

Interventions to Improve Pedestrian and Cyclist Safety in Latin America: a Systematic Review and Metasummary

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ABSTRACT

Road user fatalities account for a leading cause of preventable death in Latin America with pedestrians and bicyclists at higher risk for more extensive injuries as compared to other road users. Despite these vulnerable road user (VRU) risks, encouraging individuals to walk and cycle is an important public health strategy for addressing the region's obesity epidemic through promoting physical activity via active transportation (AT). However, in order to promote AT as a viable source of physical activity, safety of the VRU must be considered. The purpose of this systematic review and metasummary is to describe the effectiveness of interventions that have been implemented in Latin America to improve pedestrian and bicyclist safety. A systematic search of public health, policy, and engineering databases was completed using terms generated through the PICO method. The PRISMA framework was used for article screening. Eight articles detailing nine interventions across four countries were included for final synthesis and organized according to the Three E's Model of Injury Prevention, including three education-based interventions, two engineering, three enforcements, and one utilizing all Three E's. VRU outcomes assessed ranged from attitudes and behaviors to fatal injuries, with only enforcement-based interventions reporting on the latter. No interventions reported on non-fatal injury outcomes. Interventions rooted in each arm of the Three E's demonstrated limited ability to improve VRU outcomes, with enforcement-based interventions providing the strongest body of evidence. Findings demonstrate the limited research on VRU safety in Latin America, and further efforts should be of urgent public health priority.

Keywords: Pedestrian, Cyclists, Vulnerable Road Users, Safety, Interventions, Latin America, Active Transportation

Road traffic crashes are one of the leading causes of preventable death globally (Staton et al., 2016). In addition to fatalities, traffic crashes can lead to both chronic and debilitating injuries (Pan American Health Organization, 2019). This is a growing public health issue, with the number of road traffic injuries (RTIs) increasing worldwide (World Health Organization, 2018). This trend is largely attributable to the disproportionate burden of injuries and deaths in low and middle income countries (LMICs), where 90% of road traffic deaths occur (Hyder et al., 2016; Pan American Health Organization, 2019). The accompanying economic impact of RTIs and deaths in LMICs is estimated to cost these nations \$65 billion dollars annually (Martinez et al., 2019). In order to address the public health, societal, and economic burden of RTIs and deaths, the United Nations set specific targets for reducing these deaths by half by 2030 as part of Sustainable Development Goal 3.6; however, current global progress is not on track to meet these goals (United Nations Statistics Division, n.d.; Mohan et al., 2021; World Health Organization, 2018).

Vulnerable road users (VRUs), defined as pedestrians, bicyclists and motorcyclists, are at particular risk for poor health outcomes caused by traffic crashes. Because these individuals lack the protective support and mass provided by a larger vehicle, they are at higher risk for more extensive and complex injuries as compared to other road users (Radjou & Kumar, 2018). In Latin America, VRUs make up nearly half of all traffic death victims (Pan American Health Organization, 2019). Moreover, pedestrians across Latin America account for a quarter of these deaths, and up to 80% of all road traffic deaths within parts of the region. (Pan American Health Organization, 2019). Indeed, the true burden of VRU deaths might be significantly higher than currently reported, since the type of road user is unreported in 18% of these deaths in Latin America (Pan American Health Organization, 2019). Although a significant public health issue in the region, distinct geographic and sociodemographic disparities exist in VRU fatality risks across Latin America (Pan American Health Organization, 2019). For example, the Mesoamerica and Non-Latin Caribbean subregions have the highest rates of pedestrian and cyclists' deaths in the Americas, accounting for approximately 1 in 3 traffic fatalities, while the Andean subregion has the lowest proportion of pedestrian and cyclist deaths in Latin America at 13.9% (Pan American Health Organization, 2019). LMICs in the Americas experience the greatest burden of these deaths as compared to their neighboring high income nations (Martinez et al., 2019; Otero & Rau, 2017).

In spite of the safety concerns, non-motorized VRUs are engaging in active transportation (AT), a form of physical activity which can contribute to overall well-being and serve as a preventive measure against another significant public health concern in Latin America, the growing obesity epidemic (Centers for Disease Control and Prevention, 2021). Obesity has increased substantially in many Latin American countries, with recent data noting that nearly 60% of adults over 18 years old and 20% of youth under 18 years old are classified as overweight or

obese (Food and Agriculture Organization of the United Nations, 2021; Rivera et al., 2014). Regular physical activity is one strategy that can help prevent and reduce the risk for obesity and other chronic diseases, and the World Health Organization (WHO) recommends at least 150 minutes of moderate physical activity per week to achieve significant physical health benefits (World Health Organization, 2010). Despite known benefits, nearly 25% of adults globally do not meet physical activity recommendations, including those in Latin America (World Health Organization, 2020a; Poggio et al., 2016). While there are many strategies that can be used to promote increases in population-level physical activity, one evidence-based strategy that focuses on incorporating activity in daily routines is AT, getting from one place to another (Community Preventive Services Task Force, 2016; Community Preventive Services Task Force, 2018).

AT is characterized by modes of transportation generated by human energy expenditure and is a widely recognized and evidence-based strategy to promote physical activity regardless of age, racial/ethnic background, or socioeconomic status (Young et al., 2020; Sallis et al., 2004). In Latin America, the prevalence of populations that participate in AT varies, with the median prevalence at 12.0%, ranging from 5.1% in Palmas, Brazil to 58.9% in Rio Claro, Brazil (de Sá et al., 2017). Walking is the most common form of AT in Latin America, with the average prevalence at 15.5%, ranging from 8.9% in Corrientes, Argentina to 27.1% in Bogotá, Colombia. The median prevalence of cycling was 3.2%, ranging from 1.3% in Paraná, Argentina, to 16.0% in Recife, the capital city of the state of Pernambuco in northeast Brazil (de Sá et al., 2017). While walking and bicycling for transportation may be a recommended strategy for increasing population-level physical activity and benefiting obesity and chronic disease outcomes, this approach exacerbates the current challenges with VRUs. Creating safe and supportive communities for VRUs to engage in AT is necessary for reducing the risk of injury and death, while providing opportunities for regular physical activity for the most vulnerable (Pollack et al., 2014).

Despite VRUs accounting for more than half of all road traffic deaths, and the value of AT as a means of promoting equitable physical activity opportunities and overall well-being, VRU safety has been overlooked as a public health issue. If this continues, road deaths are forecast to dramatically increase despite these deaths and injuries being preventable (Staton et al., 2016; Young et al., 2020). WHO, recognizing the complex challenges that exist to overcome this burden, has put forth a multifaceted global action plan which highlights (successful) safety initiatives that have worked in high income countries (World Health Organization, 2021). In spite of the public health need, there is a lack of literature synthesizing the evidence from interventions aimed at improving safety outcomes for VRUs engaging in AT in Latin America. It is imperative that the experience of these successful initiatives outlined in the WHO's Global Plan on Road Safety are transferred to LMICs, such as those in Latin America, and these

experiences serve to provide a body of evidence to policy makers and leaders for implementing effective measures to protect those engaging in AT across the region (World Health Organization, 2018). Therefore, the specific aims of this systematic review and metasummary were to (a) identify VRU safety interventions that have been implemented in Latin America and (b) describe the effectiveness of these interventions to improve pedestrian and cyclist safety in the region.

METHODS

The five member research team utilized the evidence-based Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodology to establish the review protocol (Moher et al., 2009). The team conducted an initial review of the literature on VRU injuries and deaths in Latin America. Latin America was defined for the purpose of the review as Mexico and Central America, Haiti and the Latin Caribbean, the Andean nations and Brazil, and the Southern Cone (Ramos-Castañeda et al., 2017).

Eligibility Criteria

Relevant articles were defined as those published through March of 2022 that described outcomes of interventions conducted in Latin America that intended to improve the safety of non-motorized VRUs (bicyclists and pedestrians). To be included in the review, the article needed to meet the following criteria: a peer reviewed publication in a scholarly journal, include a population in Latin America which may be of all age groups and genders, present outcome data specific to pedestrians and/or cyclists, and describe results from an intervention implemented with the purpose to improve safety. Included articles were those available in English, Spanish and Portuguese. Studies that presented only observational data and/or did not distinguish

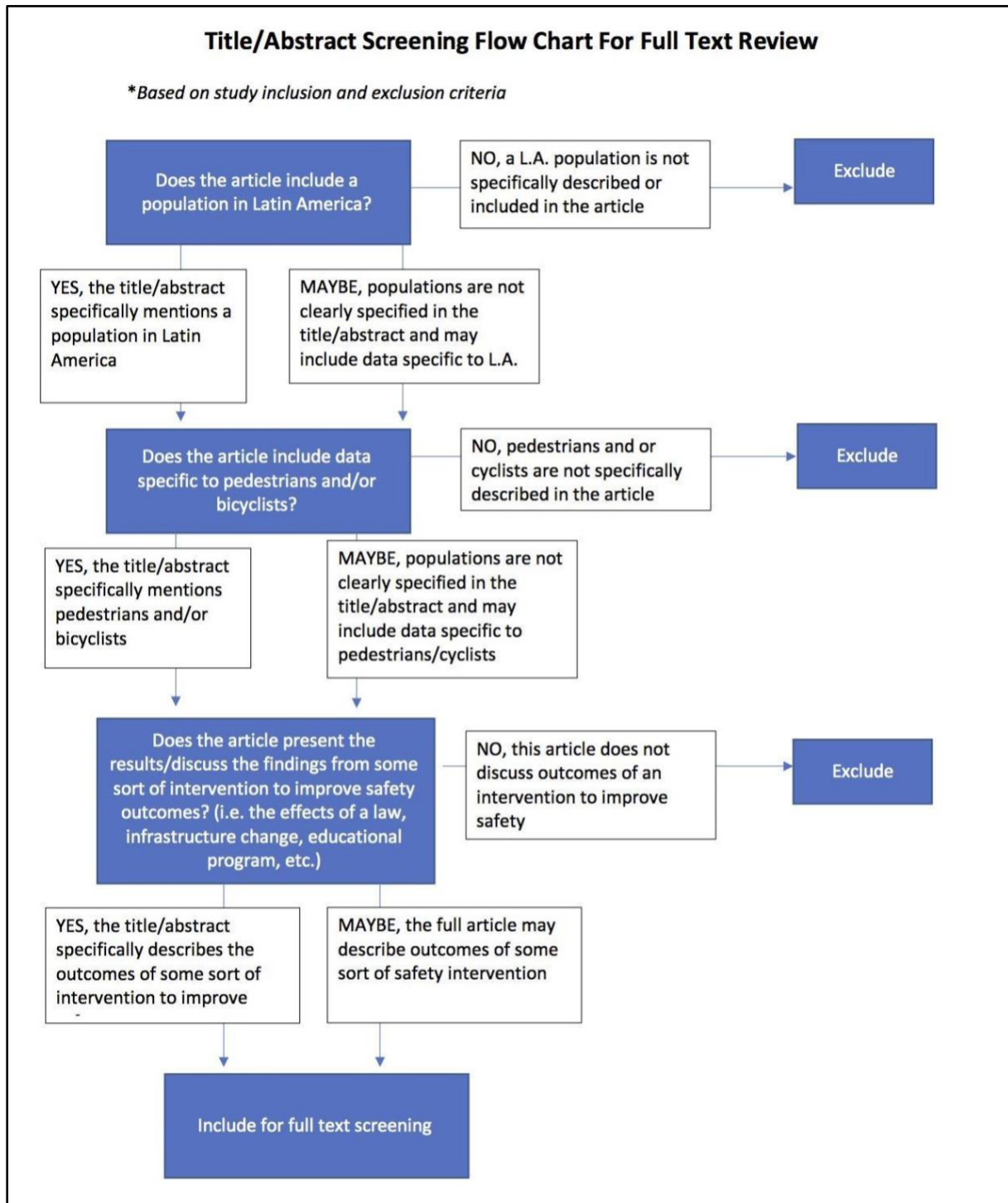
between motorized and non-motorized VRUs (e-bikes, motorized scooters, motorcycles) were not included. Gray literature, including books, were excluded from analysis.

Search Strategy

A complete list of relevant and appropriate public health, public policy, medical, and infrastructure databases were identified via guidance from a subject specific college librarian. Databases searched included PubMed, CINAHL Complete, Web of Science and the college's internal and external databases. Keyword search terms were created utilizing natural language and medical subject heading MeSH terms. A total of 30 search terms were generated using the PICO method which took into account "Population" (i.e., pedestrian, cyclist), "Intervention" (i.e., natural experiment, injury prevention), "Location", in place of "Comparison" due to the nature of the study (i.e., Latin America, Mesoamerica), and "Outcome" (i.e., injuries, deaths). Additionally, a title screening of reference lists from included articles was done.

Two members of the research team (MH and AB) independently searched the selected databases. The results were filtered to include only articles where the search terms appeared in the title and/or abstract. All results were exported into Zotero, a reference management software, and then organized according to the PRISMA framework. Upon completion of the database searches, a minimum of two team members screened article titles based upon the predetermined inclusion criteria. Any discrepancies were resolved by a third reviewer. A flowchart indicating the protocol for title screening is included in Figure 1. Following title screening, included articles were reviewed at the abstract stage by two independent reviewers, while a third reviewer resolved disagreement when necessary. Finally, abstracts meeting inclusion criteria were then screened at the full text level following the same process.

Figure 1. Title and Abstract Screening Tool



DATA EXTRACTION AND ANALYSIS

Figure 2 illustrates the number of articles screened at each step. A total of eight articles met criteria for inclusion in the metasummary. Studies were organized by the type of

intervention according to the Three E's (Education, Engineering, and Enforcement) model of injury prevention. The Three E's model is a commonly used framework in the injury prevention field for conceptualizing and categorizing effective risk reduction strategies (Groeger, 2011) . Public

health experts advocate for use of the model in order to holistically and comprehensively reduce injury risk by initiating efforts grounded in each arm of the Three E's. Specifically, the Three E's include education efforts to inform the public on injury risk behaviors and safer alternatives, engineering interventions that manipulate the physical environment where the injury occurs and/or designing a safer environment that helps to completely avert the injury or minimize damage if an injury occurs, and enforcement efforts which encompass developing and implementing policies or legislation that aim to reduce or prevent risky behaviors (Giles et al., 2020; Groeger, 2011). Subsequent iterations of the Three E's model have been expanded to include Equity and Evaluation as fourth and fifth E's. These changes emphasize the need to consider interventions that promote health equity and injury prevention for all members of a community, particularly those at highest risk. It also addresses the critical need to

formally evaluate Three E interventions to understand successes and failures of injury prevention efforts (Giles et al., 2020; The 6 E's of Safe Routes to School: Embracing Equity, Safe Routes Partnership, n.d.). In addition to categorizing each article by intervention type, the general characteristics of each study including the location, population demographics, intervention type, and outcome measure were extracted and recorded in Table 1. Outcomes assessed were the observed changes in VRU safety or perceived safety which included changes in the number of crashes, injuries, and deaths involving pedestrians and/or cyclists as well as the changes in knowledge and attitudes regarding pedestrian and cyclists' safety and injury prevention. Due to the variability in the included studies' objectives, methods and reported outcome measures, a metasummary has been used to organize results and analyze major findings from the included studies.

Figure 2. PRISMA Flow Diagram

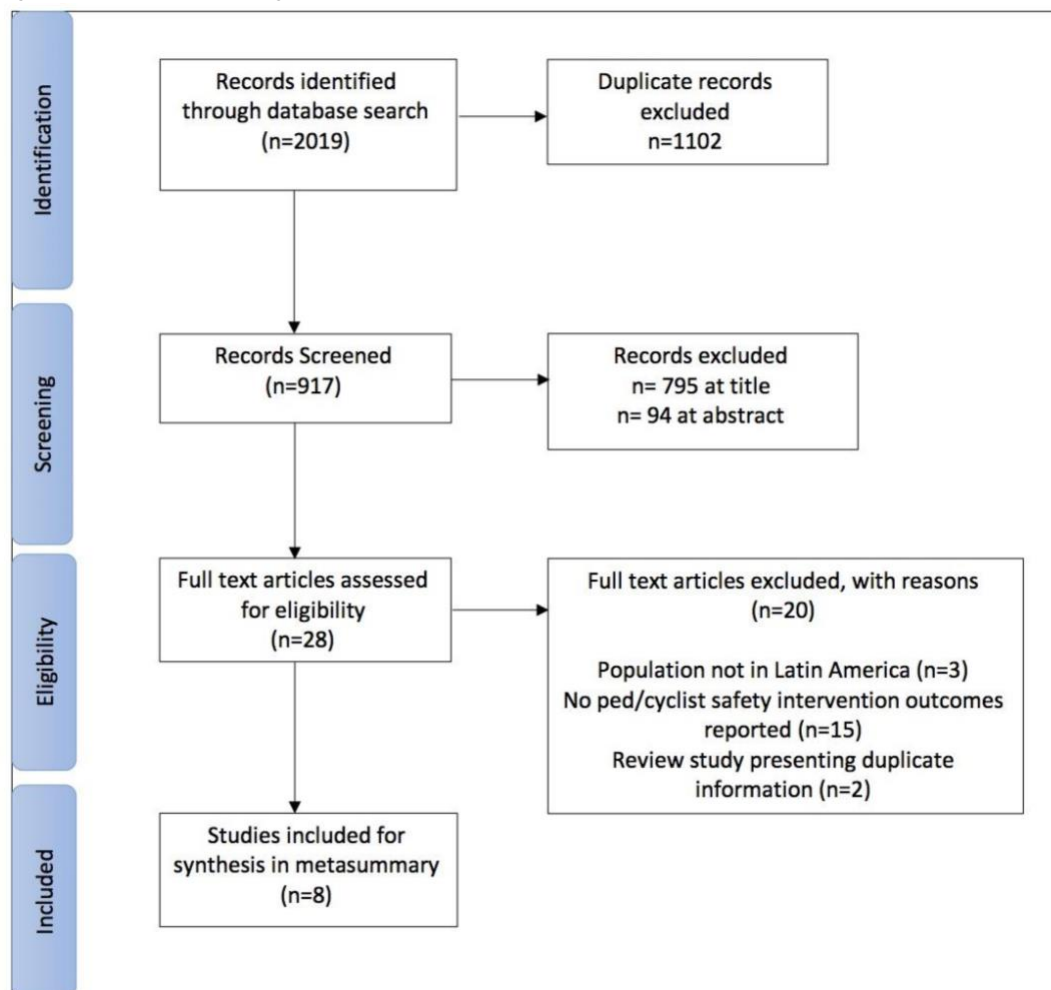


Table 1. Summary Intervention Characteristics and Outcomes

Author & Year	Intervention	Population	Outcomes Assessed	Results
Falavigna, et al., 2012	Pense Bem (Think Well) Educational Intervention	1,049 second year high school students in Caxias do Sul, Brazil	Frequency of safety behaviors while cycling (helmet and protective gear use)	Number of students who reported using helmet while cycling increased from pre intervention to 1 week post intervention, 8.6%, 14.5%, $p=0.0039$) which was sustained at 5 months post intervention, 17.7%, $p=0.034$
Trevino-Siller, et al., 2017	Education Empowerment Theory based intervention	219 secondary school students in Mexico	Street crossing behaviors including (1) making eye contact with drivers (2) looking both ways before crossing and (3) identifying cell phone use, socialization and music as distractions when crossing	(1) Frequently or always makes eye contact with drivers significantly improved for both females ($p<0.001$) and males ($p=0.002$) pre to post intervention (2) Males who “always” look both ways before crossing decreased from 72.07% pre intervention to 58.04% post intervention ($p=0.05$) (3) Females who felt it was dangerous to play with friends while crossing the street increased pre to post intervention ($p=0.005$)
Bacchieri et al., 2010	Commuter cyclist safety equipment and behavior education intervention	1,133 adult male commuter cyclists in Pelotas, Brazil	Frequency of cycling crashes and perceived near-miss crashes per 1,000 cyclist-months	No observed protective benefit or reduction of relative risk for both accidents and near accidents between the control and experimental groups
Torres, et al, 2013	Ciclovía (cycling route temporarily closed to cars) and Cicloruta (permanent bike lane) engineering intervention	2,000 adult cyclists in Bogota, Colombia (1,000 from each intervention)	(1) Cyclists perceptions of feeling unsafe regarding traffic crash risk as well as (2) perceived safety regarding traffic crash risk	(1) 16.7% of Ciclovía user respondents reported feeling unsafe as compared to 29.5% of Cicloruta users (2) Similarly, 51.2% of Ciclovía users felt safe regarding traffic crash risk as compared to 45.8% of Cicloruta users
Zieff, et al., 2018	30 minute walk in an OS event, in Latin America the Calles Abiertas and Ciclovía engineering initiatives	50 adult residents of Bogota, Colombia (n=32), Temuco, Chile (n=8), & San Francisco, USA (n=10)	Qualitative assessment of pedestrians perceived safety while engaging in AT in the city streets during an OS event and a non OS day	74.2% of participants in the Bogota OS reported improved perceived safety while walking during an OS while only 25% of participants in Chile reported improved perceived safety. “Improved safety” emerged as a theme from qualitative data analysis at every OS site in the study
Martinez & Contreras, 2020	The 2005 National Traffic Law reform, enforcement intervention	Children in Chile (national)	(1) Traffic deaths in children 0-14 per 100,000 vehicles. Included pediatric pedestrian and vehicle occupants. (2) Population level	(1) Pediatric road deaths fell from 2.48 per 100,000 vehicles in 2002 to 0.63 per 100,000 vehicles in 2013. There was a significant interaction between time and the implementation of the traffic law reform in 2005 and a reduction in pediatric road traffic death trends, Incidence Risk Ratio

			socioeconomic risk factors associated pediatric pedestrian death risk	0.87, 95% CI 0.79, 0.96 (2) Regions with higher rates of poverty (IRR 1.04, 95% CI 1.02–1.05, $p = 0.000$), income inequality (IRR 1.02, 95% CI 1.00–1.04, $p = 0.033$) and unemployment (IRR 0.94, 95% CI 0.90-0.98, $p = 0.003$) were associated with an increased risk for pediatric pedestrian death
de Oliveira Moura Abreu, et al., 2018	Two enforcement interventions, (1) implementation of the CTB in 1998 and (2) the creation of the national “Dry Law” in 2008	Adult residents of Parana, Brazil (statewide)	Pedestrian traffic crash deaths per 100,000 residents	(1) During the first year following implementation of BTC, pedestrian deaths fell an average of 6.90 deaths per 100,000 residents, which was a significant decrease, $p=0.001$. (2) While there was an average decrease of 0.71 pedestrian deaths per 100,000 residents following implementation of the amended CTB in 2008, this decrease was not significant ($p=0.270$)
Monteiro Andrade, et al., 2005	Multifaceted approach that included educational campaigns and signage, construction of bike lanes and wider roadways and establishment of a traffic focused law enforcement group and enforcement of a national helmet law.	Sobral-Ceara, Brazil (city wide)	Traffic fatalities amongst VRUs per 100,000 inhabitants	Traffic fatalities fell from 33.4 per 100,000 residents in 2001 to 15.25 per 100,000 residents in 2003. More than 50% of these deaths were amongst either pedestrians or cyclists

RESULTS

A total of 2,019 articles were identified through the search. The PRISMA Flow Chart in Figure 2 indicates the number of articles remaining for analysis following each screening stage, with a total of eight articles detailing nine interventions meeting the full criteria for inclusion in the analysis. Three articles assessed education interventions, two reported on engineering interventions, two assessed enforcement interventions, and one study described a multifaceted approach that included interventions from all Three E’s. Studies in the final analysis reported on interventions with data from 1980 through 2015 and included populations in Brazil, Chile, Colombia, and Mexico. The included studies described interventions for both pedestrians and cyclists that ranged in age from birth and childhood through older adulthood. Outcomes assessed included changes in safety behaviors and perceptions of safety as well as frequency of crashes and VRU deaths. Primary findings from each intervention as well as several key characteristics are described in Table 1.

Education Interventions

Three studies assessed VRU safety outcomes following the implementation of an education based intervention (Falavigna et al., 2012; Bacchieri et al., 2010; Treviño-Siller et al., 2017). Two studies were focused on cyclists in Brazil and included discussions and promotion of protective equipment use while cycling as well as risk reduction behaviors for avoiding crashes. The third study focused on young pedestrians in Mexico and improving street crossing behaviors. All three studies differed in the safety outcomes assessed. Intervention effectiveness using the education approach was mixed, one cyclist intervention finding sustained positive behavior change while the other cycling intervention found no positive outcomes related to VRU safety. The pedestrian-based program showed improvements in some safety behaviors with regressions in other positive behaviors.

Of the two education based interventions focused on safety behaviors in youth, the Pense Bem (“Think Well”) program in Brazil was the only one to demonstrate

sustained positive behavior changes. This program was implemented in an urbanized region of southern Brazil and included second year students (n=1,049) attending 10 schools throughout the city, mean age=16.15 (Falavigna et al., 2012). The two-part comprehensive intervention featured a video of a peer sharing a personal experience with a traumatic injury followed by an informative lecture delivered by a member of the research team with discussion topics including anatomy, risk behaviors and injury reduction strategies relevant to brain and spinal cord injuries. The number of students in the intervention group who reported using safety equipment while cycling significantly improved from the pre-intervention stage to the one-week follow-up and the improvements were sustained at five months post intervention, see Table 1 (Falavigna et al., 2012). A second educational intervention directed at reducing RTIs among youth ages 10- to 15-years-old (n=219) attending public secondary schools in Mexico and demonstrated mixed results (Treviño-Siller et al., 2017). The intervention was based upon the Education Empowerment Theory and included six weekly one hour sessions of lectures, videos and role playing activities covering a multitude of road traffic risk behaviors and pedestrian specific practices (i.e., safe street crossing behaviors). Improvements in frequency of some safe street crossing practices such as making eye contact with drivers and the need to avoid distractions such as mobile phones when crossing were found; however, there were actually declines in male students who reported always looking both ways before crossing, see Table 1 (Treviño-Siller et al., 2017).

The third education-based intervention assessed yet a different outcome, crashes or near crashes and was focused on adults. This intervention was conducted in Pelotas, Brazil, between 2006 and 2007 and focused on adult male commuters aged 20 and older (n=626) and was created to teach the participants strategies for accident prevention and safety while cycling (Bacchieri et al., 2010). The program utilized a step-wedge design with pre-intervention cyclists serving as the control group compared to the participants that completed the program (experimental group). Individuals participated in a one-time session that lasted 2 hours with three components: an educational lecture, a video presentation, and the distribution of an informational booklet. Information provided encompassed the health benefits of cycling and risk reduction strategies for crashes with motor vehicles, defensive cycling strategies and maintaining safety features on the bike; the take home informational booklet reiterated and summarized these messages. Cyclists also received a reflective sash, reflective tape and a brake check. The intervention failed to produce any significant observed protective benefit for either accidents per 1,000 cyclists-months or near accidents per 1,000 cyclist-months when comparing data before and after the intervention, see Table 1 (Bacchieri et al., 2010).

Each education intervention used multiple approaches, such as traditional lectures and videos to convey their safety messages for both youth and adults populations. Even with these similarities across studies, the outcomes

measured varied across each study, ranging from use of individual safety equipment, safety behaviors involving other persons, and direct safety outcomes measuring the rate of accidents or near accidents (Falavigna et al., 2012; Treviño-Siller et al., 2017; Bacchieri et al., 2010). Effectiveness of the education based approach was mixed, across and within studies. Each of these types of outcomes are important to understand VRU safety and prevention, but the lack of consistency of measured outcome within education based interventions makes it difficult to summarize the impact of a multicomponent educational program.

Engineering Interventions

Both engineering interventions that met inclusion criteria for the study were focused on *ciclovía*, or open streets (OS), initiatives. OS interventions are characterized by temporary street closures that allow cyclists and pedestrians to use streets that typically prioritize motor vehicles (Torres et al., 2013; Zieff et al., 2018). These engineering interventions may also include changes in the physical infrastructure, or built environment, used by cyclists and pedestrians. The two studies utilizing this engineering approach to improving VRU safety reported the results of two separate OS interventions and one additional engineering intervention, separated bike lanes (“*cicloruta*”) in Latin America. Each study assessed perceived safety among users, including both cyclists and pedestrians, as the primary intervention outcome. These OS initiatives took place in Colombia and Chile and focused on adult and older adult populations. Each intervention indicated improvements in perceived safety, however the extent of the improvement varied across each initiative.

In Bogota, Colombia the *ciclovía* OS intervention occurs weekly with about 70 events per year spread throughout the city, whereas the *Cicloruta*, an additional engineering intervention, is an expansive (~300km) separated cyclist path network. Torres et al. (2013) surveyed users of the two initiatives (n=2,000) and for safety, users were asked to report their perceptions of “not feeling safe in regards to traffic” as well as their perceptions of “safety in regards to traffic” during the events. A higher proportion of *ciclovía* users reported feeling safe in regards to traffic as compared to *cicloruta* users, similarly fewer of the *ciclovía* users reported feeling unsafe as compared to the *cicloruta* users. In another OS study, Zieff et al. (2018) also evaluated safety perceptions of *ciclovía* participants and the *Calles Abiertas* initiative (six OS events per year) that was established in Temuco, Chile. This mixed methods study compared perceptions during intervention implementation and regular days (i.e., no implementation). Quantitative results indicated that several safety perceptions were ranked higher when the street closure intervention was being implemented, including overall safety of the neighborhood (74.2%, 25.0% reported ‘seemed better’ during intervention in Bogota and Temuco, respectively) and the number of cars (74.2%, 87.5% reported ‘seemed better’ during intervention in Bogota and Temuco, respectively). Qualitative results

also showed that the theme of safety emerged as a benefit for both interventions in Bogota and Temuco. One participant stated that "...the implementation of the ciclovía changes the safety perception. It make[s] us feel safer to transit." (Zieff et al., 2018)

Enforcement Interventions

Two studies examined three enforcement measures on VRU safety in Latin America (Martínez & Contreras, 2020; de Oliveira Moura Abreu et al., 2018). The studies reviewed the immediate and long-term impact of either the establishment or reform of national traffic laws on trends of pediatric and adult pedestrian mortality in Chile and Brazil. The outcomes of these wide-reaching measures were assessed, and results indicated mixed efficacy of the enforcement interventions. Unlike the Education and Engineering based interventions, these interventions were the only ones to directly assess VRU safety outcomes through pedestrian mortality, and while two of the interventions were associated with a significant reduction in pedestrian mortality the third enforcement intervention failed to demonstrate any significant reduction in pedestrian deaths.

The first enforcement intervention assessed the effectiveness of a sweeping national traffic law change in Chile put into effect in 2005 on the impact of traffic deaths among children aged 0-14 years using a 12-year interrupted time series analysis (Martínez & Contreras, 2020). The implementation of the traffic reform policy included new protective measures for young automobile passengers as well as measures to improve driver safety, such as prohibiting cell phone use while driving and stricter penalties for driving under the influence. Pediatric pedestrian deaths (child deaths for 14 years of age) fell from 2.48 per 100,000 vehicles in 2002 to 0.63 per 100,000 vehicles in 2013. The annual rate of pediatric pedestrian deaths fell significantly from 2002 to 2013 and results indicated a significant interaction between time and the implementation of the traffic law reform, see Table 1. The second enforcement-based intervention examined the impact of traffic law reform among 15- to 49-year-olds in Paraná, Brazil (de Oliveira Moura Abreu et al., 2018). The study considered the impact of two separate enforcement interventions, the Brazilian Traffic Code (CTB) in 1998 and an amendment to the CTB in 2008, the Dry Law. CTB was a large-scale piece of legislation that established general traffic regulations along with standardized penalties for any infractions. The Dry Law introduced a zero-tolerance policy for driving while having any detectable level of alcohol in the blood of the driver. Prior to the implementation of the CTB in 1998, pedestrian deaths had been steadily increasing in Paraná. During the first year of implementation in 1998, pedestrian deaths fell significantly, see Table 1. Researchers found the most dramatic declines in pedestrian deaths amongst the youngest population included in the study, 15- to 19-year-olds. Following that year, pedestrian deaths stabilized for all ages and genders. While there was a small decrease in the average number of pedestrian deaths following

implementation of the Dry Law, this decrease was not significant, see Table 1.

(Multi-faceted) Interventions (Interventions that Combined 2+ of the Three E's Methods)

The final intervention demonstrated the impact of utilizing a multifaceted approach incorporating strategies from all Three E's on VRU deaths in Brazil (Monteiro Andrade et al., 2005). In 2005, Monteiro Andrade and colleagues documented a multifaceted urban development policy implemented in Sobral-Ceará, Brazil in 1997. Overall, this urban development focused on four key areas, with traffic and transportation most closely aligned with VRUs. This approach incorporated education through a public awareness campaign highlighting the "human and financial consequences of increasing the number of deaths from traffic accidents" and instructional road signage. Engineering changes were also implemented and included the widening of roads, establishing a 9-kilometer network of bicycle lanes, and began the municipalization of traffic flow. Enforcement was represented with the creation of the Municipal Guard, a public safety enforcement agency that helps police traffic violations, and enforcement of national helmet legislation. Pedestrian and cyclists' deaths accounted for more than half of all road traffic deaths prior to this comprehensive approach to improving road safety and following implementation road traffic deaths decreased significantly from 2001 to 2003, see Table 1.

DISCUSSION

VRU safety continues to be a persistent public health issue in Latin American countries, with disproportionately worse outcomes among low-income individuals, youth populations, and those living in certain geographic regions such as Mesoamerica and Non-Latin Caribbean sub regions (Martínez & Contreras, 2020; Pan American Health Organization, 2019). Considering the increased risk for severe injury and death, safety poses a major deterrent when promoting AT as means to improve population levels of physical activity as an obesity prevention strategy. This review encompassed intervention studies aimed at improving safety outcomes for non-motorized VRUs in Latin America. Following the Three E's model (Giles et al., 2020), results demonstrated that interventions rooted in each arm model, as well as comprehensive interventions incorporating multiple approaches, have the ability to improve a number of safety outcomes for VRUs in Latin America. Effective interventions included both cyclists and pedestrians and assessed a variety of outcomes that ranged from perceptions of safety to mortality rates. Although promising results from these interventions have been reported, this review highlights the limited scope of research done on VRU safety in the region and the urgent need for more robust evidence on effective interventions for policymakers and key stakeholders in order to promote safe AT in the region.

Of the eight peer-reviewed studies documenting nine distinct interventions conducted across four Latin

American nations, the primary finding of the review is that initiatives rooted in each the Three E's model have demonstrated improvements in perceived and actual safety measures for VRUs of varying ages and sociodemographic characteristics. Selected education and enforcement based interventions improved youth safety behaviors and reduced pediatric mortality, respectively, while engineering based efforts improved adult and older adult perceptions of safety while utilizing *ciclovia* programs (Falavigna et al., 2012; Martínez & Contreras, 2020; Torres et al., 2013; Zieff et al., 2018). Although these results indicate the potential of the Three E's, no comparison could be drawn between arms of the model as no intervention across arms included the same outcome measures. Additionally, some limitations to the effectiveness of interventions across the Three E's were seen. Of studies assessed, those describing legislative interventions may be considered to provide the strongest evidence, having included the largest number of participants utilizing national and state level datasets, as well as assessing the most direct outcome measure related to VRU safety, road traffic deaths. This further provides support to previous findings from LMICs globally that legislative interventions may provide one of the most effective methods for injury reduction (Rivara, 2001; Staton et al., 2016). However, while these interventions demonstrated the potential of sweeping traffic law reform to reduce pedestrian deaths, not all legislative interventions proved effective in reducing pedestrian deaths, such as Brazil's Dry Law (de Oliveira Moura Abreu et al., 2018). Similar limitations exist with the other two arms of the model. While positive outcomes resulted from some of the included interventions, it cannot be determined if the behavior changes resulting from the education-based programs or perceptions from engineering-based efforts translated to improved safety outcome measures in terms of VRU injuries and deaths. Furthermore, amongst the education-based initiatives only one uniformly produced sustained positive behavior change, while the other two resulted in either mixed outcomes or failed to demonstrate any VRU safety improvements. The WHO promotes education based initiatives to improve road safety in LMICs as part of its Decade of Action for Road Safety, and while education based initiatives might offer low-cost opportunities to improve VRU outcomes, evidence from high income nations suggest that these interventions may be limited in their effectiveness, highlighting the need for stronger evidence on the impact of education based measures in the region (World Health Organization, 2021; Duperrex et al., 2002). Huicho et al.'s (2012) qualitative assessment of road traffic interventions in Peru similarly discouraged the use of stand-alone education based initiatives and this review further highlights some potential limitations of these interventions in LMICs.

This study demonstrates the limited body of peer-reviewed work on this public health issue in Latin America, mirroring a global issue. Although the majority of VRU deaths globally occur in LMICs, very few interventions to address this issue have been evaluated in

these settings (Namatovu, 2022). It is important to highlight that some known initiatives were not included in the review due to the lack of academic evaluation and/or failure to meet inclusion criteria, specifically studies that communicate VRU safety outcomes following the implementation of an intervention. Peer-reviewed evidence may be limited, but the health issue has been recognized by the broader community and a number of grass-roots initiatives exist to address it. For example, one well-known initiative in Bolivia is the *cebitas* program, a volunteer-based program that promotes pedestrian safety by integrating individuals dressed as zebras to nudge both pedestrians and motorists towards safer behaviors (Henderson, 2017). Other regional initiatives such as the mimes in Colombian cities who are situated at busy intersections and mock drivers that exhibit aggressive behavior towards VRUs, or *Peatónito*, the "superhero" who appears in Mexico City crosswalks to defend those engaging in AT around the city, have helped to increase dialogue and draw attention to the safety issues faced by pedestrians and cyclists (Allerton, 2001; Casey, 2013). Though this work has been written about in multiple international news outlets, no formal evaluation of the effectiveness of these programs have been conducted or published.

Beyond grassroots initiatives, regional governments have recognized the increasing health risks for VRUs and have invested in enforcement, engineering and education based efforts such as construction of expanded biking and walking pathways, and the development of social norms campaigns such as the "Yo Respeto" initiative aimed at improving road traffic behaviors amongst Peruvian road users (World Health Organization, 2020b). However, formal evaluation of these programs' impact on VRU safety is again absent from the peer-reviewed literature. In a qualitative study of road traffic interventions in Peru, the absence of process and outcome evaluation was highlighted as a significant concern in spite of more than 17 known initiatives being conducted across the country at that time. Furthermore, key stakeholders and policy makers interviewed for the study expressed concern about the lack of consideration of evidence-based effectiveness when selecting which interventions to implement, raising additional concerns about the need for robust evidence in resource constrained settings (Huicho et al., 2012). This mirrors challenges that have been demonstrated in LMICs globally. For example, in Uganda a qualitative study of existing pedestrian safety interventions highlighted the need for a greater emphasis on monitoring and evaluation of existing efforts amongst other issues (Osuret, et al., 2021). Similarly, some of the available academic work in this area reflects more of a commentary than the description and outcomes of specific interventions. Highlighting an important engineering idea, one review article described the construction of a pedestrian bridge, or "pasarela," in Rio de Janeiro, Brazil. Theoretically, the bridge would provide a safe crossing space over a super highway that divided a densely populated portion of the city, yet pedestrian deaths continued to occur among working age adults (ages 15-64), rather than the very

young or old, the often typical VRU victim. Authors shared reports about the difficulty of carrying items on the stairs that led to the pedestrian bridge, so pedestrians continued to attempt the super highway crossing and face risk of severe injury or death. As such, barbed wire was installed over the concrete barrier to deter pedestrian crossers, which anecdotally reduced the number of pedestrians crossing although no data was provided to support this statement (Baker, 1975). These examples illustrate some of the many local and regional attempts to improve VRU safety that are not academically evaluated. While not included in this review, many of these interventions may be useful in providing policy makers and public health practitioners with insight into effective approaches to injury control.

Implications

Building a robust body of evidence on the effectiveness of VRU injury prevention programs in Latin America is a critical need. Future efforts should target improving surveillance of road traffic deaths in the region. Given that road user type is not reported in nearly 20% of RTIs in Latin America, accurate data is needed to fully comprehend the scope of the problem (Pan American Health Organization, 2019). Furthermore, valid, reliable, and publicly accessible surveillance data can be used to more rigorously evaluate formal and informal interventions to improve VRU safety. Additionally, evaluation of ongoing community based and government efforts in the literature can help to strengthen their effectiveness and make best use of limited resources. Future efforts should also focus on expanding the number and geographical representation of VRU safety interventions. There is a need for targeted interventions in areas with the highest burden of VRU injury and death such as the nations in Mesoamerica and Non-Latin Caribbean (Pan American Health Organization, 2019). Aside from strategic interventions utilizing the pillars of the Three E's framework, additional considerations of these efforts should focus on the "fourth and fifth" E's including equity and evaluation. The incorporation of equity includes the urgent need for initiatives aimed at populations and communities at greatest risk including the very young, elderly, and areas of lower socioeconomic status. Evaluation efforts should include information on both deaths and non-fatal injuries, as well as how changes in knowledge, attitudes and behaviors may translate into reduced deaths and injuries. Beyond evaluation data, development of interventions that build effective multi sectoral partnerships, gather more broad community support and utilize systems thinking approaches have also been identified as critical needs for future efforts (Huicho et al., 2012; Raffo et al., 2013).

Limitations

While this review provided detailed information on multifaceted interventions aimed at improving VRU safety, several limitations should be noted. During the systematic review process, the majority of articles were




excluded because they focused on determinants, or correlates, of VRU safety, rather than interventions preventing VRU injury or death. This likely reflects the current state of the science in this region, utilizing epidemiological methods to identify priority areas for intervention. Similarly, many studies were excluded from the review because the primary focus was physical activity outcomes. Though many of these studies would have fit within at least one element of the Three E model for the intervention approach, these studies did not evaluate perceived or objective safety measures, which was central to the review. In order to promote built environment strategies for improving population-level physical activity, safety must be incorporated. We urge researchers to integrate safety measures into their physical activity studies that may impact VRUs. Finally, due to the lack of uniformity of outcomes reported and varied intervention methodologies, critical analysis was limited to a metasummary of existing data.

CONCLUSION

VRUs are at a higher risk for experiencing negative health outcomes caused by traffic accidents in Latin American countries. This disproportionate impact on low-income individuals and children as well as the influence on promoting AT as a means of physical activity and preventing obesity is a major public health issue. This review evidenced the need to implement effective and multifaceted safety interventions following the Three E model and demonstrated that although limited in nature, evidence-based interventions, particularly those rooted in legislative initiatives may positively impact VRU safety in the region. This review highlights the critical need for expanded evidence-based initiatives aimed at creating safer environments for walking and cycling in Latin American communities.

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CONFLICT OF INTEREST STATEMENT

We have no conflicts of interest to disclose.

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