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The role of Body Mass Index in child pedestrian injury risk

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ABSTRACT

The goal of the current investigation was to examine obesity as a potential risk factor for childhood pedestrian injury. A racially diverse sample of 7- and 8-year-old children completed a road-crossing task in a semi-immersive virtual environment and two pedestrian route selection tasks. Multiple linear regression analyses revealed that children with a higher Body Mass Index (BMI) waited less before crossing, had a smaller temporal buffer between themselves and oncoming traffic while crossing, and had more collisions with traffic. Girls were more cautious than boys when crossing the virtual roadway. Unlike the results from the virtual road-crossing task, BMI was not associated with risky route selection. Instead, race emerged as the strongest predictor, with African–American children selecting riskier routes for crossing. Together, these findings suggest overweight and obese children may be at increased risk for pedestrian injury. The discussion considers explanations for why obese children may exhibit riskier road-crossing behavior.

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1. Introduction

Pedestrian injury ranks as the 9th leading cause of death and 14th leading cause of disability in children aged 6–11 years (National Center for Injury Prevention and Control [NCIPC], 2013). Reports estimate that deaths resulting from pedestrian-motor vehicle crashes cost 1.52 million dollars annually in medical care alone for children in this age range (NCIPC, 2013).

Previous work identifies a number of factors that increase risk for childhood pedestrian injuries. One risk factor is age, with child pedestrians between the ages of 6 and 8 years experiencing 1.5 times more motor vehicle crash-related deaths than pedestrians between the ages of 9 and 11 years (NCIPC, 2013). Another risk factor for pedestrian injuries is gender. Boys experience almost double the number of pedestrian injuries than girls, with nearly 7000 non-fatal injuries reported among males aged 6–11 in 2013 (NCIPC, 2013). Location is yet another risk factor, with mid-block crossings having the highest incidence of pedestrian injury in children aged 5–9 years (Agran et al., 1994; DiMaggio and Durkin, 2002).

Another potential risk factor for child pedestrian injuries is obesity. Rates of pediatric obesity have doubled over the past 30 years (Ogden et al., 2014), and childhood obesity is associated with various health risks including high blood pressure, high cholesterol levels, diabetes, and joint problems (Freedman et al., 2007; Taylor et al., 2006). However, the role of obesity in childhood pedestrian injury risk is not well understood.

1.1. Crossing roads safely

Crossing roads safely involves two essential components: (1) choosing a gap that affords safe crossing, and (2) successfully timing movement through the gap. A gap affords crossing if the time available for crossing (i.e., the temporal size of the gap) is greater than the time needed to cross through the gap (Lee et al., 1984). Choosing an appropriate gap for crossing requires accurately judging time to arrival (i.e., when the lead and tail vehicles will reach the crossing point), as well as accurately estimating the time needed to cross the road. To successfully time movement through a narrow gap, individuals must cut in closely behind the lead vehicle in the gap while crossing before the tail vehicle reaches the crossing point. Given the dynamic nature of traffic, gap decisions and crossing movements must be tightly coordinated (Plumert and Kearney, 2014). A gap will no longer afford crossing if the child waits too long before moving. Previous work indicates that both child pedestrians and cyclists often delay initiation of crossing, resulting in close calls with approaching traffic (Barton and Schwebel, 2007a; O'Neal et al., 2015; Plumert et al., 2004; Plumert and Kearney, 2014).

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Along with decisions about which gap to cross and when to start moving, children must also decide where to cross the roadway. Like gap affordances, judging route affordances requires that pedestrians evaluate the tradeoff between timely arrival at their destination and safe places to cross roads, while simultaneously considering their own road-crossing skill. Crossing diagonal to the roadway usually results in less time to reach the final destination, but also increases exposure to traffic and the possibility for a collision, whereas crossing perpendicular to the roadway reduces exposure to traffic, thereby decreasing the likelihood of a motor vehicle collision. Compared to children aged 6–11 years, adults most often chose to cross roadways using direct, perpendicular routes and marked crosswalks when presented with road-crossing scenarios on a computer screen (Tabibi and Pfeffer, 2003, 2007). Other studies have shown that young children often select routes that maximize exposure to traffic by crossing roads diagonally and not crossing at marked crosswalks (Barton and Schwebel, 2007b; Barton et al., 2012).

1.2. Obesity as a potential contributor to pedestrian injury

Although little is known about the link between BMI and childhood pedestrian injuries, past work has revealed a positive association between obesity and injury in children 9–17 years old (Bazelmans et al., 2004). Several studies have identified obesity as a risk factor for injuries to the lower extremities. For example, Kessler et al. (2013) examined the association between BMI and all types of fractures, sprains, strains, and dislocations, and found that fractures to the foot, ankle, leg, and knee were associated with higher BMI. Similarly, in a study of children aged 3–14 years presenting with a traumatic injury in the emergency department, Pomerantz et al. (2010) found that obese children had more injuries to the lower extremities than non-obese children. Yet another study found that in cases of motor-vehicle collisions, obese older children and adolescents displayed an increased pattern of injuries to the lower extremities (Haricharan et al., 2009; Pollack et al., 2008).

Obesity also adversely affects children's walking. A recent study of normal weight, overweight, and obese 5- to 9-year-old children found that compared to normal weight children, overweight and obese children had a larger base of support while walking, poorer explosive leg strength, and decreased balance (Pathare et al., 2013). Others have found that obese children ages 8–13 also show deficits in gait cycle, gait velocity and cadence (Hills and Parker, 1991; McGraw et al., 2000). These traits result in an increase in energy costs (Hills and Parker, 1992) and may create slower walking speeds, which are associated with riskier pedestrian situations (Langlois et al., 1997). Further, childhood obesity has been implicated in abnormal knee loading when walking (Gushue et al., 2005), which could be painful (Chan and Chen, 2009). Together, these findings indicate that obesity contributes to added stress on children's bodies when engaged in physical activities such as walking. In the context of pedestrian behavior, this added stress is likely to influence the way in which overweight and obese children choose to cross roads. Specifically, they may compromise safety in order to expedite crossing.

Beyond physical aspects of obesity that may influence pedestrian safety, obesity is associated with deficits in executive functioning, including impulsivity and disinhibition (Braet et al., 2007; Cserjési et al., 2007). Some scholars have speculated that the same executive functioning traits that are associated with attention-deficit hyperactivity disorder (ADHD), such as poor self-regulation and increased reward sensitivity, also affect how children respond to food, leading to weight gain (Davis, 2010; Holtkamp et al., 2004; Puder and Munsch, 2010). Other work has shown that lower levels of aerobic fitness, often comorbid with obesity (Ogden and Carroll, 2010), are associated with children's poorer performance in school and on measures of cognitive control such as selective attention and response inhibition (see Chaddock et al., 2011 for a review).

These executive function deficits may negatively impact road-crossing performance as well. Stavrinos et al. (2011) found that safe street crossings were less common among children diagnosed with ADHD, who also exhibited executive dysfunction, compared to children not diagnosed with ADHD. In a comparison of how 10- to 14-year-old children with and without ADHD cross roads in a bicycling simulator, Nikolas et al. (2015) found that hyperactive-impulsive symptoms uniquely predicted risky decision-making (i.e., taking smaller gaps when crossing intersections), whereas inattention symptoms uniquely predicted timing deficits (i.e., worse timing of entry and less time to spare). In a similar study, Stevens et al. (2013) found that child cyclists lower in inhibitory control had less time to spare upon exiting the lane compared to children higher in inhibitory control. Chaddock et al. (2012) found that 8- to 10-year-old children who were low in aerobic fitness had fewer successful crossings on a virtual road while distracted by cell phone use compared to children who measured higher in aerobic fitness. Together, these studies suggest that overweight and obese children may engage in risky road crossing due to deficits in executive functioning such as greater impulsivity, poorer attention, and reduced inhibitory control.

The goal of the present study was to examine associations between 7- and 8-year-old children's Body Mass Index (BMI) and pedestrian safety by measuring road crossing performance and route selection. These ages were chosen because children in this age range are at high risk for pedestrian injury (NCIPC, 2013). As part of a larger study testing the effectiveness of virtual reality as a pedestrian safety training tool (Schwebel et al., 2014), children performed a road-crossing task in a semi-immersive virtual environment and completed two pedestrian route selection tasks, one using vignettes and the other using a tabletop model. We hypothesized that children with higher BMI would perform more poorly on all measures of pedestrian behavior compared to their normal weight peers.

2. Material and methods

2.1. Participants

Two hundred and forty 7- and 8-year-old children (42% male; average age: $M = 7.97$ years, $SD = 0.64$) were recruited from community sources in the Birmingham, AL area, of which 206 were included for analysis. The sample was racially diverse, with 55% of parents reporting their children as Caucasian, 41% as African–American, and 4% as other races/ethnicities. Thirty-four children were excluded from analysis for the following reasons: discovered ineligible based on age after consenting and enrollment ($n = 3$), unable to understand and follow the study protocol ($n = 3$), failure to complete the full assessment ($n = 14$), or failure to obtain accurate BMI measurements ($n = 14$).

Body Mass Index (BMI) was calculated using Centers for Disease Control calculations (CDC, 2014). Using height, weight, gender, and age, each child's BMI percentile ($M = 70.80$%-ile, $SD = 27.45$, BMI range: <1–99.80%-ile) was calculated based on BMI-for-age growth charts for boys and girls. BMI percentiles were similar for males ($M = 73.41$%-ile, $SD = 26.32$, BMI range: 0.80–99.80%-ile) and females ($M = 68.88$%-ile, $SD = 28.20$, BMI range: <1–99.70%-ile), but there were differences in BMI percentiles across racial and ethnic groups, with lower BMI percentiles for children classified as Caucasian ($M = 63.47$%-ile, $SD = 29.19$, BMI range: <1–99.30%-ile) and "Other" ($M = 69.98$%-ile, $SD = 25.72$, BMI range: 2.60–99.80%-ile), and higher BMI percentiles for children