Systematic Review and Meta-Analysis of Behavioral Interventions to Improve Child Pedestrian Safety

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Objective Pedestrian injuries represent a pediatric public health challenge. This systematic review/meta-analysis evaluated behavioral interventions to teach children pedestrian safety. Methods Multiple strategies derived eligible manuscripts (published before April 1, 2013, randomized design, evaluated behavioral child pedestrian safety interventions). Screening 1,951 abstracts yielded 125 full-text retrievals. 25 were retained for data extraction, and 6 were later omitted due to insufficient data. In all, 19 articles reporting 25 studies were included. Risk of bias and quality of evidence were assessed. Results Behavioral interventions generally improve children’s pedestrian safety, both immediately after training and at follow-up several months later. Quality of the evidence was low to moderate. Available evidence suggested interventions targeting dash-out prevention, crossing at parked cars, and selecting safe routes across intersections were effective. Individualized/small-group training for children was the most effective training strategy based on available evidence. Conclusions Behaviorally based interventions improve children’s pedestrian safety. Efforts should continue to develop creative, cost-efficient, and effective interventions.

Key words accidents and injuries; evidence-based practice; meta-analysis; prevention/control; public health; systematic review.

Pediatric unintentional injury is a significant public health problem worldwide. In the United States, >3,000 children aged 1–14 years die annually from unintentional injuries (National Center for Injury Prevention and Control [NCIPC], 2013). Morbidity rates are also enormous, with >6 million hospital visits annually in the United States and a tremendous financial burden placed on society. For example, in 2005, the total cost of medical expenses and lost wages for U.S. children aged 1–14 years who were hospitalized following unintentional injury was >15 billion dollars (NCIPC, 2013).

The present focus is on pedestrian injury, the fifth leading cause of unintentional injury death to U.S. children aged 1–14 years (NCIPC, 2013) and an even more significant public health challenge internationally. Although pedestrian injuries comprise just 11% of road traffic fatalities in the United States (>100 pediatric fatalities annually and ~11,000 medically attended injuries; NCIPC, 2013), they account for >50% of road traffic fatalities in a range of nations, including Bangladesh (54%), Ethiopia (55%), Mozambique (68%), and Peru (78%) (World Health Organization [WHO], 2009). Also notable are the high rates of pedestrian injuries among road traffic fatalities in the world’s most populated nations (China 26%, India 13%), in high-income countries (Japan 32%, United Kingdom 21%), and in the most populated U.S. territory, Puerto Rico (32%) (WHO, 2009).

Pediatric pedestrian injuries pose a serious public health concern for at least two reasons. First, the nature of such injuries is often severe, with trauma typically to the
lower extremities and head resulting from contact with a vehicle and the road surface. Second, many communities are actively trying to increase the use of walking as a mode of transportation through efforts such as Safe Routes to School, Walking School Buses, and via transportation engineering within the concept of “complete streets.” Thus, although promotion of walking is a desirable goal that will increase overall health of a community, the safety of children must be intertwined within such efforts. Young children often lack the cognitive skills and experience necessary to negotiate pedestrian routes safely (Barton, 2006).

Efforts to reduce child pedestrian injuries are not new. In 1937, Mansfield, Ohio Traffic Commissioner Fred Boals and kindergarten teacher Ruth Robbins developed the first Safety Town program, a free community program designed to teach young children about traffic safety (http://mansfieldpolicedepartment.com/stown.html). Since then, hundreds of programs have been concocted, with varying success, to reduce the risk of children suffering injury or death from motor vehicles. Our present goal is to analyze those efforts that have been evaluated empirically and rigorously and to consider which components of pedestrian safety and which types of behavioral interventions are more and less effective at teaching children to be safer pedestrians.

One key aspect of our review is our objective to consider pedestrian safety not just as a whole but as a set of components. Crossing a street safely is a complex cognitive-perceptual task that requires multiple steps. Children must choose an appropriate location to judge traffic from, must judge the location and speed of oncoming traffic in multiple directions, and must cross the street in an appropriate manner. Cognitive-perceptual tasks vary at intersections (also called junctions) and at mid-block locations. Among younger children, dash-out incidents, where children enter roadways without even stopping to attempt a safe route selection and crossing, are of concern. We reasoned that existing interventions may be more effective for some aspects of pedestrian safety (e.g., route selection, dash-out prevention, judging oncoming traffic) than others.

Several scholars have previously reviewed the child pedestrian safety literature (Duperrex, Bunn, & Roberts, 2002; Hotz, Kennedy, Lutfi, & Cohn, 2009; Rothengatter, 1984; Schwebel, Davis, & O’Neal, 2012; Stevenson & Sleet, 1996). Of those, only one (Duperrex, Bunn, & Roberts, 2002) was framed as a systematic review; results were also published as a Cochrane review (Duperrex, Roberts, & Bunn, 2002). In general, previous reviews concluded that available evidence suggests pedestrian safety training can improve children’s safety but critiqued the state of current evidence as lacking high-quality research studies, having no evidence of translation to actual pedestrian injury reduction, and being conducted only in high-income countries (e.g., Duperrex, Bunn, & Roberts, 2002). There is some indication that multifaceted interventions targeting multiple aspects of child pedestrian safety in multiple ways may be most effective (Schwebel, Davis, & O’Neal, 2012).

No previous reviews used meta-analytic techniques, and no previous reviews considered carefully the multiple components of pedestrian safety. Our review, conducted according to Cochrane Review recommendations, extends previous work in the following ways: (a) by conducting a meta-analysis rather than just a systematic review, (b) by considering the efficacy of different types of behavioral interventions, (c) by considering the efficacy of training in different aspects or components of pedestrian safety, and (d) by updating advancements in the literature in the 10 years since previous systematic reviews were published (Duperrex, Bunn, & Roberts, 2002; Duperrex, Roberts, & Bunn, 2002).

Methods
Search Strategy
The following databases were searched: MEDLINE (PubMed), PsycINFO, and SafetyLit. We used the following search term for all searches: “(pedestrian or street) and (injury or injuries or safety) and (prevention or intervention or train* or education or educating or teach*) and (child* or pediatric or paediatric)”. To supplement those searches, we contacted prominent authors in the field, posted inquiries on relevant scientific society listservs, reviewed our personal libraries, and followed references in relevant articles and books. We also searched databases of the Transport Research Laboratory in the United Kingdom and the National Highway Traffic Safety Administration in the United States and conducted a post hoc review of abstracts in the ProQuest database, which yielded no new relevant sources. The review protocol is unregistered and available from the authors upon request.

Manuscript Inclusion Criteria
This systematic review and meta-analysis included all randomized trials in which children aged 1–14 years were randomly assigned to two or more conditions, including no-contact control groups, for training in one or more components of pedestrian safety. We did not include older children because most children are safe pedestrians by the age of 10 years (AAP Committee on Injury, Violence, and Poison Prevention, 2009), and it is developmentally
Manuscript Inclusion

As shown in Figure 1, manuscript inclusion and data extraction occurred in four steps. First, two authors independently screened 1,951 manuscript abstracts for relevance. Two authors reviewed each abstract and excluded those that were not eligible based on inclusion criteria. Inter-rater reliability was strong (κ > .9), and differences were resolved by retaining any studies rated by either reviewer as one that should be included. Full-text manuscripts were obtained when abstracts were absent or vague.

Second, for the 125 manuscripts retained as relevant from the first step, full articles were retrieved for more detailed evaluation. Two authors reviewed each manuscript and excluded those that were not eligible based on inclusion criteria. Inter-rater reliability was strong (κ > .9), and differences were resolved by retaining any studies rated by either reviewer as one that should be included. Bilingual experts in the field were consulted as needed to assist with this process (the authors had sufficient ability in French and Spanish themselves and consulted experts for assistance with other languages). Figure 1 lists reasons for exclusion.

Data Extraction

The third step of manuscript inclusion and data extraction was to extract data using a standardized form. This was conducted for the 25 manuscripts retained from the second step. Two researchers extracted data for each manuscript. Rare disagreements were resolved by discussion between both of the data extracters and a third researcher.

Extracted data included bibliographic information, country where data were collected, demographic information concerning the intervention and control groups, sample sizes allocated to groups and studied at each time of assessment, type(s) of intervention, type(s) of behavioral outcome measures focused on children, and results for each time of assessment and outcome measure.

Data Processing

Seven of the 25 articles eligible for inclusion lacked sufficient data required to compute effects (Fisk & Cliffe, 1975; McComas, MacKay, & Pivik, 2002; Reading, 1973; Rothengatter, 1984; Rothengatter, Dijkstra, & de Ruyter, 1979; Sandels, 1968/1975; Thomson et al., 2005). In those cases, extensive attempts to locate and obtain data from the authors were made. Two authors were located, and a third was identified as deceased; of those, one author had data still available to share (Thomson et al., 2005). The other authors could not be located and were presumed to be deceased or no longer active in scholarship.

Therefore, 19 articles reporting 25 studies were included in the quantitative analysis. Data were entered into the Review Manager 5.2 software (Revman; Review Manager, 2012) to compute effect sizes.

Type of Outcome Measures

We included studies targeting any aspect of child behavior or cognition surrounding pedestrian safety on roads. After data processing was complete, three researchers examined and discussed outcome measures used in each of the 25 included studies, matching them to a priori outcomes outlined in the study protocol. The lead researcher proposed two decisions: which outcome measure was primary and which component of pedestrian safety it assessed. Two other researchers reacted to those proposals, and rare disagreements were resolved through discussion until consensus was reached. Primary outcomes were components of pedestrian safety that were determined primarily by the authors of the original study, who emphasized or highlighted one result most prominently. The component of pedestrian safety being assessed was never disputed among the researchers and fell into six categories: crossing safely at mid-block locations, crossing at junctions (intersections), crossing between parked cars, preventing dashboard crossings, judging the speed of oncoming traffic, and selecting safe routes to cross intersections.

Table 1 lists outcome measures, each a component of pedestrian safety, used in each study. Mid-block crossings were generally assessed using real or simulated crossings at actual roadside locations, yielding outcome measures such as simulated crashes with traffic, times until impact with
oncoming vehicles, or decision times until entry into traffic
gaps. Junction/intersection crossing was typically assessed
in actual street situations, either with real or simulated
traffic and yielding outcome measures such as proper
looking at oncoming traffic and correct route selection
across intersections. Crossing between parked cars was
typically assessed by having children cross in simulated
real-traffic situations or showing researchers where they
would cross in actual situations, yielding outcome mea-
sures such as stopping in the correct location to view traffic
and looking properly at oncoming traffic. Dash-out behav-
ior was most often assessed using simulations near roads,
with controlled traffic, and deceptively throwing a ball over
the child’s head and into the road. Outcome measures to
assess dash-out behavior included failure to stop at the
curb and appropriate looking before entering the road.

Judging the speed of oncoming traffic was assessed in
just one study, where children judged traffic that was
driven by researchers; the outcome measure was a dichot-
omous correct versus incorrect judgment of traffic speeds.
Selecting safe routes to cross intersections was assessed in
various ways across studies, including simulations,
pointing at actual street corners, and table-top model
tasks. Outcome measures were most often the frequency
and/or accuracy of choosing the correct route across the
intersection.

Some studies assessed primary outcomes continuously
and others dichotomously. It seemed artificial to convert
continuous measures to dichotomous ones, so we retained
the original authors’ measurement strategies and analyzed
continuous and dichotomous data separately in our
analyses.
<table>
<thead>
<tr>
<th>Author(s), year</th>
<th>Sample N, M age in years, range in years, % male</th>
<th>Intervention description</th>
<th>Comparison groups</th>
<th>Methodology and procedure</th>
<th>Outcomes</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albert &amp; Dolgin, 2010</td>
<td>40, 4.7, 4–5, 50</td>
<td>Classroom training: game, story, and song delivered over 4 weeks</td>
<td>Read unrelated stories as part of normal lessons</td>
<td>Baseline test, post test at 1 week and follow-up at 6 months</td>
<td>Mid-block cross (continuous): walking behaviors on a real street</td>
<td>United States</td>
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<tr>
<td>Bart, Katz, Weiss, &amp; Josman, 2008</td>
<td>21, 8.94, 7–11, 38</td>
<td>Computer-based or virtual reality training: series of 1–3 20-min sessions in a virtual street crossing simulation</td>
<td>Played unrelated computer games</td>
<td>20-min sessions with posttest 2 weeks later</td>
<td>Mid-block cross (continuous): behaviors assessed on a real crossing with the Street Crossing checklist</td>
<td>Israel</td>
</tr>
<tr>
<td>Colborne, 1971, Experiment 2</td>
<td>110, not reported, 6–7, 0 (all girls)</td>
<td>Individualized or small-group training: outdoor training in a “traffic garden”</td>
<td>Classroom training</td>
<td>40-min session delivered by police officer; training in classroom versus traffic garden; posttest 1 week later</td>
<td>Mid-block cross (continuous): behaviors assessed on an actual crossing</td>
<td>Austria</td>
</tr>
<tr>
<td>Cross &amp; Prickett, 1991</td>
<td>50, not reported, 6–7, not reported</td>
<td>Classroom training: interactive classroom training to improve understanding of speed and distance</td>
<td>No-contact control group</td>
<td>Separate tests in which children judged distance and speed of approaching controlled vehicles; pretest and posttest for a 2–3-week period</td>
<td>Judge speed (continuous): Judging speed and distance of cars driven by researchers</td>
<td>Australia</td>
</tr>
<tr>
<td>Downing &amp; Spendlove, 1981</td>
<td>960, not reported, 3–11, not reported</td>
<td>Classroom training: community and school-level “Operation Dashout” campaign</td>
<td>No-contact control group</td>
<td>Children and drivers exposed to media campaign and school classroom instruction from May to August; pretesting in May, posttesting in June</td>
<td>Cross at parked cars (dichotomous): percent of stopping and looking both ways at curbs and near parked vehicles in the simulation on playground</td>
<td>United Kingdom</td>
</tr>
<tr>
<td>Jones &amp; Fleischer, 1979</td>
<td>870, not reported, not reported, not reported, children in kindergarten to third grade participated</td>
<td>Classroom training: knowledge and behavioral pedestrian safety curriculum</td>
<td>No-contact control group</td>
<td>Pretesting in first weeks of school year; instruction by teachers over 1 month ranging from 1 to 7.5 h total during October; posttesting in early November</td>
<td>Cross at junctions (dichotomous): looking properly during actual crossings</td>
<td>United States</td>
</tr>
<tr>
<td>Kendrick et al., 2007</td>
<td>459, not reported, 7–10, 32</td>
<td>Classroom training: Risk Watch program</td>
<td>No-contact control group</td>
<td>Risk Watch program delivered in class by teachers; pre and posttest measures taken ~126 days apart</td>
<td>Mid-block cross (continuous): demonstration of safe pedestrian skills mixed with a few bicycling skills</td>
<td>United Kingdom</td>
</tr>
<tr>
<td>Limbourg &amp; Gerber, 1981, Pilot Study 1</td>
<td>58, not reported, 3–7, not reported</td>
<td>Film or video training: behavioral and theoretical safety training</td>
<td>Theoretical road safety instruction only</td>
<td>Eight sessions of training between pre and posttesting</td>
<td>Prevent dash-out (dichotomous): real street crossing, including stopping at curb, looking left and right; reaction to ball thrown into street by researcher</td>
<td>Germany</td>
</tr>
<tr>
<td>Limbourg &amp; Gerber, 1981, Final Training Program</td>
<td>658, not reported, 3–6, not reported</td>
<td>Film or video training: behavioral training</td>
<td>No-contact control group</td>
<td>30-min video and behavioral training delivered by parents; pretest and posttest 4 weeks later</td>
<td>Prevent dash-out (dichotomous): stopping at the curb under conditions of distraction</td>
<td>Germany</td>
</tr>
<tr>
<td>Nishikawa et al., 1991</td>
<td>79, not reported, 4–5, 56</td>
<td>Individualized or small-group training; verbal instruction</td>
<td>Verbal instructions with no caution about risk</td>
<td>Verbal instruction differing in content regarding dash-out behaviors; posttraining evaluation conducted on the same day</td>
<td>Prevent dash-out (dichotomous): frequencies of safe or unsafe behaviors after ball thrown into street by researcher</td>
<td>Japan</td>
</tr>
<tr>
<td>Author(s), year</td>
<td>Sample N, M age in years, range in years, % male</td>
<td>Intervention description</td>
<td>Comparison groups</td>
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<td>Renaud &amp; Suissa, 1989 (data also reported in Renaud &amp; Stolovitch, 1988; Renaud, 1988)</td>
<td>136, not reported, 5, not reported</td>
<td>Board games or peer-group activities: board games/activities simulating route selections and street crossings</td>
<td>No-contact control group</td>
<td>Two 3-hr sessions with immediate posttesting</td>
<td>Mid-block cross (continuous): transfer of learning using street-crossing simulation in gymnasium</td>
<td>Canada</td>
</tr>
<tr>
<td>Schwebel, McClure, &amp; Severson, 2014b</td>
<td>231, 8.0, 7–8, 43</td>
<td>Multiple intervention strategies: virtual reality and street-side training</td>
<td>No-contact control group</td>
<td>Pre and immediate posttest assessment, six training sessions of 30 min each, follow-up assessment 6 months later</td>
<td>Mid-block cross (continuous): hits/close calls in roadside simulation task</td>
<td>United States</td>
</tr>
<tr>
<td>Schwebel &amp; McClure, 2014a</td>
<td>231, 8.0, 7–8, 43</td>
<td>Film or video training: video training</td>
<td>No-contact control group</td>
<td>Pre and immediate posttest assessment, six training sessions of ~30 min each, follow-up assessment 6 months later</td>
<td>Select safe routes (continuous): routes chosen on table-top models</td>
<td>United States</td>
</tr>
<tr>
<td>Thomson et al., 1992</td>
<td>30, 3-46, 5 year olds, 30</td>
<td>Individualized or small-group training: training in small groups focused on choosing safer routes and considering visual occlusions</td>
<td>No-contact control group</td>
<td>Pretesting; six sessions by a researcher over several weeks, in small groups; immediate posttesting, and follow-up 2 months later</td>
<td>Select safe routes (dichotomous): route selections chosen on real streets and table-top models by pointing</td>
<td>United Kingdom</td>
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<tr>
<td>Thomson &amp; Whelan, 1997, Chapter 4</td>
<td>104, not reported, not reported, “balanced for gender”</td>
<td>Individualized or small-group training: interaction with trained volunteers to help children recognize and select safer routes</td>
<td>No-contact control group</td>
<td>Pretesting; six training sessions over 6 weeks, comprising 24 route selections; immediate posttesting, and follow-up 2–3 months later</td>
<td>Select safe routes (dichotomous): selection of routes on real streets</td>
<td>United Kingdom</td>
</tr>
<tr>
<td>Thomson &amp; Whelan, 1997, Chapter 6, Year 1</td>
<td>102, 6 years 1 month, not reported, “balanced for gender”</td>
<td>Individualized or small-group training: step-by-step method of teaching children to safely cross near parked vehicles; based on Social Learning Theory</td>
<td>No-contact control group</td>
<td>Pretesting in roadside simulation 1 week before training; then training once per week for 4 weeks; immediate posttest; follow-up 2–3 months later</td>
<td>Cross at parked cars (dichotomous): multiple behavioral indices including stopping at the curb, correct walking speed, and attending to traffic</td>
<td>United Kingdom</td>
</tr>
<tr>
<td>Thomson &amp; Whelan, 1997, Chapter 6, Year 2</td>
<td>91, 6 years 0 months, not reported, “balanced for gender”</td>
<td>Individualized or small-group training: step-by-step method of teaching children to safely cross near parked vehicles; based on Social Learning Theory</td>
<td>No-contact control group</td>
<td>Pretesting in roadside simulation 1 week before training; then training once per week for 4 weeks; immediate posttest; follow-up 2–3 months later</td>
<td>Cross at parked cars (dichotomous): multiple behavioral indices including stopping at the curb, correct walking speed, and attending to traffic</td>
<td>United Kingdom</td>
</tr>
<tr>
<td>Thomson &amp; Whelan, 1997, Chapter 7</td>
<td>88, 6 years, 3 months, not reported, not reported</td>
<td>Individualized or small-group training: teaching children to position, search, identify alternatives, and apply safe behaviors at intersections</td>
<td>No-contact control group</td>
<td>Pretesting apparently in roadside simulation; children trained in groups of three in five sessions across 3 weeks; immediate posttest and follow-up at unspecified interval</td>
<td>Cross at junctions (dichotomous): stopping at curb, correct position at curb, adequate view of traffic, attention to traffic, and selection of a safe route</td>
<td>United Kingdom</td>
</tr>
<tr>
<td>Author(s), year</td>
<td>Sample N, M age in years, range in years, % male</td>
<td>Intervention description</td>
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<td>Methodology and procedure</td>
<td>Outcomes</td>
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<td>Thomson et al., 1998</td>
<td>60, 5 years 6 months (intervention group) and 5 years 7 months (control group), not reported, “balanced by gender”</td>
<td>Individualized or small-group training; training focused on choosing safer routes and considering visual occlusions</td>
<td>No-contact control group</td>
<td>Pretesting 2 weeks before training; six 30-min sessions led by parents with groups of three children over several weeks at roadside and on table-top models; immediate posttesting; follow-up 40 days later</td>
<td>Select safe routes (dichotomous): route selections chosen on real streets by pointing</td>
<td>United Kingdom</td>
</tr>
<tr>
<td>Thomson et al., 2005</td>
<td>189, ~9, 7–11, “balanced by gender”</td>
<td>Computer-based or virtual reality training; teaching children to improve recognition of speed, planning, and reduce start delays/tight fits</td>
<td>No-contact control group</td>
<td>Roadside evaluations preintervention, postintervention, four 30–40-min training sessions in small groups to complete computer-simulated crossings; follow-up 8 months later</td>
<td>Mid-block cross (continuous): tight fits at roadside simulation</td>
<td>United Kingdom</td>
</tr>
<tr>
<td>Tolmie et al., 2003, Study 1</td>
<td>50, 6 years 9 months, 3–8, 64</td>
<td>Multiple intervention strategies: adult- and peer-guided groups</td>
<td>No-contact control group</td>
<td>Pretesting; 14 scenarios in blocks of three; children and adults or peers worked together to identify safe crossing opportunities; posttesting 7–10 days after training</td>
<td>Mid-block cross (continuous): tight fits at roadside simulation</td>
<td>United Kingdom</td>
</tr>
<tr>
<td>Whelan, Towner, Errington, &amp; Powell, 2008, Skill 1</td>
<td>400, 6, 4–7, ~30</td>
<td>Individualized or small-group training: Kerbcraft; recognizing safe crossing places</td>
<td>No-contact control group</td>
<td>Roadside pretesting; 4–6 training sessions occurring once per week; immediate posttesting and follow-up 2–4 months later</td>
<td>Select safe routes (dichotomous): routes selected in roadside simulation</td>
<td>United Kingdom</td>
</tr>
<tr>
<td>Whelan et al., 2008, Skill 2</td>
<td>284, 6, 4–7, ~49</td>
<td>Individualized or small-group training: Kerbcraft; crossing safely near parked cars</td>
<td>No-contact control group</td>
<td>Roadside pretesting; 4–6 training sessions occurring once per week; immediate posttesting and follow-up 2–4 months later</td>
<td>Cross at parked cars (dichotomous): proportions of safe behaviors such as looking at traffic, stopping at the curb, and checking status of parked cars during actual crossings</td>
<td>United Kingdom</td>
</tr>
<tr>
<td>Whelan et al., 2008, Skill 3</td>
<td>121, 6, 4–7, ~48</td>
<td>Individualized or small-group training: Kerbcraft; crossing safely at intersections</td>
<td>No-contact control group</td>
<td>Roadside pretesting; 4–6 training sessions occurring once per week; immediate posttesting and follow-up 2–4 months later</td>
<td>Cross at junctions (continuous): looking in the correct directions when stopping at actual intersections</td>
<td>United Kingdom</td>
</tr>
<tr>
<td>Zeedyk, Wallace, Carcary, Jones, &amp; Larter, 2001</td>
<td>47, not reported, 5–6, 33</td>
<td>Board games or peer-group activities: knowledge-building activities</td>
<td>No-contact control group</td>
<td>Pretest and intervention on same day; intervention involved single 20-min peer-group activity session with board game, playmat model, or flip-chart; posttest at unspecified interval</td>
<td>Mid-block cross (dichotomous): choices of crossing location and strategy at three locations varying in potential for injury risk</td>
<td>United Kingdom</td>
</tr>
</tbody>
</table>
Type of Intervention

Three researchers also determined the type of intervention used in each study, using a strategy similar to determination of the outcome measures. The lead researcher proposed the category, and two other researchers reacted to the proposal. No disagreements emerged. Studies were divided into five categories: individualized or small-group training, classroom training, computer-based or virtual reality training, board games or peer-group activities, and film or video training. A sixth category was used for studies that included multiple intervention strategies either across or within groups of children. The categories were created because they relied on similar educational processes to teach children about pedestrian safety. Thus, all computer-based and virtual reality programs relied on repeated practice of the cognitive/perceptual task of crossing a street. All board games and peer-group activities involved shared learning via peer mentoring and discussion.

Risk of Bias Assessment

Two forms of bias can exist in a systematic review and meta-analysis, bias at the level of the meta-analysis and bias at the level of the individual included studies. At the meta-analysis level, our systematic review was conducted to locate and include all research, including unpublished studies, so we believe there to be minimal risk of bias across studies based on publication bias.

At the study level, risk of bias was assessed using guidelines in the Cochrane Handbook for Systematic Reviews of Interventions (Higgins & Green, 2011). Our goal was to identify any systematic biases in the way included studies were conducted that could influence results and therefore overestimate or underestimate the effect of the intervention. Bias can emerge through a wide range of factors. Following Cochrane recommendations (Higgins & Green, 2011), we rated each included study on selection bias (potential bias in allocating participants into intervention groups, evaluated based on random sequence generation and allocation concealment), detection bias (potential bias in how study outcomes are assessed or determined, evaluated based on blinding of the outcome assessment), attrition bias (potential bias in participant withdrawal from the study, evaluated based on incomplete outcome data), and reporting bias (potential bias in authors reporting significant rather than nonsignificant study results, evaluated based on selective reporting). We also noted other biases that were present. Evaluation of risk of bias was conducted by the lead author. Two other researchers reviewed all evaluations and noted any discrepancies, which were resolved through discussion. Interrater reliability was strong (κ > .9).

Quality of Research Assessment

Quality of the research was assessed using GRADE guidelines (Guyatt et al., 2011). As recommended by GRADE guidelines, the quality of research ratings indicate our confidence that effect size shown in the study represents the actual effect of the intervention. Quality was downgraded based on five factors: poor methodological quality (risk of bias within the study), indirect evidence of results, heterogeneity of results (tested with I² statistic, following Palermo, Eccleston, Lewandowski, Williams, & Morley, 2010), imprecision of results based on wide confidence intervals (CIs), and risk of publication bias. I², a standard measure of heterogeneity between intervention studies, indicates how much variability in the effect estimates is a result of heterogeneity rather than sampling error. Consistent with Palermo and colleagues (2010), we considered an I² > 50% as indicative of substantial heterogeneity. Evaluation of quality of the research was conducted by one researcher. Two other researchers reviewed all evaluations and noted any discrepancies, which were resolved through discussion. Interrater reliability was strong (κ > .9).

Data Analysis

Data analysis proceeded in six steps. First, descriptive data on each included study were reviewed. Second, overall "omnibus" tests of the effect of all behavioral interventions on all aspects of pedestrian safety were computed. For all meta-analyses presented, two results are provided, one for dichotomous (categorical) outcomes and a second for continuous outcomes. All studies were weighted according to sample size using a least-squares approach, such that studies with larger samples were weighted more heavily than those with smaller samples. Categorical results are reported as risk ratios (RRs) and continuous results as standardized mean differences (SMDs; after standardizing results and reversing the direction of measures as needed, the difference in mean outcome between groups over standard deviation of outcome among participants), both with 95% CIs. The effect sizes of SMDs were interpreted according to Cohen’s (1988) criteria, with an SMD of 0.2 considered a small effect size, an SMD of 0.5 a medium effect size, and an SMD of 0.8 a large effect size. In all cases, positive effects favor the active intervention group achieving safer behavior.

Third, we considered included articles based on the component of pedestrian safety targeted in the intervention. Six pedestrian safety components were
considered: crossing safely at mid-block locations, crossing at junctions or intersections, crossing between parked cars, preventing dash-out crossings, judging the speed of oncoming traffic, and selecting safe routes to cross intersections. Fourth, we considered included articles based on the intervention implemented, without regard to the component of pedestrian safety used as an outcome. Five types of interventions were considered: individualized or small-group training, classroom training, computer-based or virtual reality training, films or videos, and multiple intervention strategies combined.

Fifth, we considered both the targeted component of pedestrian safety and the intervention approach used to train children in that component of safety. Last, we rated each included study for risk of bias. Risk of bias was unclear for most categories in most studies based on insufficient information, and we retained all studies in analyses.

Results

Characteristics of Included Studies

Table I lists the studies included in the systematic review and meta-analysis. As shown, 25 studies from 19 manuscripts were included. All studies, including those published in the same manuscript, used independent samples. Data were collected in eight countries: Austria, Australia, Canada, Germany, Israel, Japan, the United States, and the United Kingdom, with the majority (14 of 25, or 56%) occurring in the United Kingdom. Child participants ranged in age from 3–11 years, with the bulk of studies on crossing behavior targeting children aged 6–9 years and studies targeting route selection and especially dash-out behavior focused on younger children (e.g., aged 3–6 years). These targets are developmentally sensible given the cognitive development of skills relevant for such behaviors as well as the pedestrian injury risks at those developmental stages. No information was reported in any of the included articles to indicate there had been adverse events.

Overall Meta-Analysis Results

Table II shows the overall results of the meta-analysis, including all studies and all outcomes, divided into continuous and dichotomous outcomes and studies with immediate postintervention assessment (all 25 studies) and those with a follow-up assessment several months later (13 studies). As shown, the standardized mean pedestrian safety score among intervention groups was 0.31 higher than that of control groups (95% CI = 0.12–0.50), for studies with continuous outcomes (10 studies and 1,052 participants), indicating a small to medium effect.
size. For studies with dichotomous outcomes, the RR was 3.44 (95% CI = 2.05–5.75; number needed to treat to benefit [NNTB] = 4.77). Data for each study are displayed graphically in Forest plots (See Figures 2–5). Taken together, these findings suggest behavioral interventions to improve children’s pedestrian safety are effective.

Results of follow-up assessments also indicate efficacy for behavioral pedestrian safety interventions. Continuous outcomes showed an SMD of 0.17 (95% CI = 0.00–0.34; five studies and 563 participants), indicating a small effect size favoring interventions over controls, and dichotomous outcomes showed an RR = 2.88 (95% CI = 1.89–4.39; eight studies and 744 participants; NNTB = 7.19), indicating safe behaviors were significantly more likely among participants in intervention groups than participants in control groups.

Meta-Analysis Results: Targeted Component of Pedestrian Safety

We next considered the included articles based on the component of pedestrian safety the research targeted. As discussed above, pedestrian safety is multifaceted, requiring multiple cognitive, perceptual, and motoric functions for safe engagement. Included studies targeted six components of pedestrian safety: crossing safely at mid-block locations (eight studies), crossing at junctions or intersections (three studies), crossing between parked cars (four studies), preventing dash-out crossings (three studies), judging the speed of oncoming traffic (one study), and selecting safe routes to cross intersections (six studies).

Table III presents results across each of the six components of pedestrian safety, measured separately for continuous and dichotomous outcomes and for postintervention and follow-up assessments. As shown, and replicating the overall results of Table II, there was a tendency for interventions to be effective compared with controls. Results for many components are challenging to interpret because they are based just on few studies, but there was a general trend for interventions to prevent dash-outs, to cross at parked cars, and to select safe routes to be effective across multiple studies.

Meta-Analysis Results: Type of Intervention

Table IV presents meta-analysis results organized by the type of intervention that was implemented. Included studies used individualized or small-group training (11 studies), classroom training (5 studies), computer-based or virtual reality training (2 studies), board games or peer-group activities (2 studies), films or videos (3 studies), or multiple intervention strategies combined (2 studies).

When sufficient studies were available to permit valid interpretation, some types of interventions were generally more effective than others. Individualized or small-group training in particular tended to be the most effective intervention strategy with data available from multiple studies.

Meta-Analysis Results: Targeted Component of Pedestrian Safety and Intervention Approach

The next analytic step examined both the targeted component of pedestrian safety and the intervention approach to train children in that domain. There were five combinations of pedestrian safety component and intervention approach with data available from more than one study at immediate postintervention assessment (and two others at follow-up assessment). Of those, the largest effects appeared from individualized or small-group training to...
train children to cross at parked cars (RR = 4.93, 95% CI 2.43–10.00, based on three studies and 422 participants; NNTB = 6.06) and to select safe routes (RR = 3.83, 95% CI 1.05–13.95, based on five studies and 610 participants; NNTB = 2.54). Those same two outcomes also showed significant effects at follow-up assessment (RR = 2.92, 95% CI 1.50–5.65, k = 3, N = 325, NNTB = 7.13 and RR = 2.77, 95% CI 1.60–4.80, k = 4, N = 331, NNTB = 6.35, respectively).

Quality of the Evidence

All meta-analysis results must be interpreted with the quality of the evidence ratings in mind. Following GRADE guidelines (Guyatt et al., 2011), we downgraded all four outcomes based on risk of bias; there was poor methodological quality among all outcomes. All comparisons in the studies were direct, so no outcomes were downgraded based on indirect evidence. One outcome (dichotomous postintervention outcome) was downgraded for inconsistency ($I^2 > 50\%$).

We assessed imprecision based on sample size and CIs. All outcomes had sufficient sample size based on GRADE criteria. GRADE criteria indicate outcome quality should be downgraded even if sample size is adequate when there is both no effect and appreciable benefit or appreciable harm. Three outcomes had an effect so were not downgraded. For the fourth outcome (continuous outcomes at follow-up), the effect was borderline (starts at

**Figure 3.** Forest plots demonstrating clinical significance of child pedestrian safety interventions (studies with continuous outcome, assessment at follow-up several months following intervention).

**Figure 4.** Forest plots demonstrating clinical significance of child pedestrian safety interventions (studies with dichotomous outcome, immediate postintervention assessment).
0.00), but the upper confidence limit was not appreciable (upper CI < 0.50), so we did not downgrade the outcome. Given the rigor of our systematic review, we did not downgrade any outcomes based on publication bias.

The final column of Table II shows quality of research evidence ratings for our outcomes. Quality of research evidence was low for the dichotomous pedestrian safety outcome immediately postintervention and moderate for the other outcomes. Those evaluations rated as having low quality must be interpreted with great caution; the Cochrane Library suggests this about low-quality ratings: “Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.” Those with moderate quality offer somewhat greater confidence in the estimates but still must be interpreted cautiously. Future research with strong methodology is needed in the field.

**Risk of Bias**

Ratings for risk of bias were made in five categories: random sequence generation, allocation concealment, blinding of outcome assessment, incomplete outcome data, and selective reporting. Ratings for each included study appear in Figure 6, with individualized tables and
ratings available in Supplementary Tables 1–25. As shown, a large portion of the manuscripts provided insufficient data to rate evidence for risk of bias. Specifically, of the 25 studies, the following number had insufficient data in each category: 17 studies for random sequence generation, 22 studies for allocation concealment, 22 studies for blinding of outcome assessment, 12 studies for incomplete outcome data, and 23 studies for selective reporting. When evidence was available, it was mixed. Five studies had high selection risk based on random sequence generation, and two studies had high detection risk based on blinding of outcome assessments. Low risk was rated for 3 studies in random sequence generation, 3 studies for allocation concealment, 1 study for blinding of outcome assessment, 13 studies for incomplete outcome data, and 2 studies for selective reporting. Although it was unclear based on materials written in the manuscripts, there is reason to presume significant risk of bias in several categories for most of the included studies.

Discussion

Results of this systematic review and meta-analysis demonstrate that behavioral interventions targeting children’s pedestrian safety by improving children’s behaviors and cognitions in pedestrian environments are generally effective. Behavior generally became safer both immediately following the intervention program and, to a somewhat reduced degree, at follow-up several months later. These results replicate and extend those reported in previous reviews (e.g., Duperrex, Bunn, & Roberts, 2002; Schwebel, Davis, & O’Neal, 2012). Child pedestrian safety remains a significant pediatric global health challenge, and efforts to reduce the impact of child pedestrian crashes on pediatric morbidity and mortality are urgently needed.

Beyond our omnibus finding that behavioral interventions are generally effective, available evidence suggested that some components of child pedestrian safety may be more responsive to behavioral interventions than others. Pediatric safety is not a unique and single action but rather a multilayered complex cognitive-perceptual-motoric task. Developing children are likely to struggle with various aspects of that complex task.

Our systematic literature review yielded intervention research targeting six different aspects of pedestrian safety. Some intervention programs—especially those designed to reduce dash-out behavior, to cross at parked cars, and to select safe routes across intersections—were generally effective in improving children’s pedestrian safety. Other components of pedestrian safety appeared to improve also through behavioral intervention, although evidence was poor because of the small number of randomized trials conducted with most types of outcomes.

Our third goal was to determine whether some types of behavioral intervention are more effective than others. Included articles considered five types of interventions: individualized or small-group training, classroom training, computer-based or virtual reality training, board games or

<p>| Table IV. Summary of Meta-Analytic Results for Behavioral Interventions to Improve Children’s Pedestrian Safety, Separated by Type of Intervention |</p>
<table>
<thead>
<tr>
<th>Pedestrian safety as continuous outcome</th>
<th>k</th>
<th>Total N</th>
<th>SMD</th>
<th>95% CI</th>
<th>I^2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individualized or small-group training, postIV</td>
<td>1</td>
<td>230</td>
<td>0.48</td>
<td>0.22, 0.74</td>
<td>NA</td>
</tr>
<tr>
<td>Individualized or small-group training, follow-up</td>
<td>1</td>
<td>139</td>
<td>0.21</td>
<td>-0.13, 0.54</td>
<td>NA</td>
</tr>
<tr>
<td>Classroom training, postIV</td>
<td>3</td>
<td>250</td>
<td>0.54</td>
<td>0.08, 1.00</td>
<td>56%</td>
</tr>
<tr>
<td>Classroom training, follow-up</td>
<td>1</td>
<td>40</td>
<td>0.64</td>
<td>-0.09, 1.38</td>
<td>NA</td>
</tr>
<tr>
<td>Computer-based or virtual reality training, postIV</td>
<td>2</td>
<td>149</td>
<td>0.14</td>
<td>-0.22, 0.50</td>
<td>5%</td>
</tr>
<tr>
<td>Computer-based or virtual reality training, follow-up</td>
<td>1</td>
<td>118</td>
<td>0.22</td>
<td>-0.16, 0.59</td>
<td>NA</td>
</tr>
<tr>
<td>Board games or peer-group activities, postIV</td>
<td>1</td>
<td>128</td>
<td>0.62</td>
<td>0.20, 1.04</td>
<td>NA</td>
</tr>
<tr>
<td>Film or video training, postIV</td>
<td>1</td>
<td>107</td>
<td>0.06</td>
<td>-0.62, 0.44</td>
<td>NA</td>
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<tr>
<td>Film or video training, follow-up</td>
<td>1</td>
<td>107</td>
<td>0.12</td>
<td>-0.26, 0.50</td>
<td>NA</td>
</tr>
<tr>
<td>Multiple intervention strategies, postIV</td>
<td>2</td>
<td>188</td>
<td>0.02</td>
<td>-0.32, 0.28</td>
<td>0%</td>
</tr>
<tr>
<td>Multiple intervention strategies, follow-up</td>
<td>1</td>
<td>159</td>
<td>0.04</td>
<td>-0.28, 0.37</td>
<td>NA</td>
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</table>

Pedestrian safety as dichotomous outcome

<table>
<thead>
<tr>
<th>k</th>
<th>Total N</th>
<th>RR</th>
<th>95% CI</th>
<th>I^2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individualized or small-group training, postIV</td>
<td>10</td>
<td>1,191</td>
<td>3.79</td>
<td>1.79, 8.02</td>
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<td>Individualized or small-group training, follow-up</td>
<td>8</td>
<td>744</td>
<td>2.88</td>
<td>1.89, 4.39</td>
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<td>Classroom training, postIV</td>
<td>3</td>
<td>1,424</td>
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<td>Board games or peer-group activities, postIV</td>
<td>1</td>
<td>47</td>
<td>0.83</td>
<td>0.26, 2.73</td>
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<tr>
<td>Film or video training, postIV</td>
<td>1</td>
<td>58</td>
<td>3.80</td>
<td>1.64, 8.80</td>
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</tbody>
</table>

Note. SMD = standardized mean differences; CI = confidence interval; IV = intervention; RR = risk ratio.
<table>
<thead>
<tr>
<th>Manuscript</th>
<th>Random sequence generation (selection bias)</th>
<th>Allocation concealment (selection bias)</th>
<th>Blinding of outcome assessment (detection bias; all outcomes)</th>
<th>Incomplete outcome data (attrition bias; all outcomes)</th>
<th>Selective reporting (reporting bias)</th>
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<tr>
<td>Albert &amp; Dolgin, 2010</td>
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<td>Cross &amp; Pitkethly, 1991</td>
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**Figure 6.** Risk of bias ratings for articles included in the meta-analysis. Note. White circle indicates low risk; fading gray indicates unclear risk; solid black circle indicates high risk.
peer-group activities, and films or videos. In general, individualized or small-group training strategies were effective. Other types of interventions typically showed mixed results, often with poor evidence for evaluation due to the number of studies implementing them.

The inconsistent findings from other intervention strategies, and especially from classroom and computer/virtual reality training, may result from individual study differences among the few randomized studies available. Perhaps some types of classroom interventions and some types of computer-based interventions are more effective than others. For example, it may be that computer-based interventions, which offer repeated practice at the cognitive-perceptual task of street crossing but fail to address other aspects of pedestrian safety, are most effective when supplemented with other learning modes that teach basic road safety rules (Schwebel & McClure, 2014b). Similarly, classroom interventions may be effective when combined with multimodal pedestrian safety training (e.g., Downing & Spendlove, 1981) that incorporates lessons addressing multiple aspects of pedestrian safety. The poor evidence from studies using films and videos indicates more interactive health behavior change mechanisms might be required. Evidence from board games and peer-group activities is intriguing, as those sorts of interventions are comparatively rare in the pediatric public health literature and might be explored further to prevent child pedestrian injury as well as in other domains.

The finding that individualized and small-group training programs were effective is encouraging, as they have been studied for many years and have been described as the most effective child pedestrian safety strategy targeting children rather than adults or the pedestrian environment (Schwebel & McClure, 2010). Unfortunately, such interventions also are highly expensive and labor intensive to implement. An appeal of alternatives such as films and videos is that, once developed, they are easy and inexpensive to disseminate widely. Given our findings that some peer-group, board game, and computer/virtual reality interventions were effective in individual studies, continued efforts to develop such interventions that are effective and can be disseminated widely for low cost should be pursued. Such programs, if theoretically based and carefully evaluated, hold excellent promise to replace labor-intensive individualized training as the first choice for child pedestrian safety intervention programming.

Several of the included studies included long-term data assessing retention of learned skills two to eight months after the intervention. Results from such long-term follow-ups tended to mimic those immediately postintervention, although effect sizes were lower and sometimes nonsignificant. This suggests children retain over time some of the pedestrian skills they learn via behavioral interventions, although other learning is lost. This result is promising for prevention programming, as it indicates that learned pedestrian skills may be retained over time.

All results must be considered with respect to quality of evidence ratings. Included studies often had low quality of evidence ratings, and some effect estimates may change as further evidence is gathered.

**Pedestrian Safety From the Perspective of Child Development**

Our results highlight the need to consider pedestrian safety from the perspective of child development. Dash-out behavior (also called dart-out behavior), which creates particularly high risk of pedestrian safety from about ages 5–9 years (Agran, Winn, & Anderson, 1994), was successfully reduced with fairly basic intervention strategies. In the study by Limbourg and Gerber (1981), for example, behavioral strategies were used to train parents, who were then expected to engage with their children to reduce children’s dash-out behaviors. Nishioka and colleagues (1991) used a different strategy. In their study, adults cautioned children to be cautious about moving (simulated) traffic as they played with a ball near the road. Compared with controls, children who had recently been cautioned displayed safer behavior in retrieving a ball the experimenter intentionally threw over the children’s heads.

One component of pedestrian safety we studied that was fairly resistant to the behavioral interventions was mid-block crossings. One of the most cognitively complex pedestrian tasks included, a mid-block crossing requires children to judge speeds, distances, and acceleration/deceleration of vehicles coming from at least two directions. Safe crossings also require estimation of the distance across the road and the child’s own walking speed. Such cognitive complexity may be developmentally impossible for many 5- or 6-year-old children to accomplish, no matter how much practice or training is provided. By the age of 7 or 8 years, children may develop those skills with training, and typically developing children may not master the cognitive complexity of mid-block crossings until the age of 10 years or later.

Future research must continue to approach pedestrian safety from a multidimensional child development perspective to understand which relevant cognitive skills develop and at what age, among trained and untrained children. In doing so, we must be wary of Vygotsky’s (1978) “zone of proximal development.” Pedestrian safety intervention programs might push children’s cognitions to some degree, but there will be a limit of that zone, and that limit may...
vary across children and across pedestrian tasks. In the end, the intervention goal must be to target children with the cognitive complexity to learn what is being instructed, but not those who have already learned the skills.

Interventions with explicit child developmental theory underpinnings are rare in the literature. A small, but growing, body of research examines various aspects of cognitive development in relation to pedestrian injury risk (e.g., Barton, Ulrich, & Lyday, 2012; Dunbar, Hill, & Lewis, 2001; Kovesdi & Barton, 2013; Whitebread & Neilson, 2000), but accumulating evidence has yet to be widely applied in intervention development. As an example of what might be developed, the intervention used by Tolmie and colleagues (2005) explicitly drew on Vygotskian principles of group interaction. Social interaction was harnessed to help children teach one another safe pedestrian skills and also to promote conceptual growth. Much potential remains to be realized in applying developmental knowledge to intervention. Future interventions should continue to look toward developmental theory and seek to tailor the delivery of interventions to developmental levels of the targeted children.

Pedestrian Safety From the Perspective of Global Public Health

Our meta-analysis included 25 studies conducted in eight different nations over the course of >40 years. The problem of child pedestrian safety is neither a new problem nor one specific to a particular geographic locale. The greatest risk lies in low- and middle-income countries (WHO, 2008, 2013), nations conspicuously absent from the meta-analysis results. In those nations, traffic is often more chaotic, children are left unsupervised on and near roadways more often, and trauma care postcrash is often inferior. As scientists and interventionists move toward preventing child pedestrian injuries, the focus must be international in scope. Many of the successes of high-income countries can and should be adapted to other cultures so that child pedestrians can be protected worldwide.

Measurement Issues in Pedestrian Safety

The articles included in our meta-analysis used a range of clever and innovative strategies to assess children’s pedestrian behavior and safety. Of course, such innovation was necessary because of the ethical challenges of placing children in real streets, with real traffic, for research purposes. Some studies used simulation to gauge children’s pedestrian behavior—simulation was done with models (e.g., three-dimensional table-top models of street environments)—in gymnasiaums and parks with real or remote-controlled vehicles and with virtual reality. Some studies used real roads but vehicles operated by researchers and controlled in their movement. Other studies used real roads and real traffic, having children make judgments but not crossing streets in most cases. One glaring omission emerges: no studies used actual pedestrian injuries as an outcome measure. This is not surprising given that pedestrian injuries are rare events, and an extremely large sample size would be required, but ultimately this methodological challenge must be addressed by scholars in the field.

Limitations

Like all research, this study had limitations. We focused only on behavioral interventions targeting child cognition and/or behavior. This artificially isolates child pedestrian safety as impingent only on the child, ignoring the street environment children might cross within, the behavior of drivers who might strike child pedestrians, the role of parents, crossing guards, and other adults who might supervise children near traffic, and many other variables that play a role in individual crash events. Our analysis was also limited by including only randomized trials. Rich data are available from pre–post research designs that lack control groups, from descriptive and epidemiological research, and from other research designs on child pedestrian safety. The included trials had mostly no-contact control groups, but several had active control groups that may have learned some relevant lessons also. Further, we were unable to include information on the many community-based pedestrian safety programs that are in practice globally but have not been subject to empirical evaluation. Interventionists should consider the broad picture of child pedestrian safety along with the issues raised in this review.

As in any meta-analysis, we merged studies that used different methodology and different outcomes into groupings. We did so judiciously and thoughtfully, working to create logical categories, but still we merged studies that were somewhat unlike. The computer-based and virtual reality training strategy, for example, included both nonimmersive two-dimensional computer-based simulation learning and semiimmersive three-dimensional learning in a virtual pedestrian environment. Similarly, in some categories, such as the selecting safe routes outcome, we combined studies that assessed the outcome with real or simulated crossings in actual street crossings and studies that assessed the outcome using table-top models.

Finally, we were limited by our inability to obtain data from authors of six studies that were eligible for inclusion. Most of those studies were older—five of the six were published between 1968 and 1984—but still reported rich
experimental designs and findings that would contribute to the present results.

**Implications**

Behavioral interventions should be one facet of society’s strategy to reduce the global burden of child pedestrian injuries (Damashek & Kuhn, 2014; Gielen, Sleet, & DiClemente, 2006; Liller, 2012). Implementation of such interventions might be conducted by local, regional, or national government bodies; by nonprofit agencies; by school districts; or by any number of other interested stakeholders. Creative strategies like use of volunteers such as retired individuals to train children in safe pedestrian skills (Thomson & Whelan, 1997), development of virtual reality programs that might be disseminated broadly over the internet (Schwebel, McClure, & Severson, 2014a), or other techniques that will deliver safety lessons broadly, efficiently, and economically are a necessity.

In comparison with many domains of pediatric psychology, child pedestrian safety is not a new science. Child pedestrian safety training efforts began at least as early as the 1930s initiation of Safety Town in Ohio, and empirical evaluation of such efforts were pioneered by Stina Sandels’ inspiring work in 1960s Sweden (Sandels, 1968/1975). Despite the comparatively long history of child pedestrian injury prevention, much work remains to be done. Children are dying on our streets at an alarming rate, and behavioral strategies appear to improve safety. Work should continue to prioritize identification of the most cost-efficient and effective prevention strategies. Simultaneously, dissemination efforts must be considered. The act of balancing identification of the most effective strategies with dissemination of strategies known to be effective is always challenging, but preventionists must be content to disseminate programs that are effective rather than squandering time—and children’s lives—awaiting identification of the optimal program.

Of course, behavioral strategies designed to improve children’s decisions in pedestrian settings cannot be implemented in isolation. Other proven strategies to improve child pedestrian safety, including construction of pedestrian-friendly built environments, reducing risky driving behaviors, improving adult supervision of child pedestrians, and many others must be implemented in conjunction with behavioral strategies targeting children themselves (WHO, 2013).

**Conclusion**

Our results generally match those of previous nonsystematic reviews (Hotz, Kennedy, Lutfi, & Cohn, 2009; Rothengatter, 1984; Schwebel, Davis, & O’Neal, 2012; Stevenson & Sleet, 1996) as well as the only systematic review previously published (Duperrex, Bunn, & Roberts, 2002; Duperrex, Roberts, & Bunn, 2002). Behavioral interventions can teach children safer pedestrian skills. Some components of pedestrian safety appear to be more successfully taught via behavioral strategies than others, and some intervention strategies seem to be more effective than others. All strategies and outcomes could benefit from further research of high rigor, especially research conducted with attention to child development, to global needs, and to interventions that might be disseminated broadly at low cost.

**Supplementary Data**

Supplementary data can be found at: http://www.jpepsy.oxfordjournals.org/

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**References**


