate overweight or obese children during walking?
   A. Walking while listening to music
   B. Walking with eyes closed
   C. Walking while carrying a box
   D. Walking while counting numbers

2. In general when compared to normal weight counterparts overweight and obese children have all of the following differences in gait pattern except:
   A. Longer step length
   B. Wider step width
   C. Slower velocity
   D. Shorter swing time

3. In this study, which gait parameter was not affected by dual-task constraints for overweight and obese children?
   A. Velocity
   B. Step width
   C. Stride length
   D. Stance time

4. In this study the overweight and obese group demonstrated increased peak normalized foot force increase under the impact of dual-task constraints in which direction?
   A. Medial/lateral force
   B. Vertical force
   C. Anterior/posterior force
   D. Friction force

5. In this study, there were significant differences in upper extremity control between overweight and obese children when compared to normal weight counterparts in all of the following except:
   A. Normalized vertical hand range of motion
   B. Normalized lateral hand range of motion
   C. Elbow excursion
   D. Shoulder excursion

(Continued next page)

The answers to any essay questions must be typed or computer printed on a separate piece of paper and attached to this page.

After finishing this exam:

1. Check your answers with the correct answers on page 522.
2. Photocopy and complete the CME Evaluation and Certification on the next page and mail to CME Department, AAP National Office, 7250 Parkway Drive, Suite 130, Hanover, MD 21076.
3. This educational activity must be completed and postmarked by December 31, 2014. AAP Members may complete and submit this CME Answering Sheet and the following Standardized CME Activity Evaluation page and Certification page online through the membersonly section of the AAP web page at www.physiatry.org.

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Circle the appropriate answers.

1. A B C D
2. A B C D
3. A B C D
4. A B C D
5. A B C D

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	Agree	Neutral	Disagree	Not Applicable
The CME activity was consistent with the stated objectives.	☐	☐	☐	☐
The activity prepared me to achieve its stated objectives	☐	☐	☐	☐
The activity enhanced my professional skills.	☐	☐	☐	☐
The activity confirmed the effectiveness of previous skills.	☐	☐	☐	☐
I learned new techniques or skills.	☐	☐	☐	☐
I learned new diagnostic strategies.	☐	☐	☐	☐
The activity was free of industry bias.	☐	☐	☐	☐
I acquired new skills and competencies not listed above– *please list here:*	☐	☐	☐	☐

These new skills will improve my work performance and professional competencies in the following areas:

(Check all that apply):

- ☐ Provision of patient care
- ☐ Communication with patients and families
- ☐ Teaching and educational tasks
- ☐ Administrative duties
- ☐ Research endeavors
- ☐ Team and co-worker interactions
- ☐ Medical knowledge
- ☐ Practice-Based learning and improvement
- ☐ Interpersonal and communication skills
- ☐ Professionalism
- ☐ Systems-based practice
- ☐ Other please list here:

Please provide additional comments about the Activity and make any suggestions for improvement:

Please list any topics you would like to see presented in the future:

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I, ______________________________ certify that I have met the criteria for CME credit by studying the designated materials, by responding to the self-assessment questions, by reviewing those parts of the article dealing with any question(s) answered incorrectly, and by referring to the supplemental materials listed in the references.

This educational activity is designated for 1½ category 1 CME credits.

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