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Review Essay

Toward environments and policies that promote *injury-free* active living—it wouldn't hurt

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ABSTRACT

Although being active is vital to the health and well-being of children, increases in physical activity can lead to an elevated risk of injury, which is a leading cause of childhood mortality globally. This article provides an overview of the evidence base concerning unintentional injuries associated with popular forms of physical activities for youth, and describes how injury prevention and child obesity professionals can work together to prevent injuries while promoting active lifestyles. Policy and environmental interventions that are beneficial to both outcomes are highlighted and recommendations for future research for these complementary areas are also provided.

1. Introduction

Physical activity during childhood and adolescence has been associated with numerous benefits to health including lower adiposity, improved cardiovascular risk factors, reduced symptoms of depression, and better academic performance (DHHS, 2010). The Surgeon General of the United States (U.S.) recommends that all youth participate in 60 min of moderate activity most days of the week; however, many youth do not meet this recommendation. The overall low prevalence of physical activity among children and adolescents is one of the contributing factors to the current childhood obesity epidemic, which is a problem globally (CDC, 2010a; Spruijt-Metz, 2011).

In 2009, the U.S. Centers for Disease Control and Prevention (CDC) released a report highlighting recommended evidence-based community strategies to prevent and control obesity (Keener et al., 2009). One section of this report, "Strategies to Create Safe Communities That Support Physical Activity" included improving access to outdoor recreational facilities such as parks and community playgrounds; enhancing infrastructure to support walking and bicycling; and enhancing traffic safety in areas where individuals are or could be physically active. Although the report included evidence as to *why* these strategies are needed, it did not describe *how* to create safe communities, nor did it comment on injury risks that should be minimized as strategies are implemented.

Injuries are the leading cause of death for individuals between the ages of 1 and 44 in the U.S. (CDC, 2010b). Nonfatal injuries are also prevalent, and in 2009, approximately 25.5 million individuals were treated for a nonfatal injury in U.S. hospital emergency departments (CDC, 2010b). As public health efforts to promote physical activity increase in response to obesity, it is important that programs to increase physical activity partner with programs to prevent injuries to maximize the benefits of physical activity programs, and avoid the possible unintended consequence of increased injury rates. We have not yet fully integrated injury prevention into chronic disease prevention (Ikeda, 2010), let alone into active living initiatives, and as a result, active living professionals are not as familiar with how to lower injury risks as they are with how to lower obesity risks. Furthermore, injury prevention professionals are not as aware of how and why they should partner with those working in the active living research field.

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The purpose of this article is to present the evidence base concerning unintentional injuries associated with popular physical activities for youth, and describe how injury prevention and child obesity professionals can work together to prevent injuries while promoting active lifestyles. We present relevant frameworks and theories, useful for both fields, followed by the epidemiology of injuries for specific physical activities. Since injury prevention and active living share a focus on environments, we also discuss policy and environmental interventions that can benefit both outcomes. Next, we present a case from Sweden that describes a comprehensive strategy to reduce injury that is relevant for active living. Finally, we conclude with a call for a research agenda that integrates these two complementary disciplines, and offer suggestions for improving partnerships between injury prevention and active living.

2. Injury prevention framework applied to active living

Several injury prevention frameworks and conceptual models help identify injury risks and potential strategies to optimize safety during activity. One of the most commonly used frameworks in the field of injury prevention, which may help identify built environments to support active living and injury prevention, is the Haddon Matrix (Haddon, 1973, 1980). This framework was developed by identifying the causes of and contributors to injury, and identifying different injury phases in which these causes and contributors can be eliminated or modified (Table 1).

Injury results when the transfer of energy to a person is in an amount that exceeds the threshold for injury—energy serves as the agent of injury. For example, an individual may be injured when he/she falls while jogging or is hit by a car while on a bicycle. In each of these cases, the injury occurred when kinetic energy was transferred to the person. This exchange of energy – its timing and the amount of energy – is affected by many contributing causes. In Haddon's Matrix, the environment (which includes both physical and socio-cultural components) is a critical element in this process. The physical environment includes the built environment and how people interact with it—on roadways, in homes, on playgrounds and sports fields, or the many other places people are active. The socio-cultural components encompass factors that affect individuals' access and exposure to contributing causes. Socio-economic status, neighborhood resources, and community norms all influence the interactions between individuals and their environments in ways that affect physical activity and injury risk. For example, the availability of safe recreational spaces varies among communities and reflects, in part, the priorities of decision-makers about how to allocate available resources. Other important contributors to injury include characteristics of the hosts themselves, such as gender, age, physical resiliency, or personality characteristics such as risk-taking.

The Haddon Matrix divides the injury event into three phases, each with appropriate prevention approaches. The pre-injury phase includes strategies that eliminate the transfer of energy to an individual. One example that involves changing the environment is traffic calming, which improves the walkability of a community and decreases the risk of pedestrian injury by reducing the number of cars and their speeds in residential neighborhoods (Morrison et al., 2003; Schieber and Vegega, 2002). The injury phase includes strategies that reduce the severity of injury when an energy transfer does occur. A bicycle helmet is one example: the helmet does not prevent the bicyclist from crashing, but it does reduce the severity of head injury should a crash occur (Thompson et al., 2000). An example from the built environment includes break-away goal posts, which reduce the risk of injury when a player collides with the post. The post-injury phase includes strategies that help an individual survive and recover from an injury, such as emergency medical services, trauma care, and rehabilitation.

In addition to the foundational tools offered by Dr. Haddon, others have introduced an ecologic framework that integrates approaches within the complex relationships that exist between an individual and an environment (Green and Kreuter, 2005; Allegrante et al., 2010). According to this framework, prevention approaches nest individuals within their interpersonal networks, nest these networks within organizational and community organizations, and nest all of these components within public policies at the local, state, and national levels (Dahlberg and Krug, 2002). Interventions that simultaneously influence multiple levels and multiple settings of an ecological system may be expected to lead

Table 1
Haddon matrix with intervention examples from the bullet environment. A tool for identifying approaches for injury prevention and control.

	Host	Vehicle/vector	Physical environment	Socio/cultural environment
Pre-event (Primary)	• Education to encourage use of bicycle and pedestrian walkways and overpasses. • Wearing reflective materials to increase visibility. • Swimming lessons to reduce risk of drowning. • Neuromuscular and strength training.	• Increase visibility of bicycle on the roadway. • Add four-sided enclosures to pools to reduce access.	• Traffic calming measures to reduce risk of bicycle and pedestrian injuries (traffic circles and bicycle lanes) • Efforts to separate bicyclists and pedestrians from vehicle traffic.	• Enforcement of traffic laws • Restrictions of motor vehicle traffic to give priority to bicycle riders on some days. • Legislation requiring pool fencing. • Rules and regulations to support safe sports play.
Event (Secondary)	• Increased use of helmets for bicycling, sports, and relevant recreational activities. • Use of life jackets.	• Supervision, such as by lifeguards and parents, during all water activities. • Breakway goal posts and break away bases to reduce injuries from sliding in baseball.	• Traffic calming measures to reduce speed of vehicles, which will reduce severity of impacts. • Safe surfaces for sports and recreational areas (e.g. adequate cushioning) • Safe surfacing for playgrounds.	• Legislation requiring use of bicycle helmets.
Post-event (Tertiary)	• Education about first aid and resuscitation when injured.	• Presence of lifeguards at pools to increase timely recovery and resuscitation.	• Neighborhood designs that allow access for emergency vehicles	• Policies to ensure that injured athletes are completely healed before returning to play.

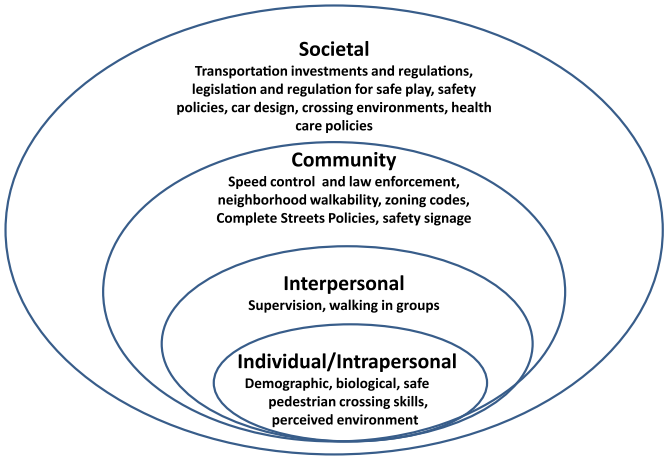

Fig. 1. Socio-ecologic model for prevention with examples for walking and pedestrian injury prevention.

to greater and longer-lasting changes in health outcomes (Cohen and Swift, 1999). Successful injury prevention requires the integration of activities at all of these levels.

The ecologic framework is also central to the field of active living. Sallis and colleagues in 2006 published an ecologic model of active living and discussed how multilevel interventions targeting individuals, social environments, physical environments, and policies must be implemented to achieve population change in physical activity (Sallis et al., 2006). These are similar principles that underlie the application of the ecological model to injury prevention. Therefore, it seems clear that efforts combining environmental, policy, and behavioral strategies with an ecologic framework can identify strategies to both encourage activity and prevent the occurrence of injuries at the population level. Fig. 1 displays an ecologic model that combines both injury prevention and active living, using walking and pedestrian injury as an example.

3. Physical activity-related injuries: epidemiology and prevention

This section illustrates evidence-based environmental and policy approaches to injury prevention during some of the most popular activities and leading causes of activity-related injuries (walking, bicycling, swimming, sports and recreation, and play on playgrounds). These approaches, which focus on children and adolescents, are presented within the context of an ecologic framework.

3.1. Walking

Walking is the most common form of leisure-time physical activity among U.S. adults (Rafferty et al., 2002; DHHS, 1999). For children, walking is also an important activity, particularly because of efforts to promote active transport to and from school through the Federal Safe Routes to Schools (SR2S) program. However there are injury risks to consider. Pedestrian injury is the second leading cause of unintentional injury-related death among children of ages 5–14 (Dukehart et al., 2007). In 2009 there were 47,205 nonfatal pedestrian injuries reported among children of ages 5–14 (CDC, 2010b). Trends suggest that the traffic-related pedestrian death rate among children of ages 14 and under has declined significantly in the most recent decade; however, this decline can be attributed, in large part, to decreased traffic exposure since children are walking less often. These injuries are a problem for youth in rural and urban areas; however, traffic-related pedestrian death rates are nearly double in urban areas compared to rural (Dukehart et al., 2007; Zhu and Lee, 2008). Worldwide, motor vehicle-related crashes are responsible for an estimated 1.2 million deaths and 50 million injuries, with many occurring among child pedestrians (Peden, 2008; WHO, 2008).

Effective interventions exist to improve pedestrian safety (Ewing and Dumbaugh, 2009), and the most beneficial of these involve ecologic-level changes to the built environment. Traffic calming measures such as speed humps and traffic circles are known for slowing traffic, which reduce the likelihood that a crash will occur at high speeds and the risk of death if a pedestrian is involved. Overpasses and underpasses separate pedestrians from traffic, thereby reducing the risk of being struck by a vehicle. Enforcement of traffic laws is also important in reducing traffic-related pedestrian mortality and morbidity. For example, efforts to ensure that drivers stop for pedestrians and obey posted speed limits are important. In addition to these place-based environmental and policy interventions, additional pedestrian injury safety initiatives at the individual level include wearing reflective materials and providing safety education and training that is tailored to those vulnerable populations at greatest risk (Dukehart et al., 2007).

At the societal level one policy intervention to promote pedestrian safety is the Federal SR2S program, operated by the U.S. Department of Transportation. The SR2S program was created to increase the number of children walking and biking to school and to address parents' safety concerns, which research has identified as a key barrier (Dellinger and Staunton, 2002; CDC, 2005; Carver et al., 2008; Papas et al., 2007; Zhu and Lee, 2008; Saelens and Handy 2008; Lovasi et al., 2009). The SR2S program accomplishes these changes through education, engineering, enforcement, and encouragement. While there is evidence to suggest that these programs effectively increase the number of children who walk to school (Davison et al., 2008), there are limited data as to whether these programs have increased active transport while also minimizing injury risk. Anecdotally, SR2S initiatives have reduced pedestrian injury risk, and empirical evidence is on the horizon as studies to measure these risks are underway (http://www.activelivingresearch.org/).

3.2. Bicycling

In 2001, an estimated 3.3 billion trips were made in the U.S. by bicycle (FWHA, 2004). While there are health benefits from bicycling, there are some injury risks. In 2007, 820 people died from bicycling injuries; 148 were children and adolescents 19 years or younger (CDC, 2010b). In 2008, nearly one-half million of all bicyclists were treated in U.S. emergency departments for injury; 29,000 of whom required hospital admission (CDC, 2010b). Concerns about safety may be an important deterrent to using bicycling for commuting (Noland, 1995).

As with walking, the optimal health approach involves increasing the use of bicycles while ensuring the safest environments for their use. There are consistent data showing that marked bike lanes on roads reduce motor vehicle–bicycle collisions by as much as 50% (Lott and Lott, 1976; Pucher et al., 2010). One study of over 40 cities in the U.S. found that there was a direct relationship between the availability of such bike lanes and the number of bike commuters: each additional one mile of bike lane per square mile of the city was associated with an approximate 1% increase in the number of bike commuters (Dill and Carr, 2003). In contrast, there are conflicting data on the effect of separate bicycle paths, with some studies finding a reduced risk of injuries

(Tinsworth et al., 1994; Mortiz, 1998), while others report an increased risk of injuries for travel on these paths (Aultman-Hall and Hall, 1998; Aultman-Hall and Kaltenecker, 1999). The increased risk of injuries for travel on paths was hypothesized as resulting from the lack of established set of operating procedures (i.e., rules of the road) that exist on roadways. A Seattle study did find that living near a bike path was associated with increased frequency of bicycling (Vernez-Moudon et al., 2005). Installation of roundabouts may actually increase the injury risk for bicyclists, but this risk can be reduced by having separated cycle tracks (Reynolds et al., 2009).

Comprehensive municipal programs can both decrease bicycle crashes and increase cycling rates (Pucher et al., 2010). These programs include traffic calming, bike lanes, mixed use-pedestrian–bike lanes, cyclist-activated traffic signals, restriction of motor vehicles on certain days of the week, and reducing car parking in city centers. Such programs have been very successful in Berlin, Paris, Bogotá, Copenhagen, and Boulder, Colorado. The prevalence of biking is inversely related to traffic density (Foster et al., 2009), so efforts to calm traffic and decrease density can result in increases in cycling and walking.

In addition to these environmental changes at the community level, interventions at the individual level, such as wearing helmets, are effective to prevent traumatic brain injuries, which account for the majority of bicycling deaths (CDC, 2010b). Rigorous case-control studies have established that helmets can reduce the risk of traumatic brain injuries by as much as 88% (Thompson et al., 1989, 1996b, 2000), and can reduce the risk of injuries to the upper and midface by two-thirds (Thompson et al., 1996a). Changes to the policy environment can be achieved through legislation requiring helmet use, which combined with various types of educational programs has been effective in increasing helmet use, especially by children, and reducing the incidence of TBI (Rivara et al., 1994).

3.3. Swimming and water sports

Swimming is one of the most popular forms of physical exercise in the U.S., with 20% of the U.S. population swimming each year (Census Bureau, 2009). It is an especially good form of vigorous physical activity for children with asthma because swimming rarely induces bronchospasm (Weisgerber et al., 2008). Swimming is generally associated with a low risk of injury, compared to many other sports (Pons-Villanueva et al., 2010). The most important cause of death related to swimming is drowning. In 2007, 1056 children and adolescents under the age of 20 years drowned in the U.S., at a rate of 1.24 per 100,000 annually, compared to 2.68 per 100,000 in 1985 (CDC, 2010b).

In the U.S., about half of child drowning deaths occur in natural bodies of water, and about one-third occur in swimming pools (Brenner et al., 2009; Saluja et al., 2006). A number of effective interventions can decrease pool-related drowning (Quan et al., 2007). Installation of 4-sided fencing around a pool with self-latching gates can reduce the risk of drowning by 73% (Thompson and Rivara, 2000). Three-sided fences that do not completely isolate the pool from the house lead to almost twice the drowning risk compared to four-sided isolation fencing (Fergusson and Horwood, 1984). Enforcement of regulations on fencing is important to achieve high levels of compliance (Gulliver et al., 2009). While pool covers and pool alarms are commonly used, there are no data confirming their effectiveness.

A recent case-control study evaluating the effectiveness of formal swimming lessons found that lessons were associated with an 88% reduction in the risk of drowning for 1–4 year olds and a potential large reduction of drowning deaths among 5–19 year olds (Brenner et al., 2009). Unfortunately, low-income and minority children, who are at greatest risk of drowning death in the U.S., are the least likely to have adequate swimming skills (Irwin et al., 2009). In low-income countries such as Bangladesh, where more children die from drowning than in any other country, promotion of swimming lessons has been very successful in decreasing drowning deaths (UNICEF, 2009). Data indicate that over 35,000 Bangladeshi children have been taught to swim and have learned about risks encountered when swimming in rivers, ponds, and deltas (UNICEF, 2009). Programs to increase swimming proficiency among the most high-risk populations bring together the community and individual levels of the ecologic model.

3.4. Sports and recreation

In the U.S., more than 45 million youths participate in organized team sports, with the three most popular being basketball, baseball, and soccer (Veigel and Pleacher, 2008). An estimated 7 million participants seek medical care each year in the U.S. for injuries sustained while participating in sports and recreation activities with more than 11,000 people per day receiving treatment in emergency departments (Gilchrist et al., 2007). Youths represent approximately 4.3 million of these sports and recreation-related injuries per year participating in both organized and free play (Ni et al., 2002).

The large number of injuries that occur during sports and recreation activities provide an opportunity to reduce the injury burden among this age group. Sports and recreation activities are comprised of similarly demanding physical moves: running, jumping, quick starts, stops, and direction changes; and throwing motions (Schiff et al., 2010). The most common injuries during sports and recreation are contusions due to falls (resulting from slips, trips, and stumbles) and being struck by or against a person or object, such as athletic equipment (Ni et al., 2002).

Interventions at the community and societal levels can reduce risk of sports-related injury by modifying equipment, surfaces, and individual behavior. For example, policies that require, and provide access to, the safest equipment for each sport are essential. A review by Schiff et al. found that helmets, the uses of which are applicable to many sports (e.g., baseball, bicycling, hockey, horseback riding, and skiing and snowboarding,), have been shown to effectively reduce the risk of head injury (Schiff et al., 2010). In addition, interventions that address field surfaces are an important part of the environment with which children interact when participating in sports and recreation activities. Proper maintenance of fields to ensure there are no holes, uneven surfaces, or debris can help to reduce lower extremity injuries (Koutures and Gregory, 2010; Dragoo and Braun, 2010).

Legislation and regulation that reduce injury risk are also an important part of safe sports play. One example is stricter rule enforcement by officials regarding elbow use while heading the ball in soccer. This regulatory change led to a 50% reduction in head injuries in the 2006 FIFA World Cup as compared to 2002 (Verhagen et al., 2010). In a study of nine U.S. high school athletic programs, the authors concluded that more than 6% of injuries may have been prevented with improved rule enforcement (Veigel and Pleacher, 2008).

3.5. Climbing and use of playgrounds

Playgrounds are one commonly used area for children to run, climb, jump, and play. They have many positive effects for communities, including increasing neighborhood cohesion and serving as a valuable community resource (Miles, 2008; Daniels and Johnson, 2009; Laraque et al., 1994). However, playgrounds are also a source of injuries. Each year over 200,000 preschool or

elementary school children in the U.S. require emergency medical care for injuries associated with playground equipment (Mack et al., 1997). On average, 17 of these cases result in death. Swings, climbers, and slides are associated with 88% of all playground equipment injuries reported to the National Electronic Injury Surveillance System (Mack et al., 1997). Falls to the surface are responsible for 70% (Mack et al., 1997).

One study of parents' decisions about the selection of play spaces for their children found that parent safety perception was a key factor in their decision-making (Sallis et al., 1997). Research has shown that the safety of playground equipment varies by neighborhood. One study of playgrounds in Boston found an inverse relationship between playground safety and the proportion of youth in poverty, residents with no high school degree, and proportion of black residents (Cradock et al., 2005). Another study of playgrounds in low and very-low income neighborhoods in Chicago found that while playgrounds were generally of good design, there were problems with lack of supervision, and surfacing and equipment maintenance, which posed safety risks (Powell et al., 2005).

Studies of school injuries show that most unintentional injuries occur on the playground, which is expected because the most active play occurs there (Limbos and Peek-Asa, 2003; Phelan et al., 2001). The goal of safe playground design is to encourage activity while reducing the risk for injury. Playground equipment, surfacing, placement, and maintenance are all critical components of safe playgrounds (Mott et al., 1997; Howard et al., 2005; Sherker et al., 2005; CPSC, 2010). Equipment should be designed at the appropriate age and developmental level of users, and considerations for safety should include equipment height, handrails and barriers to prevent falls, and reducing components where children can become trapped or caught (such as components that can catch a hood or clothing tie when sliding). Surfacing, such as sand, wood chips, rubber fragments, or foam mats, should be installed to absorb energy in proportion to the height of the equipment. These surfaces must be maintained. For example, sand is easily displaced so that surfaces directly under tall equipment do not have adequate depth. Playgrounds in schools, communities, and homes should be placed on level surfaces, away from water drainage areas, and away from potential interaction with street traffic.

Environmental approaches to increase playground safety are optimized when combined with other approaches in the ecologic framework (Staunton et al., 2007). Adequate supervision should accompany safe play equipment to reduce injury risk. Programs that coordinate supervision on school playgrounds have been effective in reducing injury (Schwebel et al., 2006). Supervision is also important in community and home playgrounds. Policies are also an effective strategy to increase the prevalence of safe playgrounds by requiring that playgrounds meet safety standards. Many states have adopted statewide legislation adopting playground safety standards, and these have been effective in reducing playground injuries (Briss et al., 1995; Kotch et al., 2003).

4. Environmental and policy approaches can increase physical activity and decrease injuries

The activities previously described are all health promoting and help children and adolescents meet the recommended guidelines for physical activity that are central to health. Given the real threats posed by the increasing rates of overweight and obese youth, the need to promote activity is clear. Equally clear is the need to promote safe physical activity. In one of the few studies on the health benefits of cycling vs. the increased risks from air pollution and traffic injuries, de Hartog and colleagues suggest that policies stimulating cycling likely have a net beneficial effect on public health when such policies are accompanied by safety measures and efforts to limit hazards, for example using cycle lanes, separating traffic, or limitations such as a ban on car traffic near schools during school start and end hours (de Hartog et al., 2010).

Interventions designed to prevent the release of energy in amounts that exceed human tolerance (identified in the Haddon Matrix as the pre-event phase) offer the most promise. We identified several pre-event strategies that have been demonstrated as effective or promising in preventing pedestrian activity-related injuries. Those findings are summarized in the completed Haddon Matrix presented earlier (Table 1). Given this Journal's focus on place, we call attention to the interventions within the physical environment column, which relate to societal and community levels of the ecologic model (Fig. 1).

Place and space are important for promoting activity and preventing injury, thus there is a need for collaboration across those fields promoting active lifestyles and those promoting the prevention of injuries. The theoretical foundations of injury prevention put forward by Haddon and the empirical research that has followed demonstrate the value of designing or redesigning physical space so that injuries are minimized. The literature for individual activities continues to evolve, with clear evidence about the value of place-based interventions to reduce activity-related injuries.

The literature also demonstrates a role for behavioral interventions (Sleet et al., 2010a), and the opportunities for designing built environments with safety in mind (Sleet et al., 2011). Although the rationale for using structural and environmental interventions might seem straightforward, there is rarely an environmental change that does not require behavioral adaptation (Sleet and Gielen, 2007). While helmets protect the head in the event of a fall from a bicycle, the cyclist still must put one on in order for it to have a preventive benefit. While 4-sided fences for residential pools work to keep out unattended young children, self-closing gates and latches on the fence must be installed, locked, and maintained. Behavioral approaches are also needed for persuading decision-makers about the need to enact legislation, change environments, or change policies that can protect many people and whole communities simultaneously. However, the public still must act appropriately for these protections to work.

Human factors also play an important role in injury prevention. Risk-taking is in no small part the result of a person interacting with the environment. The two interact to create contingencies that can either increase or reduce the likelihood of an injury. Human factors and engineering initiatives help build these contingent relationships with other predictors of behavior. Focusing on how human behavior in transportation, in sport, and in physical activity interacts with technology and the physical (and social) environment, and how these interactions affect injury, represents an ongoing challenge (Porter et al., 2010).

5. Investing in the built environment to prevent child injury: the case of Sweden

The primary goal of this paper is to make the case for incorporating injury prevention strategies into active living initiatives so that successes in promoting activity are not undermined by failures to prevent activity-related injuries. The complementary goal is to encourage consideration of promoting physical activity in injury prevention initiatives. Thus far the examples we have provided speak to injuries associated with specific activities and policy and environmental interventions that have occurred primarily at the local level. Importantly, the scale and the scope of injury prevention interventions are not limited to local communities or to a country responding to

addressing a single type of injury, as evidenced by the long-term, holistic approach to safety through environmental design that is underway in Sweden.

For several decades, a deliberate plan to reduce child injury risks has been ongoing in Sweden with remarkable success. In their paper explaining the dramatic decline in Sweden's child injury death rate during the 35-year period between 1966 and 2001, Jansson and colleagues also review the history of decisions that led to the creation of safer places for children to live and play (Jansson et al., 2006). What the authors describe as a "national program for child safety" began in 1954 with the establishment of a committee that included representatives from the government and private sectors. The committee looked to the evidence base to inform their programming that included behavioral interventions (such as mandatory swim classes for children), and environmental design changes (building communities that separated children's spaces from traffic). Given the focus of this paper, we discuss the environmental design components of the Swedish strategy in greater detail.

This national effort was well-positioned to respond to the rapid urbanization that occurred in the middle of the Twentieth Century. In what was dubbed the "Swedish Million Housing Program" the national government undertook to build 100,000 new housing units a year between 1965 and 1975 to accommodate the increasingly urban population (Jansson et al., 2006). The homes and communities constructed during this period embraced safe design principles inside and out, with particular emphasis on safe transport and explicit planning that aimed to "separate out and differentiate between different types of vehicles and pedestrians" (Jansson et al., 2006). Later expansion of the road system to connect the new communities and support the increasing commuter culture included dedicated lanes for cyclists that provided separation and space to reduce the risk of cycle travel (Jansson et al., 2006). The emphasis on assuring child safety through environmental design modifications combined with behavioral strategies likely positioned the Swedish people to think differently about how design affects injury, and the opportunities available to use design as a strategy for controlling foreseeable injury risks.

While the primary focus of the Swedish approach is to reduce injuries, the strategies certainly have implications for promoting activity. As part of a 2006 analysis of child injury rates for the 35 years between 1966 and 2001, Jansson and colleagues concluded that four factors explain much of Sweden's success in achieving impressive reductions in child injury mortality rates: (1) a functional and safety driven orientation toward architecture, planning, and transport that includes separating motor vehicles from bicycles and pedestrians,[1] and safer car design; (2) extended preschool services for the purpose of increasing supervision; (3) mandatory swim lessons for school children; and (4) locally-based safety programs that address the specific needs of communities (Jansson et al., 2006). Using policy to promote environmental and behavioral changes to address pedestrian, play, cycling, and swimming injuries, this national initiative offers a model for injury prevention, and an example of how much overlap exists between the priorities of injury prevention and the targeted activities of the active living community. This case provides support for how environmental modifications can be made to reduce the likelihood of injuries while supporting increased physical activity.

Swedish attention to child injury prevent through environmental design, evolved to focus specifically on roadways when, toward the end of the 1990s, the Swedish Road Administration introduced Vision Zero. The initiative, which seeks to "build a safe system where all predictable crashes and collisions had tolerable health losses", offers another example of environmental modifications that provide safer, appealing spaces for activity (Johansson, 2009). The people behind Vision Zero embrace an ethical approach to their work, declaring, "it can never be ethically acceptable that people are killed or seriously injured when moving within the road transport system" (Johansson, 2009), and placing road designers at the center of the strategy for eliminating all road traffic related deaths and injuries within Sweden. The impact of the Vision Zero approach has been the redesign of many roadways in communities throughout Sweden, and corresponding reductions in fatalities among road users (Johansson, 2009). The use of separate spaces for cyclists and pedestrians that are distinct from cars; narrow roads to slow cars where other road users are present; and maximum speeds for cars based on epidemiologic data about the speeds that pedestrians can survive an impact with a car are a few examples of the approach to design that characterizes Vision Zero.

In the U.S., recent efforts to translate the Vision Zero approach into an initiative that could begin to address road traffic risks to cyclists and pedestrians is organizing, and in some areas it is underway (http://safety.fhwa.dot.gov/tzd/). Whether the approach for road traffic that has been so successful in Sweden will be replicated in the U.S remains to be seen. If progress is made, it will be easier to be active and safe in the communities affected, with the environmental designs that are oriented toward safe travel and a place in the transport system for all users.

6. Conclusions

To facilitate the integration of injury prevention with active living, researchers must build the evidence base for interventions that are effective and safe, and then translate these interventions for use in community settings. A research agenda is needed that addresses relevant injury prevention issues related to increasing physical activity, changing the environment, modifications in city planning, changes in legislation, and the opinions and desires of community members.

Efforts to increase physical activity optimally occur in partnership with safety, so that all individuals can maximize their activity with the lowest possible risk of injury. Safe environments help ensure that while people are more active (our desired result) the risk of injury for any given exposure is reduced (also our desired result) (Peek-Asa and Zwerling, 2003). This is an important concept when evaluating strategies to increase physical activity: although there may be an increase in the number of injuries, the important measurement is the rate of injuries (number of injuries *per* exposure). More research is needed to collect necessary data to better quantify these various injury risks, related to exposure to various activities and settings (e.g., urban, rural, parks, traffic flow, etc.).

In the most comprehensive review to date on implementing strategies to improve physical activity while preventing injuries, Martin-Diener et al. (2010) noted a need for physical activity promotion to accompany injury prevention efforts. Conducting joint research projects that combine the talents of physical activity professionals, environmental specialists, and injury prevention researchers, may be the best way to proceed in the future. One way to do this is for those working in physical activity to partner with injury researchers at one of the many CDC-funded Injury Control Research Centers (http://www.cdc.gov/injury/erpo/icrc/).

[1] For additional information on how the road traffic component is being operationalized, please see the Vision Zero website 〈www.visionzeroinitiative.com〉.

These partnerships may help those working in the active living field to more easily obtain data on pedestrian injuries, and other active living-related injuries, which are widely available and can be obtained from the CDC, emergency departments, or police records. Such collaborations can also expand the reach of the active living community.

Effective partnerships should be also bidirectional to most effectively create safe environments for physical activity; in addition to physical activity researchers reaching out to injury prevention researchers, injury prevention researchers should reach out to those working to address the obesity epidemic by promoting physical activity. For example, the 2011 U.S. National Prevention and Health Promotion Strategy (http://www.healthcare.gov/center/councils/nphpphc/) calls for the implementation of policies and environmental changes to support physical activity. Investments will likely be made to strengthen and create communities that facilitate active lifestyles, which will undoubtedly create opportunities for injury prevention professionals to partner with individuals working to promote activity, to ensure safety is adequately considered.

As a result of renewed emphasis on the built environment and research focusing on "Place", several new research priorities have been identified that, if funded, could have dramatic impacts on knowledge, design, and implementation of effective place-related interventions (Sleet et al., 2010b). Below we highlight a select number of research needs that are relevant to both obesity prevention and injury prevention priorities.

6.1. Epidemiology of place-related injury

- Assess differences in pedestrian and cycle injury risks (which account for exposure) in communities that have used alternative built environments.
- Document the relationship between use of mobile devices and technology (cell phones, iPods, etc.) while walking or biking, and injury risks.
- Conduct GIS-based investigations looking not only at physical activity levels (intensity, duration, frequency), but also exposures to traffic, mishaps, and near misses.

6.2. Measurement

- Collect pedestrian, cycle, and sports and recreation exposure (by setting, intensity, etc.) information to calculate injury rates, which can be used for risk assessment comparisons.
- Develop tools to document objective measures of public behaviors by place, including traffic patterns, movement in public places, traffic and pedestrian/cycle mix, to inform better community designs that encourage physical activity while protecting against injury.

6.3. Intervention effectiveness

- Quantify the economic effects of increased physical activity, including the potential side effects of increasing injury.
- Evaluate the impact of community programs, like safe routes to schools, or the walking school bus, on injury reduction.
- Evaluate the safety impact of new legislative initiatives and federal incentives aimed at promoting walking, biking, and other obesity-prevention strategies, on population level physical activity and injury rates.
- Measure the impact of converting places and spaces to support active living (e.g., converting commercial streets to pedestrian malls) and the effect of conversion on injuries, activity levels, and 'accident migration' to adjoining streets.

Adding these additional steps to an active living research agenda may accelerate our knowledge on how to lower injury risks as physical activity and strategies for active living continue to gain relevance and priority in the public health agenda.

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