Plight of the distracted pedestrian: a research synthesis and meta-analysis of mobile phone use on crossing behaviour

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► Additional material is published online only. To view please visit the journal online (http://dx.doi.org/10.1136/injuryprev-2019-043426).

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Received 16 August 2019
Revised 15 November 2019
Accepted 19 November 2019
Published Online First 3 February 2020

To cite: Simmons SM, Caird JK, Ta A, *et al*. *Inj Prev* 2020;**26**:170–176.

ABSTRACT

Background Pedestrians are commonly involved in vehicle collisions that result in injuries and fatalities. Pedestrian distraction has become an emerging safety issue as more pedestrians use their mobile phones while walking and crossing the street.

Objectives The purpose of this research synthesis and meta-analysis is to determine the extent to which cell phone conversation, text messaging or browsing, and listening to music affect a number of common pedestrian behavioural measures.

Methods A keyword search was developed with a subject librarian that used MeSH terms from selected databases including PsycINFO, SPORTDiscus, Medline and TRID. Supplemental searches were also conducted with Google Scholar and Mendeley.

Effect size coding Thirty-three studies met inclusion criteria and were subjected to data extraction. Statistical information (ie, *M, SD, SE, 95% CI, OR, F, t*) was extracted to generate standardised mean difference effect sizes (ie, Cohen's d) and *r* effect sizes.

Results Fourteen experimental studies were ultimately included in an N-weighted meta-analysis (*k*=81 effect sizes), and eight observational studies were included in a qualitative overview. Both mobile phone conversation and text messaging increased rates of hits and close calls. Texting decreased rates of looking left and right prior to and/or during street crossing. As might be expected, text messaging was generally found to have the most detrimental effect on multiple behavioural measures.

Limitations A variety of study quality issues limit the interpretation and generalisation of the results, which are described, as are future study measurement and methods improvements.

INTRODUCTION

Worldwide, approximately 270 000 pedestrian deaths occur each year, which is about one-fifth (22%) of all road traffic fatalities.[1] In Canada, pedestrians as a category of vulnerable road users accounted for 14.3% of serious injuries and 16.9% of fatalities in 2017.[2] In the US, 5987 pedestrians were killed in crashes in 2016 based on Fatal Analysis Reporting System (FARS) data.[3] The number of pedestrian deaths has increased to the highest recorded number since 1990. From 2012 to 2017, the number of pedestrians that have died each year in the US, and the percentage of road traffic fatalities that are pedestrians, has increased.[3 4]

Pedestrian contributions to vehicle collisions may include consuming alcohol or drugs, walking at night with insufficient conspicuity, running into the road and failing to yield to vehicles.[3 5] Pedestrian distraction has become an emerging safety issue as more and more pedestrians use their smart, mobile or cell phones while walking and crossing the street.[6] Observations of pedestrians crossing streets in cities around the world indicate that pedestrian distraction from mobile phones is an immediate and common problem. The percentage of observed distracted pedestrians crossing streets ranges from about 12% to 45% and tends to vary by country, city, traffic controls, observation date and time, and pedestrian age and sex.[7–15] Pedestrian injuries resulting from using cell phones and wearing headphones to listen to music appear to be rising.[16–20] For example, Nasar and Troyer[19] found that 1506 visits to the emergency department in 2010 were associated with mobile phone use in public places, based on data from the National Electronic Injury Surveillance System for the years 2004–2010. Over this span of time, injuries, such as walking into a pole and tripping and falling, increased from 0.4 % to 3.7 % of pedestrian injuries, and injury rates were higher for males and those under 30 years of age. When extrapolated to the US population, an estimated 2 million pedestrian injuries were related to cell phone use, which does not take into account exposure or under-reporting. Based on FARS data from 2008 to 2011, 23 fatal crashes were related to portable electronic devices. Injury and fatality estimates are fundamentally limited by pedestrian under-reporting of cell phone use and the inability of police to adequately identify that a cell phone was in use at the time of a collision. Although cell phone injuries may be increasing, evidence that pedestrian distraction is a major contributor to road traffic injuries and fatalities is limited.[18]

Teens and children may be at greater risk when distracted due to increased cell phone use and less experience with traffic. Observations of 34 325 teens crossing streets in school zones in 2013 indicated that about 1 in 5 high-school and 1 in 8 middle-school students were distracted.[21] Texting and wearing headphones were the most frequently observed activities (39% each) followed by talking (20%) and playing games (2%). Stavrinos *et al*[22] conducted a systematic review and meta-analysis of the effects of distraction on children and teens' distracted walking, bicycling and driving. After a comprehensive search, four studies were identified that specifically examined children's distracted walking using experimental methods in virtual environments[23–26] and one study used observational methods.[27] Qualitatively, youth pedestrians (aged 17–25) tended to wait longer to cross the street when distracted, missed more opportunities to cross,[23] and walked more slowly than when not distracted.[25] Quantitatively, the combined effect size for two studies involving 103 children talking while crossing on rates of hits and near misses (ie, close calls) was small with significant heterogeneity. Only one study examined children interacting (eg, texting, browsing) with a cell phone and it produced a moderate effect size for hits and near misses. While the Stavrinos *et al*[22] synthesis is important in understanding the effects of children's cell phone use on street crossing safety, pedestrian ages across the life span and a range of behavioural measures are likely to more completely characterise the relation between pedestrian distraction and safety.

To date, more than 50 experimental and observational studies have investigated the effect of distractions on pedestrian walking and street crossing behaviour. The literature on this issue is mixed. For example, some studies report that pedestrians slow their walking speed when distracted,[11] but others do not.[13] Traditional literature reviews[6 28] and research synthesis[14] do not resolve conflicting results, which may be due to methodological, contextual or measurement differences. Meta-analysis combines the statistical results of included studies. The purpose of this meta-analysis is to quantitatively synthesise the effects of mobile phone conversation, text messaging or browsing, and listening to music on the behavioural measures of initiation duration, missed opportunities, crossing duration, looking left and right, and hits and close calls. Based on previous distracted driving meta-analyses, cell phone tasks that require prolonged visual attention, cognitive workload and manual interaction, such as texting or browsing the internet, were expected to affect more pedestrian crossing measures.[29–32] Cognitive tasks such as talking or listening to music were expected to affect fewer measures, but still show distraction costs relative to distraction-free comparison conditions.

METHODS

Inclusion criteria

Study designs, conditions

The literature search targeted experimental (ie, simulated street walking or crossing studies) and site observation studies and measures of the effects of secondary tasks on pedestrian behaviours. A contrast of experimental and site observation studies with respect to effect size magnitude was planned. For both study types, an undistracted baseline condition and at least one distraction condition (described below) was required. Reviews, policy studies, opinion pieces and prevalence studies were not eligible for inclusion.

Talking on a handheld or hands-free phone, texting or browsing on a handheld phone, and using earbuds or headphones to listen to music were required to be a condition in an included study. In addition, a non-distracted baseline condition where a participant walks without engaging in the secondary task was targeted for inclusion. If distraction conditions collapsed across two or more of these secondary task categories, the study was not eligible for inclusion.

Participants

There was no restriction on the age of participants eligible for inclusion in this synthesis. Most studies involved adults; however, as previously noted, a number of studies have focused exclusively on children. Effect sizes from all age groups were pooled. Pedestrians who belonged to specific clinical populations such as Alzheimer's or cerebral palsy were excluded. Studies that recruited both clinical participants and healthy controls were eligible for inclusion so long as relevant data were reported separately for each group, such that healthy control data could be extracted and included in the meta-analysis.

Measures

Studies that included at least one of five measures related to walking and street crossing were eligible for inclusion. These measures were initiation duration, missed opportunities, crossing duration, looking left and right, and hits and close calls. The definition of each measure is as follows:

- *Initiation duration:* a measure capturing the time taken to start walking or begin crossing. To qualify as *initiation duration*, the measure had to be an interval of time ending when the participant began to walk. However, the start of the interval could vary. For example, the interval could begin at the very start of the trial, at the onset of a green light, when the pedestrian arrived at the crossing location, or when the last or most recent vehicle passed a point perpendicular to the path of the participant. Some studies included multiple measures relevant to this category. When this occurred, multiple measures were aggregated.
- *Missed opportunities:* the number of safe crossing opportunities that the pedestrian could have taken but chose not to take.
- *Crossing duration:* the amount of time taken to cross a street or a specific area.
- *Looking left and right:* observed turns of the head towards the left and/or right. Head turns prior to initiating a crossing and during a crossing were pooled.
- *Hits and close calls:* hits and close calls included collisions between pedestrians and vehicles, and near misses between pedestrians and vehicles. Outcomes involving bumping into objects or other pedestrians were excluded.

Information sources and search strategy

A keyword search strategy was developed in consultation with a subject librarian. Keywords were chosen after testing a number of control variables and MeSH terms from selected databases, as well as reviewing authors' chosen keywords from a number of studies identified during a preliminary literature review. In addition, the keywords that the Stavrinos *et al* meta-analysis[22] used were included. The final search terms that were used can be found in S1 of the online supplementary material. A formal systematic search of PsycINFO, SPORTDiscus, Medline and TRID was conducted in June 2017. Additional supplemental searches for papers were conducted with Google Scholar, during full-text reviews (ancestry), and based on Mendeley email suggestions through October 2018.

Study selection and data synthesis

Study search and selection was conducted following Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines.[33] First, all identified studies were uploaded to Mendeley Desktop for sorting. After removing duplicate citations, two coders (SMS, AT) screened abstracts and removed any studies that were unrelated to the focus of the research synthesis. After the abstracts were screened, full-text papers and reports were obtained for the resulting set of studies and independently judged against the inclusion criteria. Some studies were flagged if certain aspects of the methods or measures were unclear and these studies were discussed. Disagreements about study eligibility for inclusion were resolved through discussion with a third coder (JKC).

Means, SD, SEs, 95% CIs, *F* statistics and *t* statistics, and ORs were extracted from included studies and stored in electronic spreadsheets. Standardised mean difference effect sizes were computed preferably from means and SD, which were extracted either directly or converted from SEs or 95% CIs.[34 35] If these data were unavailable, effect sizes were computed from *F* and *t* statistics or converted from ORs.[34] Standardised mean difference effect sizes were converted to *r*. These *r* effect sizes were meta-analysed using a macroenabled spreadsheet called *Meta-Excel* (provided by Dr. Piers Steel; unreferenced).

Subgroup and publication bias analyses

One subgroup analysis and one meta-regression were planned. The purpose of the subgroup analysis was to test whether experimental and site observation studies differ in effect size magnitude. However, due to difficulties in extracting data from observational studies, we later elected to quantitatively synthesise experimental studies and qualitatively synthesise observational studies (see the *Included studies* section). A metaregression was planned to test the potential for publication bias, with *N* (a proxy for precision) set as predictor, *r* (effect size) set as criterion and inverse sampling error as the weight.[36] This weighted-least-squares regression tests whether there is a significant inverse relationship between sample size and effect size, such that smaller and less precise studies yield larger effect sizes. If statistically significant, then there is reason to believe that the meta-analysed effect size is inaccurate, possibly due to a bias against publishing studies reporting a particular result.

RESULTS

Included studies

The identification, screening, eligibility and inclusion phases of the database search, including reasons for exclusions, are shown in S2 of the online supplementary material. The search yielded 1813 citations. Of these, 33 met inclusion criteria. Numerous studies did not adequately report results in a form that allowed effect sizes to be calculated. For example, experimental studies lacked SEs, SD, F statistics or df. Observational studies did not report relationships between talking, texting or listening to music with pedestrian behaviours, or relationships were reported in multivariate models. Unfortunately, the inability to extract statistical data for effect size calculations precluded the generation of a meta-analysis specifically for observational studies. A qualitative summary of observational study results is provided in place of a meta-analysis and appears below.

For experimental studies, 14 studies,[23 24 26 37–47] which contained 17 experiments, were ultimately included in the meta-analysis (see S3 of the online supplementary material). This meta-analysis represents 872 pedestrians, of which approximately 39% were male (n=820). One study did not report the number of males included. The sample includes children and adults of all ages. The mean age of participants was 21.5 years (n=808). Two studies did not report participant age. The details of the included studies appear in S3 of the online supplementary material. The typical included study used a simulation system that comprised a curb-like platform or a treadmill integrated into a graphics computer with a projection system. Participants were instructed to perform multiple street crossings safely while engaged and not engaged in various cell phone activities.

Meta-analysis of experimental studies

A total of 81 effect sizes were extracted and used to compute an *N*-weighted meta-analysis. The results of the meta-analysis of experimental studies are listed in table 1. Effect sizes (r) are used to present results and are described as small, moderate and large in accord with Cohen's terms.[48]

Initiation duration

Both talking on a cell phone and texting or browsing on a cell phone were associated with small (*r*=0.25) and moderate (*r*=0.32) increases in initiation duration, respectively. Pedestrians who engage in these types of cell phone tasks tend to wait longer before crossing the street. However, listening to music was not associated with a significant change in initiation duration (*r*=0.09, 95% CI −0.09 to 0.26).

Missed opportunities

Talking on a cell phone was also associated with slightly more missed safe-crossing opportunities (*r*=0.17). However, texting or browsing did not have a statistically significant (*r*=0.18, 95% CI −0.09 to 0.46) or generalisable (95% credibility interval (CrdI) −0.14 to 0.51) effect. The CrdI indicates that the overall effect of texting or browsing on missed opportunities to cross is variable. The CrdI, which crosses 0, ranges from slightly fewer missed opportunities to many missed opportunities. The large range of the CrdI indicates that a number of moderating factors are likely present.[49] Listening to music did not have a statistically significant (*r*=−0.03, 95% CI −0.47 to 0.41) or generalisable (95% CrdI −0.39 to 0.33) effect on missed safe-crossing opportunities. The CrdI also crosses 0 and is relatively wide.

Crossing duration

None of the cell phone tasks were associated with a statistically significant change in crossing duration (*r*=0.14, 95% CI

Table 1 Results of the meta-analysis of experimental studies for measures and distraction (ie, distracted–undistracted) conditions

					95% CI		95% CrdI	
Variable	k	N	r	d	L	U	L	U
Initiation duration								
Talking*	9	306	0.25	0.51	0.14	0.35	0.25	0.25
Texting/browsing*	5	216	0.32	0.68	0.16	0.49	0.07	0.58
Music listening	5	126	0.09	0.17	−0.09	0.26	0.09	0.09
Missed opportunities								
Talking*	6	316	0.17	0.34	0.06	0.28	0.17	0.17
Texting/browsing	2	153	0.18	0.37	−0.09	0.46	−0.14	0.51
Music listening	1	65	−0.03	−0.06	−0.47	0.41	−0.39	0.33
Crossing duration								
Talking	6	149	0.14	0.28	−0.02	0.30	0.14	0.14
Texting/browsing	3	96	0.01	0.02	−0.19	0.21	0.01	0.01
Music listening	4	98	0.01	0.03	−0.19	0.22	0.01	0.01
Looking left and right								
Talking	11	473	−0.14	−0.29	−0.36	0.08	−0.80	0.52
Texting/browsing*	5	245	−0.43	−0.94	−0.67	−0.19	−0.91	0.06
Music listening	6	191	0.05	0.11	−0.09	0.20	0.05	0.05
Hits and close calls								
Talking*	10	465	0.17	0.34	0.12	0.22	0.17	0.17
Texting/browsing*	4	217	0.34	0.73	0.23	0.46	0.34	0.34
Music listening	4	137	0.18	0.37	−0.12	0.49	−0.32	0.69

*Confidence interval does not cross zero.
CrdI, credibility interval; d, Cohen's d-effect size transformed from r; k, number of datapoints; N, total number of participants; r, weighted mean correlations.

−0.02 to 0.30, talking; r=0.01, 95% CI −0.19 to 0.21, texting/browsing; r=0.01, 95% CI −0.19 to 0.22, music).

Looking left and right

Texting or browsing significantly reduced participants' looks to the left and right before and/or during crossing (r=−0.43). However, talking on a cell phone and listening to music did not (r=−0.14, 95% CI −0.36 to 0.08, talking; r=0.05, 95% CI −0.09 to 0.20, music).

Hits and close calls

Talking on a cell phone was associated with a small increase in rates of hits and close calls (r=0.17), and texting or browsing was associated with a moderate increase in rates of hits and close calls (r=0.34). Listening to music did not have a statistically significant (r=0.18, 95% CI −0.12 to 0.49) or generalisable (95% CrdI −0.32 to 0.69) effect on hits and close calls. The width of the CrdI indicates that the effect of music was highly variable.

Publication bias

A low number of studies may contribute to each meta-analytic comparison, which is a meta-analytic limitation. A general guideline states that at least ten studies are required to assess publication bias for any given comparison.[50] Based on this criterion, only 2 of the 15 comparisons could be tested for publication bias using metaregression, and both distraction conditions involved conversation. Results were computed using a multiple comparisons p value of 0.025. There was no evidence of publication bias for either *looking left and right: conversation* [F (1, 9)=0.519, p=0.490] or *hits and close calls: conversation* [F (1, 8)=1.942, p=0.201].

Qualitative overview of observational studies

Results from observational studies were qualitatively summarised. A number of statistical, measurement and reporting issues of screened observational studies prevented meta-analysis. A total of eight studies[11 27 51–56] met inclusion criteria and are qualitatively analysed (see S2 and S4 of the online supplementary material). In the typical observational study, pedestrians were observed at multiple crossings by multiple observers who coded behaviour immediately or coded behaviour from digital video. Common observational codes included crossing locations, type of pedestrian distraction, age and gender of pedestrian, crossing alone or in a group, pedestrian volumes and various measures such as looking left and right, clearance times and walking pace. Four studies were conducted on university campuses[51 53 54 56] while three studies collected observations in larger cities (ie, Belgrade, Seattle, Sydney).[11 27 55] Across studies, the types of distraction observed included talking, texting, socialising, listening to music and 'other' categories. Listening to music may have also included talking over the earbuds, not listening to a source at all or listening to a podcast. Common results indicated that distracted pedestrians looked less at vehicles before and during crossing.[11 27 54 55] Unique observations of pedestrian behaviour while distracted across studies were common. Across studies, the percentage of pedestrians distracted ranged from 12%[52] to 45%.[53]

Measurement, methods and statistical analysis varied appreciably across studies. Observed crossing behaviour was affected by a variety of environmental and individual variables including: gender, time of day, lone or group crossing, presence of approaching cars, type of crosswalk, signal timing, signal phase and walking speed. The representativeness of observational samples compared with pedestrian populations who use a crossing across time of day and over seasons was a fundamental limitation.[52]

DISCUSSION

The experimental effects of mobile phone conversation, texting or browsing, and listening to music on the behavioural measures of initiation duration, missed opportunities, crossing duration, looking left and right, and hits and close calls were meta-analysed. As expected, texting or browsing had the most detrimental effects on hits and close calls and looking left and right. Texting requires a pedestrian to repeatedly divert their eyes away from the walking environment and traffic, towards the screen of the phone, to type and read messages. Browsing requires repeated device interactions and information scanning. If pedestrians do not look left and right when crossing a street, detection of vehicles likely also decreases. The extent to which reductions in head turning necessarily translate into greater real-world crash risk, however, is still largely unknown. Texting and browsing affected crossing duration and missed opportunities to a lesser degree. In the driving distraction literature, texting produced the highest rates of crashes and near crashes[31 57] and performance costs to hazard response times and lateral and longitudinal vehicle handling.[29]

Pedestrians who engage in cell phone conversation, compared with those who do not, tend to wait longer to start crossing the road, may miss more safe crossing opportunities and may be involved in more hits and near misses. Listening to music did not produce performance decrements for any of the measures examined in this meta-analysis. The generalisability of these risky behaviours to pedestrian safety is limited because these measures, despite their frequent use within the experimental and observational literature, require validation against real-world collision or conflict involvement. While *driving*, conversation on a mobile phone produced modest increases in crash and near crash rates[57] and moderate driving performance costs to reaction times and crashes.[30]

Study limitations

Several measurement validity issues were identified. First, site observation studies observed using headphones or earbuds, which was assumed to be listening to music. It is possible that pedestrians who wore headphones or earbuds may have been walking in silence or listening to music or podcasts. Active listening that requires the construction of a narrative may require greater processing resources than passive listening to ambient music. The exact nature of the pedestrian auditory stimulus in observational studies is unknown. Second, turning the head to the left and right is assumed to be a positive safety behaviour. Turning the head in the direction of a hazard does not necessarily correspond to looking at or seeing a hazard, such as approaching vehicles. In addition, pedestrians may scan left and right with their eyes, which cannot be observed without eye tracking. Within the distracted driving literature, visual scanning of the traffic environment is affected by the types of distraction tasks engaged in by drivers.[30] Cognitive tasks such as conversation may limit scanning to the periphery, whereas visual-manual tasks such as texting cause gaps in hazard detection and environmental awareness as drivers look away from the roadway. The use of eye-tracking methods to determine where pedestrians look while crossing a street while distracted is needed.[38 58 59]

Researchers who examine pedestrian distraction need to agree on the meaning and interpretation of measures. Current measures of pedestrian safety may be indicative of compensatory behaviours that may improve safety such as walking behind a group of pedestrians while texting, while others are clearly detrimental to safety such as stepping in front of an oncoming vehicle. Other measures such as observed delays in initiating crossing the street have been interpreted as risky behaviour,[23] whereas the same behaviour could be considered as compensatory because a delay in street crossing prevents exposure to crossing vehicles.[41] Other measures including crossing duration and missed opportunities can be interpreted as having safety-positive or safety-negative effects, depending on the overall pattern of findings across measures included in a study. Behaviours that prevent or increase exposure to vehicle threats require validation against real-world crashes, including near misses from distracted drivers. The validity of hits and close calls obtained in a virtual environment needs to be confirmed in actual traffic environments. The ethics of putting pedestrians into potential collision events versus the non-consequences of a video game-like environment requires further validation and consideration.

Future research

Given the ubiquity of smartphones, social media, apps, digital video and streaming music, which has infiltrated most aspects of daily life, distracted walking and street crossing will be a road safety issue for the foreseeable future. Establishing the relationship between distracted walking behaviour and crash risk is an essential research need. Additional analyses of serious injuries and the extent that underreporting is an issue is needed before the inference that pedestrian distraction leads to numerous road traffic injuries and deaths can be made. Knowledge about the extent that pedestrian injuries and fatalities occur in lower and middle income countries is needed.[1] The interaction of contributory factors to pedestrian–vehicle collisions such as crossing at night, midblock in the rain while texting requires more in-depth investigation. A variety of compensatory behaviours by pedestrians and drivers likely avert many potential collisions. Do groups or packs of pedestrians shield those among them who are distracted or do groups assume that other group members are paying attention?[6 10 54] In addition, are children and teens more at risk while distracted?[19 22] Are elderly pedestrians who are distracted and slower more prone to conflicts with vehicles?[52]

Being distracted while walking leads to variability in gait kinematics. A body of research on the effects of distractions on gait parameters was not included in the present meta-analysis because gait parameters measured on a treadmill or while walking down a hallway are not directly related to street crossing. Nevertheless, other researchers may consider synthesising this active body of research because the use of the hands to stabilise a phone affects balance and coordination of pedestrians that range in age and mobility capability. In general, pedestrians who texted or conversed tended to walk slower, looked down at their phones, looked less at the roadway and stepped more cautiously.[58 60 61]

If vision guides locomotion and glances to the environment are curtailed by looking away during typing and texting, some aspects of the environment may be missed completely while others may be looked at, but insufficiently processed. Inattention blindness or 'looked, but failed to see' is characterised by an inability to see obvious objects and events while engaged in absorbing tasks.[62–66] Some researchers attribute inattention blindness to pedestrians and drivers engaged in secondary tasks who do not see obvious hazards that are present in the visual field such as clowns riding unicycles or money growing on trees.[63 64] Pedestrian hazard detection and response measures to safety-critical stimuli or events such as vehicles failing to obey stop signs or other pedestrians disobeying crossing signals could be included in future research. Pedestrian hazard detection may also include street furniture, curbs, other pedestrians, pets or even overhead hazards.

Policy, engineering and environmental suggestions for prevention and mitigation of distracted walking abound.[18 21 43 67] Proposed solutions include e-walking lanes, traffic tickets+enforcement, wrapping poles with padding, having mobile phones alarm when at crossings, taking personal responsibility for not being distracted and restricting exposure to vehicles. Signs[14] and a public awareness intervention[68] were found to be ineffective at changing distracted pedestrian behaviour. Evaluation of interventions that promise to change behaviour over time is needed such as vehicle speed reduction at crossings with additional infrastructure protection.

What is already known about this subject?

- Pedestrian injuries and fatalities may result from a variety of risk-taking behaviours.
- Mobile phone use has become increasingly identified as a contributor to pedestrian injuries.

What does this study add?

- This study meta-analysed experimental studies where a number of mobile phone tasks were related to common pedestrian behavioural measures.
- Talking and texting or browsing decreased the frequency of looking left and right before and during crossing.
- Pedestrians who were talking or texting had higher rates of near misses with vehicles than those who were not engaged in these tasks.
- In general, texting negatively affected more behavioural measures than other distraction tasks.

Acknowledgements The authors would like to thank Laura Koltutsky for assisting in the development of the search strategy and Dr. Piers Steel for reviewing an early version of the manuscript.

Contributors JKC proposed the research project and edited the manuscript and the synthesis of observational studies. SMS conducted a preliminary literature review and refined the research method for the current manuscript. SMS conducted the meta-analysis of experimental studies and wrote the first manuscript draft. SMS, in consultation with a subject librarian, developed a search strategy and conducted the electronic search. SMS and AT conducted study selection (ie, abstract screening, full-text review). SMS extracted data, and AT and FS double checked the extracted data for accuracy. FS conducted the synthesis of observational studies (see supplementary materials). BEH provided critical review of the manuscript for important intellectual content. All authors approved the final version of the manuscript.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None declared.

Patient consent for publication Not required.

Provenance and peer review Not commissioned; externally peer reviewed.

Author note * Indicates experimental study included in the meta-analysis and # indicates an observational study that was included in the qualitative summary.

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