2017

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Published in *Applied Neuropsychology: Child*, 2017
doi 10.1080/21622965.2017.1340158

PMID: 28657773

Patterns of referral in high school concussion management programs: A pilot study of consultants from different disciplines

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Abstract
School-based concussion management programs cover thousands of young athletes, yet there is little in the way of research to assess program processes or outcomes. This study examined the referral patterns of consultants working with ten high school concussion management programs. In addition to the number of referrals made to specialists, other potential outcome variables were explored. The sample included over 5,000 athlete-seasons and 298 concussions managed directly by certified athletic trainers. All programs used computerized neuropsychological testing (both baseline and post injury). Two groups were compared: five programs used a clinical neuropsychologist (NP) as the testing consultant and five used nonneuropsychologists (non-NP) with advanced clinical degrees as the testing consultant. There was no significant difference in concussion incidence rates between

groups. Referrals to outside specialists were significantly higher for the non-NP group: $X^2(1) = 16.474$, $p < .0001$. Further, concussions in the non-NP group took longer to recover overall (Mann-Whitney *U*, $p = .013$) and had significantly more cases taking longer than 2 weeks to complete their testing protocol: $X^2(1) = 9.672$, $p = .003$. The findings of this pilot study support the idea that neuropsychologists are best suited for the role of testing consultant to high school concussion management programs.

Keywords: Computerized neuropsychological tests, concussion management, consultation, ImPACT, sport-related concussion

Introduction

The management of sports-related concussions has been a national and international concern for many years. Technologies and procedures have been developed to provide population-based programs that include baseline neuropsychological testing (often with computerized tests), and management services through sports medicine services, typically a certified athletic trainer (AT). In the high school setting, these programs cover thousands of student-athletes in schools, youth recreation groups, and elite-level teams or organizations. The primary aim is usually focused on reducing risks of re-injury and returning athletes to play as safely as possible, but do not typically treat those with lingering symptoms or postconcussion syndrome (PCS), instead referring those more complicated/prolonged cases to specialist practitioners.

The use of computerized neuropsychological tests (CNT) for testing is probably one of the most striking changes in sports medicine in the last 10 years, and use has increased dramatically. In a systematic review of neuropsychological studies of sports concussion, Comper, Hutchison, Magrys, Mainwaring, and Richards (2010) noted that between 1999 and 2002, there were ten studies using paper and pencil batteries, with only one using computerized testing. Between 2003 and 2008, there were eight studies utilizing paper and pencil batteries and 15 using computerized testing. Similarly, using the High School Reporting Information Online (HS RIO) surveillance system, a 15% increase in the use of computerized neuropsychological testing for the management of sports-related concussions was reported between the 2008 and 2009 academic year alone (Meehan, d'Hemecourt, &

Comstock, 2010; Meehan, d'Hemecourt, Collins, & Comstock, 2011). With the growing use of computerized neuropsychological testing in concussion management, researchers have begun to examine the implications, execution, and variability of such use.

A number of studies have surveyed aspects of concussion management practices and the use of neuropsychological testing. Covassin, Elbin, and Stiller-Ostrowski (2009) surveyed a large number of high school and college certified athletic trainers (ATs) about their concussion management practices. Almost 95% of the 266 athletic trainers (ATs) reported that they administered baseline CNTs to their athletes. However, only 51.9% examined the baseline tests for validity. Positively, nearly all respondents (95.5%) stated that they would not return a symptomatic athlete to play even if the athlete's neurocognitive scores were back to baseline. In contrast, when asked if they would return an athlete who was symptom-free, but who scored below his or her baseline on neurocognitive assessment, 86.5% responded they would not, 9.8% responded they would allow the athlete to return to play, and 3.8% indicated that it depended on the importance of the competition. The authors concluded that while the use of CNTs was increasing, the ATs in the study appeared to rely more on symptoms than on neurocognitive test scores when making return-to-play decisions. This is notable as at least one study has documented continued neurocognitive impairment even after concussive symptoms have resolved (see Broglio, Macciocchi, & Ferrara, 2007). Such findings speak to the importance of a multidisciplinary approach when making return to play decisions.

One of many findings yielded through the review of injuries sustained for the 2009–2010 school year using the HS RIO surveillance system (Meehan et al., 2011) was that high school athletes who undergo testing with CNTs are less likely than those who do not to be returned to play within ten days of injury. In the HS RIO report, 1,056 sports-related concussions were documented for the 2009–2010 year, which represented 14.6% of all injuries. CNTs were used for 41.2% of these concussive injuries, and 93% utilized the ImPACT (Immediate Post-Concussion Assessment and Cognitive Testing) program, specifically. Of relevance to the present study, test results were most often interpreted by ATs (78.9%) and/or physicians (78.8%), rather than by neuropsychologists (16.9%). These physicians largely included primary care physicians rather than sports medicine subspecialists; this is significant, as such providers may lack appropriate resources and have a limited understanding of the most up to date concussion management practices (Meehan et al., 2011).

Meehan et al. (2011) raised the question: does it matter who interprets neuropsychological tests? Consensus statements regarding concussion in sport have cited neuropsychologists as being, "in the best position to interpret NP tests by virtue of their background and training" (McCrory et al., 2013). Indeed, in order to appropriately interpret neuropsychological tests in the context of sports-related concussion, several areas of knowledge are thought to be required. These include knowledge of psychometric properties, test characteristics specific to the population, the impact of psychological and physiological factors, and premorbid characteristics of the individual (Echemendia, Herring, & Bailes, 2009).

As there is no gold-standard for determining when any concussion is healed, the primary goal of concussion management is to minimize the risk of a repeat injury while the athlete is still recovering. Returning the athlete to school and play as soon as safely possible is also important. Both can be seen as secondary prevention. Thus, for the present study, the number of repeat or second concussions within the same school year was felt to be a reasonable outcome of the management practice. While repeat concussions may occur due to causes other than poor management, second concussions should be identified and reviewed as a matter of practice. Reducing the risk of prolonged recovery is another goal of secondary prevention. In the current study, the aim was to determine the length of time to the last CNT and the point at which the student was "back to baseline." Referral to a concussion specialist was seen as a related aim, as clinical practice typically considers referral when the process of recovery seems stalled or is somehow problematic.

These metrics do not infer causality, but were felt to provide an overview of program function from a public health perspective. This naturalistic observational study compared two groups based on the professional training of the program consultants. We hypothesized that differences would emerge that could inform program development and further evaluation.

Methods

Overview

Data was collected via a survey of prospectively identified programs. Programs were contacted at the beginning of the school year and permission to collect the de-identified data was obtained. Programs prospectively agreed to the criteria including the relevant data tracking. The research team collected the data after the school year. The study team also confirmed that a similar protocol for following the injury was followed across programs: the *a priori* definition of "recovery" for this project was the point at which the consultant determined that ImPACT scores were acceptable, and no further ImPACT testing was needed. This variable was the most available objective metric for defining the end of the process. In all cases, athletes had yet to complete a stepwise physical progression.

The surveys were completed after the target school year. No data was collected or analyzed until after the index school year. Survey data included credentials of ImPACT consultant, verification of the process of concussion management, use of ImPACT, and level of training of the AT. In addition to the dates of injury and dates of ImPACT assessments, the survey asked if the case had been referred to a specialist during the index injury. Satisfaction with the consulting process was also asked.

Participants and program characteristics

Institutional Review Board approval was received for this study. To meet participation criteria, schools had to have been using ImPACT for baseline and postinjury testing, and have had an AT who provided direct management of the concussions. Due to IRB concerns, no information was gathered about the consultants other than level of professional training. All programs had certified ATs identifying and managing the care of the student-athlete after concussion. Consultants all had advanced clinical degrees, were licensed health care providers within their state, and had completed ImPACT training.

All programs provided baseline and postinjury serial testing using ImPACT under the supervision of the licensed health care providers/

consultants. As noted, all cases provided a final ImPACT test before final return to play decisions were made. In most cases, a physical challenge to provoke symptoms was undertaken after the final test. In no cases were there symptom increases that required retesting. While the amount, content, and degree of specific interactions between consultants and ATs was not characterized, the clinical consultations determined the need for additional testing and recommendations for next steps. The consultants accessed ImPACT test protocols via ImPACT's online interface, and then communicated with the AT to relay interpretation of test data and further discuss additional information about the student, which was often provided by the AT. Communications were by email or telephone.

All schools were in the same state; thirteen schools were solicited with ten schools agreeing and able to participate in the study. Of the three schools that were not included, one school did not follow an accepted protocol, and two schools did not have ATs (although they used ImPACT). Two schools from each group were in metropolitan areas and three were in more rural areas. The total school enrollment was 4,144 for the five NP schools and 5,314 for the non-NP schools. Data from seventeen high school sports teams (8 boys, 8 girls, 1 coed) was collected, and schools received a stipend for their participation. Of the 17 sports queried across groups, ten sports were played at all schools. The enrollments of the high schools varied greatly (from 775 students to 4,000). There were three schools from rural areas and two from more urban areas in each group. Socio-economic status of the school district as indexed by eligibility for free and reduced lunch was significantly greater relative to enrollment in the non-NP group: $X^2(1) = 69.69$, $p < .001$, with a higher percentage getting free and reduced lunch in the non-NP group (24%) than the NP group (17%).

The standard clinical protocol required that once the concussion was identified, athletes were monitored and tested until symptoms and neuropsychological test scores were back to the individual's baseline as determined by the consultant. As part of the agreed-upon protocol, and confirmed after the fact, each concussion was consulted on, and the consultant determined the acceptability of test scores for "clearance" from testing.

No individual data was identifiable in the surveys. Only concussions obtained during school-sanctioned sporting activities were included in the analyses. ATs verified that the concussions were acquired in a sanctioned sports activity, as well as the dates of injury, final dates of testing, and the sport in which the concussion occurred.

Measures and analyses

As part of their data collection, ATs tracked whether or not the individual case was sufficiently problematic to warrant additional health care provider input (i.e., "specialist" referral). This was determined by the consultant or in agreement between AT and consultant. Cases were included as a specialist referral only if the AT or the consultant felt that follow-up was needed; cases where parents unilaterally took their child to a specialist were not included. The other variables of interest were the concussion incidence rates, the number of CNTs administered for postinjury evaluations, the length of time from injury to the last test administered, and the number of repeat concussions within the school year.

The percentage of outside referrals by group was calculated as the number of referrals to outside specialists divided by the number of concussions for that school, and the ratios of typical and prolonged cases that were referred to specialists. "Typical" concussions were defined as those that resolve within 14 days, while "prolonged" required longer than 14 days to recover. This latter comparison was seen as important because it may be expected that more prolonged cases than typical cases would be referred to specialists.

Incidence rates of concussion (IR) were calculated by sport at each school as a function of the exposure rates. The exposure rate was defined as the sport participation number that is provided to the state high school athletic association as part of yearly reporting requirements. Skiing was included in total statistics, but not in the sex-based statistics because several schools had mixed-sex teams. While this approach is not as typical as calculating hours of exposure, this was the only reasonable and consistent method available.

We also examined "recovery" and second concussions as potential indicators of program activity. Recovery was defined as the point in time of the last CNT, when ImPACT scores were either "back to baseline" or were deemed acceptable by the consultant. We calculated number of days from injury to the last CNT. Separately, cases were then binned according to the last CNT happening within 2 weeks of injury (“typical”), or longer than two weeks (“prolonged”). In all cases, final return to play (RTP) decisions were made based on the athlete meeting three criteria: medical and symptom clearance (by either an MD or an AT), cognitive clearance (ImPACT scores back to baseline, unless an exception was made by the consultant), and successful completion of a stepwise physical exertion protocol supervised by the AT (see McCrory et al., 2013 for that protocol).

A second concussion was defined as any repeat concussions within the same school year. The number of second concussions within the school year was calculated as a percentage of the number of first concussions. Second concussions were felt to be a potential indicator of ineffective management and determination of recovery. We also examined time to second concussion. This was calculated as the time in days from the first injury to the second injury. Second concussions within a month of the first were felt to be more telling of management ineffectiveness than the number of second concussions within the year.

Results

Sample characteristics

The incidence rates of concussions by sport are presented in Table 1, along with the number of schools that provided data for each sport. The IR between the two target groups was nonsignificant: $X^2(1) = 3.724$, $p > .05$. There was no sex by IR by group interaction. Some sports had too few participants with injuries to compare sport-IR by group. The chi-square of sex differences between groups for concussion incidence rates was nonsignificant $X^2(1) = .002$, $p > .05$. The difference in incidence rates between the two target groups was also nonsignificant: $X^2(1) = 3.724$, $p > .05$.

Specialist referrals

The percentage of cases referred to outside specialists was calculated for each group. For the NP group, significantly fewer referrals were

Table 1. Incidence rates (IR) by sport and gender by consultant group (number of teams in group).

	Group	
Sport	NP	Non-NP
Baseball (male)	0.02 (5)	0.01 (5)
Basketball (male)	0.04 (5)	0.06 (5)
Basketball (female)	0.03 (5)	0.10 (5)
Field Hockey (female)	0.04 (5)	0.02 (5)
Football (male)	0.15 (5)	0.20 (5)
Ice Hockey (male)	0.06 (4)	0.05 (5)
Ice Hockey (female)	0.00 (1)	0.13 (2)
Lacrosse (male)	0.03 (5)	0.03 (5)
Lacrosse (female)	0.04 (5)	0.06 (3)
Ski (Co-ed)	0.04 (4)	0.04 (4)
Soccer (male)	0.02 (5)	0.02 (5)
Soccer (female)	0.05 (5)	0.05 (5)
Softball (female	0.02 (5)	0.01 (5)
Cheer (female)	0.03 (5)	0.07 (5)
Volleyball (male)	0.00 (3)	0.00 (0)
Volleyball (female	0.06 (4)	0.01 (4)
Wrestling (male)	0.07 (5)	0.06 (3)
Total	0.05 (76)	0.06 (71)
Male Sports Total	0.06	0.08
Female Sports Total	0.04	0.05

NP = Neuropsychologist; Non-NP = Nonneuropsychologist

made to outside specialists overall (7%) than the non-NP group (43%): $X^2(1) = 18.867$, $p < .0001$, $\varphi = .356$. However, since it might be argued that the difference in exposure and IR per group could skew the results, a referral incidence rate was calculated by comparing number of specialist referrals to exposure rates. The rate of referral to outside specialists (per exposure factor) was .007 for the NP group, and .028 for the non-NP group: $X^2(1) = 26.62$, $p < .001$, $\varphi = .073$.

The difference between referring cases that recovered in typical fashion to those with prolonged recovery were striking. Figure 1 demonstrates the differences in referrals (by percent) for typical and prolonged cases. The NP group consistently referred less than the non-NP group, but the recovery time did not matter in the non-NP group as their percent of referral was statistically equal for either recovery time-frame (NP referral by recovery: $X^2(1) = 4.345$, $p = .033$, $\varphi = .201$;

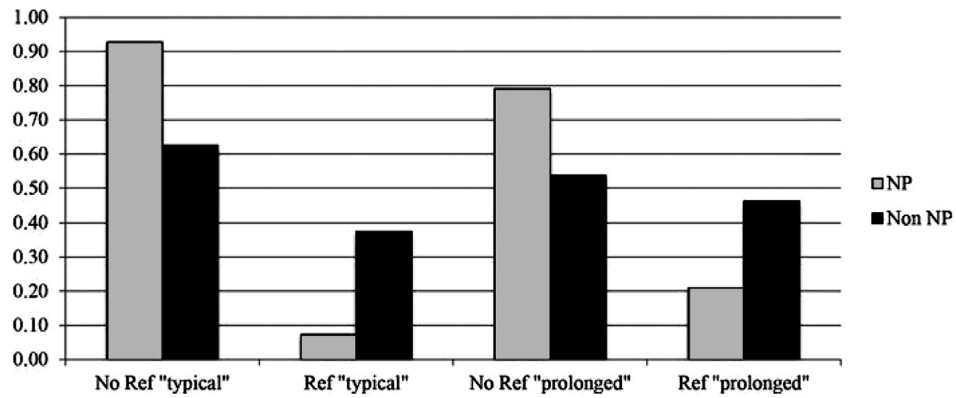

Figure 1. Referrals by percentage by group for typical vs. Prolonged recovery cases. “No Ref” = no referral; “Ref” = referral; NP = neuropsychologist; Non NP = nonneuropsychologist.

non-NP referral by recovery: $X^2(1) = 1.421$, $p = .233$, $\varphi = .013$). That is, nonneuropsychologist consultants appeared to have referred typical and prolonged cases equally (57 and 49, respectively), while neuropsychologist consultants referred a higher percent of prolonged cases than typical (4% and 9%, respectively).

Referral patterns of case-type by group demonstrated a five-fold increase of typical cases referred by non-NP consultants (7% compared to 38%): $X^2(1) = 12.088$, $p < .0001$, $\varphi = .285$. However, the referral rates for prolonged cases were only marginally greater by the non-NP group: $X^2(1) = 3.951$, $p = .046$, $\varphi = .163$ despite a 2:1 difference in percentage of referral. Table 2 presents the numbers and percentages of referral patterns.

Table 2. Percentage (%) and number (*N*) of referred cases by injury recovery type and consultant group.

Concussion type	Group	% Referred to specialist (N)
Typical	NP	7 (5/69)
	Non-NP	38 (30/80)
Prolonged	NP	21 (9/43)
	Non-NP	46 (49/106)

NP = Neuropsychologist; Non-NP = Nonneuropsychologist

Days to last CNT

Due to the nonnormal distribution of days to last ImPACT test, non-parametric analyses were conducted to determine how long cases were involved in testing and management based on these criteria. The median number of days to last ImPACT test was 13 for the NP group, and 16.5 for the non-NP group. The Mann-Whitney *U* statistic was used to test the difference between distributions of independent samples and was significant (p = .013). There were no gender differences in this aspect of recovery time (Independent Samples Median Test, p = .903). Thus, it appeared that the NP group "cognitive recovery" rate was significantly faster on the whole.

We determined that concussions that met our recovery criteria within 2 weeks were "typical" and those that took longer than 2 weeks were "prolonged." Overall, there were significantly more prolonged cases in the non-NP group than the NP group: $X^2(1) = 9.672$, $p = .003$, $\varphi = .180$.

Second concussions

There were 9 cases of second concussions within the school year across all programs. Of these, only 1 (0.1% of first concussions) was recorded from the NP group and 8 (4% of first concussions) from the non-NP group. A chi-square using Yates' correction for small samples yielded a nonsignificant result: $X^2 (1) = 2.59$, $p > .05$. Also notable was the timing of the second concussions in the non-NP group; specifically, three of the eight repeat (second) concussions occurred within 30 days of recovery from the first injury.

Discussion

The primary aim of this naturalistic observational study was to identify referral rates to specialists from concussion management programs in order to better understand concussion management practices. To determine the usefulness of this metric, data from programs managed by two distinct professional groups were compared: neuropsychologists and nonneuropsychologists. Secondary aims were to compare incidence rates and cognitive recovery times.

In regard to referral patterns, there were differences in the frequency of referral. The neuropsychologist group referred far fewer cases (as a whole or by concussion recovery type) than the non-NP group. Furthermore, the non-NP group referred about half of their cases, whether typical or prolonged. As an outcome, length of time to last ImPACT test may not equal full recovery or clinical stability. However, it does represent the amount of time an athlete is held out of participation. Considering that a reduction in activities due to illness or injury is a highly significant factor in adolescent depression (Lewinsohn, Gotlib, & Seeley, 1997), prolonged recovery is an important consideration.

This pattern of referrals was related to identifiable improved outcomes. Cases took significantly longer to recover cognitively in the non-NP group, thus differentiating the groups. Overall, the NP group had significantly shorter cognitive recovery times and fewer cases taking longer than two weeks to resolve. Although the number of second concussions was not statistically different by group, the presence of three repeat concussions within 30 days of initial injury in the non-NP group is notable (as compared to none in the NP group).

Despite the differences in gross socio-economic status between groups, the incidence rates of concussion were not significantly different using the athlete-season exposure metric. While not ideal, this was the only metric available and was consistently applied across all schools. Other demographic factors such as ethnicity and race, as well as premorbid conditions that could affect outcomes should be explored in future studies. Since all consultants reported having specific training in ImPACT, other elements of training may account for differences in referrals. One's sensitivity to the need for additional help when managing cognitive sequelae following brain injury is likely a result of training and experience. Clinical neuropsychology is vastly more comprehensive than what can be covered during an ImPACT training and may account for differences in referral thresholds.

These data also point to areas that can be further explored. Specifically, more information regarding reasons for lengthier recovery times with non-NP consults would be beneficial. The number of prolonged concussions (those that take longer than 2 weeks to recover) represents a small percentage of total concussions, but is an important subset of cases due to implications for serious injury and prolonged recovery times (Semple et al., 2015). The median time to the last CNT was longer in this cohort than that reported in the literature, as was the number of cases taking longer than 2 weeks. Several studies have demonstrated that anywhere from 80–90% of concussions resolve within 2 weeks (Covassin, Elbin, & Nakayama 2010; McCrea et al., 2013; McCrea, Prichep, Powell, Chabot, & Barr, 2010; Sim, Terryberry-Spohr, & Wilson, 2008). It is not clear why both groups in this sample required a lengthier recovery time, although anecdotal reports from ATs indicated that a number of cases did not comply with the testing protocols and did not return for repeat assessment as requested. This factor may also be related to these concussion management programs being based in schools, where vacations, in-service days, and other scheduling conflicts may bar follow-up examinations from occurring, thereby delaying official days to recovery.

The number of second concussions in this study within the same school year was not statistically different by group, but the low base rate makes reliable statistics somewhat problematic. Second concussions are rare events and can happen for many reasons. The NP group recorded only a single second concussion, while eight were recorded for the non-NP group. More critically, of those in the non-NP group, three occurred within 30 days of recovery from the first concussion. The increased incidence of second concussions within one month of the first should always raise concerns, and in the clinical setting, warrants investigation by the treatment team. As such, it is recommended that management programs track these figures and review the cases to identify potential programmatic solutions.

The difference between NP and non-NP consultant groups may also highlight the particular importance of utilizing neuropsychological consultation when ImPACT is used as part of a school's concussion management program. One specific difference may be the use of more advanced statistical procedures, such as regression-based change statistics for interpretation of test scores (Crawford & Garthwaite, 2007; Heilbronner et al., 2010). The neuropsychologist's ability to utilize their knowledge of psychometrics allows for a more individualized interpretation of ImPACT. Without such understanding, the consultant interprets postinjury scores in a dichotomous fashion: either the student-athlete is back to baseline (no "red scores") or not back to baseline (the presence of "red scores"). Furthermore, this model of interpretation requires the student's baseline to have been representative of their actual ability, and while ImPACT has embedded markers of questionable validity for baseline tests (noted by the + + signal), they are neither evidence-based nor always followed-up upon (Covassin et al., 2009). Postinjury ImPACT interpretation is more complicated than a binary outcome. However, to become proficient in the nuance and many irregularities that occur in this process requires years of experience with assessment and evaluating cognitive change. Unfortunately, standard ImPACT training cannot provide such extensive instruction.

One example of the specific advantage of applying the neuropsychologist's particular skill set to postinjury ImPACT interpretation is that student-athletes may not be held back from beginning gradual physical activity just because a score exceeds a reliable change metric. Furthermore, when baseline scores are questionable, the neuropsychologist can evaluate postinjury performance against normative data instead of making a comparison against a faulty baseline. This is what neuropsychologists do within the context of most evaluations, in which premorbid test scores are not available. Taken together, we suggest that the present findings, while preliminary, are indicative of the notion that neuropsychological tests should be interpreted by neuropsychologists.

There are limitations to this study that make the empirical evidence tentative. First, this was not a randomized clinical trial, but a cohort comparison within a naturalistic setting; thus, we cannot rule out systematic effects due to selection or other threats to validity. Only ten schools were compared, with five schools per group. Several assumptions needed to be made about the processes and data. Due to IRB limitations, we were not able to determine what types of specialists were the recipients of the consultant's referrals. This somewhat limits the understanding of where prolonged cases of recovery were being sent for further evaluation (e.g., were MD consultants referring student-athletes to neuropsychologists?). Future studies should examine these patterns in more detail, including when and why referrals were made. Additionally, using the time to last CNT as a proxy for "recovery" was a convenience metric that represented the most available and objective measure that could be obtained. The study was also limited by the fact that we did not have specific data regarding the student-athletes complete return to cognitive activity (i.e., homework, classroom-based functioning), nor did we have specific information regarding time between last CNT and full return to play clearance.

Specific idiosyncrasies of practices by athletic trainers and consultants could have resulted in some systematic biases in data. While all programs asserted that they followed the specified protocol, there was only verbal confirmation that protocols were consistently followed for assessments. No fidelity checks were obtained. While examining protocols to identify deviations was beyond the scope of this study, the inclusion of robust fidelity monitoring in future studies will be important. Other important factors that may have influenced time to recovery were also not examined (e.g., amount of cognitive rest, prior medical, psychiatric, and learning history, the nature or type of outside specialist referrals, factors affecting severity of injury, school vacations during recovery, days of school attended, etc.). The choice of outcome variables was made based on a theoretical rationale, but in the end was difficult to operationalize in a controlled manner. Though important clinically, second concussions are too infrequent for any meaningful analyses. There is clearly not enough data from this study to generalize about neuropsychologists or MD's, but we believe these outcomes do provide some function. This pilot study presents findings that will require replication and extension. Furthermore, this study should point to potential metrics for outcome

Future studies should also include measures of fidelity and competence, clearer specification and measurement of consultant activities, more detailed analysis of AT activity, and more groups for comparison. The current study was designed and carried out by one of the authors (author 3). Thus, independence of findings can be questioned, although attempts at blinding were made, including analysis of findings and conclusions drawn mainly by the other authors (authors 1 and 2). By definition, concussions are mild injuries, but significant consequences can occur if they are not managed properly. All consensus statements assert the need for inter-disciplinary management. In an interdisciplinary setting, the neuropsychologist's interpretation of test scores is an important factor in clinical decision making.

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