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Pedestrian Safety and Distraction: A Contemporary Perspective

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Abstract

The present study, conducted in accordance with the PRISMA guidelines, aims to provide a contemporary perspective on the issue of pedestrian safety and distraction. The review was conducted using a systematic search strategy and included studies published between 2005 and 2022. A total of 250 studies were identified from the literature search on Google Scholar, EBSCO, Scopus, Web of Science etc., from which 30 studies were scrutinized for the final comprehensive study. The five study components considered for categorizing research papers were the frequency of mobile phone distraction, observational sites, performance measures, analysis methodologies, and other features related to mobile phone use among pedestrians. Most of the investigations were conducted in China and Australia. Numerous studies have examined factors like age and gender that may affect pedestrian behavior. The highest numbers of studies were conducted in 2022, 2021, and 2019, while the fewest studies were conducted in 2005, 2007, 2008, 2015, and 2017. Road junctions were the most common observation sites. Regression analysis was the primary method used in most of the studies. The review highlights the need for further research on this topic, particularly in the context of emerging technologies and changing pedestrian behaviors. Overall, the study emphasizes the importance of continued efforts to raise awareness and improve pedestrian safety in an increasingly distracted world.

Keywords

distracted pedestrians, crossing behavior, mobile phone, pedestrian safety

1 Introduction

With a total of 1.35 million fatalities each year, road traffic accidents are one of the main causes of human death globally (WHO, 2018). Pedestrians are involved in about 25% of road deaths, which equates to approximately 273,000 pedestrian fatalities each year worldwide, accounting for around 22% of all traffic deaths (WHO, 2004; WHO, 2018). Vulnerable road users, such as cyclists, motorcyclists, and pedestrians, are responsible for more than half of all accidents. Road traffic injuries are the leading cause of death among children and young adults aged 5 to 29, with 93% of all traffic fatalities occurring in low- and middle-income countries. In the United States, 16% of all traffic deaths in 2016 involved pedestrians (Retting, 2017), while in Australia, pedestrians accounted for approximately 14% of road deaths between 2003 and 2012, with 160 pedestrian fatalities reported in 2017 and 174 in 2016 (BITRE, 2017; Williamson and Lennon, 2015). Distraction, particularly from cell phone use, has become a problem for pedestrian safety, with road accidents now ranking as the eighth leading cause of death globally, surpassing diseases like tuberculosis, diarrhea, and HIV/AIDS. The highest road traffic death rates are found in Africa (26.6/100,000) and the lowest in Europe (9.3/100,000). Depending on the location of the study, it has been estimated that between 5% of pedestrians may be distracted when crossing the street (Kadali and Vedagiri, 2016a; Kadali and Vedagiri, 2016b; Kadali and Vedagiri, 2016c; Simmons et al., 2020). Road traffic accidents occur more frequently in developing countries than in industrialized ones.

Pedestrian safety is a global issue of great concern. With the rapid increase in motorization and urbanization, pedestrian accidents have become a major cause for alarm. Pedestrian distraction is one of the primary reasons for pedestrian accidents. The advent of smart-phones, tablets, and other digital devices has significantly increased the number of distracted pedestrians. In addition to digital

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devices, other factors such as speeding, visual clutter, and environmental distractions also contribute to pedestrian accidents. This study aims to provide a contemporary perspective on pedestrian safety and distraction, focusing on the current research in this area.

The literature review study aims to provide a contemporary perspective on pedestrian safety and distraction, focusing on current research in this area. The review also seeks to identify gaps in the existing literature and suggest areas for future research. To achieve these objectives, a systematic review of the literature was conducted following the PRISMA guidelines. The search was carried out using various electronic databases, and the final sample included 30 research papers from different countries. The papers included in this review were published between 2005 and 2022 and were limited to peer-reviewed journal articles. Technical reports, conference papers, book chapters, and commentaries were not included in the review. Overall, this literature review paper provides a contemporary perspective on pedestrian safety and distraction. The study highlights the need for more research on pedestrian behavior and distraction, particularly in developing countries. It also emphasizes the need for more research into the impact of external stimuli and visual clutter on pedestrians' behavior and attention. Finally, the study calls for more research on the efficiency of audio and visual pedestrian warnings in an environment where they are obstructed out by broadband noise.

1.1 Pedestrian fatalities in developing countries

It is further noted that low-income nations have the highest rates of fatal traffic accidents. Nearly 85% of all traffic-related fatalities globally are believed to occur in low- and middle-income (LMIC) nations. The average fatality rate was found to be 17.4/100,000 individuals. The annual road traffic fatality rate was highest in low-income countries (24.1/100,000), while it was lowest in high-income countries (9.2/100,000). According to Ministry of Road Transport and Highways (MoRTH) report in 2020 (MoRTH, 2020), total of 412,432 accidents occurred, resulting in 153,972 fatalities and 384,448 injuries. The age group most seriously affected by road accidents is 18–45 years, accounting for 67% of total accidents. According to World Bank data from 2019 (World Bank, 2019a; World Bank, 2019b; World Bank, 2019c), India ranked first in road accidents among the top 20 countries for road accidents. The MoRTH report (MoRTH, 2020) noted that 17.8% of pedestrians were killed in road accidents. Between 2007 and 2017, the overall mortality toll from traffic accidents rose by 31%, while the number of fatal crashes increased by 25.6% during the same period. In 2016, 15,746 pedestrians were killed in traffic accidents, up from 13,894 in 2015, accounting for 10.5% of all traffic fatalities. This indicates an 11.7% rise in pedestrian fatalities compared to the previous year. Among all pedestrian fatalities in traffic accidents, 60% occurred in cities, and 85% of these incidents took place at crosswalks, indicating frequent pedestrian-vehicle confrontations at crossing locations. However, in large cities with populations over 5 million, such as Bangalore, Chennai, Delhi, Hyderabad, and Mumbai, there was a significant decline in pedestrian fatalities by approximately 30%. Increased traffic congestion in these places has forced drivers to slow down, reducing the overall accident rate. Despite the decline in overall fatalities, the total number of pedestrians, cyclists, and motorized two-wheeler riders killed on roads in these five major cities remains concerning. There are various distractions that affect pedestrian safety, including mobile phones, handheld devices, and auditory and visual distractions from the use of headphones, earphones, and Bluetooth devices. Other distractions include walking in groups and signal violations. Nowadays, people use iPads, smart watches, and other digital gadget, engage in texting, listening to music, and gaming while crossing roads. This leads to delayed crossing times, reducing crossing speed due to distraction. Additionally, pedestrians are distracted by the overloading of their belongings. Historically, there has been limited literature on distracted pedestrians, with most studies focusing on mobile phone distractions and distractions from digital devices (Arafat et al., 2023; Hasan and Hasan, 2022; Pawar and Yadav, 2022; Simmons et al., 2020). Stoker et al. (2015) reviewed pedestrian safety and risk factors associated with pedestrian distraction, while Ridel et al., (2018) reviewed pedestrian behavior in urban scenarios. The present study is novel in many ways compared to previous systematic literature reviews on this topic. Few studies have explored overall pedestrian distraction from factors other than digital devices. Therefore, this study will investigate other factors that contribute to pedestrian distraction. This study includes literature from 30 research papers, covering signalized and unsignalized intersections, mid-block crossings, railway crossings, and T-intersections. The literature considered studies from 2005 to 2022, offering insights into behavioral changes due to modern technologies and advancements. Research from more than 10 countries have been included, representing both developed and developing countries. Through this study, we aim to answer the following key questions:

1. How many studies have been conducted in different years?
2. Which countries have been included in the studies?
3. What data analysis techniques have been used?
4. What methods were used for data collection?
5. What is the proportion of distracted pedestrians in various studies?
6. What performance measures have been considered in numerous studies?
7. What different models have been used to understand the behavior of distracted pedestrians?

The scope of this study includes literature published in English and focusses solely on peer-reviewed journal articles. Technical reports, conference papers, book chapters, viewpoints, letters, comments, and commentaries were excluded from the review. Most studies consider either qualitative or quantitative parameters, and very few incorporate both.

2 Methodology

2.1 Systematic literature review

This systematic review included studies published up to 2022. Peer-reviewed research papers were sourced from Google Scholar, Web of Science, EBSCO, and Scopus databases. In addition to the key word "distractions", the literature search included terms such as "mobile phones", "cell phones", "speaking", "SMS", "listening to music", "digital distractions" and "social distractions". Other keywords used included "distracted street crossing", "walking distractedly", and "street crossing". The review followed the PRISMA (Priority Reporting Elements of the Systematic Review and Meta-Analysis) guidelines to ensure a thorough and systematic analysis of the literature. Studies were identified through the electronic database searches, as illustrated in Fig. 1. A combination of keywords such as "pedestrian distraction", "pedestrian crossing behavior", "pedestrian safety", "distracted pedestrian", was used to identify the relevant studies. A total of 250 publications were found during the search. Google Scholar yielded the largest number of papers, followed by library database and EBSCO as presented in Fig. 1.

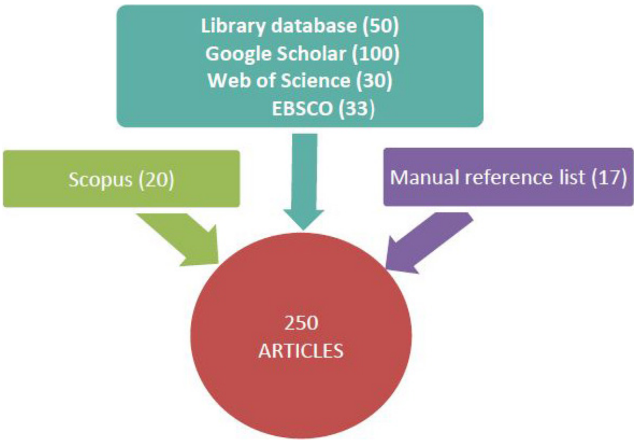

Fig. 1 Distribution of studies taken from different databases

2.2 PRISMA guidelines and PRISMA flow diagram

The present study conducts a comprehensive review of the literature on the utilization of pedestrian facilities, with a focus on the qualitative, quantitative, and combined factors as well as crossing behavior. The flow diagram illustrating the literature search framework, following the PRISMA methodology, is presented in Fig. 2. A total of 250 research records were identified through the database searches. After removing duplicates, 150 articles remained. The titles of these articles were screened, leading to the elimination of 50 articles. Based on their abstracts, the remaining 100 publications were further evaluated, resulting in the exclusion of 60 records. A comprehensive analysis was conducted on the 40 remaining publications, and the final systematic review included 30 research articles. The review only considered researches that were written in English. Additionally, only peer-reviewed journals

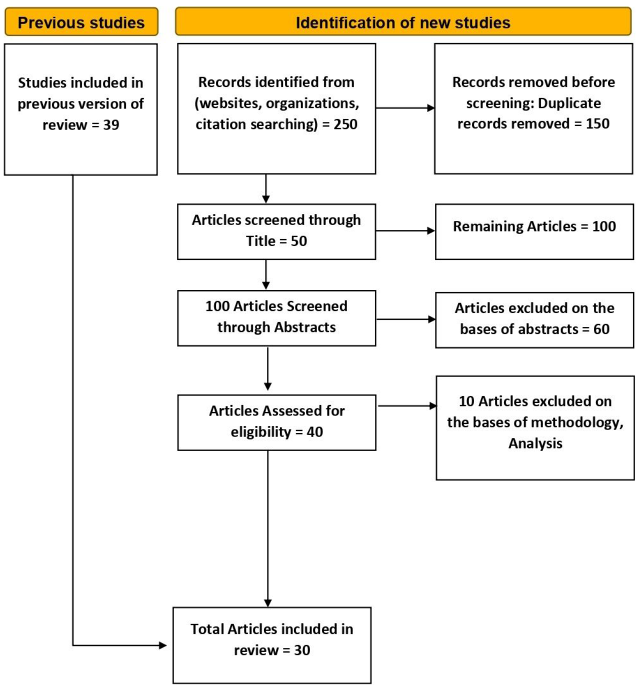

Fig. 2 PRISMA flow diagram

were included, while conference papers, technical reports, book chapters, viewpoints, letters, opinions, and comments were excluded. The systematic review focused specifically on the pedestrian distraction, covering studies conducted in both virtual environments and laboratories, as well as research based on surveys.

3 Literature review

3.1 Distribution of studies by year

A breakdown of the study results by year revealed that the topic has gained significant importance in recent years. Most of the research was conducted in 2022, 2021 and 2019, while fewer studies were available in 2005, 2007, 2008, 2012, 2013, 2015 and 2017. An average number of studies were conducted in 2016 and 2020 (Fig. 3).

3.2 Distribution of studies by countries

The country-by-country distribution of research (Fig. 4) reveals that most studies were conducted in the USA (Gillette et al., 2016; Mohammed, 2021; Nasar et al., 2008; Russo et al., 2021; Schwebel et al., 2012), Australia (Hatfield and Murphy, 2007; Horberry et al., 2019; Larue and Watling, 2022; Osborne et al., 2020), and China

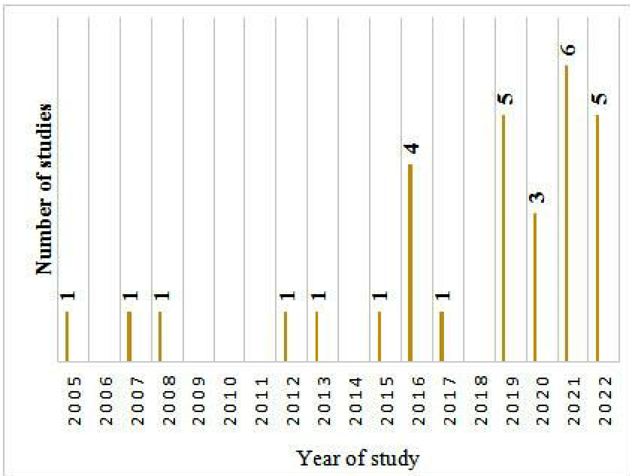

Fig. 3 Distribution of studies by year from 2012 to 2022

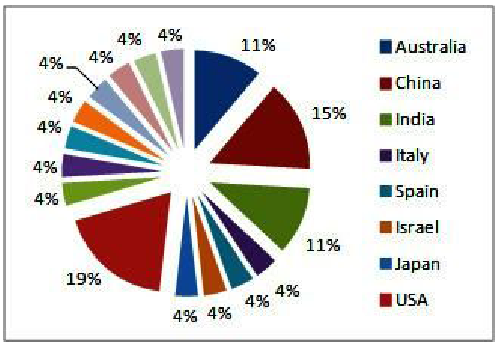

Fig. 4 Presents country-wise distribution of studies

(Hou et al., 2021; Zhou et al., 2019). An average number of studies were conducted in India (Raoniar and Maurya, 2022) and Vietnam. Fewer studies were conducted in Iran, Qatar, Taiwan, Columbia, UK, Mexico, Serbia, US, Japan, Spain, Italy, and Israel.

3.3 Overall literature review

Table 1 presents the study locations of various literatures. Some studies were conducted at signalized intersections (Gruden et al., 2021; Hatfield and Murphy, 2007; Horberry et al., 2019; Larue and Watling, 2022; Muley et al., 2017; Nasar et al., 2008; Truong et al., 2022; Zhou et al., 2019), unsignalized intersections (Gillette et al., 2016; Gruden et al., 2021; Hatfield and Murphy, 2007; Horberry et al., 2019; Mukherjee and Mitra, 2020; Pešić et al., 2016), T-intersections (Bungum et al., 2005; Muley et al., 2017), roundabouts (Zareharofteh et al., 2021), mid-block intersections (Ferenchak, 2016; Mohammed, 2021), railroad crossings (Russo et al., 2021), and linear segments of sidewalks (Gruden et al., 2021). Additionally, some observational and experimental studies were conducted in virtual environments (Byington and Schwebel, 2013; Campisi et al., 2022; Osborne et al., 2020; Tapiro et al., 2020; Tian et al., 2022; Truong et al., 2019; Zaki et al., 2016).

3.3.1 Location-wise distribution of studies

Truong et al. (2022) covered seven types of intersections, signalized and unsignalized, including 2 linear sidewalk segments, 3 pedestrian signalized crossings, and 3 unsignalized crossings (Gruden et al., 2021). In Bangalore, Karnataka, India, four different midblock crossings were studied (Ferenchak, 2016). Schwebel et al. (2012) surveyed media use at a university, while Muley et al. (2017) examined a signalized T-intersection. Russo et al. (2021) focused on two highway railroad grade crossings in Arizona. This study aims to encompass various potential study sites to better understand distracted pedestrian behavior.

3.3.2 Observation-wise distribution of studies

Truong et al. (2022) collected data over a 2 h period (4–6 p.m.) from April to June 2019 during the afternoon peak. Larue and Watling (2022) estimated that the average afternoon peak period to be 1 h and 10 min. Nasar et al. (2008) gathered data during the first two weeks of March 2005, from noon to 2 p.m. Raoniar and Maurya (2022) considered non-peak hours from 10 a.m. to 2 p.m. on a weekday (September 11, 2018) in sunny, dry weather conditions. Data collection in Washington, DC

Table 1 Summary of the various research studies

S. No.	Author	Country	Location for study	Observation period	Number of pedestrians seen
1	Truong et al. (2022)	Hanoi, Vietnam	Seven signalized and un-signalized intersections	April to June 2019. 2 h period (4:00 p.m. – 6:00 p.m.) of the afternoon peak	731
2	Larue and Watling (2022)	Brisbane, Australia	5 Australian level crossings and a signalized road intersection	1 h 10 min on average during the afternoon peak times	585
3	Tian et al. (2022)	Tokyo, Japan	In virtual environment	Not available	60 participants in 60 min
4	Raoniar and Maurya (2022)	Kolkata, India	Dalhousie Square (Site 1), 818 in BB Ganguly Street (Site 2), and 624 in General Post Office (Site 3)	10:00 a.m. to 2:00 p.m. (non-peak hours) for a weekday (Tuesday, September 2018) during bright, dry weather conditions	2360
5	Campisi et al. (2022)	Enna, Sicily	Urban location of Enna city in the center of Sicily (Italy)	08 March 2021 - 14 March 2021 08:30 a.m. and 09:30 p.m.	Not available
6	Gruden et al. (2021)	Maribor, Slovenia	3 unsignalized crossings, 3 signalized pedestrian crossings, and 2 linear segments of the sidewalk	Not available	Not available
7	Useche et al. (2021)	Spain	17 regions of Spain, responding to an electronic questionnaire, were analyzed	Not available	1,070
8	Hou et al. (2021)	China	10 provinces in China Online questionnaire	Not available	387
9	Liu et al. (2021)	China and Canada	Three locations in China and Canada using videography	42 h over four days in April 2016 and May 2018	781
10	Mohammed (2021)	USA	23 midblock crossings in three cities of Oregon: Albany, Corvallis, and Eugene	95 h during daytime.	1,045
11	Zareharofteh et al. (2021)	Iran	17 sites including intersection, roundabouts, streets	(08:00 a.m. – 09:00 a.m., 11:00 a.m. – 12:00 p.m. 01:00 p.m. – 02:00 p.m., and 04:00 p.m. – 05:00 p.m.) in May and October 2017	391
12	Osborne et al. (2020)	Melbourne, Australia	5 Central Business District (CBD) locations and two inner suburban locations	Weekdays during business hours. Each interview took 5 min	84
13	Mukherjee and Mitra (2020)	Kolkata, India	55 sites of Kolkata	Peak hours (10:00 a.m. – 12:00 p.m. or 5:00 p.m. – 6:00 p.m.) off-peak hours (12 a.m. – 1:00 p.m. and 3:00 p.m. – 4:00 p.m.).	3,250
14	Russo et al. (2021)	USA	2 highway railroad grade crossings in Arizona	175 h (11 days)	1,522
15	Horberry et. al. (2019)	Melbourne, Australia	Melbourne cities mix of signalized and non-signalized locations	Weekdays in February and March 2018 between the hours of 8 a.m. and 3 p.m.	4,129
16	Tapiro et al. (2020)	Israel	Virtual simulator	Not available	83
17	Truong et al. (2019)	Hanoi, Vietnam	An observational survey was conducted in Hanoi, Vietnam in March 2017	A weekday between 11:30 a.m. and 01:00 p.m.	608
18	Zhou et al. (2019)	China	4 signalized intersections.	4 peak hours in two periods (from 8:00 a.m. to 10:00 a.m. and from 4:00 p.m. to 6:00 p.m.) on 21 June 2016.	4,196
19	Narváez et al. (2019)	Mexico	3 Road crossing	3 working days with a total of 12 h of observation	402
20	Muley et al. (2017)	Doha, Qatar	Signalized T intersection	5th October (9:00 a.m. to 9:00 p.m.)	235

Table 1 Summary of the various research studies (continued)

S. No.	Author	Country	Location for study	Observation period	Number of pedestrians seen
21	Pešić et al. (2016)	Belgrade, Serbia	2 unsignalized intersections.	2 h period (from 12 p.m. to 2 p.m.) at each intersection	1194
22	Gillette et al. (2016)	Texas	3 intersections in College Station, Texas	Data collected for 27 h in (8:00 a.m. to 11:00 a.m. or 11:00 a.m. to 2:00 p.m.) 9 days	760
23	Nurwulan et al. (2016)	Taiwan	Not available	Data collected from 18 studies	Not available
24	Ferenchak (2016)	Bangalore, India.	4 separate midblock crossings in Bangalore, Karnataka, India	Weekdays between 11:30 a.m. and 4:45 p.m.	195
25	Zaki et al. (2016)	Columbia	Experiments are performed on a video data set from Surrey, British Columbia	Not available	Not available
26	Byington and Schwebel (2013)	Birmingham	At the University of Alabama at Birmingham	2 separate 10-crossing sessions with a short (10 min) break	92
27	Schwebel et al. (2012)	USA	Media use questionnaires in the university	During weekdays and weekend days	138
28	Nasar et al. (2008)	USA	3 intersections	From noon to 2:00 p.m. during the first two weeks of March 2005	127
29	Hatfield and Murphy (2007)	Sydney	3 signalized intersections, 3 unsignalized intersections	2 h period	546
30	Bungum et al. (2005)	Las Vegas, NV, USA	T intersection	Mid-April to December 2002	866

was conducted on both weekdays and weekends (Schwebel et al., 2012). Most researchers gathered their data during the afternoon rush hour, with each data set typically collected for at least 1 h. Russo et al. (2021) gathered a maximum of 175 h of data over 11 days, with data collected on both weekdays and weekends. Generally, data is collected for an average of 2 h in every study.

3.3.3 Studies based on the total number of distracted pedestrians

A study conducted in China by Zhou et al. (2019) observed 4,196 pedestrians at four signalized intersections. Horberry et al. (2019) recorded 4,129 pedestrians at both signalized and non-signalized intersections. Additionally, a virtual simulator study by Tapiro et al. (2020) observed 83 pedestrians.

3.4 Review based on various data analysis methods used in studies

Table 2 presents an overall summary of various methods used for data analysis. Most of the studies have adopted regression analysis, log-binomial regression analysis (Byington and Schwebel, 2013; Truong et al., 2022), linear logistic regression (Byington and Schwebel, 2013; Ferenchak, 2016; Liu et al., 2021; Mukherjee and Mitra, 2020; Muley et al., 2017; Nasar et al., 2008; Pešić et al., 2016; Schwebel et al., 2012; Truong et al., 2022), binary logistic regression (Hou et al., 2021; Mohammed, 2021; Raoniar and Maurya, 2022), multivariate regression (Byington and Schwebel, 2013; Hatfield and Murphy, 2007; Mohammed, 2021). Using log-binomial and logistic regression, associations between pedestrian distraction and risky behavior or conflict situations were found (Truong et al., 2022). To understand the risky behavior of inattentive pedestrians, a logistic regression model was applied. Age-related factors cause pedestrian delays and affect crossing usage. According to Ferenchak (2016), six multiple linear regression models were created to examine the factors that influence pedestrian walking speed at various road intersections to better understand this behavior (Mohammed, 2021). Signal cycle length, crossing speed, and waiting time for a safe crossing were all significant factors in the binary logistic regression model that was used to predict signal violation behavior (Raoniar and Maurya, 2022). To determine whether the structures within the Theory of Planning Behavior (TPB) framework are useful for predicting behavior, binary logistic regression analyses were performed by Hou et al. (2021). Nurwulan et al. (2016) considered multivariate multi-scale entropy (MMSE). Multivariate regression was also employed in the investigation of Schwebel

Table 2 Summary of studies using various data analysis techniques

Sr. No.	Author	Data analysis techniques								
		Log binomial regression	Linear logistic regression	Binary logistic regression	Multivariate regression	SPSS	ANOVA	Chi square test	Generalized linear mixed model	Other analysis technique
1	Truong et al (2022)	Y		Y						
2	Larue and Watling (2022)							Y		
3	Tian et al. (2022)								Y	
4	Raoniar and Maurya (2022)			Y					Y	
5	Campisi et al. (2022)									Survey campaigns
6	Gruden et al. (2021)									Manual mapping, metrics analysis, Anderson-Darling normality test, Mann-Whitney U test
7	Useche et al. (2021)					Y	Y	Y		SEM, MGSEM
8	Hou et al. (2021)			Y			Y	Y		Theory of planned behavior
9	Liu et al. (2021)									
10	Mohammed (2021)			Y			Y			F-test
11	Zareharofteh et al. (2021)			Y			Y	Y		
12	Osborne et al. (2020)									Group discussion
13	Mukherjee and Mitra (2020)			Y				Y		Forward inclusion "negative binomial and passion models"
14	Russo et al. (2021)			Y						Ordinary least squares (OLS) regression
15	Horberry et al. (2019)							Y		
16	Tapiro et al. (2020)			Y					Y	
18	Zhou et al. (2019)							Y		Odds ratio analysis
19	Narváez et al. (2019)									Pearson's correlation coefficient
20	Muley et al. (2017)					Y	Y	Y		
21	Pešić et al. (2016)									
22	Gillette et al. (2016)								Y	
23	Nurwulan et al. (2016)		Y	Y		Y				T-test IBM

Table 2 Summary of studies using various data analysis techniques (continued)

Sr. No.	Author	Data analysis techniques								
		Log binomial regression	Linear logistic regression	Binary logistic regression	Multivariate regression	SPSS	ANOVA	Chi square test	Generalized linear mixed model	Other analysis technique
25	Zaki et al. (2016)						Y			
26	Byington and Schwebel (2013)	Y	Y	Y					Y	Confidence interval
27	Schwebel et al. (2012)		Y		Y			Y		
28	Nasar et al. (2008)		Y			Y	Y	Y		
29	Hatfield and Murphy (2007)		Y			Y	Y			
30	Bungum et al. (2005)									

et al. (2012). Useche et al. (2021) used SPSS for all their analysis. All statistical analysis was done using IBM SPSS statistics 23.0. Muley et al. (2017) and Ferenchak (2016) also used SPSS for the analysis. ANOVA is used in numerous studies because the distribution of factors is not normal. Chi-square tests were performed among distinct subgroups to see if the dependent variables were connected to the characteristics of pedestrians. Campisi et al. (2022) employed survey techniques. Gruden et al. (2021) performed manual mapping, metrics analysis, the Mann-Whitney U test, and the Anderson-Darling normality test. Useche et al. (2021) conducted the Structural Equation Modelling (SEM). Hou et al. (2021) took a course in theory of planned behavior (TPB). Mohammed (2021) used the F-test to determine whether a variable was significant. Mukherjee and Mitra (2020) used negative binomial and Poisson models. Russo et al. (2021) utilized the ordinal logistic regression method. Several studies also used confidence intervals, odds ratio analysis, Pearson's correlation coefficient, t-tests, sensitivity analysis, accuracy, and kappa statistics.

3.5 Methods used for data collection

Various methods used for data collection include videography (Horberry et al., 2019; Liu et al., 2021; Truong et al., 2022), questionnaires (Hou et al., 2021; Schwebel et al., 2012; Useche et al., 2021), observational data from various organizations like WHO, census data, accident data from different countries, experimental studies with virtual simulators (Tapiro et al., 2020; Tian et al., 2022), field observations in journals (Ferenchak, 2016), observational surveys (Truong et al., 2019).

3.6 Proportion of distracted Pedestrians in numerous studies

Fig. 5 presents the percentage of pedestrians who were distracted in numerous studies between 2005 and 2022. Pedestrian distraction has increased in recent years due to more advanced technology and innovation. Individuals frequently use headphones, ear buds, smart watches, mobile phones, and other devices, which distract them when crossing the street or strolling. Zareharofteh et al. (2021) found that 84.70% of pedestrians were distracted, while Russo et al. (2021) observed the lowest number of distracted pedestrians. Between 2021 and 2022, pedestrian distraction reached its peak.

4 Performance measures

In these studies, numerous factors are considered, such as demographic factors like gender and age, (Campisi

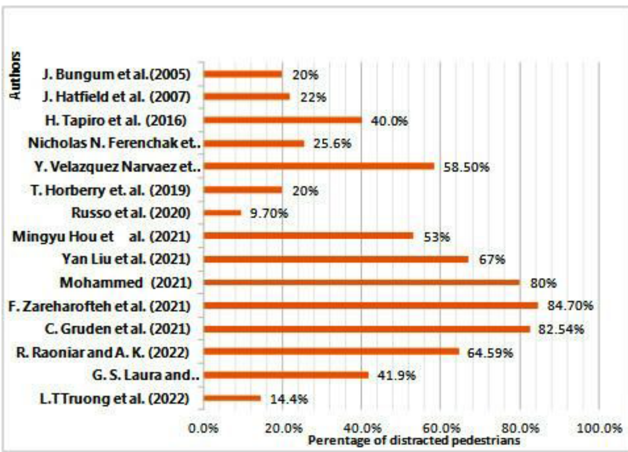

Fig. 5 Percentage of pedestrian distraction studies

et al., 2022; Gruden et al., 2021; Larue and Watling, 2022; Truong et al., 2022), infrastructure characteristics (Campisi et al., 2022; Ferenchak, 2016; Osborne et al., 2020), and walking characteristics, such as whether pedestrians are walking in groups or not (Horberry et al., 2019; Gruden et al., 2021; Schwebel et al., 2012; Tapiro et al., 2020; Truong et al., 2022). Phone use in various forms, such as hand-held, auditory, texting, visual is also analyzed (Mukherjee and Mitra, 2020; Pešić et al., 2016; Schwebel et al., 2012; Zhou et al., 2019). Truong et al. (2022) considered conflict situations while crossing the road, where pedestrians may encounter conflicts with other pedestrians, vehicles, or objects. It is important to consider conflict situations as they can lead to severe accidents, risky behaviors, and signal violations. Other digital devices like headphones, smartwatches, iPads, ear pods, and Bluetooth devices are also considered in numerous studies. Social characteristics of individuals vary across areas and are a major factor in influencing crossing behavior, though considered only in very few studies (Raoniar and Maurya, 2022). Traffic characteristics (Raoniar and Maurya, 2022; Tapiro et al., 2020; Tian et al., 2022) such as start delay, waiting time, and missed opportunities (Byington and Schwebel, 2013), crossing gap acceptance, crossing initiation time, crossing duration, and time gap size, along with secondary tasks and traffic flow characteristics (Tian et al., 2022) are also examined. Pedestrian trajectories and speed profiles are analyzed by Zaki et al. (2016). Table 3 presents summary of studies using various performance measures.

4.1 Age

Each study considers age as a performance measure. Studies found that crossing behavior is different with age (Useche et al., 2021). The study showed a large concentration of younger age groups among pedestrians with stronger educational backgrounds and these persons also tended to report higher traffic infraction rate. Hou et al. (2021) found that young adults made up most mobile phone users. As a result, the likelihood of young adults crossing the roadway carelessly was slightly higher than that of older individuals.

4.2 Gender

Barton and Schwebel (2007) found that female pedestrians waited longer and paid more attention to traffic than men. Conversely, men were observed to miss fewer crossing opportunities compared to women. Useche et al. (2021) suggest that road distractions are a significant factor in explaining unintentional risky behaviors among female pedestrians.

4.3 Safety and security

An integrated approach combining elements such as pedestrian infrastructure separation, publicity, legislation, and shared responsibility for safety among road users was deemed the most promising solution. Osborne et al. (2020) found that no single category of countermeasures was perceived by end-users as fully effective in eliminating the road safety risks posed by smartphone use among pedestrians.

4.4 Pedestrian crossing speed

Mohammed (2021) found that the average walking speed of pedestrians at midblock crossing was 1.46 m/sec. Compared to those who were not distracted, pedestrians crossing the street with headphones on walked 0.28 m/sec faster. Additionally, other categories of distraction, such as texting, handheld, auditory and visual, were associated with a reduction in walking speed ranging from 0.09 m/sec to 0.25 m/sec.

4.5 Traffic parameters

Mohammed (2021) found more variation in crossing speed among pedestrians using roads without crosswalk. It was observed that they walked faster when vehicles were yielding or when there were brief pauses in traffic flow, but more slowly during longer gaps in traffic.

4.6 Pedestrian waiting time

Ferenchak (2016) found that as people get older, they tend to use crossings more frequently and wait longer for pedestrians. It was also observed that men's waiting times are approximately half those of women. Gruden et al. (2021) found that cell phone use while walking can make it more difficult for both adults and children to cross the street safely. It has been observed that older children and adults make crossing decisions more effectively. Tapiro et al. (2020) found that both children and adults are less safe when crossing the street while using a phone. Mohammed (2021) found that a distracted pedestrian would need more time to cross the road than an older pedestrian.

5 Discussion

The present study found that most research on distracted pedestrians has been conducted in recent years,

Table 3 Summary of studies using various performance measures

Sr. No.	Author	Performance measures											
		Age	Gender	Safety and security	Comfort and convenience	Socio-economic and demographic factor	Pedestrian crossing speed	Pedestrian volume	Traffic volume	Crossing time	Traffic parameters	Waiting time	Crossing initiation time
1	Truong et al. (2022)	Y	Y				Y			Y		Y	
2	Larue and Watling (2022)	Y	Y			Y							
3	Tian et al. (2022)	Y	Y							Y	Y	Y	Y
4	Raoniar and Maurya (2022)	Y	Y			Y	Y				Y	Y	Y
5	Campisi et al. (2022)	Y	Y			Y		Y		Y		Y	
6	Gruden et al. (2021)	Y	Y				Y			Y			
7	Useche et al. (2021)	Y	Y										
8	Hou et al. (2021)	Y	Y				Y	Y		Y		Y	Y
9	Liu et al. (2021)	Y	Y				Y			Y		Y	Y
10	Mohammed (2021)	Y	Y				Y					Y	Y
11	Zareharofteh et al. (2021)		Y				Y					Y	
12	Osborne et al. (2020)	Y	Y	Y			Y					Y	Y
13	Mukherjee and Mitra (2020)	Y	Y				Y			Y		Y	Y
14	Russo et al. (2021)	Y	Y				Y			Y		Y	
15	Horberry et al. (2019)	Y	Y							Y		Y	
16	Tapiro et al. (2020)	Y	Y			Y	Y			Y		Y	Y
17	Truong et al. (2019)	Y	Y			Y	Y	Y		Y		Y	Y
18	Zhou et al. (2019)	Y	Y				Y					Y	
19	Narváez et al. (2019)	Y	Y				Y						
20	Muley et al. (2017)	Y	Y	Y		Y	Y			Y		Y	Y
21	Pešić et al. (2016)	Y	Y				Y						
22	Gillette et al. (2016)	Y	Y	Y	Y				Y				
23	Nurwulan et al. (2016)	Y	Y	Y	Y		Y			Y		Y	Y
24	Ferenchak (2016)	Y	Y				Y			Y		Y	
25	Zaki et al. (2016)			Y			Y			Y		Y	
26	Byington and Schwebel (2013)	Y	Y	Y	Y		Y	Y		Y	Y	Y	Y
27	Schwebel et al. (2012)	Y	Y				Y			Y		Y	Y
28	Nasar et al. (2008)		Y	Y	Y		Y					Y	Y
29	Hatfield and Murphy (2007)	Y	Y				Y			Y		Y	Y
30	Bungum et al. (2005)	Y	Y		Y		Y			Y		Y	Y

predominantly in developed countries like USA and Australia. Regarding study locations, most studies considered signalized intersections, unsignalized intersections, and midblock sections. Only a few studies were conducted at T-intersections, linear sidewalk segments, and railroad crossings, which should be prioritized as study locations in future research to understand the social characteristics and crossing behavior that contribute to these fatalities caused by distraction. Factors such as road geometry, sidewalk characteristics, and qualitative measures should also be addressed in further research. Most studies have used regression analysis for modelling.

For data collection, methods like videography, questionnaires, observational data, census data and experimental data in virtual simulators were commonly used. Age and gender were considered the major factors affecting pedestrian distraction in most studies. While phone distraction was a key focus, distractions from other sources, such as overloading of goods while crossing, have been largely ignored. Factors like pedestrian volume, crossing speed, crossing time, waiting time, traffic volume and traffic parameters were also considered in various studies.

Future research could focus on collecting data with larger sample sizes. Observations during nighttime were not considered in most studies. Some studies were conducted in virtual environments, which may not fully reflect naturalistic conditions. Most studies focused on peak-hour observations, non-peak-hour data were rarely collected, which may provide additional findings. Social characteristics of pedestrians were largely overlooked, and qualitative measures were employed in only a few studies. Furthermore, the presence of traffic enforcement was not considered in any of the reviewed studies. Most studies focused on specific age groups, with very few addressing children. The review suggests that distraction is a significant risk factor of pedestrian safety. However, other factors such as age, gender and cognitive ability also play crucial roles. Further research should explore the interaction between these factors and distraction. The study identifies several potential interventions for promoting pedestrian safety, such as education and technological solutions and urban design interventions. Future studies could focus on developing and testing the effectiveness of these interventions. Most studies primarily addressed the impact of distraction on adults, yet distraction may affect children, older adults, and people with disabilities. Further research should explore these differences. Overall, there is a need for more research to understand the complex interactions between pedestrian behavior, urban design, and technological distractions, and to develop effective interventions for improving pedestrian safety in the context of distraction.

6 Conclusion

The present systematic literature review aims to provide a contemporary perspective on pedestrian safety and distraction by reviewing 30 research papers published between 2005 and 2022. The review focuses on identifying types of distractions, the proportion of distracted pedestrians, and the performance measures employed in various studies.

Key findings suggest that most research has concentrated on distractions caused by mobile phones and digital devices, while few studies have examined distractions from other sources. The review emphasizes the need for a standardized definition of pedestrian distraction and more consistent use of performance measures across studies to improve comparability. Notably, there is a significant gap in research focusing on pedestrian behavior in developing countries, particularly in India.

Furthermore, the review found that most of the studies have used either qualitative or quantitative parameters, with only a few studies integrating both. Common data analysis techniques used in the reviewed studies included regression analysis, logistic regression, and decision tree analysis.

However, the review has certain limitations, such as the exclusion of non-English literature and omission of technical reports, conference papers, book chapters, points of view, letters, comments, and commentaries. Despite these limitations, the findings provide valuable insights for policymakers and researchers aiming to improve pedestrian safety and reduce distractions. The study serves as a foundation for future research, offering insights and recommendations that can help generate research questions and hypotheses. Also, it provides a foundation for the future. It also provides guidance on designing more effective studies. Additionally, this review has an educational function, aiding in the dissemination of current knowledge on pedestrian distraction to key stakeholders.

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