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An Integrative Review of Return to Driving After Concussion in Adolescents

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Abstract

Concussion is a common injury among adolescents. It is unknown how a concussion affects driving behavior and performance in adolescents. Although there are guidelines for return to learn, exercise, and sports that school nurses can help support in school, little is known about return to driving after concussion. The goal of this integrative review was to summarize the current literature on return to driving after concussion in adolescents. Six articles published between 2016 and 2020 were included in the review. Physicians and nurse practitioners find providing driving recommendations to adolescents to be appropriate; however, they are unclear what metrics to use to determine whether a patient is fit to drive. Future studies should explore clinical predictors of readiness to return to driving in adolescents. School nurses have an opportunity to support adolescents in their resumption of typical activities after concussion including school, sports, and, as more evidence becomes available, driving.

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Authors' Note

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Author Contribution

Divya Jain contributed to conception, design, acquisition, analysis, or interpretation; drafted the manuscript; critically revised the manuscript; gave final approval; and agreed to be accountable for all aspects of work ensuring integrity and accuracy. Kristy B. Arbogast, Christina L. Master, and Catherine McDonald contributed to conception, design, acquisition, analysis, or interpretation; critically revised the manuscript; gave final approval; and agreed to be accountable for all aspects of work ensuring integrity and accuracy.

Declaration of Conflicting Interests

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Keywords

adolescence; concussion; return to driving; driving safety

Approximately 1.1–1.9 million children under the age of 18 in the United States are diagnosed with a concussion annually, with most occurring in 14- to 17-year-olds (Bryan et al., 2016; Centers for Disease Control and Prevention [CDC], 2007). The mainstay for concussion management is a period of physical and cognitive rest followed by a gradual return to daily activities. Practitioners have stepwise management strategies for guiding adolescents back to school and sports postinjury, but no such guidelines exist for returning to driving, a common adolescent daily activity that can be affected by concussion (Harmon et al., 2019; Zemek et al., 2015).

Concussions can affect neurological domains that are required for driving and thus may particularly influence the safety of adolescents behind the wheel (Preece et al., 2010). For example, there is a high prevalence of visual disturbances postconcussion in adolescents (Master et al., 2016). Of particular concern, a concussion may affect the cognitive processes that are required for driving. Driving is a cognitively demanding task, requiring simultaneous monitoring, updating, planning, and attention control (Romer et al., 2014). In adolescents, impairments to motor and visual integration, as well as cognition, can persist past symptom resolution (Brown et al., 2015; Field et al., 2003; Shrey et al., 2011). While it is not known how the cognitive deficits adolescents experience postinjury affect their driving performance, it is known that healthy adolescents who have greater difficulty with executive functions tend to display worse driving performance (Mäntylä et al., 2009; Pope et al., 2016).

Typically, research on adolescent driving safety has focused on risk factors such as the presence of other adolescent passengers, in-vehicle distractions, and hazard anticipation (Curry et al., 2012; Foss & Williams, 2015; Romer et al., 2014). Little is known about the risk of driving postconcussion in adolescents as most research of the effects of concussion on driving performance focuses on the adult population (Baker et al., 2015b; Hoffman et al., 2018; Preece et al., 2010; Schmidt et al., 2017). Research from the adult population indicates that deficiencies in cognitive processes such as attention and working memory that occur after a concussion or mild traumatic brain injury are associated with worse driving performance (Schmidt et al., 2017). There is also evidence to suggest that adult drivers have worse hazard perception within 48 hr postinjury (Preece et al., 2010), but few studies focus on changes in driving performance throughout recovery.

Both the Centers for Disease Control and the American Medical Society for Sports Medicine agree that adolescents should be counseled on returning to driving postconcussion (CDC, 2018; Harmon et al., 2019); however, many practitioners, patients, and families are not aware that driving could potentially be dangerous after a concussion (Preece et al., 2013; Schmidt et al., 2018, 2019). School nurses are in an optimal position to support adolescents and families after a concussion as injured youth return to school, sports, and exercise and often have many resources available given the breadth and depth of research guiding return to these cognitive and physical activities. However, the area of return to driving in

adolescents is not as well known. Therefore, the purpose of this integrative review is to summarize the current literature on return to driving after concussion in adolescents.

Method

The electronic databases PubMed, Scopus, and PsycINFO were searched August 4, 2020, using the following key words, mapped to Medical Subject Headings when available: (concussion* OR concussed OR mild traumatic brain injury) AND (automobile driving OR driving OR driver's license* OR licensure OR driving restriction*) AND (resume OR resumption OR return* OR allow* OR continue) AND (adolescen* OR teen* OR youth*).

Inclusion criteria for the integrative review were databased, peer-reviewed publications written in English that examined driving after concussion as an independent or dependent variable; focused on the adolescent age-group, 13–18 years of age; and published between 2000 and 2020. Research studies, case reports, and quality improvement articles were included. Exclusion criteria included review articles, dissertations, theses, and editorials.

Results

A total of 70 articles were identified in the search strategy. After removing duplicates, 53 articles remained. Of these, 46 articles were excluded based on title and abstract review, leaving seven articles. After full-text review, one article was excluded because the focus was not on changes to driving behavior in adolescents after concussion. Six articles published between 2016 and 2020 were included in the integrative review. The preferred reporting items for systematic reviews and meta-analyses (PRISMA) flow diagram (Moher et al., 2009) illustrates search results (Figure 1), and a summary of results is presented in Table 1. The level of evidence was determined using the Johns Hopkins Nursing Evidence-Based Practice Research Appraisal Tool (Dang & Dearholt, 2017). Of the six studies, one case study and one survey reported on data collected from adolescents. Four studies focused on data from clinicians and their use of the electronic health record with adolescent patients and/or their clinical guidance/recommendations. Two themes emerged through the studies: changes to adolescent driving performance and behavior after concussion and the current state of clinician recommendations with respect to driving.

Changes to Driving Behaviors and Performance Postconcussion

Two studies examined changes in driving behavior and performance in adolescents after concussion. One case study of an 18-year-old collegiate athlete who sustained a concussion during ice hockey practice showed a decline in executive function, via the Trail Making Test–Part B, and increased infractions on a driving simulation assessment 48-hr postinjury as compared to a preseason baseline (Raukar et al., 2018). These results suggest that cognitive deficits that arise after a concussion may impact driving performance in adolescents.

Another study leveraged the Youth Risk Behavior Survey, a survey administered biannually by the CDC that has two questions related to risky driving behavior: How often the high school student has driven drunk and how often they have been a passenger in a car of a driver who has been drinking (Knell et al., 2020). While these survey items do not

encompass all kinds of risky driving behaviors, female participants who had sustained a sports- or recreation-related concussion in the last 12 months were more likely to ride in a vehicle with a driver who had been drinking than female participants who had no history of concussion. No such association was found for male participants, and neither male nor female participants had an association between driving drunk and prior history of concussion.

Clinician Recommendations for Driving in Adolescents After Concussion

Two different quality improvement projects at children's hospital systems in Ohio and Texas amended the electronic medical record (EMR) to prompt sports medicine physicians to provide adolescent concussion patients with driving recommendations (Santana et al., 2020; Stuart et al., 2016). Both projects were successful, with over 97% of patients receiving driving recommendations without significantly lengthening the visit after changes to the EMR were adopted. However, a common challenge for physicians at both locations was objectively determining whether a patient was fit to return to driving. So while most patients were given time-based or behavior-based (i.e., driving at night) driving recommendations during their visit, physicians highlighted the fact there is no single test, time frame, or published guideline for health care providers to follow.

Objectively measured data also served as an important indicator for provider recommendations for driving status. One of the quality improvement projects captured reasons why a sports medicine physician recommended restrictions or limitations to driving. The most common reason was vestibular dysfunction (46%) determined by a validated vestibular-ocular-motor screening assessment (Santana et al., 2020). In addition, a retrospective chart review of 183 patients seen at one sports medicine clinic showed that the administration of a computerized neurocognitive assessment increased the odds of a patient being cleared to drive by nearly 6-fold (MacDonald et al., 2018). These two studies indicate that objectively measured data, rather than subjectively reported symptoms, were associated with a physician's recommendation for driving status. In contrast, a survey of nurse practitioners licensed in Washington and Oregon found that most recommended restrictions or limitations to driving for an adolescent patient are based on symptoms, most commonly the presence of headache, nausea, and other visual symptoms (Klein et al., 2017). Only 1% of these survey respondents recommended the use of a standardized tool or protocol to guide driving recommendations.

Discussion

This integrative review has shown a scarcity of published studies with respect to returning to driving after concussion in the adolescent population. All studies were either of Level III (nonexperimental studies) or Level V (quality improvement projects and case reports) evidence (Dang & Dearholt, 2017). The majority focused on clinician recommendations. Physicians and nurse practitioners alike find providing driving recommendations to adolescents after a concussion to be appropriate; however, they are unclear what metrics to use to determine whether a patient is fit to drive. Two studies examined changes in driving behavior and performance in adolescents after concussion. Both studies suggest that some

adolescents may engage in riskier driving behaviors and display worse driving performance after a concussion.

Guidance for clinicians on determining recommendations was challenging given the lack of current evidence. Some rely on objective assessments of neurological domains highly implicated in driving to give driving recommendations like the cognitive and visual domains. Others rely primarily on the presence of specific symptoms like headache or nausea. Because there are no standardized guidelines for health care providers to follow, clinicians not only rely on a range of criteria to determine readiness to return to driving, but they also provide a range of driving restrictions and limitations—time-based (e.g., no driving for 7 days), symptom-based (e.g., no driving until headache resolves), or assessment-based. This is in contrast to return-to-learn protocols that begin with a period of both physical and cognitive rest, followed by a gradual, controlled reintroduction of cognitive activity (Grady et al., 2012). Ramp-up of cognitive activity is generally determined by a standardized symptom monitoring tool, with patients advancing only when a given cognitive activity is tolerated without exacerbation of symptoms (Master et al., 2012). For example, a patient would advance to returning to school for a partial day once they can tolerate homework or school work at home without symptoms. Similar guidance in return to driving may be warranted.

While the addition of driving recommendations provides important guidance to adolescent patients and their families and rarely lengthens the duration of their visit, this review highlights that there is not enough evidence to support the development of standardized return-to-driving recommendations similar to return-to-learn protocols. Only two primary research articles related to the changes in driving behavior postconcussion in adolescents were found. One article suggested that adolescents may be more likely to engage in risky driving behaviors postinjury but only assessed alcohol-based driving risks. One case report found decrements on a simulated driving assessment in one collegiate athlete 48 hr postinjury. It is important to note that these studies did not assess the relationship between changes in driving behavior or performance and the criteria commonly used by practitioners to determine readiness to return to driving like vestibular dysfunction. In the adult driver population, standardized neuropsychological assessments have been used to predict return to driving after moderate and severe traumatic brain injury, but few studies exist to support the use of these assessments to determine readiness to return to driving in the adult concussion population (Baker et al., 2015a). The identification of standard clinical assessments that can predict driving performance in concussed adolescents is particularly necessary as even healthy adolescent novice drivers have difficulty with cognitively demanding driving skills like hazard recognition and focusing on the forward roadway (Curry et al., 2011; McDonald et al., 2014; McKnight & McKnight, 2003). The neurocognitive effects of a concussion could further impair their ability to complete cognitively demanding aspects of driving safely and successfully. Therefore, future studies should directly explore changes in driving behavior and performance after concussion and determine clinical predictors of readiness to return to driving.

This integrative review highlights the fact that the consequences of returning to driving too quickly after concussion in adolescents are not fully understood. While return-to-learn

practices recommend gradual reintroduction of cognitive activities to mitigate the risk of symptom exacerbation, the risks of returning to driving are unknown (Master et al., 2012). Early return to driving not only may exacerbate symptoms, but the neurocognitive sequelae of concussion may put adolescent drivers, and the road users around them, at an increased risk of motor vehicle crash. A survey of collegiate student-athletes found that, while most believed that driving immediately following a concussion is unsafe, many did not refrain from driving after sustaining a concussion. The student-athletes who did refrain from driving postinjury most commonly did so based on advice from a health care provider (Schmidt et al., 2018). A better understanding of how driving performance and risk of motor vehicle crashes change after concussion in adolescents is needed to provide health care providers with evidence-based driving recommendation guidelines.

Implications for School Nursing and School Health Services

School nurses are part of the front line of helping adolescents recover from concussion and resume normal activities as during the school year, they have an opportunity for almost daily interaction with injured youth (National Association of School Nurses, 2016). Although school nurses have access to return-to-learn and -sport guidelines, no such guidelines exist for return to driving. Being at the interface between health and education, school nurses can deliver pertinent information to both adolescents and their parents/guardians. School nurses also can work with the primary health care provider, athletic trainer, and/or other school staff to support return to physical and cognitive activities (Weber et al., 2019; Welch Bacon et al., 2017). While evidence in the adolescent population is limited, school nurses are uniquely situated to monitor symptoms and administer standard clinical assessments throughout recovery to better assess readiness to return to the cognitively demanding task of driving. As more information about the types of clinical assessments that can predict the driving performance of adolescents after a concussion becomes available, school nurses may be able to administer and monitor performance on these assessments regularly and relay that information to the adolescent's health care team and family to develop individualized steps for gradual return to driving.

Limitations

It is acknowledged that this review has some limitations that are likely to affect the external validity and implications of the findings. There were only six studies, and many focused on a single-center, in particular, specialty care clinics. However, adolescents can be treated for a concussion in a variety of settings by a variety of providers, such as the emergency department, urgent care, or their primary care physician or athletic trainer. Further assessment of driving recommendations given by different clinicians in different settings is required. Some studies did not include asymptomatic adolescents even though cognitive deficits can persist past symptom resolution. Only one case report assessed deficits in driving performance in the acute phase of injury. Studies determining deficits in driving performance in a larger sample and throughout recovery are needed to develop an evidence base for driving recommendations. No studies explored the relationship between driving performance and patient factors used by clinicians to determine readiness to return to driving. This research is needed to standardize the guidelines for providing recommendations on driving to adolescents and their families.

Conclusion

This integrative review demonstrated that clinicians believe counseling adolescent patients and their families on driving after concussion is important, but there is a lack of evidence to guide recommendations, restrictions, or limitations to driving postinjury. While there is growing research evidence for return-to-driving outcomes in adults with concussion, there is a dearth of information with respect to adolescents. Additional research is required to provide school nurses with evidence-based directives for returning adolescents to driving. This evidence will also be of value to patients, their families, and other clinicians. As this evidence grows, school nurses have an opportunity to support adolescents in their resumption of driving.

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Figure 1. Preferred reporting items for systematic reviews and meta-analyses flowchart reporting the literature selection process. Source: Moher et al. (2009).

Table 1.

Summary of Studies Included in the Integrative Review.

Author, Year, Level of Evidence	Study Design Purpose	Sample Characteristics and Setting	Variables: Independent, Dependent	Data Analysis	Main Findings	Limitations	Implications
Stuart et al. (2016), Level V	Design: Quality improvement project Purpose: Increase % of patients receiving driving recommendations	Setting: Physicians at eight sports medicine clinics of Nationwide Children's Hospital Sample: 983 Patient visits, aged 16 or older seen at new or follow-up visits	IV: Interventions — speaking to physicians, flyers, changes to EMR DV1: Percent of patients receiving driving recommendations DV2: Changes to flow in clinic visit with changes to EMR	Determine percentage of patients who received driving recommendations	<ul style="list-style-type: none"> Flyers led to modest improvement, 30% of patients received recommendations EMR requirements led to 97.6% of patients with driving recommendations Physicians estimated spending less than 30 s per patient on counseling 	<ul style="list-style-type: none"> Did not include permitted drivers Only specialty care clinic No analysis of verbal instructions Physicians noted that they could not determine if a patient is fit to drive No test, time frame, or published guideline for recommendations No assessments for predicting safe driving ability 	<ul style="list-style-type: none"> Physicians were able to adopt changes to EMR but were not sure how to objectively determine if a patient is fit to drive
Santana et al. (2020), Level V	Design: Quality improvement project Purpose: Increase documentation of driving restrictions in adolescents postconcussion	Setting: Texas Children's Hospital sports medicine clinic Sample: 321 patients, aged 15 and older seen for initial evaluation of concussion	IV: 'Concussion driving' smart phrase implementation in EMR DV1: % of patients receiving driving recommendations DV2: Reasons for issuing driving restriction	Determine % of patients who received driving recommendations Determine common reasons for issuing driving restrictions	<ul style="list-style-type: none"> 6 months after completion of project, providers included driving recommendations for 52/53 (98%) patients 46% of patients who were given driving restrictions were given these recommendations due to vestibular dysfunction 	<ul style="list-style-type: none"> Documentation on why restrictions were placed were not always clear Only specialty care clinic Did not look at duration for driving patients to be cleared or clinical reasoning for clearance 	<ul style="list-style-type: none"> EMR changes can be implemented, but evaluation of the criteria providers use to determine readiness to return to driving and their relationship to driving performance is needed
Klein et al. (2017), Level III	Design: Web-based survey Purpose:	Sample characteristics: 1,051 Actively	IV: Driving recommendation for standardized	Description of recommendations given and clinical	<ul style="list-style-type: none"> 93.8% Recommended 	<ul style="list-style-type: none"> 44.9% Had not seen a concussion in their practice 	<ul style="list-style-type: none"> NPs are providing clinical recommendations

Author, Year, Level of Evidence	Study Design Purpose	Sample Characteristics and Setting	Variables: Independent, Dependent	Data Analysis	Main Findings	Limitations	Implications
	Guidance given by nurse practitioners (NPs) on driving and clinical basis for restriction or limitations following adolescent concussion	licensed primary and psychiatric mental health NPs in Washington and Oregon	adolescent patient with a concussion IV: Clinical basis for restriction or limitation to driving	basis of those recommendations	<ul style="list-style-type: none"> some level of driving restriction ~33% time-based driving limits— 70.7% Recommended limiting driving for 7 days or less 49.8% Recommended symptom-based driving limits, most (56.8%) did not identify specific symptoms—most commonly identified symptoms were headache, nausea, visual symptoms, or changes in reaction time 28.5% Recommended limiting driving until additional medical evaluation Only 1% recommended the use of a standardized tool or protocol 	<ul style="list-style-type: none"> in the past 6 months, some had never seen a concussion Only half (49.8%) had received continuing education on concussion 	<ul style="list-style-type: none"> for driving, mostly using symptoms to recommend limitations to driving 70.2% Recommended driving within 7 days or less postinjury, but symptoms can persist up to 1- month postinjury
MacDonald et al. (2018), Level III	Design: Retrospective chart review Purpose: Determine clinical measures that influence a physician's decision to restrict driving postconcussion in adolescents	Setting: Nationwide Children's Hospital sports medicine clinic Sample characteristics: 183 Patients ages 16 and older seen at the clinic with a sports-related	IV: Physician clearance to drive at initial visit DV: Patient- reported symptom burden, postural stability, reaction times from CogState CNT	Mann-Whitney U and χ^2 tests to compare continuous and categorical variables between patients who were and were not cleared to drive Multivariable	<ul style="list-style-type: none"> Patients who were cleared were significantly more likely to have a shorter duration of symptoms, lower symptom score, lower scores for each symptom, and CogState 	<ul style="list-style-type: none"> Single-center, retrospective design Only assessed what influenced decision making, not correlations between the patient factors/ symptoms and 	An assessment of reaction time measures using CNT was highly associated with a clinician's recommended driving status for their adolescent patients, but this does not indicate that good reaction times on this assessment is related to better driving performance

Author, Year, Level of Evidence	Study Design Purpose	Sample Characteristics and Setting	Variables: Independent, Dependent	Data Analysis	Main Findings	Limitations	Implications
		conclusion within 30 days of injury; only 113 of which had CogState computerized neurocognitive test (CNT) data		logistic regression to determine patient factors and symptoms associated with driving status	<ul style="list-style-type: none"> CNT administration CogState CNT administration had the largest effect size (nearly 6x) Total symptom score and symptom of "feeling slowed down" were significantly associated with driving status 	<ul style="list-style-type: none"> actual driving performance All subjects did not complete CogState CNT 	
Rankar et al. (2018), Level V	Design: Case report Purpose: Determine changes in executive function and driving performance after a sports-related concussion	Sample: 18-Year-old collegiate athlete who sustained a concussion during ice hockey practice	IV: Preseason performance on Trial Making Test-Part B (TMT-B) and driving simulator evaluation DV: Postinjury performance on TMT-B and driving simulator evaluation	Description of preseason and postinjury performance	<ul style="list-style-type: none"> Preseason: 32.8 seconds on TMT-B; seven driving infractions with simulation 48-hr postinjury: 41 s on TMT-B (25% increase); 15 driving infractions 	<ul style="list-style-type: none"> Single-case report Only one cognitive assessment used to examine executive function 	<ul style="list-style-type: none"> There was an objective change in executive function as measured by TMT-B and simulated driving performance postinjury Because it was one case, no relationship between TMT-B and driving performance could be established
Knell et al. (2020), Level III	Design: survey Purpose: Determine the association between concussion history and cognitive, emotional, and behavioral health in high school athletes	Setting: 2017 administration of Youth Risk Behavior Survey by the CDC Sample characteristics: 6,454 Female and 6,814 male high school athletes	IV: Sports or recreation-related concussion in the last 12 months DV1: Drinking and driving DV2: Riding in a vehicle with a driver who has been drinking	Weighted logistic regressions to model the association of at least one concussion with the health factors of interest	<ul style="list-style-type: none"> Among female participants, statistically significant associations with a recent history of concussions included riding in a vehicle with a driver who has been drinking, but no such associations were found for male participants and 	<ul style="list-style-type: none"> The purpose of this study was not to determine changes in driving behavior or performance postconcussion, so only two questions about risky driving behavior were asked and assessed 	<ul style="list-style-type: none"> Concussions among female participants were associated with factors in the domain relating to decision making (entering a vehicle with a drunk driver) It is unclear whether concussions

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					neither male nor female participants had an association with driving drunk and concussion history		affect participation in other kinds of risky driving behaviors for both male and female high school athletes

Note. EMR = electronic medical record; CDC = Centers for Disease Control and Prevention; IV = independent variable; DV1 = dependent variable 1; DV2 = dependent variable 2.