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Effects of overweight and obese body mass on motor planning and motor skills during obstacle crossing in children

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ABSTRACT

Little is known about how obesity relates to motor planning and skills during functional tasks. We collected 3-D kinematics and kinetics as normal weight ($n = 10$) and overweight/obese ($n = 12$) children walked on flat ground and as they crossed low, medium, and high obstacles. We investigated if motor planning and motor skill impairments were evident during obstacle crossing. Baseline conditions showed no group differences (all $ps > .05$). Increased toe clearance was found on low obstacles ($p = .01$) for the overweight/obese group and on high obstacles ($p = .01$) for the normal weight group. With the crossing leg, the overweight/obese group had larger hip abduction angles ($p = .01$) and medial ground reaction forces ($p = .006$) on high obstacles and high anterior ground reaction forces on low obstacles ($p = .001$). With the trailing leg, overweight/obese children had higher vertical ground reaction forces on high obstacles ($p = .005$) and higher knee angles ($p = .01$) and anterior acceleration in the center of mass ($p = .01$) on low obstacles. These findings suggest that differences in motor planning and skills in overweight/obese children may be more apparent during functional activities.

1. Introduction

Obesity, now classified as a disease by the American Medical Association (AMA, 2013), is at 16% for children in the United States (Ogden, Carroll, Kit, & Flegal, 2012) and has led to a call for increased physical activity for children. Current recommendations are for children to participate in a minimum of 60 min of daily physical activity (DHHS, 2008). Unfortunately, these recommendations are not being met (Hills, Andersen, & Byrne, 2011) and are instead concurrent with increases in sedentary activities (Vandewater, Shim, & Caplovitz, 2004).

Differences in motor planning and motor skills may thwart efforts to increase physical activity for children who are overweight and obese. There is evidence that obesity has a negative impact on the cognitive processing needed to adequately plan movements. Obese children and adolescents perform worse on tasks of visuospatial organization, global executive functioning, and tasks of executive function involving planning and mental flexibility (Boeka & Lokken, 2008). A diversity of activities has been shown to improve executive functioning needed for motor planning (Diamond & Lee, 2011), however children who are overweight and obese engage in limited physical activity thereby increasing chances for poor motor planning. Impairments in these components of cognitive processing weaken the ability to plan movements leading to poor

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motor planning and decreased motor performance on tasks (Wolpert & Miall, 1996). For example, when walking on flat ground, adolescents with obese body mass index (BMI) scores demonstrate poor motor planning via slower velocities in their center of mass during gait initiation: the phase between standing still and steady-state walking (Colne, Frelut, Peres, & Thoumie, 2008). Children who are overweight and obese have higher rates of falls compared to normal-weight children (Bazelmans et al., 2004). Difficulty with motor planning can increase their predisposition to falls and injuries. Although research suggests that there is a relationship between obesity and motor planning difficulties, few studies have examined how motor planning affects motor skills and motor performance in this population.

In addition to motor planning, motor skills are affected by obesity, particularly skills related to walking (Gill, 2011; Shultz, Browning, Schutz, Maffeis, & Hills, 2011). In comparison to their normal-weight counterparts, overweight and obese children walk more slowly, take shorter steps, spend less time supporting their weight with one leg, walk with their feet farther apart, and keep both feet on the ground for longer periods of time (Deforche et al., 2009; McGraw, McClenaghan, Williams, Dickerson, & Ward, 2000; Wearing, Hennig, Byrne, Steele, & Hills, 2006). They also demonstrate altered hip and knee mechanics like larger joint powers during weight acceptance (Shultz, Hills, Sitler, & Hillstrom, 2010), higher peak pressures under the feet during walking (Yan, Zhang, Tan, Yang, & Liu, 2013), and less knee flexion (i.e., straighter knees) at initial foot contact (McMillan, Phillips, Collier, & Blaise Williams, 2010). Excess weight also makes it difficult to accelerate the center of mass during walking because of the metabolic cost and the amount of mechanical work required (Peyrot et al., 2010). Common interventions for childhood obesity involve increased physical activity via walking (Wing & Phelan, 2005). However, walking characteristics of overweight and obese children may hinder efforts to encourage increased walking.

While the walking characteristics discussed above may increase stabilization in overweight and obese children to counteract poor balance (Singh, Park, Levy, & Jung, 2009), these characteristics are positively correlated with difficulty recovering balance once it has been lost leaving them susceptible to falls and injuries (Deforche et al., 2009). These walking characteristics combined with motor planning difficulties amplify the risk of injuries in overweight and obese children (Gill, 2011). Most research on differences in motor planning and motor skills in the overweight and obese population has focused on activities that have few imposed task constraints (i.e., walking over flat ground) (Wearing, Hennig, Byrne, Steele, & Hills, 2006). However, the propensity for increased injuries for overweight and obese children is most evident during functional activities, which typically involve higher task constraints (e.g., stair climbing) (D'Hondt et al., 2013; D'Hondt et al., 2011; Hung, Gill, & Meredith, 2013; Strutzenberger, Richter, Schneider, Mundermann, & Schwameder, 2011). For example, when crossing obstacles with heights similar to everyday environmental obstacles like door thresholds and steps, overweight and obese children demonstrate slower movement times and decreased stability due to landing heel-first after obstacle crossing (Gill & Hung, 2012; Hung, Gill, & Meredith, 2013). Therefore, while it is useful to know how walking differs between overweight and obese children compared to normal-weight controls, understanding walking differences with little imposed task constraints may not reveal deficits in motor planning and motor skills that correlate with fall risks. Little work has been done to investigate how the motor planning and motor skills of overweight and obese children translate into performance during activities that are more similar to everyday functional activities with higher task constraints (Gill & Hung, 2012; Strutzenberger, Richter, Schneider, Mundermann, & Schwameder, 2011).

The purpose of the present study was to examine whether body mass index would influence the ability of 4- to 13-year olds to plan and coordinate their movements to cross obstacles of various heights. Our aims were: (1) to examine whether a task beyond flat ground walking would be more sensitive to problems with motor planning and motor skills in children with overweight and obese BMI scores and (2) to investigate if difficulty with motor skills would influence lower extremity movements and the acceleration of the center of mass during obstacle crossing. For children with overweight and obese BMI scores, we predicted that obstacle crossing will better detect differences in motor planning and motor skills and that both lower extremity movements and the acceleration of the center of mass will be affected during obstacle crossing.

2. Methods

2.1. Participants

Twenty-two children (9 girls, 13 boys, M age = 8.62; SD = 0.93) who were volunteers from a children's summer camp participated. Inclusion criteria consisted of having normal cognitive abilities, no known physical conditions that would preclude independent walking, and being between 4 and 13 years old. These criteria were confirmed via parent reports and experimenters' observations. BMI classification was based on BMI and on weight-for-recumbent length growth charts from the Centers for Disease Control and Prevention (Kuczmarski, 2000). BMI classifications were as follows: normal weight (between the 5th and 85th percentile), overweight (at or above the 85th percentile and below the 95th percentile), and obese (at or above the 95th percentile). Based on this, children were divided into two groups: 10 normal weight (M BMI = 15.85; SD = 0.68, *Minimum* = 5th, *Maximum* = 84th) and 12 overweight/obese (M BMI = 21.85; SD = 0.50, *Minimum* = 85th, *Maximum* = 95th).

2.2. Procedure and experimental setup

Following an auditory go signal, children crossed obstacles at a self-selected pace on a 4.06-m-long path with two AMTI OR6-6 force platforms (each 46 cm × 50 cm) located in the center of the path. There were five conditions: initial baseline, low