Smartphone use during ambulation and pedestrian trauma: A public health concern

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The authors have nothing to disclose.

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The reviewers have nothing to disclose.

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Submitted: January 9, 2018, Accepted: July 11, 2018, Published online: August 20, 2018.

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DOI: 10.1097/TA.0000000000002051

Smartphone ownership is nearly ubiquitous in the United States. According to the Pew Research Center, up to 77% of all Americans (and 92% of Americans aged 18–29 years) reported owning a smartphone in 2016—a greater than twofold increase from the 35% ownership rate reported in 2011.[1] While smartphone technology has undoubtedly improved global connectivity, accessibility of information, and overall convenience, it has also led to a concurrent rise in distracted behaviors. Much attention has been directed toward the dangers associated with smartphone use while operating a motor vehicle, and recommendations against talking on the phone or texting while driving have been well documented in the medical literature.[2,3] Legislative efforts have followed suit.[4] More recent evidence suggests that smartphone use also leads to distracted behaviors and subsequent injury during more mundane activities, such as walking.[5–8] Despite this, there is a relative paucity of data addressing the dangers associated with simultaneous smartphone use and ambulation, and few reports exist in the surgical literature about injuries specifically related to this scenario. This review summarizes current knowledge regarding the impact of smartphone-related distraction on pedestrian ambulation and trauma, reviews interventions and legislation targeting both distracted ambulation and driving, and makes recommendations for future directions.

METHODS

The articles for this narrative review were derived from several different sources. An initial search of PubMed, Ovid MedLine, and Cochrane databases was performed to identify studies describing phone-related distracted behaviors, along with interventions and legislation targeting such behaviors, using combinations of the following keywords: "texting," "text," "phone," "pedestrian," "distraction," "distracted," "inattention," "walk," "walking," "ambulation," "injury," "surgery," "trauma," "intervention," "legislation," "ban," "motor vehicle." Articles from inception to July 2017 were considered for inclusion. Inclusion criteria were limited to (1) articles describing visual and cognitive (i.e., texting, emailing, browsing the internet, using applications, playing video games, taking photos) and auditory (i.e., talking) phone-related distracted pedestrian ambulation and (2) behavioral interventions and legislation targeting phone-related pedestrian ambulation or phone-related distracted driving. Articles regarding phone-related distracted ambulation primarily consisted of observed and self-reported rates of distracted ambulation, injuries, and outcomes resulting from distracted ambulation, effects of distraction on ambulation and cognition, and motivations for distracted ambulation. Exclusion criteria included (1) editorial, commentary, and policy statement articles; (2) original articles providing descriptive data only, such as studies outlining interventions without providing evidence of effectiveness; (3) non–phone-related technological distraction, such as headphones connected to an MP3 player; (4) studies examining the effect of phone distraction on ambulation in nonhealthy patients with gait disorders, such as those with Parkinson's disease and multiple sclerosis; and (5) non–US-based legislation studies.

The initial search yielded 2,090 citations. After removal of duplicates, titles were screened for relevance by one of the authors (C.S.G.), and 241 abstracts of relevant, original, and review studies were analyzed. Ninety-six papers were selected for full-text review. Of these, 67 met final inclusion criteria. An additional seven papers were included after manual reference check of these articles for a total of 74 papers. These included 51 papers on phone-related distracted pedestrian ambulation, seven papers on interventions against distracted pedestrian ambulation or distracted driving, and 16 papers on legislation targeting distracted driving (Fig. 1). US public health data was acquired from the Center for Disease Control and Prevention

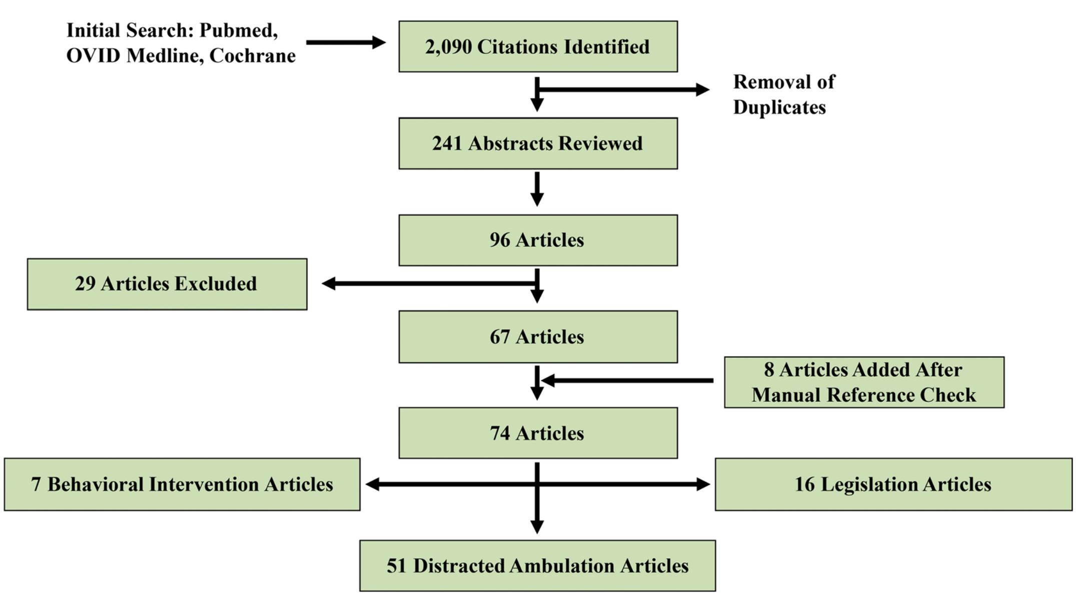

Figure 1. Trial flow diagram.

TABLE 1. Total Number of Phone-Related Pedestrian Injuries in the United States, 2005–2010

	2005	2006	2007	2008	2009	2010
Total phone-related pedestrian injuries						
Nasar and Troyer[5]	256	396	597	1055	1113	1506
Smith et al.[6]	795	653	1,247	1,444	951	1,786

(CDC), the Pew Research Center, the Governors Highway Safety Association, and the National Highway Traffic Safety Administration.

RESULTS

Prevalence of Smartphone-related Distracted Ambulation

Several observational studies have examined the prevalence of visual and cognitive (e.g., texting) smartphone distraction while walking in risky situations, such as crossing the street, and have reported rates ranging from 1.1% to 8.4% of observed pedestrians.[9–14] Thompson et al.[11] reported that pedestrian texting was associated with an 18% increase in time required to cross the street and a 3.85-fold increased risk of exhibiting at least one unsafe crossing behavior when compared with undistracted pedestrians. Basch et al.[9,10] found that 8.1% to 8.5% of pedestrians crossed illegally while visually distracted by their smartphones. The observed frequency of auditory distraction from talking on the phone while crossing appears to be similar to that of visual distraction, with rates ranging from 5.0% to 6.5%.[9–16]

Survey-based studies have found higher rates of distracted ambulation than observational studies, with greater frequencies for younger pedestrians.[17,18] One study found that about 20% of individuals aged 17 years to 65 years, and a higher proportion of those aged 18 years to 30 years, admitted to being distracted by their smartphone while crossing the street at least once per week.[18] College students reported that 40% were distracted by a smartphone during ambulation in the past week and that 5.4% had been involved in a crossing-related adverse event due to smartphone distraction.[17] Middle and high school students with "Problematic Mobile Phone Use" (i.e., phone addiction) reported significantly higher rates of road traffic injuries, pedestrian collisions, and falls than those without.[19] Evidence from observational and survey-based studies suggest that distracted smartphone-related ambulation is not uncommon, is associated with risky street crossing behavior and increased risk of injury, and is more problematic for younger pedestrians.

Incidence of Smartphone-related Pedestrian Injuries and Fatalities in the United States

To our knowledge, there are currently no accurate estimates of the absolute number of pedestrian injuries and fatalities related to smartphone distraction in the literature, though two studies have described relative epidemiological trends.[5,6] Nasar and Troyer[5] studied cellphone-related injuries as reported by emergency departments in the National Electronic Injury Surveillance System (NEISS) database and noted a near sixfold relative increase in the number of pedestrian-related traumas attributed to phone use from 2005 to 2010. This included a near 10-fold increase in the proportion of phone-related pedestrian injuries compared to all pedestrian injuries during the same period. Smith et al.[6] similarly looked at the incidence of cellphone-related traumas in the NEISS database, but used an expanded definition of pedestrian (i.e., Nasar and Troyer restricted pedestrians to those who were ambulating in public settings, while Smith et al. included those who were ambulating in private settings, such as their homes) and found a near 2.5-fold increase in the relative number of phone-related injuries suffered from 2005 to 2010. The estimates made by Nasar and Troyer[5] and Smith et al.[6] of the absolute number of phone-related pedestrian injuries are reported in Table 1.[5,6] Notably, neither Nasar and Troyer nor Smith et al. reported any fatal injuries in their respective studies.

Smartphone-related Pedestrian Injuries by Age and Sex

Nasar and Troyer[5] and Smith et al.[6] both reported the incidence of phone distraction-related pedestrian trauma by age, and their findings are aggregated in Figure 2. Nasar and Troyer examined pedestrian injuries from 2004 to 2010, while Smith et al. looked from 2000 to 2011. Both studies demonstrated an increased risk of injury for younger pedestrians: 51% and 43% of those injured were 30 years or younger in the Nasar and Troyer and Smith et al. studies, respectively. This risk of injury to younger individuals is congruous with data showing higher rates of smartphone ownership among younger people and self-reported greater likelihood to engage in smartphone-related distracted street-crossing behavior for young pedestrians—further underlining the need for prevention and intervention in this age group, specifically.[1,17,18]

Finally, Nasar and Troyer and Smith et al. both estimated the rate of phone-related pedestrian trauma by sex, and Nasar and Troyer[5] reported that females accounted for 48% of injuries, while Smith et al.[6] showed they accounted for 68% of the injuries. The reasons for this discrepancy are not obvious, and it is unclear from current evidence whether male or female sex is associated with increased risk of phone-related distraction pedestrian injury.

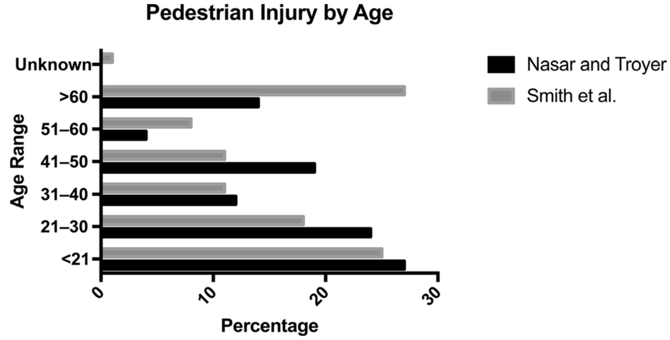

Figure 2. Phone-related pedestrian injury by age. Younger pedestrians are at greater risk for smartphone-related distraction injury. Data from Nasar and Troyer and Smith et al.[5,6]

Mechanisms, Patterns of Injury, and Outcomes for Smartphone-related Pedestrian Trauma

Evidence from the Nasar and Troyer and Smith Smith et al. studies, three case reports, two prospective emergency department studies, and one review article reveals three primary mechanisms of injury from smartphone-related distracted ambulation: (1) being struck by a motor vehicle,[6,8,20–23] (2) falling,[6,8,23,24] and (3) walking into an unseen object.[6,23,25] Interestingly, the smartphone trend of self-photography, or taking a "selfie," has been associated with several other injury mechanisms, including muggings and injuries from "selfie-sticks."[8] Taking a selfie is, to our knowledge, the only smartphone function used by pedestrians that has been explicitly linked to fatalities in the medical literature (e.g., 10 selfie-related deaths were reported in the Russian Federation in 2015), suggesting that this behavior may be particularly distracting and dangerous during ambulation.[8]

To date, only Smith et al.[6] has studied the distribution of distracted pedestrian injury mechanisms and reported that 4% were due to pedestrian motor vehicle collisions, 9% were due to pedestrians striking motionless objects, 78% were due to falls, and 9% were unspecified in his cohort. At the time of injury, 62% of pedestrians were talking on the phone, 12% were texting, and 27% were labeled as other/not specified. Smith et al. also reported a distribution of injuries and noted that 27% of pedestrians suffered head injuries, while 21%, 25%, 25%, and 0% suffered upper extremity, lower extremity, trunk/neck/shoulder, and whole body injuries, respectively. Eighty-five percent of patients were either treated and released or released without treatment, 14% were admitted for treatment, and 1% left without being seen or against medical advice.[6] There were no recorded fatalities.

Though no reports exist in the literature detailing injury patterns and outcomes associated with smartphone-related distracted pedestrian motor vehicle trauma (PMVT), there are a large number of studies describing injury patterns in pedestrian motor vehicle collisions. Though a full review of PMVT is beyond the scope of this text, such data are included in this review given the particularly severe morbidity and mortality risk following PMVT. Findings of studies stratified by age groups (i.e., pediatric, adult, and/or elderly) and reporting injury distributions along with outcomes are shown in Table 2.[26–31] In all three age groups, head and extremity injuries occur with greatest frequency. Though the risk of smartphone-related distracted ambulation appears to be greatest for young pedestrians, injury severity and mortality in PMVT are inversely related with age, with elderly pedestrians presenting with the most severe injuries and highest mortality rates (Table 2). Outcomes and mortality in PMVT are dependent on other factors besides age, such as the vehicle type involved in the collision.[32]

Effects of Distracted Ambulation on Gait, Attention, and Cognition

Smartphone use during ambulation has been demonstrated to profoundly affect gait. Walking with visual distraction, such as texting, is associated with gait modifications that cause pedestrians to walk more slowly and weave laterally as an adaptive response to the decreased attentional focus on walking.[33–44] Writing text messages is associated with greater gait modification during ambulation than reading text messages, likely due to the added motor demands of physically typing a message.[36,44,45] Unlike walking while reading or writing a text, walking with auditory distraction (i.e., talking on the phone) has only been associated with decreased walking speed.[33,34,45] Smartphone distraction during ambulation has also been shown to have negative effects on dynamic balance and trunk stability, though one study has reported improved frontal plane stability in experienced texters, suggesting that positive adaptive changes may be possible.[46–49] Nevertheless, the largely maladaptive effects on gait and balance create a potentially devastating scenario for distracted pedestrians crossing busy intersections.

Smartphone-related distracted ambulation has been shown to result in decreased situational awareness, reduced perception of environmental stimuli, and visual field impairment by approximately 50%.[23,50–52] Texting while walking has been found to make pedestrians more reliant on their central vision to detect roadside events and to affect visual search behavior.[45,53] Both visual and auditory smartphone distractions during ambulation have also been associated with unsafe street crossing behaviors including looking left and right less frequently before crossing, waiting longer to cross the street, missing more safe opportunities to cross, and being less able to detect oncoming cars.[23,54–61] Strikingly, Schwebel et al.[7] demonstrated that pedestrians who texted while crossing the street in a validated semi-immersive virtual environment were more than five times as likely to be struck by an oncoming vehicle than pedestrians who crossed without distraction. This further emphasizes the high visual, auditory, cognitive, and/or motor demands of smartphone use during ambulation and highlights the hazardous implications of simultaneous smartphone use during walking.

Motivations for Smartphone-related Distracted Ambulation

Three studies by Jiang et al.,[17] Lennon et al.,[18] and Koh and Mackert[62] have used the Theory of Planned Behavior

TABLE 2. Distribution of Injuries and Outcomes in PMVT for Three Age Groups

	Head (%)	Spine (%)	Chest (%)	Abdomen/Pelvis (%)	Extremity (%)	Mean ISS	Mortality Rate (%)
Age group							
Pediatric[26–29]	31.5–57.0	0.0–0.4	1.0–8.0	4.6–23.0	20.6–60.0	6.8–9.0	1.4–9.0
Adult[27,28,30]	24.4–33.8	2.6–4.1	2.9–15.4	9.8–13.5	31.8–58.7	8.8–11.0	5.4–9.1
Elderly[27,28,30,31]	18.1–40.4	1.9–3.0	5.4–44.4	8.8–27.0	28.1–69.2	11.6–17.6	13.5–32.0

Age group definitions: Pediatric—Peng and Bongard <15 years old; Kong et al., Derlet et al. <16 years old; Snyder et al. <18 years. Adult—Peng and Bongard (15–65 years), Kong et al. (16–59 years), McElory et al.[18–64]; Elderly—Kong et al. >59 years, McElroy at al., Takanishi et al. >64 years, Peng and Bongard >65 years.

(TPB) to examine psychosocial factors that motivate individuals to use smartphones while ambulating to better understand why pedestrians engage in such behaviors and, ultimately, tailor interventions aimed at prevention.[17,18,62] The TPB posits that behavioral intention most closely predicts voluntary behavior. Intention is influenced by three factors:[1] an individual's attitudes (i.e., how favorably or unfavorably an individual views a behavior),[2] subjective norm (i.e., perception that the behavior in considered acceptable by "important" people, like parents or friends), and[3] perceived behavioral control (PBC) (i.e., perception of personal control over performing a behavior). Other variables may also be examined if they are thought to enhance the predictive ability of the model toward a specific behavior.

All three studies examined the role of standard TPB variables (i.e., attitude, subjective norm, and PBC) along with different additional variables in expanded models.[17,18,40] Jiang et al.[17] determined that attitude, subjective norm, and PBC predicted behavioral intent, along with descriptive norm (i.e., what individuals perceive others actually do), mobile phone involvement (i.e., measure of excessive phone use), and perceived ability to compensate (i.e., how well one can overcome negative effects of behavior). Lennon et al.[18] found that attitude and subjective norm, along with mobile phone involvement and group norm (i.e., perception of how friends view behavior) to be the strongest predictors of behavioral intent. Koh and Mackert[62] found that subjective norm, along with personal norms (i.e., how congruous a behavior is with an individual's values) and self-efficacy (i.e., related to PBC; confidence in one's ability to successfully perform a behavior) most strongly predicted behavioral intent. The discrepancies between these studies may be explained by several factors, including differences in additional variables examined in each model. Additional differences may be explained by demographic and cultural variations between the study populations. While the studies are largely discordant, all three studies reported that subjective norm was predictive of behavioral intent to cross the street while distracted.

Behavioral Interventions for Smartphone-related Distracted Ambulation

One study examined the efficacy of a behavioral intervention aimed at risk education and reduction of smartphone-related distracted ambulation. Schwebel et al.[63] staged a week-long program at a college campus using a virtual pedestrian crossing environment along with a secondary traditional and social media campaign aimed to raise awareness regarding the dangers of this behavior. The intervention was successful at increasing the perceived risk of distracted street crossing among virtual environment participants, along with increasing the percentage of students who reported to rarely or never be distracted by their smartphone during street crossing—suggesting that the intervention had educational benefits. However, significant communitywide changes in distracted pedestrian street crossing frequencies were not observed.

Behavioral Interventions for Smartphone-related Distracted Driving

Six studies have evaluated the effectiveness of behavioral interventions aimed at curbing distracted driving.[64–69] Similar to the Schwebel et al. study, such interventions were associated with increased self-reported awareness of the dangers of distracted driving along with self-reported decreases in distracted driving among drivers of all ages.[64,67–69] However, the effects on actual observed behavioral change have been mixed. For teenage drivers, only one study by Unni et al.[68] demonstrated long-term effectiveness. This intervention consisted of a two-phase hospital-school campus hybrid program targeting high school students. Phase one selected student leaders to visit hospitals in order to learn about the risks and consequences of distracted driving. In the second phase, these student leaders organized a multitude of awareness and simulation campaigns at their schools that lasted 12 months. The campaign was successful in reducing both self-reported texting while driving as well as the observed rates of texting while driving (18% to 7%) 4 months into the second phase of intervention.

Conversely, behavioral interventions targeting teens with just campus-based education have not demonstrated sustained levels of decreased distracted driving.[65,66] A study by Joseph et al.[67] showed that a week-long educational intervention in a hospital setting was associated with an observed decreased rate of distracted driving in a population of healthcare workers, who were significantly older as a cohort than the teenagers in the Unni et al. study. No other studies aimed at reducing distracted driving have been shown to be effective at sustaining behavioral change.

Current Legislation Against Distracted Behaviors

US legislation against distracted behaviors has focused on distracted driving. To date, 47 US states plus D.C. have banned texting, while 15 US States plus DC have banned handheld mobile phone use (i.e., talking) while driving.[4] While no states ban all cellphone use for drivers, 38 states plus D.C. have banned all cellphone use for young or novice (i.e., those with learner's permits or intermediate licenses) drivers.[4] Legislative and enforcement efforts targeting distracted pedestrians are

TABLE 3. Existing Legislation Against Distracted Walking

City	Passage	Law	Fine
Honolulu, HI	July 2017	"No pedestrian shall cross a street or highway while viewing a mobile electronic device" except in emergencies and for emergency responders	• US $15–35, first offense • US$35–75, second offense • US $75–95, third offense
Montclair, CA	January 2018	"No pedestrian shall cross a street or highway while engaged in a phone call, viewing a mobile electronic device or with both ears covered or obstructed by personal audio equipment," except in emergencies, for those with medically prescribed hearing aids, and for emergency responders	• US $100, first offense • no more than US $200, second offense within 12 mo • no more than US $500, any additional violation within 12 months

nascent. In March 2012, the city of Fort Lee, NJ, began to aggressively issue US $85 tickets for jaywalking if the pedestrian was distracted by his or her phone while crossing the street. Current laws against distracted ambulation in the US are summarized in Table 3. Notably, legislation against distracted ambulation currently exists only at the city level, and statewide efforts have failed in Arkansas, Illinois, Nevada, and New York, among others. Given the recency of the Honolulu and Montclair city laws, no studies evaluating their efficacy have been published to date (Table 3).

Effects of all Driver Handheld Phone Bans on Observed Distracted Driving Behaviors

A number of single-state studies have examined the effects of all driver handheld cellphone bans on observed frequencies of talking while driving in New York State (NY), DC, and Connecticut (CT).[70–75] In all three locations, observed handheld phone use rates declined sharply following implementation of laws, and immediate postlaw rates were 43% to 76% lower than prelaw rates.[70,73,74] Rates stayed below what was expected for years afterward, though to varying degrees (24% to 65% lower for 3.5 to 7 years after implementation).[74] Two national studies have also examined the effects of all driver handheld phone bans on observable distracted driving behaviors.[76,77] Zhu et al.[76] reported significantly reduced observed rates of talking while driving for drivers younger 25 years in states with handheld phone bans than for those without such bans. Rudisill and Zhu[77] similarly reported significantly decreased rates of observed handheld phone use in states with all-driver handheld bans versus states without such bans for all drivers of all ages. Thus, there is evidence that all driver handheld phone bans have had success in reducing the prevalence of observed handheld phone use while driving.

Effects of Young Driver Cellphone Bans on Observed Distracted Driving Behaviors

Two observational studies have examined the short- and long-term effects of a young driver cellphone ban in North Carolina.[78,79] This law began prohibiting cellphone use for drivers younger than 18 years in 2006, with exceptions for parental calls. The studies showed that the observed rate of distracted driving increased 5 months postlaw, while the observed rates in South Carolina, an adjacent state without distracted driving legislation that was used as a control, were unchanged.[78] The rate observed 2 years postlaw decreased, though this was not significant given a larger magnitude decrease observed in South Carolina.[79] While teens are the most at-risk population with regard to both distracted driving and walking, laws specifically targeting teenagers have not been effective in reducing distracted driving behaviors.

Effects of Handheld and Texting Bans on Crash Rates, Injuries, and Fatalities

Studies of the effects of handheld and texting bans on crash rates, injuries, and fatalities have been less conclusive than those on observed distracted driving behaviors.[75,80–84] McCartt et al.[75] reviewed all published studies through 2013 and found that, while some papers reported that handheld phone and texting bans were associated with lower fatal crash rates, the methodological limitations and disparities in the overall body of literature made it unclear whether such laws were truly reducing fatal crashes. In a more recent single state-study, Ehsani et al.[80] examined the effects of an all driver texting ban in Michigan and did not find a decrease in crash rates following the ban.

Four national studies have examined the effects of texting bans with primary enforcement (i.e., driver can be ticketed for talking or texting while driving with no other moving violations) on crash rates, injuries, and fatalities.[81–84] Ferdinand et al.[83] and Lim and Chi[84] both found significant reductions in young driver crash-related fatalities in states with all driver texting bans compared with states without such bans. Ferdinand et al.[83] and Abouk and Adams[81] also found evidence of reduction of fatalities for drivers of all ages following all driver texting bans with primary enforcement, though Abouk and Adams did note that fatality reductions faded over time. Conversely, all driver texting bans with secondary enforcement (i.e., driver can only be ticketed for texting while driving if committing another violation) were associated with increased fatal crashes.[81,83] In another study, Ferdinand et al.[82] examined the effect of primary texting bans on motor vehicle crash-related hospitalizations and reported a significant 7.2% reduction among all age cohorts in states with such bans versus those without. Thus, while there is no consensus in the literature regarding the overall effect of handheld phone and texting bans on crash rates, injuries, and fatalities, recent evidence from national studies suggests that primarily enforced texting bans may be more effective than secondarily enforced bans.

DISCUSSION

Smartphone-related distracted ambulation is an emerging public health concern. Certain findings have been well-established in the literature. Most Americans (and especially younger Americans) now own smartphones.[1] Data from observational and survey-based studies have demonstrated that smartphone distraction during ambulation is not uncommon, is associated with more dangerous street crossing behaviors, and is more common among younger pedestrians.[9–19] Such distraction also has well-established maladaptive effects on gait and attention and creates potentially dangerous scenarios for pedestrians, especially during street crossing.[43,54,55] Common mechanisms for injury resulting from smartphone-related distracted ambulation include falls, walking into stationary objects, and PMVT.[5,6,20–25] However, there is a dearth of information regarding other important aspects of smartphone-related distracted ambulation requiring further investigation.

The incidence of injuries and fatalities due to smartphone-related pedestrian trauma is unknown. Two studies (Nasar and Troyer from 2004 to 2010, and Smith et al. from 2000 to 2011) have made attempts to estimate the absolute injury incidence (Table 1).[5,6] However, these calculations likely represent significant underestimates of the total injury incidence based on the methodology employed and limitations of the NEISS database. Pedestrians may not go the emergency room for treatment following injury, as they may see their primary physician, or not see a physician at all. Patients may not report phone distraction as associated with their injury, their response may not be coded in the NEISS database, or they may die from their

TABLE 4. Estimated Total Number of Unintentional Phone-Related Pedestrian Traffic Injuries in the United States, 2005–2010

	2005	2006	2007	2008	2009	2010
Total unintentional nonfatal traffic-related pedestrian injuries[85]	120,815	125,266	118,278	138,241	137,507	160,512
Total unintentional fatal traffic-related pedestrian injuries[85]	4,917	5,021	4,820	4,489	4,109	4,383
Percentage of pedestrian injuries related to cellphone use[5]	.37	.66	1.11	1.99	2.06	3.67
Nonfatal cellphone-related pedestrian injuries	447	827	1,301	2,751	2,833	5,891

Data combined from total number of unintentional pedestrian traffic injuries reported by the CDC and the percentage of pedestrian phone injuries related to phone use reported by Nasar and Troyer.[5,85]

injuries before they ever report their cell phone use. This last limitation is exemplified by the observation that neither Nasar and Troyer nor Smith et al. reported any fatalities from phone-related distraction in their cohort, while fatal smartphone-related injuries have been reported by another study.[8]

A different estimate can be made by combining available CDC public health data on the number of pedestrian injuries with the proportion of pedestrian injuries attributed to phones calculated by Nasar and Troyer. This method yields that there were approximately 447 total cell phone-related pedestrian injuries in 2005 and 5,891 in 2010 (Table 4). To contextualize these findings, consider that the National Highway Traffic Safety Administration reported an estimated 24,000 injuries and 408 deaths associated with crashes by cell phone-related driver distraction in 2010.[86] Thus, while the number of cell phone-related pedestrian injuries appears to be growing, cell-phone related driver distraction unsurprisingly still has a more substantial overall impact on injuries and mortality.

The most recent data from the CDC (2015) reported 128,810 nonfatal and 5,719 fatal unintentional traffic-related pedestrian injuries in the US, while the number of fatalities rose to 6,348 in 2016.[85] It is unclear how many of these injuries and fatalities were associated with smartphone use. One notion remains certain: the paucity of high-quality data on the incidence of smartphone-related pedestrian injury warrants further research. In addition, more recent data is needed. Given the increasing trend of smartphone ownership, it is likely that the number of pedestrians injured due to smartphone-related distraction in 2017 was higher than that in 2011.

The mechanisms of injury from smartphone-related distracted ambulation have been largely established as being due to PMVT, falls, and walking into unseen objects.[5,6,8,20–22,24,25] However, there are no accurate studies of the distribution of injuries. Smith et al. reported that 78% of injuries were due to falls, 9% were due to walking into objects, and 4% due to PMVT.[6] However, given his decision to include falls at home as part of pedestrian injuries—and that such falls made up 52% of the total injuries in his cohort—it is likely that the frequency of falls is greatly overestimated and the frequency of other mechanisms is underestimated for pedestrians on roadways. Furthermore, the effect of distracted ambulation on injury risk and severity has not been quantified. More studies are needed to accurately describe the risk of injuries, distribution of injuries, and outcomes associated with distracted ambulation.

To date, the only intervention targeting distracted ambulation has been successful in educating but not in enacting behavioral change.[63] Given the lack of such studies in the literature, this review also examined the multiple studies evaluating interventions targeting distracted driving behavior. The Unni et al. study, which utilized a hybrid hospital-school approach, was the only one successful in enacting long-term behavioral change in high school drivers.[68] Future interventions against distracted ambulation may be more efficacious if they are modeled after this approach. Furthermore, given that the three TPB studies found subjective norm to be associated with distracted ambulation, future behavioral interventions should also aim to reduce perceived societal tolerance and acceptance of smartphone-related distracted ambulation.[17,18,62]

Given the dearth of laws against distracted ambulation, this study also reviewed evidence regarding the effectiveness of distracted driving laws. Several lessons from legislation and

TABLE 5. Summary of Findings and Recommendations

Objectives	Recommendations
• Smartphone-related distracted ambulation is not uncommon, associated with risky street crossing behavior, and increased risk of injury • Younger pedestrians are at greater risk • Relative rates of smartphone-related ambulation are increasing • There are no accurate estimates of the incidence of injuries and fatalities from smartphone-related distracted ambulation • Smartphone-distraction has well-established negative effects on gait and attention • Mechanisms of injury include pedestrian motor vehicle collisions, falls, and walking into objects • Patterns of injuries are unknown • "Selfies" have been linked to pedestrian fatalities and may be particularly distracting and hazardous • Motivations for texting and walking are associated with subjective norm • One behavioral intervention to date has been effective in educating but not effective in changing behavior • Two cities have passed legislation related to distracted street crossing	• Epidemiological research to understand scope of issue (injuries and fatalities) • Hybrid hospital-community interventions to target most vulnerable teenage and young adult population • Legislation banning smartphone-associated distracted ambulation during street crossing for pedestrians of all ages • Primary enforcement of such bans • Well-publicized, high visibility, targeted enforcement campaigns

enforcement targeting distracted driving may be learned for designing laws against distracted ambulation. Bans against distracted driving behaviors of all ages have been shown to be effective in reducing distracted behavior, while bans targeting specific age groups have not.[70–79] This is likely due to a difficulty in enforcing laws against a particular age group. Primary enforcement of driving laws appears to be more effective than secondary enforcement.[81–84] Finally, high-visibility, targeted enforcement has been shown to enact significant behavioral change in distracted driving behaviors.[87] Well-publicized, targeted enforcement campaigns have been crucial for success in other areas of public health. One example comes from efforts to improve seatbelt wearing compliance, where educational campaigns only marginally improved rates of wearing seatbelts; and, when legislation was first passed, compliance initially increased, but then faded over time. It was not until highly publicized and targeted enforcement campaigns, such as "Click it or Ticket", that high levels of sustained compliance were achieved.[74,75] Thus, future laws targeting smartphone-related distracted ambulation may consider banning smartphone-related distracted street crossing, be applicable to pedestrians of all ages, be enforced primarily, and be associated with well-publicized and visible targeted enforcement campaigns.

CONCLUSION

The observed rates of smartphone-related distracted street crossing, common mechanisms of injury, and the effects of texting and talking on gait and attention, are well established. However, there are no accurate estimates of the absolute number of injuries or fatalities associated with distracted ambulation. The increased risk of injury associated with smartphone-related distracted street crossing is unknown. While the mechanisms of injury from distracted ambulation have been described, it is unknown if the patterns of injuries for distracted pedestrians differ from those of pedestrians overall. Our cumulative findings and evidence-based recommendations for future interventions and legislation are summarized in Table 5. Clearly, there is much more work to be performed in understanding the magnitude of this problem and finding solutions to prevent injuries related to distracted ambulation.

AUTHORSHIP

C.S.G. provided substantial contributions to conception and design, acquisition of data, analysis and interpretation of findings, drafting the article and revising it critically for important intellectual content, and final approval of the version to be published. C.L. provided substantial contributions to conception and design, acquisition of data, analysis and interpretation of findings, drafting the article and revising it critically for important intellectual content, and final approval of the version to be published. M.V.DF. provided substantial contributions to conception and design, acquisition of data, analysis and interpretation of findings, drafting the article and revising it critically for important intellectual content, and final approval of the version to be published. D.L.M. provided substantial contributions to conception and design, acquisition of data, analysis and interpretation of findings, drafting the article and revising it critically for important intellectual content, and final approval of the version to be published. D.H.S. provided substantial contributions to conception and design, acquisition of data, analysis and interpretation of findings, drafting the article and revising it critically for important intellectual content, and final approval of the version to be published.

DISCLOSURE

There are no financial disclosures, commercial associations, or any other conditions posing a conflict of interest to report for any of the above authors.

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