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Project Title: Do Concussions or Mild Traumatic Brain Injuries Affect Academic Outcomes in Students

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Summary (250 words max single spaced):

Impact to the head and neck or elsewhere in the body, often occurring in youth while playing sports may cause a concussion due to traumatic forces transmitted to the brain, which can lead to alterations in brain physiology. Symptoms include headache, dizziness, nausea, vomiting, light sensitivity, blurred or double vision, noise sensitivity, attention and concentration difficulties, memory problems, confusion, depression, anxiety, and sleep disturbances. Treatment of concussion typically involves physical and cognitive rest followed by gradual return to activity based on return-to-play guidelines. Cognitive rest includes avoiding tasks that require attention and concentration, such as school, watching television, texting, or reading. However, the school environment is not conducive to cognitive rest and premature return may prolong recovery, worsen symptoms, and result in poorer academic performance, cognitive difficulties, and greater absenteeism.

Only a few studies analyzed post-concussion academic outcomes in the form of grade point average or scores on national exams and compared these measures to pre-concussion academic performance or to non-concussed controls. There is an increasing need to address the extent to which academic outcomes are affected following a concussion in order for education leaders to adequately develop a plan for effective reintegration of concussed youth back into the classroom. Therefore, the objectives of this study were to 1) systematically identify and summarize literature concerning the effects of a concussion or mild traumatic brain injury (mTBI) on academic achievement in a student population and 2) prospectively compare report card grades and absenteeism of students as they recover from their sport-related concussion.

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Introduction

Impact to the head and neck or elsewhere in the body, often occurring in youth while playing sports, may cause a concussion due to traumatic forces transmitted to the brain, which can lead to alterations in brain physiology.[1,2] Although the terms concussion and mild traumatic brain injury (mTBI) are often use interchangeably in sports medicine and in the literature, a concussion represents a functional injury while an mTBI refers to functional and structural injuries.[1] Sports-related concussions make up approximately half of all pediatric concussions.[3] The annual incidence of head injury in children and adolescents is estimated to be 317 per 100,000 in the USA.[4] The Centers for Disease Control estimates that 1.6 to 3.8 million concussions occur in sports and recreational activities annually.[5] Concussions are a major public health concern and present a direct burden on health care resources, in addition to the indirect economic costs associated with a loss of productivity, with associated costs estimated at sixty billion dollars in the USA in 2000.[6]

Symptoms include headache, dizziness, nausea, vomiting, light sensitivity, blurred or double vision, noise sensitivity, attention and concentration difficulties, memory problems, confusion, depression, anxiety, and sleep disturbances.[7,8] Treatment of concussion typically involves physical and cognitive rest followed by gradual return to activity based on return-to-play guidelines.[9] Cognitive rest includes avoiding tasks that require attention and concentration, such as school, watching television, texting, or reading. However, the school environment is not conducive to cognitive rest and premature return may prolong recovery, worsen symptoms, and result in poorer academic performance, cognitive difficulties, and greater absenteeism.[10,11] Many concussed youth make a full recovery within one to two weeks.[12,13] However, 20% to 30% of students may have persistent symptoms lasting more than one month, meeting the ICD-10 diagnosis criteria for post-concussive syndrome (PCS), which may result in prolonged difficulties with school, work, and decreased quality of life.[14,15,26, 27]

Previous research on academic outcomes following a concussion has generally shown no adverse effects, with a few studies claiming that concussions negatively affect academic outcomes.[16] However, many of these studies were flawed due to issues with defining cases, inconsistences regarding follow-up, participant ascertainment, controlling for pre-injury risk factors, and a lack of objective assessment methods, relying on self-report questionnaires or telephone surveys.[17] Studies measuring academic achievement or academic performance using standardized methods of assessment (e.g. standardized testing results or cognitive testing) have generally found no adverse effects of a concussion.[17] The majority of these studies utilize cognitive, neurobehavioral, and neuropsychological tests, including the Wechsler Intelligence Scale for Children (WISC), Trail Making Test, California Verbal Learning Test, and Wide Range Achievement Test (WRAT) to assess intelligence, adaptive problem solving, memory, and academic skills, such as reading, spelling, and arithmetic.[18]

Only a few studies analyzed post-concussion academic outcomes in the form of grade point average or scores on national exams and compared these measures to pre-concussion academic performance or to non-concussed controls. There is an increasing need to address the extent to which academic outcomes are affected following a concussion in order for education leaders to adequately develop a plan for effective reintegration of concussed youth back into the classroom. Therefore, the objectives of this study were to 1) systematically identify and summarize literature concerning the effects of a concussion or mTBI on academic achievement in a student population and 2) prospectively compare report card grades and absenteeism of students as they recover from their sport-related concussion.

Methods: Systematic Review

Sources and selection

In order to identify relevant literature, search terms were used to systematically search four electronic databases for eligible articles. The specific search strategy for each database and the dates searched can be found in **Table 1**. The identification of relevant studies involved a two-step process. First, titles and abstracts were independently reviewed by two reviewers and identified as potentially relevant or excluded. Next, the full text of all potentially relevant studies was obtained and the two reviewers independently applied a priori inclusion and exclusion criteria. Differences were assessed and resolved through discussion between the two reviewers.

Inclusion criteria

Studies were included in the systematic review providing they met all four inclusion criteria: (1) primary research published in English, including randomized control trials, cohort, case-control, cross-sectional, longitudinal, and controlled before-after; (2) participants were students enrolled in primary, secondary, or post-secondary education (including university, college, and trade/apprenticeship programs); (3) patients received a physician diagnosis of a concussion or mild traumatic brain injury (mTBI); and (4) post-injury academic outcomes were assessed in form of numeric or alphabet grade/grade point average (GPA), school attendance records, or national exam scores and compared to pre-injury or a control group. Case reports were excluded. Studies assessing academic achievement or academic performance only in the form of cognitive, neurobehavioral, and neuropsychological tests or self-report questionnaires and telephone surveys were also excluded.

Assessment of methodological quality

The methodological quality of all selected studies was evaluated using the Risk of Bias Tool from the Cochrane Handbook.[19] A quality assessment of the study data was conducted by two of the authors and the quality of each study was scrutinized for selection bias (non-random and consecutive recruitment), detection bias (data collection methods), performance bias (blinding), attrition bias (withdrawals and dropouts), reporting bias (outcomes measured, but not reported), and other sources of bias (possible confounders). Scores of high, medium, or low risk were given for each category and an overall risk of high, medium, or low was established. Two reviewers independently assessed methodological quality and discrepancies were resolved through consensus.

Data extraction and analysis

A structured form was used for data extraction for all of the included studies. The data extracted included study design, method of recruitment, study population (age of participants, sample size, sex), setting (inpatient, outpatient), diagnosis and diagnostic criteria of concussion or mTBI (case definition), cause of injury, inclusion and exclusion criteria, duration of study, academic outcomes measures, method of comparison, and results (estimate of each effect reported or calculated, including confidence intervals and p values, and statistical methods used for each reported outcome). Data extraction was performed by one reviewer and checked for completeness and accuracy by the second. Some studies reported more than one measure of academic outcomes. Due to heterogeneity in study design, age of participants, and academic outcomes measured, a meta-analysis was not performed. A summary of the study design, mTBI definition, sample size, age range, academic outcomes measured, and results of all included studies are presented in **Table 2**.

Results

Literature search

The results of the systematic literature search are summarized in Table 1. A total of 738 unique studies were identified though database searching. Of these, 633 were excluded at the

title- and abstract-review stage, leaving a total of 105 unique articles that were assessed for eligibility. After two authors independently applied the inclusion criteria, 98 papers were excluded, leaving 7 papers, consisting of 6 full text articles and 1 abstract. Two additional papers were identified from a systematic review by Lloyd et al. and 1 paper was found through a literature search for another systematic review, bringing the total up to 10 papers that were included in this review.

Study characteristics

The studies were published from 1994 to 2016. Seven were completed in the USA, one in Wales, one in New Zealand, and one in South Africa. The number of participants in each study ranged from 30 to 609 youth with traumatic brain injury. Ages of participants ranged from 0 to 18 years old. Two studies only included children under 10 years old at time of injury. The duration of study periods varied from two years up to twelve years. Of the 10 included studies, 7 were prospective cohorts and 3 were retrospective cohorts. Information and results from each individual study that met the inclusion criteria for this review are summarized in **Table 2**. The risk of bias in the included studies ranged from low to medium. Studies deemed to have medium bias included two studies that measured but did not report academic outcomes[20,21], two studies that had issues with missing and incomplete data[21,22], and four studies that measured absenteeism via telephone surveys[26-29].

Grade point average

Three prospective cohort studies met the inclusion criteria for assessing academic outcomes in form of grade point average. One study collected the most recent pre-injury grades for cases and the most recent pre-enrolment grades for non-injured controls, collected grades again closest to the 1-year assessment, and coded grades as above average (2), average (1), and below average or special education (0) to account for differences in grading systems between schools.[20] Grades in reading, mathematics, and spelling were coded individually and the average across the three academic areas was recorded as “grade.” Fay et al found that children who have sustained mild TBI show negligible deficits relative to their matched peers, with no important differences from controls in grades.[20]

One study collected annual grade point average (GPA) from cases and children with an uncomplicated arm injury as controls from three years pre-injury to three years post-injury and found that GPA showed little relation to injury severity and suggested that children suffering a mild TBI may need continued support in school several months after the recovery period.[21] In their abstract, Hendrickson et al concluded data interpretation was difficult due to missing data and other barriers to collecting achievement data, including permission, school transfers, incomplete records, and gaps in testing.[21]

One study acquired grades from the quarter or semester immediately before the injury and again from the grading period closest to 1 year from initial testing for cases, other injury, and non-injured controls; grades were equated to a 5-point rating scale and averaged over all academic classes.[22] There were no significant main effects for school grades and the magnitude of differences were small (range of effect sizes: 0.13 to 0.38).[22] The mean pre-injury school grade of the head injury, other injury, and non-injury groups were 2.3, 2.5, and 2.2, respectively. The mean post-injury school grade of the head injury, other injury, and non-injury groups were 2.3, 2.4, and 2.2, respectively and this was not significantly different from pre-injury grades. Light et al concluded that mild head injuries do not affect academic outcomes.[22]

One study collected grades over two years from students with very mild TBI (vmTBI), mTBI, and non-injured controls in the subjects Afrikaans, English, math and science. No statistically significant differences were found in English, math and science, comparing the pre- and post-test academic results.[23] However, there was a statistically significant decrease in

academic performance in Afrikaans in both the vmTBI (61.5% to 58.6%, p = 0.017) and mTBI (65.4% to 59.2%, p = 0.016) groups, while the control group indicated no significant decrease (69.5% to 67.2%, p = 0.567).[23]

National exam scores

Five articles measured academic outcomes defined as national exam scores. Three studies used non-injured controls, one study used other injury controls, and one study used both non-injured and other injury controls. One study collected the most recent pre-injury national achievement test scores for cases and the most recent pre-enrolment national achievement test scores for non-injured controls and again closest to the 1-year assessment.[20] Scores from national achievement test scores included the areas of reading, language, and arithmetic. Fay et al found that children who have sustained an mTBI show negligible deficits, with no significant differences from controls in national achievement test scores.[20]

One study collected annual exam scores from state reading and mathematics achievement tests (WASL, MSP, HSPE in Washington and PSSA in Pennsylvania) from cases and children with an uncomplicated arm injury as controls from three years pre-injury to three years post injury and found that test data showed little relation to severity, but concluded that children suffering from a mild TBI may need further assistance in school even several months after they recover.[21]

One study acquired pre- and 1 year post-injury achievement test scores from standardized testing records for the test occasion immediately before injury (or first testing), which were averaged over national percentile scores for all academic subtests available, providing a mean achievement test score (in percentile) for cases, other injury, and non-injured controls pre- and 1 year post-injury.[22] A significant main effect for group emerged for mean school achievement scores ($p < 0.05$). The non-injury group scored significantly higher than the other-injury group on both pre- (effect size 0.59) and post-test scores (effect size 0.58).[22] However, the head- and other-injury groups did not significantly differ from each other and neither did the non-injury nor head-injury group. Light et al concluded that mild head injuries do not affect academic outcomes when measured using nationally exam scores.[22]

One study from Wales assessed performance on the KS1 National Curriculum assessment administered to children 5-7 years old from 2003 to 2008 via the Wales Electronic Cohort for Children (WECC), a total, population-anonymized but linkable e-cohort study of all children born between 1990 and 2008 in Wales.[24] The KS1 assessment included a phonics test and assessment task administered informally as a part of normal classroom activity and students were classified as either level achieved or level not achieved. KS1 results were available for 90 661 eligible children in the study timeframe. Of the 90 661 children, 90 371 had no record of head injury and 290 (0.3%) had sustained a head injury: skull fracture (n = 153), intracranial injury (n = 107), or concussion (n = 30). There was no difference between the group with head injury, and those not sustaining a head injury, with respect to age at the time of KS1 assessment (p = 0.28), birth weight (p = 0.26), and gestational age (p = 0.30). Apgar score was associated with sustaining a head injury (p = 0.01). 77% of concussion cases achieved a satisfactory KS1 result compared to 81% of children without head injury. There was no statistically significant association between head injury and satisfactory performance on KS1 assessment (crude OR: 0.85; 95% CI: 0.33 – 2.16 and adjusted OR: 0.87; 95% CI: 0.31 – 2.49).[24] Gabbe et al concluded there was no evidence of a difference in achieving a satisfactory KS1 result when comparing children admitted to hospital for skull fracture or concussion with children who had not been admitted to hospital for head injury.[24] Children admitted for skull fracture or concussion demonstrated comparable odds of achieving expected levels of performance.

One study from New Zealand used performance on national examinations (School Certificate) to assess general academic achievement at 15-16 years old for children who had a reported a mild head injury between the ages of 0 to 10.[25] The 132 children were divided into an inpatient group (n = 36) and outpatient group (n = 96); in the 20 cases where multiple head injuries were sustained, the most severe injury was used to assign group (7 inpatient group cases).[25] Effects of mild head injury before age 10 were examined, followed by separate analyses for injury before age 5 exclusively (0 to 5 years old) and injury after age 5 exclusively (6 to 10 years old). 101 mild head injury cases were reported between 0 to 5 years old and 53 cases occurred between 6 to 10 years old. McKinlay et al found that although the inpatient group tended to score more poorly on the cognitive and academic measures, no significant group or pair wise effects were identified.[25] The separate analyses based on head injury before or after age 5 also produced no significant differences.

Absenteeism

Four prospective cohort studies measured school attendance following a concussion or mTBI. Two studies included elementary students and measured absenteeism in students 5-18 and 8-18 years old.[26,27] One study included junior high and high school students 11-17 years old.[28] One study included high school and college students with a median age of 15.5 years old. All four studies inquired about the number of school day absences through follow-ups via telephone interviews ranging from three days to three months post-injury. Two of four studies that measured absenteeism compared students who developed post-concussion syndrome (PCS) with those who did not. Babcock et al found that a mean of 3.8 school days were missed, 29.3% of patients with an mTBI developed PCS, and those who developed PCS missed a mean of 7.4 days compared to those who did not develop PCS missing a mean of 2.2 days.[26] At the three month follow-up, 28.9% of all patients missed >2 days of school, 44.3% with PCS missed >2 days of school, and 22.5% without PCS missed >2 days of school. Furthermore, patients who missed >2 days of school were at an increased risk of developing PCS compared to those who missed fewer days, with a relative risk of 1.89 (95% CI: 1.39 – 2.58).[26] Grubenhoff et al found that the median number of school days missed was 2 (IQR 1 – 3 days), 21% of patients with an mTBI developed PCS, and those who developed PCS missed a median of 3 days compared to those who did not developed PCS missing a median of 1.5 days ($p < 0.001$).[27] At the 30 day follow-up, 69% of patients without PCS missed at least 1 day of school and 82% with PCS missed at least 1 day of school ($p = 0.27$).[27] However, some participants were enrolled or had follow-up during school holidays and were not included in the analysis.

Thomas et al assessed post-concussive symptoms, outcomes, and complications at three day and two week follow-ups via telephone, and again at six weeks and three months if symptoms persisted, and found that the median number of school days missed was 2 (IQR 1 – 4 days).[28] Wasserman et al compared students with a sports-related concussion to musculoskeletal extremity injury at one week and one month follow-ups and found that students with a concussion took an average of 5.4 days to return to school while students with a musculoskeletal extremity injury took an average of 2.8 days to return to school.[29] Furthermore, 24% of concussed students had not returned to school at 1 week after injury. Although school absenteeism was noted, it was not included in the academic dysfunction score used in this study to assess post-concussion sequelae and no analysis was performed to determine if this result was significant.

Discussion

Grade point average: summary, main findings

Two studies measured and compared grades, but did not report numerical results.[20,21] Of these two studies, one collected and averaged grades in reading, spelling, and arithmetic, and one study collected annual grade point average. One study, where grades were equated to a 5-point rating scale and averaged over all academic classes, reported numerical results for the

grades collected.[22] All three studies that measured academic outcomes in form of grade point average did not find a significant difference in grades before and after sustaining a concussion or mTBI and when compared to controls. Any deficits in academic performance were negligible and differences were too small to be statistically or clinically significant. Laubscher et al only found a statistically significant decrease in the subject Afrikaans, but not in English, math, or science, but attributed the possibility of this result to a small sample size.[23]

National exam scores: summary, main findings

Two studies measured and compared national exam scores, but did not report numerical results.[20,21] Of these two studies, one collected national achievement test scores in the areas of reading, language, and arithmetic and one study collected exam scores from state reading and mathematics achievement tests (WASL, MSP, HSPE in Washington and PSSA in Pennsylvania). Three studies collected and reported numerical results for national exam scores.[22,24,25] One study collected standardized testing records in the USA, one study from Wales collected KS1 National Curriculum assessment results, and one study from New Zealand collected scores on national examinations (School Certificate). All five studies that measured academic outcomes in form of national exam scores did not find a significant difference in scores before and after sustaining an mTBI or mild head injury and when compared to controls. Any differences in academic performance were not significant and deficits were too small to demonstrate an effect. However, Hendrickson et al performed a separate population analysis of spring 2012 Washington state test scores and found that TBI classified students (mostly moderate and severe) consistently under-performed general education students, but no numerical results were reported and no distinction was made between mild, moderate, and severe TBI in this analysis.[21]

Absenteeism: summary, main findings

All four studies that measured academic outcomes in form of school attendance established that students with a concussion or mTBI end up missing school days. Two studies compared students that developed PCS with those who did not develop PCS, where the manifestation of PCS occurred in 21% to 29% of concussion cases, and found that that students with PCS miss a significant amount of school days.[26,27] Students without PCS missed an average of 1.5 to 2.2 days of school, while students with PCS missed an average of 3 to 7.4 days of school.[26,27,28] Babcock et al reported higher rates of PCS and a greater amount of absenteeism in both students with and without PCS compared to the study by Grubenhoff et al, but this could be attributed to a longer follow-up period (three months vs. thirty days) and a greater sample size (406 vs. 179). Wasserman et al found that students with a concussion take almost twice as long as students with an extremity injury to return to school (5.4 days vs. 2.8 days) and 24% of concussed students still have not returned to school after one week, but it would be important to determine if this result is due to the severity of concussion symptoms, recommended cognitive rest, or a combination of both.[29]

Other literature

The majority of studies that looked at the effect of a concussion or mTBI on academic performance or academic achievement opted for cognitive, neurobehavioral, and neuropsychological measures associated with successful learning instead of directly looking at GPA or national exam scores.[16] These tests evaluate attributes, including intelligence, memory, language, and executive function, which play a role in academic success in the classroom. These assessments included standardized tests, such as the Wide Range Achievement Test (WRAT), Wechsler Intelligence Scale for Children (WISC), California Verbal Learning Test, and Trail Making Test. Subsets of the widely administered WRAT include reading recognition, spelling, and arithmetic, which are commonly used as an indicator of academic proficiency in many studies looking at educational outcomes following a concussion or mTBI.[18] Other studies used subjective, self-report surveys or questionnaires, such as the Child Behaviour Checklist (CBCL), that are completed by students, parents, or teachers.[17] Several studies collected pre-injury GPA or national exam scores, but used these to match cases and controls. Although only a few studies

directly measured GPA or national exam scores, the general consensus that a concussion or mBI has an non-significant effect on academic outcomes is congruent with findings in other studies using standardized tests to measure academic outcomes, where students with a concussion or mTBI show minor to negligible long-term deficits with cognitive and neuropsychological testing.[16-18,30-33]

Limitations

Very few studies directly measured academic outcomes using school grades or national exam scores. Furthermore, two of four studies did not report numerical values of grades collected and two of five studies did not report numerical results of national exam scores collected.[20,21] Moreover, these few studies analyzed grades and exam scores from a different source, used different methods to compute results, and sampled different age groups. One study categorized grades as above average, average, or below average.[20] One study categorized exam scores as level achieved or level not achieved.[24] Three studies took place outside of North America (Wales, New Zealand, South Africa). Two studies examined concussion or mTBI exclusively in children under age ten. While all studies reached similar conclusions, it is challenging to compare results across a limited amount of studies that use different methods to assess academic outcomes in children at different levels of education. Hendrickson et al noted obstacles the collecting achievement data included parent permission, transfer to new schools, incomplete school records, gaps in longitudinal test administration, and confounding accommodations.[21] Light et al also noted logistical difficulties and problems with compliance from some schools resulting in missing or unusable school data and obtaining only approximately half of school grades and test scores.[22]

Definitions of what constitutes a concussion or mTBI also varied widely among the included studies. One study required documented loss of conscious (LOC) for an mTBI diagnosis, while other studies imposed limits on LOC in order to be classified as an mTBI, such as LOC less than 1 hour with neurological deficits or less than 6 hours without such deficits in one study to LOC less than 20 minutes in another study.[20,22,25-27] Four studies classified a concussion or mTBI as a closed head injury, while one study categorized mTBI as 1 (without CT abnormality), 2 (with skull fracture), or 3 (with brain CT abnormality).[20-22,24,25] Furthermore, some studies incorporated GCS score into the case definition, while other studies did not.[20,22,26-28] A concussion or mTBI in one study may not meet the case definition in another study or may be categorized as a moderate TBI instead. Contrasting definitions between studies can result in cases in the concussion or mTBI group presenting with a wide range of severities, which may differ in post-injury academic outcomes.

Future clinical directions

Return to School (RTS) concussion protocol developed following the National Institute for Health and Care Excellence procedures recommend no school for at least one week and cognitive rest (no television, video games, texting, reading) following a concussion, progressing to light activity (walking, fifteen minutes of screen time twice daily, light reading), and gradually returning to school with academic modifications (timetable/attendance, curriculum, environment, activities), increasing the workload as tolerated until a normal routine is established.[34] The goal is to prioritize return to school and recovery without aggravating symptoms. Even though studies show concussions or mTBIs do not affect academic outcomes, some students may develop persistent symptoms lasting more than one month, meeting the ICD-10 diagnosis criteria for PCS, which may have a more profound effect on academic outcomes.[34] Clinicians can use this information to carefully monitor symptoms and work with students, teachers, and parents to implement guidelines and individualized plans to optimize recovery and minimize absenteeism and drops in academic achievement.

Future research directions

More studies would have to be done utilizing a standardized method of collecting grades and national exam scores to confirm the effect of a concussion or mTBI on academic outcomes. Additionally, the establishment of a universal definition of what constitutes a concussion or mTBI would be beneficial to compare results across multiple studies. Studies should also be done to research to what extent accommodations affect academic outcomes. In a questionnaire-based study, Olympia et al. found 87% of concussed students were excused from physical activity, 87% received extensions on assignments, 84% were allowed excused absences, 84% received rest periods, 75% were able to postpone tests, 74% received extended testing time, and 73% were permitted a reduced workload, and 64% received accommodation for light and noise.[35] Furthermore, only 46% of school districts and 53% had policies, guidelines, or protocols in place to assist students returning to school following a concussion.[35] It would also be important to investigate to what degree these accommodations have on academic outcomes by facilitating the return to school process.

Table 1. Search strategy and results of the systematic literature search.

Electronic Database and Search Terms	**Hits, n**	**Potentially Relevant (by Title and Abstract), n**	**Selected, n**
Medline, 1946 to June 2016 1. exp Brain Concussion/ 2. concussion.tw. 3. exp Achievement/ or exp Educational Measurement/ or exp Educational Status/ 4. craniocerebral trauma/ or exp brain injuries/ or exp head injuries, closed/ or exp head injuries, penetrating/ or exp intracranial hemorrhage, traumatic/ or exp skull fractures/ 5. (“head injury” or “head injuries”).tw. 6. (“academic performance” or “academic outcomes”).tw. 7. 1 or 2 or 4 or 5 8. 3 or 6 9. 7 and 8 10. limit 9 to (english language and humans and (“all child (0 to 18 years)” or “young adult (19 to 24 years)”))	277	35	1
Embase, 1974 to June 2016 1. exp brain injury/ 2. concussion.tw. 3. (“head injury” or “head injuries”).tw. 4. exp achievement/ or exp academic achievement/ or exp educational status/ 5. (“academic performance” or “academic outcomes”).tw. 6. 1 or 2 or 3 7. 4 or 5 8. 6 and 7 9. limit 8 to (human and english language and child)	307	36	4
Scopus, 1970 to June 2016 (TITLE-ABS-KEY (concussion* OR “head injury” OR “head injuries”)) AND ((TITLE-ABS-KEY (academic W/5 (performance OR outcome* OR achievement))) OR (TITLE-ABS-KEY (education* W/5 (performance OR outcome* OR achievement))))	248	36	2
Cinahl, 1981 to June 2016 (concussion* OR "head injury" OR "head injuries") AND (((academic) N5 (performance OR outcome* OR achievement)) OR ((education*) N5 (performance OR outcome* OR achievement))) Limiters - English language, Human, Age Groups: All child	67	25	3

Table 2. Characteristics of included studies.

First author Year Country	Study design Comparison group	mTBI definition	Sample size	Age range	Academic outcomes measure	Results
Fay 1994 USA	Prospective cohort Compares TBI with non-injured controls pre-injury and 1 year post-injury	Mild, moderate, severe TBI: Closed head injury, documented LOC mTBI: initial GCS of 13-15, score of 15 must be achieved within 3 days	40 with mTBI	6-15 (7-16 at first assessment)	National achievement test scores in reading, language, and arithmetic Grades	Children who l deficits relative Socialization, c dysfunctional l teacher show Academic outc
Hendrickson 2014 USA	Prospective cohort Compares mTBI with uncomplicated arm injury 1, 2, 3 years pre-injury and 1, 2, 3 post-injury	Mild 1: without CT abnormality Mild 2: with skull fracture Mild 3: brain CT abnormality	609 with TBI (includes all mild (1,2,3), moderate, and severe)	<18	GPA State reading and mathematics achievement tests	GPA and state severity Mostly modera underperforme Academic outc
Light 1998 USA	Prospective cohort Compares head injury with other injury and non-injured controls pre-injury and 1 year post-injury	Closed head injury with documentation by ER personnel of at least two post-concussive symptoms (nausea, vomiting, headache, dizziness, diplopia, or ringing in ears) or a diagnosis of concussion and any one of the above symptoms LOC for <1 hour with neurological deficits and <6 hours without such deficits GCS of >12	119 with head injury	8-16 (9-17 at follow-up assessment)	Mean school grades Mean achievement test scores	No significant magnitude of c The injury grou other and neitl group Head injury of academic outc observing new On a 5 point s school grade (other injury, ar (0.7), and 2.2 The mean pos deviation) of th injury groups v respectively The mean pre (standard devi and non-injury 67.4 (21.9), re The mean pro (standard devi and non-injury 66.1 (21.9), re
Laubscher 2010 South Africa	Retrospective cohort Compared very mild TBI (vmTBI) and mTBI with non-injured controls	Concussion or mTBI: Rapid onset, short-lived neurological impairment; • acute clinical symptoms that reflect a functional disturbance rather than structural injury • ± LOC • neuroimaging normal vmTBI: apparent brain insult with insufficient force	26 with vmTBI and 9 with mTBI	Average age = 17.4 ± 0.68 years	Grades in Afrikaans, English, math, and science	No statistically found in Englis comparing the academic resu However in the significant dec occurred in bo 0.016) groups, significant dec Pre-injury grad 11.9), mTBI = = 12.5)

		to cause hallmark symptoms of concussion • involving very subtle changes in consciousness • symptoms usually lasting seconds to minutes				Post-injury gra 12.7), mTBI = = 13.7)
Gabbe 2014 Wales	Retrospective cohort Compares head injury with non-injured controls	Emergency admission for >24 hours, with a relevant principal 10th revision of the International Classification of Diseases (ICD-10) diagnosis of concussion (S06.0)	30 with concussion	5-7 at assessment	KS1 national curriculum assessment	77% of concus result compare injury (crude C adjusted OR: (
McKinley 2002 New Zealand	Retrospective cohort Compares 2 mild head injury groups (inpatient and outpatient) <10 years old at injury with non-injured controls via assessment of general academic achievement at age 15-16	LOC if evident of <20 minutes Hospitalization of ≤2 days, if this occurred No evidence of skull fracture Inpatient- admitted to hospital for <2 days Outpatient- seen by a general practitioner or an accident and emergency department and sent home	132 with mTBI (36 inpatient, 96 outpatient)	0-10 at injury (15-16 at assessment of general academic achievement)	National examinations (School Certificate)	Inpatient mTB the cognitive a group or pair w Regardless of mild head injur intelligence or The crude Sch outpatient, and 3.33 (SD = 2.4 The adjusted S reference, outp (SD = 2.2), 3.3 0.30)
Babcock 2013 USA	Prospective cohort Three months after the initial visit, participants or parents or guardians were interviewed by telephone and information was collected regarding the number of days of school missed owing to the TBI and PCS symptom score	One or more of the following: LOC <30 minutes Amnesia <24 hours or any alteration in mental state GCS of ≥13 measured 30 minutes or more after injury	406 (119 with PCS, 287 without PCS)	5-18	Absenteeism	A mean of 3.8 A total of 119 p presented to th Those who de days (SD = 13 missed a mea Patients who r increased risk who missed fe At the three m school, 44.3% 22.5% without
Grubenhoff 2015 USA	Prospective cohort Participants were contacted by telephone 30 days following injury to complete follow-up questionnaires regarding symptoms of persistent PCS, school absenteeism, and academic accommodations	GCS 13-14 GCS 15 with ≥2 of the following symptoms: LOC, post-traumatic amnesia, disorientation to person, place or time, subjective feelings of slowed thinking, perseveration, vomiting/nausea, headache, diplopia/blurry vision, dizziness, somnolence	179 (21 participants were enrolled or had follow-up during school holidays and were not included in analysis of school absenteeism)	8-18	Absenteeism	A total of 38 ch persistent PCS eight possible PCS) 96% of childre had returned t Subjects with days of school 2 – 5 vs. 1.5 d The median nu (IQR 1 – 3 day

						Overall, the da missed ≥1 day 69% without P with PPCS mis
Thomas 2011 USA	Prospective cohort Post-concussive symptoms, complications, and activity and exertion levels were assessed in enrolled subjects via telephone three days and two weeks after the initial visit Subjects who remained symptomatic or had not returned to normal activity by two weeks were contacted again at six weeks and three months	GCS 15 Acute Concussion Evaluation (ACE): patients must have had a force to the head and neck, and experience ≥one post-concussive sign/symptom Score >75 on Galveston Orientation and Amnesia Test (GOAT)	60	11-17	Absenteeism	The median nu (IQR 1 – 4 day Study did not f post-concussio school attenda
Wasserman 2016 USA	Prospective cohort High school and college students who had sustained a sports-related concussion or musculoskeletal extremity injury were compared at 1 week and 1 month follow-ups after injury via telephone interviews	American Congress of Rehabilitation Medicine clinical definition of mTBI Concussion: a blunt injury to the head or to the body with impulsive force transmitted to the head that resulted in any of the following symptoms: headache, nausea, vomiting, dizziness/balance problems, fatigue, drowsiness, blurred vision, memory difficulty, or difficulty concentrating	70 with concussion 108 with extremity injuries	Median age = 15.5 years (concussion) Median age = 16.0 years (extremity injury)	Absenteeism	Students with school (media students with a mean = 2.8; S 24% of concus not returned to

GCS: Glasgow Coma Scale

Methods: Prospective Case Series

A case-series study was conducted among youth with a physician diagnosis of sport-related concussion. The study was conducted at the Pan Am Concussion Clinic in Winnipeg, Manitoba. The Pan Am Concussion Program is the only provincially-funded, multi-disciplinary pediatric concussion clinic in Canada where a neurosurgeon diagnosis and manages every child after a suspected concussion. Youth who sustained a sport-related concussion and were enrolled in a Winnipeg public or private high school (grades 8 to 12) were included. The diagnosis was made by the treating neurosurgeon, Dr. Ellis, and based on the gold-standard Zurich guidelines. Concussion symptoms must have been present at their initial visit to the Concussion Program and the concussion must have occurred within thirty days. Both organized sports and recreational sports were included.

Dr. Ellis informed the youth and their parent if they were eligible to participate in the study. They were asked to meet with a research assistant if they were interested in participating in the

study. The research assistant further explained the study, obtained parental consent, and obtained assent from the youth. Youth were then asked to complete two health-related quality of life (HRQOL) scales and were given log book to track their school attendance. Participants were managed by Dr. Ellis at follow-up appointments in approximately two-week intervals, based on their clinical need, not a pre-specified protocol. Eligible patients recruited into the study were asked to complete the same two HRQOL scales at every visit, return their attendance log book, and fill out a new log book. Students were asked to bring a copy of their most recent pre-injury report card or a copy was made of the original. Students were contacted to send in a copy of their most recent post-injury report card at a later date. Midterm and final term grades for every course taken were recorded for analysis.

The primary outcomes were change in pre- and post-concussion overall and core (math, science, social studies, English, and foreign languages) teacher assigned report grades and pre- and post-concussion HRQOL (HRQOL results are under review at Journal of Pediatrics and will not be further discussed in this paper). A standardized Post-Concussion Symptom Scale (PCSS) score allowed patients to rate the severity of 22 individual concussion symptoms on a 7-point Likert scale. Absenteeism was also tabulated from attendance log books. Additional variables were collected from standardized patient intake forms included in the medical charts, such as age, grade, sex, and previous concussion history. Medical clearance to return to sport was determined by the neurosurgeon and defined as being symptom free after completing the Return to Play protocol, no evidence of vestibule-ocular dysfunction, and tolerating full-time school. Once students received medical clearance to return to sport, an exit interview was conducted to ask what school-related accommodations they believed were most helpful to their recovery.

The mean change (with 95% confidence intervals) in student's pre-concussion versus post-concussion grades for their overall grades and for each of the core subjects (math, science, social studies, English, and foreign languages) was calculated. Stratification was used to determine change in overall grades while controlling for the effects of adequate or poor school accommodations, severity of post-concussive symptoms, sex, age, concussion history, and subsequent development of PCS among concussed youth. The school related accommodations identified by the youth as most useful was tabulated.

Results: Prospective Case Series

Complete pre- and post-concussion GPA was obtained from 33 participants. Sixteen participants (48%) developed PCS. Nineteen participants (58%) were male. Nineteen participants (58%) suffered from previous concussions. Thirteen participants (39%) rated the quality of their school accommodations as poor. The pre-concussion overall GPA was 82.91% and core GPA was 80.03%. The post-concussion overall GPA was 82.70% and core GPA was 79.40%. Both pre- and post-concussion overall GPA were higher than core GPA. A drop of 0.21% ($p = 0.7501$) in the overall GPA and a drop of 0.63% ($p = 0.5621$) in the core GPA post-concussion was not statistically significant. For each increasing year of age, the overall GPA decreased by 0.25% ($p = 0.718$) and the core GPA decreased by 1.37% ($p = 0.218$). Additionally, there was no significant decrease in both overall GPA ($p = 0.072$) and core GPA ($p = 0.194$) due to severity of concussion based on initial scoring on PCSS.

Differences in overall and core GPA between participants with and without PCS, males and females, participants with and without a history of previous concussions, and quality of school accommodations were considered negligible. A summary of the stratified analysis results along with 95% confidence intervals can be found in **Table 3**. There was no significant differences in overall or core GPA by sex, previous history of concussion, developing PCS, or quality of school

accommodations. The median number of missed school days was 4 (IQR 2 – 8 days). Thirty students filled out exit interviews on what school accommodations they found most useful. Ten said cognitive and physical rest was most helpful. Eight said having less work or more time to do their work was most helpful. Five said slowly returning to school was most helpful. Three said taking breaks in school as needed was most helpful. Two said having a positive and supportive environment at school was most helpful. One said using the computer/smartboard less was most helpful and one said good communication between home and school was most helpful.

Table 3. Change in overall and core GPA with 95% confidence intervals.

Categories	GPA	Mean (%)	95% CI	Mean (%)	95% CI	Mean Difference (%)	95% CI	P Value
All Concussion		Pre-Concussion		Post-Concussion				
		N = 33		N = 33				
	Overall	82.91	79.92 – 85.91	82.70	79.87 – 85.53	-0.21	-1.57 – 1.14	0.7501
	Core	80.03	76.44 – 83.62	79.40	75.72 – 83.08	-0.63	-2.81 – 1.56	0.5621
PCS		PCS		No PCS				
		N = 16		N = 17				
	Overall	81.07	77.37 – 84.76	84.23	79.72 – 88.75	3.17	-2.47 – 8.81	0.2607
	Core	76.23	70.34 – 82.12	82.38	77.75 – 8702	6.15	-0.99 – 13.30	0.0889
	Change in Overall	-1.20	-3.35 – 0.95	0.71	-1.09 – 2.52	1.91	-0.77 – 4.60	0.1561
	Change in Core	-1.38	-5.11 – 2.35	0.08	-2.68 – 2.84	1.46	-2.95 – 5.88	0.5036
Sex		Males		Females				
		N = 19		N = 14				
	Change in Overall	-0.44	-2.26 – 1.38	0.09	-2.25 – 2.43	0.53	-2.27 – 3.33	0.7014
	Change in Core	-0.81	-3.72 – 2.10	-0.38	-4.16 – 3.39	0.43	-4.07 – 4.92	0.8479
Previous concussions		No history		History				
		N = 14		N = 19				
	Change in Overall	0.11	-2.33 – 2.55	-0.45	-2.21 – 1.30	0.56	-2.23 – 3.36	0.6835
	Change in Core	0.85	-1.91 – 3.61	-1.72	-5.05 – 1.62	2.56	-1.83 – 6.96	0.2431
School accommodations		Good		Bad				
		N = 20		N = 13				
	Change in Overall	0.12	-1.12 – 1.38	-0.735	-3.89 – 2.42	-0.86	-3.68 – 1.96	0.5395
	Change in Core	0.70	-1.05 – 2.45	-2.67	-7.79 – 2.44	-3.37	-7.75 – 1.00	0.1261
Age	Change in Overall					-0.25	-1.67 – 1.17	0.718
	Change in Core					-1.37	-3.60 – 0.85	0.218
Initial PCSS	Change in Overall					-0.56	-1.18 – 0.05	0.072
	Change in Core					-0.68	-1.72 – 0.37	0.194

Discussion: Prospective Case Series

Summary, main findings

Overall GPA was 82.91% (95% CI: 79.92 – 85.91) pre-concussion and 82.70% (95% CI: 79.87 – 85.53) after concussion recovery (decrease of 0.21%, 95% CI: -1.57 – 1.14). Core GPA was 80.03% (95% CI: 76.44 – 83.62) pre-concussion and 79.40% (95% CI: 75.72 – 83.08) after concussion recovery (decrease of 0.63%, 95% CI: -2.81 – 1.56). There were no significant differences in overall or core GPA when stratified by sex, age, initial concussion severity, previous concussion history, receiving adequate school accommodations during recovery, or subsequently developing PCS. The median number of missed school days was 4 (IQR 2 – 8 days). Most helpful accommodations from most common to least common were cognitive and physical rest (10), having less work or more time to do work (8), slowly returning to school (5), taking breaks in school as needed (3), having a positive and supportive environment at school (2), using the computer/smartboard less (1), and communication between home and school (1).

Other literature

Our findings that a concussion has no statistical of clinical significant effect on academic outcomes is congruent with findings in other studies that used standardized tests to measure academic outcomes, where students with a concussion or mTBI show minor to negligible long-term deficits with cognitive and neuropsychological testing.[16-18,30-33] Very few studies analyzed GPA following a concussion as a measure of academic outcomes and compared these results to pre-injury records or to non-injured or other injury controls. Only three primary research studies with a physician diagnosis of a concussion or mTBI were found to examine the effects of a concussion or mTBI on academic outcomes using GPA as the outcome measure. Fay et al collected grades in reading, mathematics, and spelling and categorized students as above average, average, or below average.[20] Hendrickson et al collected annual grade point average three years pre-injury to three years post injury.[21] Light et al equated academic performance to a 5-point rating scale.[22] All three studies found no significant decrease in GPA after sustaining a concussion or no significant differences compared to non-injured or other injury controls.

In a questionnaire-based study, Olympia et al. found 87% of concussed students were excused from physical activity, 87% received extensions on assignments, 84% were allowed excused absences, 84% received rest periods, 75% were able to postpone tests, 74% received extended testing time, and 73% were permitted a reduced workload, and 64% received accommodation for light and noise.[35] Schools are complying with Return to School protocol and accommodating students in areas that students feel are most helpful, but there is still variability in schools following the recommended guidelines, so more studies should be done to examine what accommodations are most helpful to students. The effectiveness of these accommodations is unknown, nor is how they are implemented by medical and educational professionals.

Grubenhoff et al found that students 8 – 18 years old missed a median of 2 school days (IQR 1 – 3 days) at the 30 day follow-up, Thomas et al found that students 11 – 17 years old missed a median of 2 school days (IQR 1 – 4 days) at 2 week, 6 week, and 3 month follow-up, and Wasserman et al found that students 15-16 years old missed a median of 4 school days.[27,28,29] These findings vary slightly from the absenteeism in this study (4 school days missed, IQR 2 – 8 days), which could be due to the severity of symptoms and recommendations for cognitive rest.

The manifestation of PCS after a concussion occurred at much higher rates in this study compared to other studies measuring academic outcomes, where 48% (n = 16) of participants developed PCS. Babcock et al found that 29.3% (n = 119) of patients with an mTBI developed PCS and Grubenhoff et al found that 21% (n = 38) of patients with an mTBI developed persistent PCS.[26,27] Patients in these two studies were recruited from the emergency department, which may be presented with concussion cases of differences in severity compared to a referral-based

tertiary clinic where this study was conducted. Although students with PCS do not perform significantly worse academically, PCS may present academic challenges and affect quality of life over a longer period of time, warranting further investigation.[34]

Limitations

One major limitation of this study is a small sample size due to incomplete data. Other studies collecting grades or exam scores as a measure of academic outcomes have also noted issues with obtaining school records due to consent, compliance, and gaps in testing.[20,21] Furthermore, participants whose pre-concussion and post-concussion grades fall in different terms or semesters may have different courses or a different number of courses in each collection period, which may be problematic when trying to compare grades before and after due to inconsistencies in difficulty and workload. This, combined with the small sample size, precluded the calculation of course specific change in grades. Discrepancies in grading between school divisions and individual teachers can also impact results in a small sample. Additionally, participants whose pre-concussion and post-concussion grades fall before and after summer may benefit from the additional recovery time in an environment more conducive to cognitive rest than the classroom. These challenges make it difficult to extrapolate the results to the general population.

Future clinical directions

While the majority of students make a full recovery within two weeks after sustaining a concussion and show no long term academic deficits, a few students may experience worse academic outcomes. It is important to recognize these students because they may not be reflective of the average and may require further care and assistance. Clinicians who are aware of these students can use this information along with Return to School protocol to carefully monitor symptoms and work with students, teachers, and parents to implement guidelines and individualized plans to optimize recovery and minimize absenteeism and drops in academic achievement.

Future research directions

More studies are needed comparing grades before and after a concussion to determine the results in a larger sample size. It would also be important to investigate to what degree school accommodations have on academic outcomes by facilitating the return to school process. Additionally, it would be beneficial to examine the few students who suffer from more significant academic deficits in order to better understand the severity of their symptoms, particular difficulties in learning, and who is at risk for poor academic performance to better treat and manage these patients.

Overall Conclusions

The studies analyzed in this review demonstrated no significant decrease in academic outcomes in the form of grades or exam scores following a concussion or mTBI. However, some findings remain inconclusive due to small sample sizes and missing data. The current evidence is not definitive enough to suggest an association between concussions or mTBIs and a decrease in academic achievement or academic performance. In our case-series study, we also found no evidence of poorer academic performance after a concussion injury.

This review increases the understanding of the effects of a concussion or mTBI on academic outcomes. A better understanding of the academic challenges faced by students post-injury should be investigated further to inform doctors, teachers, students, and parents of the role they can play in the treatment and management of a concussion or mTBI during the recovery process. More definitive data to support the development and implementation of return to school guidelines and recommendations to help students overcome academic difficulties and increase quality of life after a concussion or mTBI are needed.

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