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Adolescent development and risk of injury: Using developmental science to improve interventions

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Abstract

In adolescence, there is a complex interaction among physical, cognitive, and psychosocial developmental processes, culminating in greater risk-taking and novelty-seeking. Concurrently, adolescents face an increasingly demanding environment, which results in heightened vulnerability to injury. In this paper, we provide an overview of developmental considerations for adolescent injury interventions based on developmental science including findings from behavioral neuroscience and psychology. We examine the role that typical developmental processes play in the way adolescents perceive and respond to risk and how this integrated body of developmental research adds to our understanding of how to do injury prevention with adolescents. We then highlight strategies to improve the translation of developmental research into adolescent injury prevention practice, calling on examples of existing interventions including graduated driver licensing.

INTRODUCTION

Worldwide, injury is a leading cause of adolescent death and disability.[1] In the United States, injuries are responsible for more adolescent deaths than all other causes combined.[2] During adolescence, there is a complex interaction among physical, cognitive, and psychosocial developmental processes, culminating in increased novelty-seeking and risk-taking behavior. [3] At the same time, with growing autonomy, adolescents face the challenge of making decisions independently in situations that are new to them. The health and criminal justice consequences of risk-taking behavior become more serious as the decision-making environment expands to include access to automobiles, alcohol, drugs, and

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firearms. The confluence of pubertal-, psychosocial-, cognitive- and neuro- development is the context for adolescent vulnerability to injury; as a result, an understanding of developmental processes must be integral to adolescent injury prevention programs.

In this paper, we provide an overview of developmental considerations for adolescent injury interventions based on developmental science, including research findings from behavioral neuroscience and psychology. We examine the role that typical developmental processes play in the way adolescents perceive and respond to risk and how this integrated body of developmental research adds to our understanding of how to do injury prevention with adolescents. We then highlight strategies to improve the translation of developmental research into adolescent injury prevention practice, focusing on graduated driver licensing to reduce road traffic injury.

ADOLESCENT DEVELOPMENT AND RISK OF INJURY

Risk Behavior

Across many species of social mammals, increased risk-taking, novelty-seeking, and social affiliation are defining characteristics of adolescence. [4] Regardless of how it is measured, risk behavior is nearly always associated with increased risk of injury. [5] Evolutionarily, despite its high costs, risk-taking has been conserved (i.e., maintained stable in the gene pool) from rodents to primates, suggesting that it serves important function. [4, 6] Indeed, developmental theories of risk behavior assert that risk behaviors like smoking or dangerous driving can bring individual, interpersonal and psychosocial benefits, as well as risk of harm.[7] In fact, risk behavior is so integral to healthy adolescent development that only adopting risk-avoiding behaviors may be just as deleterious to adolescents' well-being as excessive risk taking.[8] Risk-taking provides adolescents with a means of establishing autonomy, gaining peer respect and acceptance, and proving and shaping identity.[9] Maturational changes in the structure and function of the adolescent brain, changes in the stress response system, and circulating pubertal hormones may promote exploration during adolescence, increasing the accompanying risk of injury.[4, 10]

Brain Development during Adolescence

The protracted course of pre-frontal development—In the last decade, burgeoning research in adolescent behavioral neuroscience has provided a more robust and nuanced picture of the interplay between developmental neurobiology, the environment, and risk of injury.[6, 11, 12] Indeed in the last decade, neuroimaging and electrophysiologic studies have documented structural and functional changes in brain regions that play a key role in decision-making about risk.

During childhood and adolescence, the brain's cortical areas thicken as neural connections proliferate.[13] Subsequently, rarely used connections are selectively pruned away, [11] allowing the brain to change structurally in response to its environment. [4] The frontal lobes are among the last to show these structural changes. [11, 14] With pruning, mental abilities become more localized within specific areas of the brain. [4, 15] Neural connections that survive the pruning process are "insulated" with myelin, a sheath of fatty cell material wrapped around neuronal axons. Myelin allows nerve impulses to travel throughout the

brain more quickly and efficiently. [16] Evidence suggests that the pre-frontal cortex is not fully myelinated until the early 20s or later. [17, 18]

The frontal lobes support and facilitate functions such as regulating impulsivity, overriding emotional arousal, and anticipating consequences. [14, 19] Throughout adolescence, brain regions become increasingly interconnected, improving processing speed and efficiency, and better integrating prefrontal areas with other brain regions. This is thought to underlie the more efficient and competent regulation of cognitive processes that emerges with age. [11] Although the links between changes in brain structure and behavior remain speculative for many adolescent risk behaviors, [6, 20] immaturity in the prefrontal cortex (and, by extension lack of connectivity in the brain regions that support prefrontal functions) has been associated with the propensity for drug use and problem gambling in adolescence. [4, 21]

Changes in emotional reactivity and the stress response—Puberty is accompanied by rapid acceleration in growth and changes in body composition, reproductive maturity, and changes in circulatory and respiratory systems. [22] Accumulating evidence suggests that the pubertal transition plays a role in adolescent sensation-seeking. [23] After puberty, adolescents appear to become temporarily more physiologically and psychologically reactive to stress as a result of interactions between sex hormones and neurotransmitters. [24–26] They may experience stressors as more physiologically and emotionally arousing than adults (e.g., pounding heart, surges of stress hormones such as cortisol, greater emotional intensity). [27–30] These emerging findings may help provide a biological mechanism to explain the longstanding observation that adolescents' decision-making capabilities are more impaired in stressful situations than adults'. [31, 32] Indeed, conditions of high arousal, stress, or conflict may provide the backdrop for some of the riskiest adolescent behaviors, which are particularly likely to result in injuries.[33]

The important moderating role of arousal on risky decision-making helps explain why in low-pressure circumstances adolescent function cognitively quite like adults, while at other times, their decision-making skills look very much less mature.[31] The critical distinction between decisional capacity and performance in real-world situations is likely why, for example, classroom-based drivers' education courses are not associated with reductions in the adolescent motor vehicle crash (MVC) rate.[31] It is very difficult to recreate the novel, stressful, and emotional situations novice drivers will face behind the wheel in the classroom.

Developmental asynchrony and injury risk—One theory of adolescent risk-taking suggests that risk-taking results from the interaction of two developmental processes which operate on different time courses: prefrontal functions such as cognitive control, which improve slowly over time, and drives toward sensation-seeking and vulnerability to psychosocial stress that emerge earlier.[34, 35] This temporal gap has been compared to starting the engine of a car without the benefit of a skilled driver, an analogy that is particularly apt in relation to injury prevention. [36]

PSYCHOSOCIAL DEVELOPMENT AND RISK OF INJURY

By mid-adolescence, under “ideal” conditions, adolescents demonstrate decision-making capacities that are similar to adults. [31] However, having the cognitive capacity to make decisions does not necessarily ensure that adolescents will be able to exercise these skills in practice, when the role of past experiences and social context may be paramount. In contrast to purely rationality- and cognitive maturity-based theories of development and decision-making, newer theories suggest that trading off risks and rewards gives way, with experience, to decision-making based on “gists.”[37] These cognitive shortcuts are, in effect, a mental “rolodex” of memories about similar experiences that can be called up to inform the decision at hand. Without gists, decision-making processes may be more effortful and taxing for adolescents than for adults. [37]

Reckless behavior during adolescence is often attributed to egocentrism and feelings of invulnerability. For example, teen drivers have been found to view various dangerous driving behaviors as less risky than adults. [38] Indeed, both adolescents’ and adults’ risk perceptions are “optimistically biased”, that is, they estimate their risk of negative outcomes to be lower than others like them. [39] Nonetheless, significant evidence shows that adolescents often do perceive risk in dangerous situations.[39] In fact, studies have found that younger adolescents overestimate the frequency of negative outcomes such as getting into a crash if they ride with a drunk driver, or contracting a sexually transmitted infection, whereas older adolescents perceive similar amounts of risk in these activities as adults. [3, 39] Adolescents’ risk judgments reflect their experiences. If, after engaging in risk behavior, they fail to experience the negative consequences, the perceived benefits become greater and the risks fewer over time. [40]

For many adolescents, being aware of the risks involved in a given activity does not deter their participation. [41] They may judge the risks and benefits of engaging in such behavior differently than do adults. [31] In fact, perceived benefits of engaging in risk behavior may better predict behavior than perceived risks. [42] For example, students who perceive benefits from behaviors such as smoking and drinking are more likely to adopt these behaviors than their peers. [42] In addition, adolescents may weigh proximal consequences more heavily than distal ones when making decisions.[43] Thus, prevention strategies that focus on the long-term costs of potentially injurious behaviors may be undermined when teens focus, instead, on short-term benefits.

Despite acknowledging the consequences associated with a given risk behavior, adolescents may evaluate the desirability of those consequences differently than adults.[44] For example, early adolescents are particularly concerned with conformity and peer approval. [45] Adolescents may prioritize establishing some aspect of their social identity over self-preservation. Young drivers cite “showing off” for friends as one of the key causes of MVCs.[46] In laboratory-based driving tasks, adolescents’ risk-taking behavior is similar to adults when they are alone. In the presence of friends, however, risk-taking behavior increases for subjects into the college years, but not for adults.[3] Outside of the laboratory, the risk of death in a MVC increases with each teenage passenger carried, which, in addition to the distractions posed by friends, may also be related to impressing friends.[47] Thus,

while adolescents may understand that a given behavior is dangerous (e.g., not wearing a seatbelt, carrying a weapon), they may prioritize establishing a social identity over safety messages.

Some educational injury prevention interventions are founded on the idea that youth can be persuaded to abstain from risky behaviors. However, attempts to prevent injuries by addressing cognitive distortions underlying risk behavior or increasing knowledge of risks alone is unlikely to translate into better decision making in the real world. High-profile programs like “Scared Straight” (a delinquency and violence prevention program based on showing teens what prison is like) and “DARE” (a classroom-based program implemented by police officers aimed at teaching children and adolescents to say no to drugs, gangs, and violence) have proven to be largely ineffective.[48, 49] These programs are premised on the idea that teens who understand the negative consequences of their behavior will be motivated to behave safely.[48] It is equally likely that teens understand the risks associated with delinquency or drug use and know how to avoid them; nonetheless, in-the-moment considerations, such as gaining social status or the attention of a romantic partner, or situational factors such as stress or arousal take precedence, particularly as the neural substrates of cognitive and emotional regulation are still immature. In fact, a meta-analysis of Scared Straight-type juvenile awareness programs found increased odds of delinquency among participants; one possible explanation for this finding is that bringing together youth at risk for delinquency reinforces participant’s identities as delinquents, a proximal social benefit, compared to the distal risk of incarceration.[48, 50]

Social, Environmental, and Political Context of Development

While adolescents are capable of mature decision-making, they may not always act in their own best interest, given the particular importance of contextual factors such as time pressure, arousal, or peers. Many factors affect adolescent risk of injury; therefore, intervention strategies must be multifaceted. Shoring up the social ecology of adolescent risk taking: parents, peers, policy-makers, clinicians and teachers, is key to successful intervention in this age group. The social ecological model of development and injury risk in adolescence is summarized in Figure 1.

The ecological approach situates the individual in a system of relationships: micro or individual-level (adolescent), meso-level (family/peer), community level, and macro-level (sociopolitical/cultural). Peers, parents, communities, policy-makers and adolescents form a system of relationships that either promote or prevent injury. Given reciprocal interactions between the individual and the environment, development cannot be separated from the environment in which it occurs. [51]

IMPLICATIONS FOR INJURY PREVENTION

Historically, there has been an expectation that adolescents react to the world the same way adults do; however, the needs of adolescents with respect to injury prevention are distinct from those of adults and children. There is an inherent tension between the need to protect youth from injuries and the need to allow them the autonomy to take the risks that are integral to healthy development.

Many educational interventions operate on the assumption that most adolescents can assimilate prevention messages into their decision-making, and can act in accordance with that information to protect themselves. Such injury prevention efforts employ an individual-level approach requiring the adolescent to act. Thus, in practice, if not in theory, injury prevention relies on education to compensate for developmental vulnerabilities. Unfortunately, applying these lessons often relies on skills that are most impacted by developmental processes: planning, foresight, decision-making competence, and impulse control. Further, these programs overlook the fact that adolescents may exhibit the capacity for adult-like cognitive skills, but may have different decision-making priorities in the moment, resulting in decisions that are at odds with health education recommendations.

There is a natural link between “passive” injury prevention strategies and developmental appropriateness. Passive strategies provide protection that is not operator dependent—a consideration that is particularly important when the operator may be experiencing developmental changes that put him or her at risk for injury. Developmentally appropriate interventions can include a component focused on changing the risk-taking environment—either to reduce environmental demand or to reduce negative consequences. Fortunately, injury prevention best practices research and developmental research converge with respect to implications for intervention. Intervention strategies that are community or macro-level are more effective than those that target skill-building alone; there is little evidence that educational intervention alone reduces short-term injury incidence.[52, 53]

Indeed, there is evidence that educational strategies aimed at teens are much more effective when nested within intervention strategies that operate multiple levels of the social ecology depicted in Figure 1. For example, Senserrick et al. found that an ongoing intervention to scaffold the social ecology of teenage risk-taking, including community-wide buy-in from parents, teachers and healthcare professionals, was associated with a decrease of 44% in the relative risk of a MVC compared to a driver-focused workshop alone.[54] This multilevel intervention reflects a developmentally-informed approach to injury prevention because it is not entirely reliant on the skills of individual adolescents; instead, the intervention focuses on building the scaffolding that can prevent or lessen the consequences of errors in judgment that are a predictable part of adolescence.

Graduated driver licensing as a developmental model

Developmental science suggests that injury prevention with adolescents must focus on making the environment safer, knowing that they will take risks, and gradually increasing environmental demand as maturity increases. One of the most cited examples of a developmentally-appropriate program is graduated driver licensing (GDL) to reduce road traffic injuries.[6] GDL is a nearly ideal example of developmentally-informed intervention.

Beginning in the 1990's, U.S. states began to pass GDL to address high rates of motor vehicle crashes (MVCs) among novice drivers. A macro-level legislative strategy, GDL reduces the environmental demands of driving during periods of highest crash risk, while also reducing key cognitive and psychosocial risk factors for crashes. GDL generally involves progression through a permit stage, in which driving takes places under adult supervision, to a provisional stage in which risky driving environments are limited (e.g.,

nighttime driving, driving with teenage passengers), and finally to full licensure. [55] This strategy phases in risk over time, and thereby addresses both age and inexperience, which are independent risk factors for MVCs in early licensure. [56] Allowing novice drivers to age out of some of the developmental vulnerabilities for crashes, while gaining driving experience in less demanding conditions, aptly addresses key developmental vulnerabilities for injury in adolescence.[6] GDL has consistently been found to have a major impact on reducing the crash rate among the youngest drivers. [57–60] Effectiveness of the laws has also been closely linked to the degree to which driving privileges are restricted and then phased in over time. [57–60]

Developmental research predicts that reducing passengers will reduce both social pressure to impress friends, as well as distractions. Demanding conditions such as nighttime driving are delayed until driving behaviors become more reflexive and automatic—calling on the idea of “gists” or decision-making shortcuts based on past experiences that can be summoned quickly in new situations. [37] Rather than trying to prevent all risk (i.e., raising the age at which drivers can be fully licensed) GDL reduces the chances that a momentary error in judgment will have catastrophic consequences.

One way to improve GDL programs, according to an ecological model, is to help parents better understand the developmental risks associated with driving. [55] In many US states, GDL provisions require a specific number of documented hours of parentally-supervised driving during the permit phase. Ultimately, parents are charged with enforcing the provisions of GDL. They may fail to fully enforce the provisions of GDL because they underestimate their teens’ involvement in risky behaviors, or are overconfident in their decision-making abilities. [61–64] Studies in the United States, Canada, and New Zealand have found youth-reported violations of GDL provisions to range from 23% to 80%. [65] Thus, focusing interventions on helping parents understand developmental risks for injury may help improve parental enforcement of GDL provisions.[65, 66]

CONCLUSION

There is a complex interaction between neurological development, pubertal development, cognitive development, and the environment, the result of which is a period of particular vulnerability to injury during adolescence. The nature of brain growth and change in adolescence adds to mounting evidence from the behavioral sciences that adolescents are not older children or younger adults, but that their needs with respect to injury intervention are unique.

Thus, we must examine the assumptions of injury prevention strategies with adolescents and redirect the injury prevention paradigm accordingly. Injury prevention efforts with adolescents should focus on phasing in risk over time paralleling maturity. In addition, injury prevention inventions should seek to scaffold developmental vulnerabilities by focusing on peers, parents, and policymakers. Advances in developmental research can serve as the impetus for a new way of thinking about adolescents and risk behavior. Adolescents’ developmental need for novel experiences and drive to test the boundaries of their competence should not be the targets of intervention since they are unlikely to be

modifiable. The challenge for injury prevention professionals is to create a system that takes development into account and shores up these vulnerabilities.

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Figure 1.

An ecological model of adolescent development and injury risk, which highlights the role of multiple levels of social organization in shaping both developmental biology and risk of injury.