

Abstracts

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001 RECALL OF CONCUSSION SYMPTOMS IN AUSTRALIAN FOOTBALLERS

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Background: Clinical evaluation of concussed athletes often requires the athlete to subjectively recall details of their injury. Further, many studies of concussion have used self-reported concussion signs and symptoms to classify groups of athletes (eg, by number of previous concussions, presence of LOC or PTA). However, the accuracy of self-reported concussion history has been questioned. This study examined the recall of concussion signs and symptoms among recently injured athletes (ie, within the past 7 days) and healthy athletes who had not been concussed for at least 1 month.

Method: During 2002 and 2003, a computerised concussion history questionnaire was administered pre-season to 468 healthy, non-injured male Australian rules (AR) footballers, using the CogSport™ software. A similar questionnaire was administered to 51 male AR footballers within 7 days of concussive injuries occurring during the season. The questionnaire required athletes to recall details of their most recent concussion, including whether they experienced loss of consciousness (LOC), post-traumatic amnesia (PTA) and the type and number of symptoms experienced at the time of injury.

Results: The non-injured (22.6 ± 3.9 yrs) and concussed (22.6 ± 3.6 yrs) groups were of equivalent age and educational attainment. Of the non-injured footballers tested at baseline, 186 (39.7%) reported never being concussed. The remaining 282 (60.3%) reported 2.3 ± 1.5 (range 1–8) prior concussions, with the majority (84.5%) occurring over 6mths ago. Only 92.6% of these athletes reported experiencing symptoms at their last concussion, with the most commonly reported symptoms being headache (85.1%), dizziness (68.4%), blurred vision (55.3%), drowsiness (45.0%) and confusion (41.1%). LOC was reported by 40.1% and PTA by 37.6% of athletes. Among athletes tested in the week following injury, the most commonly reported symptoms were headache (92.2%), confusion (58.8%), dizziness (49.0%) and blurred vision (41.2%). LOC was reported by 35.3% and PTA by 60.8% of these athletes. Mann-Whitney U non-parametric analysis identified significant differences in the reported incidence of PTA ($p=0.01$), dizziness ($p=0.01$), confusion ($p=0.01$), drowsiness ($p=0.001$) and memory difficulties ($p=0.01$) between groups.

Conclusion: Headache is the most consistently reported symptom of concussion. There are significant differences in self-reported symptoms of concussion between athletes injured in the past 7 days, and athletes injured at least 1 mth ago. Recall of concussion signs and symptoms may change as the time between injury and completion of a clinical history increases.

002 POST-CONCUSSION COGNITIVE FUNCTION IN SYMPTOMATIC AND ASYMPTOMATIC ATHLETES

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Background: While it is recognised that neuropsychological testing is an important part of the post-concussion medical evaluation, the 'golden rule' of concussion management remains the recommendation that athletes must not be returned to play while symptomatic (Concussion in Sport Group, Vienna, 2001). Few studies have compared post-concussion cognitive function in symptomatic and asymptomatic athletes.

Method: A total of 848 pre-season CogSport™ tests were collected prospectively in 615 individual Australian Rules (ARF) footballers between 2001 and 2003. Sixty-one footballers were concussed, and received follow-up clinical and cognitive evaluation within 7 days of injury. Footballers were classified as either symptomatic (SYMP) or asymptomatic (ASYMP) on the basis of the post-concussion clinical evaluation.

Results: As a group ($n=61$), concussed footballers displayed significant dysfunction on tests of simple, choice and complex reaction time, and divided attention, compared to their own baseline performance. There were no age differences between SYMP ($n=28$; 22.6 ± 3.8 yrs) and ASYMP ($n=33$; 23.2 ± 3.8 yrs) groups, however SYMP footballers were tested closer to the injury (1.9 ± 1.2 days) than ASYMP footballers (3.2 ± 1.7 days). At the time of testing, SYMP footballers reported 1.8 ± 1.0 symptoms (range 1–4). Group by assessment (baseline vs post-injury) ANOVA revealed that SYMP footballers displayed greater dysfunction than ASYMP footballers on tests of simple, choice and complex reaction time. Both groups were impaired relative to baseline on tests of divided attention. The magnitude of post-injury dysfunction in symptomatic footballers was large according to conventional statistical criteria (d' range: 0.55–1.02). No changes were observed on tests of working memory or new learning after concussion.

Conclusion: Symptomatic athletes display large and significant post-concussion dysfunction on tests of motor function, simple and divided attention. These changes are greater than those observed in asymptomatic athletes, who display only mild deficits in attention. These findings support current recommendations that athletes must not be returned to play while symptomatic. Consistent with prior research, tests of simple cognitive processes appear more sensitive to concussion than tests of more complex cognition.

003 COGNITIVE DEVELOPMENT IN CHILDREN: IMPLICATIONS FOR CONCUSSION MANAGEMENT

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Background: The incidence of sports-related injuries during childhood increases dramatically with age, accounting for 6% of all injuries for children aged 5–9 years, 23% for 10–11 year olds to 48% for 14–15 year olds. Although the age-specific incidence of concussion has not been formally documented, there are developmental, anatomical and physiological differences between children and adults that necessitate the development or modification of concussion management guidelines specifically for children. This study describes developmental changes in cognitive function in healthy, uninjured children, and the implications for concussion management.

Method: In a cross-sectional study, one-hundred and eighty (180) normal, healthy children aged between 9 and 18 years completed the CogSport computerized cognitive test battery, including tests of simple (SRT) and choice reaction time (ChRT), working memory (WM) and learning (LRN). Measures of response speed and accuracy are reported.

Results: The mean yearly improvement on measures of response speed were 29.7 ms (SRT), 38.5 ms (ChRT), 47.1 ms (WM) and 39.8 ms (LRN). The mean yearly improvement on accuracy measures were 0.02% (SRT), 1.0% (ChRT), 1.2% (WM) and 1.0% (LRN). With the exception of SRT accuracy, all changes were highly significant on ANOVA. On all tasks, the largest changes were observed between ages 9 and 14 years of age, accounting for between 67% and 84% of all improvement. Smaller changes between ages 15 and 18 years of age. The performance of 17 and 18 year olds performance was equivalent to that observed in young adults (Collie A, et al. *Clin J Sport Med* 2003;13:28–32).

Conclusion: There are substantial improvements in a range of cognitive functions in children aged between 9 and 18 years of age. These developmental changes may be of the same or greater magnitude as the impairments observed after concussion in adults. These findings

suggest that baseline cognitive testing should be conducted at least yearly in children participating in contact sport.

004 BASELINE COGSPORT PERFORMANCE DATA IN ELITE AND NON-ELITE ATHLETES: AN INTERNATIONAL STUDY

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Background: Neuropsychological testing is recognised as an important component of the post-concussion medical evaluation, regardless of the concussed athlete's level of competition, cultural or educational background. Many neuropsychological tests currently used in concussion management have been validated only in homogenous English speaking populations. Few studies have sought to compare samples participating at elite and non-elite levels of competition, or to compare performance in English and non-English speaking samples.

Method: Baseline, or pre-season, cognitive test data was collected in 345 elite Australian rules (AR) footballers, elite Norwegian soccer players (n=264), American college footballers (n=180), American amateur boxers (n=175) and community AR footballers (n=111) using the CogSport™ program. Norwegian soccer players were administered tasks with instructions presented in Norwegian. All other groups received English-language instruction.

Results: Elite athletes (Australian footballers and Norwegian soccer players) were significantly older than non-elite samples (USA college football, amateur boxing, Australian community football). One-way ANOVA, covaried for age, identified significant between group differences on the speed of performance for all tests administered, including simple (p<0.01), choice (p<0.001) and complex (p<0.001) reaction time, working memory (p<0.001), divided attention (p<0.001) and learning (p<0.001). Despite these mean differences, the 95% confidence intervals (ie, the normal range) for each task did not vary greatly between samples. Calculation of between-group effect sizes revealed that there was little difference between Australian and Norwegian footballers (Cohen's d range 0.04–0.29), but more substantial mean differences between elite and non-elite samples (d range 0.32–1.08).

Conclusion: Elite athletes display faster response times than non-elite athletes on a range of cognitive tasks. Despite these group mean differences, the 'normal range' of performance does not differ substantially between elite and non-elite samples. Athletes whose first language was not English (ie, Norwegian soccer players) performed as well as English-speaking athletes on CogSport tasks. The 'playing-card' metaphor employed in this computerised test battery appears to provide a language-independent cognitive assessment.

005 HEAD INJURIES DURING MAJOR INTERNATIONAL FOOTBALL TOURNAMENTS

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Introduction: In football, collision during duels or heading the ball might cause traumatic head injuries. The aim of the present study was to analyse the incidence, type and circumstances of head injuries during major international football tournaments.

Methods: During 18 major football tournaments, the physicians of all participating teams were asked to report all injuries after each match on a standardised injury report form. The report form required documentation of the following: shirt number of the player, minute of the match, injured body part and type of injury, circumstances and consequences of injury. The average response rate was 90%. Head injuries were analysed separately.

Results: A total of 223 head injuries were reported from 620 matches, which is equivalent to 15% of all injuries. The incidence was 0.36 head injuries per match. The majority of the head injuries were diagnoses as contusion (51%), followed by laceration (22%) and concussion (13%). 70% of the head injuries did not result in subsequent absence from training or matches. Approximately one time-loss injury of the head was reported per 9 matches. Four injuries lead to absence of 2 or more weeks (2 fractures of nose, 2 concussions). Almost all injuries were caused by contact with another player, only 3 injuries (no time-loss) by a hit of the ball.

Conclusion: The majority of head injuries during football tournaments did not result in time-loss in match or training. However, the incidence of concussion was on average 0.05 per match or 1.6 per tournament.

006 DOES HEADING IN SOCCER HAVE IMPACT ON BRAIN TISSUE? A FIELD STUDY USING ANALYSIS OF MARKERS OF BRAIN TISSUE INJURY S-100B AND NSE

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Introduction: Mild traumatic brain injuries/concussions are very common and they are especially frequent in contact sports e.g. soccer. The increase in popularity of soccer play among women has led to a growing concern that female players may, due to lower body mass, be at higher risk of injuries in general and head injuries/concussions associated to heading in particular, in comparison with male players. The aim of this study was to analyse the concentrations of two biochemical markers of brain tissue damage, S-100B (a protein prevailing in glial cells) and neuron specific enolase (NSE; a glycolytic enzyme which is predominantly found in neurones), in female soccer players in connection to game.

Methods: Blood samples were taken in elite female soccer players (n=44) before and after a competitive game and the number of headers and trauma events during the play were assessed from video-tape recordings.

Results: Both S-100B and NSE were significantly increased in serum samples obtained after the game in comparison with the pre-game values (S-100B: 0.18±0.11 µg/L vs 0.11±0.05 µg/L, p<0.001; NSE: 10.14±1.74 µg/L vs 9.05±1.59 µg/L, p=0.001). Changes in S-100B concentrations (post-game minus pre-game values) were statistically significantly correlated to the number of headers (r=0.430, p=0.004) and to the number of other trauma events (r=0.523, p<0.001).

Conclusion: Playing competitive elite female soccer was found to cause rise in serum concentrations of S-100B and NSE. Increases in S-100B were significantly correlated to the number of headers, and heading may accordingly have contributed to these increases.

007 THE CURRENT MANAGEMENT OF CONCUSSION IN ENGLISH LEAGUE PROFESSIONAL FOOTBALL (SOCCER)

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Background: The incidence of concussion in soccer is not as high as in some other contact sports but the problem of deciding when a player is fit to return to play is common to all contact sports. There is concern that repeated concussion may be detrimental to the future health of the player. Contact sport players generally wish to return to play as quickly as possible, putting themselves at risk of further concussion. This paper examines data from a primary research questionnaire sent to all clubs in the English Football Leagues to establish how concussion is currently managed, the degree of difficulty that the doctors involved perceive in managing the condition and their interest in the use of additional decision making aids, such as neuropsychological testing. It is hoped that this research will lead to an improved and more uniform approach to the management of concussion in soccer at all levels.

Methods: An anonymous questionnaire was sent to all team doctors of 91 clubs in the Premier League, First, Second and Third Divisions of the English Football League.

Results: There was a response rate of 51.6% to the questionnaire. 85% of team doctors reported dealing with less than 5 concussions in the year studied and 12.8% dealt with 5 to 10 concussions in that period. Almost 64% of respondents reported occasional difficulty and almost 15% reported frequent difficulty with return to play decisions for concussed players. Less than 11% used a recognised concussion rating scale and less than 9% used a recognised neuropsychological test to aid their return to play decision-making process.

Discussion: The results indicate a lack of a systematic approach to concussion management within professional soccer clubs in the Football Association. The fact that 85% of team doctors expressed interest in using an additional scientifically validated aid to decision making for return to play may also reflect their insecurity with regard to their current management of concussion.

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008 UNDER-REPORTING OF CONCUSSION IN YOUTH HOCKEY

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Introduction: The interest in concussion in sport has grown considerably in recent years among medical practitioners, sport science researchers, sport participants, and sport observers. As awareness of the importance of treating concussion has increased, so has the number of published return to play guidelines, culminating in the Summary and Agreement Statement of the First International Conference on Concussion in Sport. While we have recently reported encouraging news with respect to the importance of return to play decisions reaching the appropriate individuals, there still appears to be an underreporting of incidents. In this paper we provide converging evidence from four different sources which points to the severity of this problem.

Method: Retrospective questionnaires, reports from team personnel, reports from trained observers, and official provincial injury reports are all methods used in our ongoing efforts to examine the many facets of concussion in youth hockey. These various sources were used to provide actual and predicted rates of the incidence of concussion in minor hockey.

Results: Retrospective concussion history questionnaires distributed to 16 and 17 year-old elite male hockey players indicated 36% (178 of 497) reported having sustained one or more concussions in the previous two seasons of competitive play. A retrospective questionnaire of community-based hockey players (12–17 years) found 21% (32 of 152) reported sustaining at least one concussion within the past two years. During the 2002/3 season, youth hockey volunteers reported the details of concussions as well as incidents indicative of a concussion. The probability of at least one member of a hockey team sustaining a head incident of concern over the course of the season was calculated as over 72%. With trained observers the same incident rate was estimated at over 84%.

In contrast, a mere 77 concussions were reported to the provincial governing body throughout the 2003/4 season. With over 44,000 registered youth hockey players in British Columbia, this represents an annual concussion rate of 0.0017%, which we suggest is a gross underestimate of the true rate.

Conclusion: Based on the converging evidence cited above, the under-reporting of concussions to hockey's governing bodies, both by players and by bench staff remains a significant problem. We suspect that until the culture of hockey fully recognises the potential consequences of masking or failing to report concussive injuries, youth hockey players remain at risk.

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009 EMOTIONAL RESPONSE TO KNEE-INJURY AND CONCUSSION IN VARSITY ATHLETES

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Background: Despite suggestions that emotions influence recovery from sport injury, there is little research into the emotional sequelae of sport concussion.

Purpose and Method: This study extends recent empirical work (Mainwaring *et al.*, 2004) and compares pre-injury, post-injury, and longitudinal emotional functioning of concussed athletes ($n = 26$), knee-injured athletes ($n = 7$) and healthy athletic undergraduates ($n = 28$) using a short version of the Profile of Mood States (POMS; Grove & Prapavassis, 1992). A prospective repeated measured design examined mood states for student-athlete volunteers during a 60 minute medical and neuropsychological baseline assessment. Post-injury assessments were scheduled within 72 hours of injury, and on post-injury day 4, 8, 15, 22, and 29. Control group assessments were scheduled similarly.

Results: Mood ratings were similar at baseline for all groups. A 3×4 ANOVA revealed that post-injury, concussed and knee-injured athletes' mean mood scores differed from the control group over time. Significant interactions were observed for POMS subscales of Depression ($F, 6, 144, = 4.53, p < 0.001$), Confusion ($F, 5, 133, = 2.95, p = 0.012$) and Total Mood Disturbance ($F, 6, 144, = 2.99, p = 0.009$). The injury groups differed in that concussed athletes rated themselves as more confused ($F, 3, 45, = 4.76, p = 0.006$) and to have more generalised mood disturbance ($F, 3, 45 = 6.20, p = 0.001$) in the first few days post-injury than the athletes with knee injuries. There appears to be a differential pattern of mood disturbance over time with the concussed

and knee groups. The knee group is more severely injured, in terms of duration of injury, than are concussed athletes, and thus, the severity of injury as well as type of injury may be important factors in longitudinal changes in mood in injured athletes.

Implications: These results support the causal link suspected between athletic injury, in general, and subsequent emotional distress. In terms of our specific findings, the post-injury spike in depression ratings seems to be causally related to injury. It is possible that the greater emotional disturbance found in the concussed group may be a result of the transient biochemical disturbance following brain insult. It could also be that cognitive effects of concussion may compound confusion in athletes as they become aware of deficits in their daily cognitive functioning. The latter is supported by our neurocognitive data and needs to be explored further.

010 OUTCOME OF CLINICAL MANAGEMENT STRATEGIES FOLLOWING CONCUSSION IN AUSTRALIAN FOOTBALL

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Background: At the 1st International Conference on Concussion in Sport (Vienna, 2001) the expert consensus on decisions regarding return-to-play was that players be accurately assessed for recovery of symptoms and cognitive function post-injury. This approach has long been the accepted practice for the management of concussed players in the elite Australian football competition (AFL). The current study attempts to answer the question as to whether a concussed player who is returned to play using an individual clinical management strategy is at risk of injury or impaired performance upon their return to sport.

Methods: Data were collected prospectively on all AFL players in seasons 2000 to 2003 ($n = 805$). Objective outcome measures assessed included performance statistics (disposal rates) and occurrence of injuries on return to play. Non-injured team, position, age and size matched players were chosen as controls. A subset of players had neuropsychological tests performed at baseline and following their concussion (Digit Symbol Substitution Test (DSST), Trail-making test – Part B (Trails-B) and a new computerised test of cognitive function (CogSport)).

Results: 199 concussions were observed in 158 players [127 single concussions; 31 players with multiple concussions]. 77 were excluded from analysis due to incomplete data (62) or presence of concurrent injury (15). Of the 122 concussive injuries assessed, 111 did not result in any missed games (91%). The remainder of concussed players returned to competition after missing a single game (9%). In the subset of players for whom neuropsychological test results were available, all had returned to their individual baseline on DSST, Trails-B and CogSport testing prior to return to sport. Overall, there was no significant change in disposals rates in concussed players on return to competition when compared to baseline. Similarly, there was no differences observed between concussed and control players. Furthermore, the injury rate during the first game back (95% CI: 1.95–11.56%) did not differ significantly from the injury rate observed in the overall competition during seasons 2000–2003 (95% CI: 4.24–4.71%) or that observed in matched controls (95% CI: 2.20–4.00%).

Conclusions: 91% of concussed elite Australian footballers returned to competition without missing a game, with no detrimental effects observed in performance; no increased risk of injury and no persistent deficits in their neuropsychological function. Current guidelines from the Concussion in Sport Group (Vienna, 2001) for return to sport following a concussive injury appear to be safe and appropriate for the management of concussion in Australian football.

011 DOES BASELINE NEUROPSYCHOLOGICAL TEST PERFORMANCE CHANGE FROM YEAR TO YEAR IN NON-INJURED ATHLETES?

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Background: Current guidelines recommend baseline neuropsychological testing of all athletes prior to participation in contact sports. However, a number of issues surround baseline testing, including how often such testing should be conducted and what types of test are most appropriate (traditional "paper-and-pencil" or computerised test platforms). The aim of this paper is to describe year-to-year changes that occur with serial

baseline testing on "paper-and-pencil" and computerised neuropsychological tests in Australian Footballers.

Methods: 899 Australian football players were recruited between 2001 and 2003. Of these, 391 players completed the Digit Symbol Substitution Test (DSST) and 373 completed the Trail Making test part B (Trails B) on two consecutive occasions 1 year apart. 231 players repeated the CogSport test at the same interval. For each player, changes in raw scores between serial assessments were calculated for DSST, Trails B, simple RT (SRT), choice RT (ChRT), working memory (WM) and divided attention (DIV) tasks. Group mean (M_{diff}) and standard deviation (SD_{diff}) of the difference scores are reported here. The M_{diff} represents the average change in performance, while the SD_{diff} represents a measure of the 'stability' or 'repeatability' of each outcome measure.

Results: Mean DSST score improved by 2.9 items (4.5%), while mean Trails B score improved by 7 seconds (12.2%) between years 1 and 2. Paired samples t-tests demonstrated that these improvements were significant for both DSST ($t(1,390)=8.57$, $p<0.0001$) and Trails B ($t(1,372)=9.24$, $p<0.0001$). The SD_{diff} for DSST and Trails B were 6.71 and 15.50, respectively, representing large variations around the M_{diff} . No significant changes in the CogSport outcome measures between years 1 and 2 (SRT ($p=0.85$); ChRT ($p=0.08$); WM ($p=0.36$); DIV ($p=0.44$)). The SD_{diff} on these tasks was very small.

Conclusions: The performance of non-injured athletes on conventional "pencil-and-paper" neuropsychological tests improves significantly from year to year. There is also a wide variability in the magnitude of improvement on these tests. This makes the results of these tests difficult to interpret in the clinical setting. Conversely, performance on a computerised cognitive test (CogSport) remains very stable from year to year, and there is little variability in the magnitude of change in serial performance. This test appears to have better properties for serial follow-up of the concussed footballer.

012 DIFFERENTIATING CONCUSSION AND POST-TRAUMATIC HEADACHES IN AUSTRALIAN RULES FOOTBALL—A PILOT STUDY

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Background: Headaches are common in collision sports such as Australian Rules Football. Symptomatically, there is often significant overlap between concussion and acute post-traumatic headache syndromes. However, an accurate diagnosis is important as the management and follow-up of these two conditions differs considerably. Although neuropsychological deficits following concussion have been well documented, those following post-traumatic migraines and other forms of headache are inconsistent and poorly defined. The aim of this pilot study is to determine whether cognitive impairments are seen in footballers with post-traumatic headache syndromes and to compare any changes with those seen following concussion.

Methods: 240 players were recruited from six Australian football teams (4 elite, 1 junior elite, 1 amateur) and followed prospectively over a single season. All players performed CogSport baseline testing prior to the start of the season. Players with symptoms of concussion were referred for assessment and follow-up testing. Players who were suffering from post-traumatic headache were distinguished on clinical grounds using International Headache Society criteria.

Results: 20 players were referred for follow-up testing during the course of the season. Three players were identified as having suffered from post-traumatic headache syndromes. On follow-up testing with CogSport, there was no change from baseline in any of the domains tested. Conversely, concussed players demonstrated a significant deficit (50 ms) on a test of reaction time.

Conclusion: this pilot study suggests that players with post-traumatic headache do not display cognitive impairments such as those observed in concussed athletes. This may be useful in distinguishing concussed players from those with post-traumatic headache syndromes and may have important implications for pharmacological and clinical management.

013 EFFECT OF ICE SURFACE SIZE ON COLLISION RATES AND HEAD IMPACTS IN ELITE JUNIOR HOCKEY

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Background: Collision is the ubiquitous risk factor for concussion in sport. A study of elite hockey comparing the 2002 Winter Olympics with

the 2001 and 2002 National Hockey League (NHL) Stanley Cup finals found significantly fewer collisions on the larger international ice surface than on the smaller NHL ice (Wennberg, *Can J Neurol Sci*, 2004). The present study sought to further determine if collision rates in elite junior hockey differed between games played on the small NHL, ice surface (85 feet wide), an intermediate size Finnish ice surface (94 feet wide) and the large standard international ice surface (100 feet wide).

Methods: Videotapes of all games involving Team Canada from the 2002 (large ice, Czech Republic), 2003 (small ice, Canada) and 2004 (intermediate ice, Finland) World Junior Championships were analysed, with all collisions counted and separated into various categories (volitional player/player bodychecks, into boards or open ice, plus accidental/incidental player/boards, player/ice, head/stick, head/puck). Further subdivisions included collisions involving the head directly or indirectly and notably severe head impacts.

Results: Small, intermediate, large ice surface mean collisions/game, respectively, were: 295,258,222 (total collisions); 251, 220, 181 (volitional bodychecks); 126, 115, 88 (into boards); 125, 106, 93 (open ice); 71, 52, 44 (total head); 44, 36,30 (indirect head); 26, 16, 13 (direct head); 1.3, 0.5, 0.3 (severe head) ($p<0.05$ for small-intermediate ice and intermediate-large ice differences in total collisions, $p<0.0005$ for small-large ice difference; $p<0.05$ for small-intermediate ice differences in head impacts, $p<0.005$ for small-large ice differences in total and severe head impacts).

Conclusions: The results of this study provide further evidence of an inverse correlation between ice size and collision rates in elite hockey, including direct, indirect and severe head impacts. Uniform usage of the larger international rinks, with no rule changes or other alterations in the game, could provide direct primary prevention to reduce the number of collisions, and, by extension, concussions, that occur in the sport.

014 NEUROPSYCHOLOGICAL MANAGEMENT OF CONCUSSION IN CHILDREN AND ADOLESCENTS: EFFECTS OF AGE & GENDER ON IMPACT

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Introduction: Neuropsychological assessment has become an essential component in the management of sports concussions. While adolescents and adults demonstrate excellent reliability and validity on ImPACT, the need exists for developmentally-appropriate assessment tools in younger children. We examine gender and age effects on neuropsychological performance in a normative sample age 11–18 years with ImPACT, a battery designed for sports concussions.

Method/Results: ImPACT 2.1, tapping attention, verbal and visual memory storage/retrieval, processing speed, and reaction time, was administered to 635 participants (451 boys, 184 girls), age 11–18, with no history of learning, attentional, neurological, or psychiatric disorders. Inspection of the distributions of all task variables at each age level reveals appropriate dispersion. Differences in performance between the 8 age groups and 2 genders on the 5 ImPACT Composites were examined via MANOVA. Clear developmental trends were present for all composites (Verbal Memory $p<0.04$, Visual Memory $p<0.01$, Processing Speed $P<0.001$, Reaction Time $p<0.01$, Impulse Control $p<0.01$) while only marginal gender differences were evident for Verbal Memory and Processing Speed ($p<0.06$), and no age x gender interactions. Post hoc tests of specific ages found consistent linear effects with increasing performance with age.

Conclusions: The current findings support the use of ImPACT for children as young as age 11. Reasonable distribution of scores are found at all age levels. Significant increases in performance associated with advancing development are evident for each of the neuropsychological domains, while only marginal differences were noted between boys and girls. While these findings have significant implications for the clinical utility of ImPACT at younger ages, further detailed scale-level analyses are planned.

015 VALIDITY OF IMPACT FOR MEASURING ATTENTION & PROCESSING SPEED FOLLOWING SPORTS-RELATED CONCUSSION

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Introduction: The purpose of this study was to examine the validity of ImPACT (Immediate Post-Concussion Assessment and Cognitive Testing), a computerized neuropsychological test battery, for measuring attention and processing speed in athletes with concussions. This was accomplished by comparing the computerized testing to a traditional

neuropsychological measure, the Symbol Digit Modalities Test (SDMT).

Method: Participants were 72 amateur athletes who were seen within 21 days of sustaining a sports-related concussion (Mean = 9.4, Median = 9, SD = 5.4 days). The breakdown of athletes by concussion severity, based on the American Academy of Neurology guidelines, was as follows: Grade 1 = 33%, Grade 2 = 49%, and Grade 3 = 18%. Their average age was 17.1 years (SD = 1.9), and their average education was 10.5 years (SD = 1.8).

Results: The SDMT correlated most highly with the Processing Speed ($r = 0.70$) and Reaction Time ($r = -0.60$) composites from ImPACT. The composite scores from ImPACT and the SDMT were subjected to exploratory factor analysis. The subject to variable ratio was 12:1, and the communalities for the variables were high, ranging from 0.70 to 0.95. Three components were extracted accounting for 81.9% of the total variance (although one component was a single variable: Total Postconcussion Symptoms). Therefore, a two-factor solution was retained and interpreted as Speed/Reaction Time and Memory.

Discussion: It appears as if the Processing Speed Composite, Reaction Time Composite, and SDMT are measuring a similar underlying construct in this sample of concussed amateur athletes

016 TRACKING NEUROPSYCHOLOGICAL RECOVERY FOLLOWING CONCUSSION

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Introduction: The purpose of this study was to illustrate the serial use of computerized neuropsychological screening with ImPACT to monitor recovery in individual athletes.

Method: Amateur athletes with concussions ($n = 30$, average age = 16.1, SD = 2.1 years) underwent preseason testing and three post-concussion evaluations within the following intervals: 1–2 days, 3–7 days ($M = 5.2$ days), and 1–3 weeks ($M = 10.3$ days).

Results: Repeated Measures ANOVAs revealed significant main effects for all five composite scores. Compared to preseason, verbal memory scores were significantly lower at 1 day (Cohen's $d = 1.0$ large effect size) and 5 days ($d = 0.60$, medium effect), but not at 10 days post injury. Visual memory and processing speed scores were significantly lower at 1 day ($d = 0.53$ and 1.1 , respectively) but not at 5 or 10 days. Reaction time scores were significantly slower at 1 day ($d = 1.2$) and 5 days ($d = 0.61$), but not 10 days. Total postconcussion symptom scores were significantly greater at 1 day ($d = 1.5$), but not at 5 or 10 days. Athletes' scores were examined individually using the reliable change methodology. At 1 day post injury, 90% had two or more reliable declines in performance or increases in symptom reporting. At 10 days 37% were still showing two or more reliable changes from preseason levels.

Discussion: In group analyses, problems relating to concussion appeared to largely resolve by 5 days post injury and fully resolve by 10 days. Analysis of individual athletes, however, revealed that 37% continued to suffer adverse effects at 10 days post injury. Notably, the study selection criteria increased the probability of including athletes with more severe concussions. This study clearly illustrates how group analyses can obscure slowed recovery in a substantial minority of athletes.

017 NO CUMULATIVE EFFECTS FOR ONE OR TWO PRIOR CONCUSSIONS

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Introduction: Sports medicine clinicians and the general public are interested in the possible cumulative effects of concussion. The purpose of this study was to examine whether athletes with a history of one or two previous concussions differed on their preseason neuropsychological test performance or symptom reporting.

Method: Participants were 867 male high school and university amateur athletes who completed preseason testing with ImPACT Version 2.0. Their average age was 17.7 years (SD = 2.3) and their average education was 11.3 years (SD = 2.0). The breakdown of athletes by sport was as follows: American Football = 86.7%, Ice Hockey = 9.6%, Soccer = 2.3%, and other sports = 1.4%.

Participants were sorted into three groups on the basis of number of previous concussions. There were 664 athletes with no previous concussions, 149 with one concussion, and 54 with two past concussions.

Results: One-way analysis of variance was conducted using ImPACT Version 2.0 Verbal Memory, Visual Memory, Reaction Time, Processing Speed, and Postconcussion Symptom composite scores as dependent variables and group membership as the independent variable. There were no significant main effects for group. The group with two previous concussions was slightly older than the other two groups. Exploratory pairwise comparisons using t -tests uncorrected for family-wise error also did not yield any significant effects attributable to concussion history.

Discussion: There was no measurable effect of one or two previous concussions on athletes' preseason neuropsychological test performance or symptom reporting. If there is a cumulative effect of one or two previous concussions, it is very small and undetectable using this methodology.

018 DEVELOPMENT OF THE "HEAD INJURY TEST CARD", AN ON-FIELD CONCUSSION ASSESSMENT AND MANAGEMENT TOOL

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Objective: To develop a new concussion assessment tool that includes post-injury warnings and instructions, return to play guidelines and is usable by individuals untrained in concussion assessment and management.

Methods: Review and critique of existing methods for on-field concussion assessment; development of the Head Injury Test Card (HITC) that includes instructions, scoring criteria, return to play decision tree, plus warnings and instructions to give to the player, all on a single 12X18 cm card; pilot testing of HITC with on-field injuries. Twenty-two undergraduate implemented the HITC during the practical component of an athletic training course, where students volunteer as athletic trainers for collision sports teams. Twelve students responded to the follow-up survey reporting results.

Results: Review of relevant literature showed that, although many tools are available for assessing sport concussion on-field, no existing tool is both usable by untrained individuals and provides clear return to play decision guidelines. Results for 12 first time trainers using the Head Injury Test Card were that 100% reported that the HITC was "simple to administer", "provided a definite course of action", and "provided an appropriate course of action"; 92% reported that "the coaches respected the decision made by the HITC; and 83% reported that "the athletes respected the decision made by the HITC". In contrast, these trainers reported that the Standardized Assessment of Concussion, a well-known test, took longer and often did not provide a definite course of action or a decision that was respected.

Conclusion: The Head Injury Test Card uses a flow chart method of providing post-injury decisions based on symptom presence and severity. It includes return to play and post-injury warnings and instructions, in an easy to use format. It is suitable for use by undergraduate physical education students with minimal training in concussion assessment. Further research is required to determine whether the Head Injury Test card is suitable for all populations of coaches, trainers and participants.

019 NEURAL SUBSTRATE OF DEPRESSION IN CONCUSSIONED ATHLETES. A PRELIMINARY FMRI STUDY

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Background: Concussed athletes with persisting post concussive symptoms (PCS) often manifest negative mood states, such as anxiety, irritability and depression. Unlike cognitive deficits, which have been studied extensively, little is known about the aetiology and neural substrate of depression following cerebral concussion. In this ongoing study, we investigated in concussed athletes with persisting PCS whether a correlation exists between functional MRI (fMRI) brain activation patterns and scores on the Beck Depression Inventory (BDI).

Method: As part of their neuropsychological evaluation, 16 concussed elite athletes were assessed for the presence of depression with the BDI. They were then submitted to an fMRI study where cerebral activation patterns associated with a working memory task and a baseline conditional association task were analysed, using blood oxygen level 1 dependent (BOLD) contrasts.

Results: Nine concussed athletes (54%) showed depression of various degrees. A positive correlation was found between the scores on BDI and the severity of PCS. Results from the baseline scans revealed significant positive correlations between BDI scores and BOLD signals

in the amygdala and hippocampus while negative correlations were found in the orbitofrontal (OFC) and dorsolateral prefrontal (DLPFC) cortices. In the working memory condition, a positive correlation was found in the OFC and a negative correlation in DLPFC. Quantitative analyses of the BOLD signals indicated that, compared with the non-depressed group those with depression showed hyperactivity in the limbic structures and hypoactivity in the prefrontal regions when performing the baseline task. When engaging in a working memory task, depressed athletes had higher brain activity in the OFC but weaker activation in the DLPFC.

Conclusion: Our preliminary results indicate a difference in brain activation patterns between depressed and non-depressed concussed athletes. These findings are in keeping with existing limbic-frontal models of depression and they suggest an organic basis to the complaints of depression some concussed individuals express.

020 BEHAVIOURAL AND FUNCTIONAL IMAGING OUTCOMES IN SYMPTOMATIC CONCUSSED ATHLETES MEASURED WITH COGSPORT AND FUNCTIONAL MRI

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Background: Neuropsychological testing constitutes an integral part of the management of concussed athletes. A number of computerized cognitive test batteries have gained acceptance for assessing the effects of concussion. Similarly, functional neuroimaging is becoming a useful tool since structural imaging is mostly normal following a concussion. Our objective is to compare in athletes with chronic post concussive symptoms measures of cerebral activity with functional imaging and results on a computerized cognitive test battery.

Method: Subjects included 25 healthy male athletes from McGill University varsity teams who never sustained a concussion or did not have one at least in the past year; 9 concussed male elite athletes with mild post concussive symptoms (PCS; <22/126 on the PCS Scale-Revised); and 5 concussed male elite athletes with moderate PCS (22–84/126). Main measures included response speed and accuracy from the CogSport battery, blood oxygen level dependent (BOLD) regional brain activation in the prefrontal cortex associated with a working memory task and response accuracy in the latter task during the fMRI session.

Results: *Behavioural:* 1) On the CogSport Battery, response accuracy and response speed were comparable for the mild PCS group. For the moderate PCS group, response accuracy was also equivalent but these athletes were slower than both groups on matching ($p < 0.01$) and one-back tasks ($p < 0.01$); 2) on the working memory tasks, all groups performed similarly. *Imaging:* Weaker task-related activations in dorsolateral prefrontal cortex were observed for both PCS groups. Additional activation peaks outside the region of interests, not seen in the control group, were also noted for both PCS groups.

Conclusion: fMRI imaging studies detect atypical cerebral activation in athletes with mild or moderate PCS. The CogSport test battery optimally finds behavioural anomalies in concussed individuals with moderate rather than mild PCS.

021 CONSTRUCT VALIDITY OF THE IMPACT POST-CONCUSSION SCALE IN CHILDREN

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Introduction: Assessment of sequelae following a concussion typically involves the use of a post-concussion symptom inventory. In its current form, the ImPACT Post-Concussion Scale (PCS) provides an overall total rating of 22 symptoms. To improve clinical utility, it may be useful to differentiate specific components. Recently, Moritz *et al* described specific clusters of core symptoms in adults on the PCS. We examined the factor structure of the PCS among the youngest sample of children yet studied to date.

Methods/Results: The PCS was administered to a sample of 750 children, aged 11 through 18 years, including children with ($n = 115$) and without ($n = 635$) history of concussion. The 22-item scale was submitted to a principal factor analysis with Promax rotation. Examination of competing solutions supports a four-factor solution as most statistically and theoretically sound, accounting for 47.4 percent of the variance. The solution is defined by a Somatic Symptoms factor (7 items), a Cognitive Problems factor (6 items), a Sleep/Fatigue Problems

factor (4 items), and an Affective Problems factor (5 items). Internal consistency reliabilities were acceptable for the four factors: Somatic Symptoms $\alpha = 0.84$, Cognitive Problems $\alpha = 0.81$, Sleep Problems $\alpha = 0.78$, and Affective Problems $\alpha = 0.75$.

Conclusions: Examination of the factor structure of a pediatric version of the ImPACT -PCS reveals four specific domains of post-concussive symptoms, supporting the use of these subscales, in addition to total symptom score, in clinical interpretation. Although the number and type of factors obtained with this large pediatric normative sample was similar to adult samples, items comprising each factor were different. Future research will expand the focus of symptom report in children younger than 11.

022 DESCRIPTIVE EPIDEMIOLOGY OF CONCUSSION

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Objective: To describe the epidemiology of reported concussion derived from a large, nationally representative health survey. **Methods:** We analysed the microdata files of the Canadian National Population Health Survey (NPHS: 1996–1997). 81,804 respondents representing 28,606,500 Canadians reported whether they had “any injuries that were serious enough to limit their normal activities” in the preceding 12 months and the nature of the most serious injury. Those reporting concussions were compared to those reporting other injuries and/or the non-injured.

Results: 99.8% of 81 804 eligible respondents reported their injury experience within the preceding year, with 98 reporting a concussion. The annual incidence of Canadians reporting a concussion as their most serious injury was 1.1 per 1,000 population (95% CI: 0.9, 1.4).

Those reporting concussion were more likely to be younger (32% under 15y, 76% under 35y) ($p < 0.0001$) and male (62%) ($p < 0.0001$). Males were significantly over represented in the 16–34y group (OR = 4.6, $p = 0.001$).

At least 54% of all concussions were sport-related (95% CI: 39% 67%), occurring at a place for recreation or sport, with sport having a role in 85% of concussions in the 16–34y group (OR = 13.1, $p < 0.0001$). Other locations included home (23%), school (7%), and street/highway (4%).

Those reporting concussion were more likely to report “excellent” health ($p < 0.001$) and higher daily energy expenditure ($p < 0.001$) than those not reporting concussion.

Conclusions: We present annual incidence estimates of reported concussion, derived from a sizeable nationally representative population survey.

023 SELF-REPORTED SYMPTOMS FOLLOWING CONCUSSION IN CANADIAN JUNIOR HOCKEY PLAYERS

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Introduction: The purpose of the study was to prospectively document post-concussion symptoms (PCS) in a group of Canadian junior hockey players over a period of one month.

Methods: Baseline data were collected from 555 participants over a two year period. The assessment protocol included documentation of symptoms using the Rivermead Postconcussion Symptom Questionnaire - a 16-item form that instructs subjects to rate themselves on the degree to which they are currently experiencing PCS. Follow-up on 39 players was performed within 24 hours of being notified of the injury, at two weeks, and one month. Cohen's effect sizes were computed for all pre and post-injury contrasts.

Results: Elevated self-reported symptoms at the first follow-up included headache; dizziness; nausea; sensitivity to noise; fatigue; irritability; blurred vision; as well as problems with memory, concentration, and information processing. With limited exceptions, all effect sizes were “large” and in most cases were “very large”. The symptoms that were significantly elevated at two weeks post injury were the memory and concentration variables (both with large effect sizes). There were no changes significant at the 0.01 level for any symptoms at one-month post injury compared to baseline.

Discussion: The results of this study suggest that a wide variety of symptoms can be observed in the hours and days following a concussion ranging from somatic to purely cognitive. At two weeks, cognitive symptoms, such as problems with concentration and memory, remained. Emotional symptoms such as feeling depressed or tearful were not highly endorsed at baseline or any of the follow-up periods.

024 CHANGES IN AUDITORY AND VISUAL CONTINGENT NEGATIVE VARIATION FOLLOWING CONCUSSION IN JUNIOR HOCKEY PLAYERS

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Introduction: The contingent negative variation (CNV) is considered an electrophysiologic index of cognitive functions such as the ability to effectively "anticipate" a stimulus and to make an accurate motor response. The purpose of this study was to determine the usefulness of the CNV for the assessment of concussion severity and recovery in Canadian junior hockey players.

Methods: 271 athletes were assessed at the beginning of the season (baseline). Following notification of a concussion, injured athletes (initially 25) were re-assessed within 24 hours of notification, at two weeks, and one month. One auditory and two visual (shapes and words) stimulus sets were used to elicit responses. Post-concussive changes in initial (iCNV) and terminal CNV (tCNV) amplitude were compared to pre-injury baselines using a repeated measures analysis of variance. Pearson correlations were performed to assess the relationship between CNV amplitude and self-reported symptoms. Results: The amplitude of the auditory and visual tCNV responses at the first follow-up were significantly decreased compared to baseline. Only visual iCNV responses were significantly decreased from baseline at the first follow-up. By the two week follow-up, no statistical differences in amplitude were observed compared to baseline. Pearson correlations showed a significant relationship between auditory and visual CNV amplitude and symptoms such as poor concentration and taking longer to think.

Discussion: The CNV changes observed in this study are consistent with post-concussive behavioural deficits that include a decreased ability to anticipate play development and to make accurate motor responses. In addition, the significant correlation between post-concussive CNV changes and self-reported symptoms may indicate its usefulness for the assessment of concussion severity and recovery.

025 PROSPECTIVE STUDY OF THE NEUROPSYCHOLOGICAL PERFORMANCE OF HIGH SCHOOL ATHLETES INVOLVED IN CONTACT AND NON-CONTACT SPORT PROGRAMS

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Objective: To compare the evolution of the neuropsychological performance of high school athletes involved in sport programs with or without contacts. Design: Prospective cohort study over two years of competition.

Methods: 162 athletes (13.2 ± 1.1 years initially) playing football (n=38), soccer (n=44), hockey (n=36), golf (n=24), swimming (n=20) completed a 30 minute battery of six neuropsychological tests on three occasions: prior to the fall 2001 and 2002 academic sessions and at the end of 2002–2003 academic year. Each time, athletes completed the six tests (Boston Cancellation Task (BCT), Symbol Digit Modalities Test (SDMT), Trails Making Test A & B, Stroop Test, Brown-Peterson Test and the Verbal fluency) and a questionnaire aimed at documenting any history of concussion in the preceding year. The psychometricians were blind to the sport program of the athlete.

Results: As expected in youth population, the performance on the six tests improved with time ($p < 0.05$). Also, the SDMT, the Stroop and the Trail B test revealed differences between age groups at each evaluation. Initial values for the SDMT and Stroop tests were significantly better than reference values for the corresponding age groups ($p < 0.05$). Finally, no difference between sports was observed for 5 of the 6 tests over the study period. Only the BCT results suggested that a significant impairment of some neuropsychological skills might be associated with participation in contact sports ($p < 0.05$).

Discussion: The superior neuropsychological performance of high school athletes compared to reference values for their respective age groups suggests that normative data can underestimate the consequences of concussions in that population. Individual baseline values or specific normative data should therefore be used. The results also shown that, although most of the neurocognitive skills tested are not affected by participation in organised contact sports, a significantly slower development of the skills tested by the BCT test (mainly visual scanning and executive function) might be present compared to athletes involved in non-contact sports.

026 EFFECTS OF MULTIPLE SPORT-RELATED CONCUSSIONS ON COGNITIVE PERFORMANCE

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Introduction: The management of concussion has become a public health issue since around 300,000 concussions occur each year in the US alone. Most discussion focuses upon return-to-play decision-making, which should be based upon athletes' symptoms and cognitive function. The current study was designed to evaluate the impact of concussion history upon cognitive and symptom status with a new concussion, with measurements taken at 2 and 7 days post-injury.

Method: 201 high school and college athletes were evaluated pre-season, and at 2 and 7 days post-concussion. All athletes were evaluated using the ImPACT computerized test battery. Athletes who had never sustained a concussion prior to the current injury (n=155) and athletes who had suffered two or more concussions prior to the current injury (n=46) were compared. Dependent variables included the verbal memory, visual memory, processing speed, and reaction time composite scores from the ImPACT test battery, the total symptom score on ImPACT's Post-Concussion Symptom Scale, and athlete-reported on-field markers of injury for the current injury.

Results and Discussion: No significant differences were found between groups for any of the composite scores or total symptom score at 2 and 7 days post-injury. However, increases on on-field markers were observed in the group with a concussion history. Results suggest a decreased injury threshold for athletes with a concussion history, though no long-term neurocognitive difficulties.

027 IMPLEMENTATION OF A COMMUNITY LEVEL SPORT CONCUSSION MANAGEMENT SYSTEM IN NEW ZEALAND

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Background: New Zealand has a high sporting participation base, particularly in contact sports. There are a number of concussion management systems used in New Zealand professional sport, but few in place at the community sport level.

Aim: To develop and assess the effectiveness of a sideline concussion check (SCC) tool to provide interim management of a suspected concussion at the community sport level.

Methods: The content of the SCC was developed based on the card used by the University of Pittsburgh Medical Centre that utilised "Maddocks questions" as well as a series of questions designed to identify the presence of anterograde or retrograde amnesia. Changes were made to reflect the New Zealand linguistic context and to align with Sports Medicine New Zealand's policy document titled 'Head Injury in Sport'. The SCC fits into the palm of the hand and contains a fold out pouch with insert cards. The best practice content of the insert card is designed to communicate guidelines for the management of concussion for the first 24–48 hours. The insert card can be given to the player/player's support network to manage any symptoms until the player seeks medical advice. If the player doesn't seek immediate medical advice after a suspected concussion, (as is believed to occur in a large number of cases) the insert card can act as a stimulus to seek medical advice if the symptoms outlined in the card become manifest. Extra insert cards and SCCs can easily be obtained at no cost through a website (www.acc.co.nz) or free phone number. The SCC has been distributed to sports coaches and medical practitioners (doctors, emergency departments, and ambulance staff) throughout New Zealand. Evidence of the effectiveness of the intervention was established using injury entitlement compensation claims. An entitlement claim is a moderate to serious injury requiring entitlement beyond medical treatment only, as defined under the Injury Prevention, Rehabilitation, and Compensation Act 2001.

Results: 60,000 cards have been distributed in New Zealand from July 2003. Between July 2002 and June 2003 there were 247 new sport and recreation concussion/brain injury (CBI) entitlement claims. From July 2003 (when SCC was implemented) till the end of May 2004 there were 188 new sport CBI claims with new serious sport traumatic brain injury claims reduced from four a year to zero. Non sport CBI claims increase by approximately 5% during the same period. There were no changes made to the CBI policy or data collection system between the two years. A final analysis of the data

including cost savings as a result of the SCC will be presented at the Symposium.

Discussion: The primary aim was to encourage best practice early treatment and management of concussion and in so doing decrease the risk of long-term adverse outcomes. An expectation that education of people about concussion in sport, and encouragement of management of a suspected concussion through referral to acute medical care would lead to an increase in the number of CBI entitlement claims, was not borne out by the CBI claim statistics. Key issues addressed in the development and delivery of the SCC included coach education, distribution, and its use by sporting and medical communities. Further work will include investigation of the efficacy of the three week stand down period currently mandated by a number of sporting organisations in to ensure participants do not return to play until they are fully recovered.

028 SYMPTOM RECOVERY FOLLOWING CONCUSSION: IMPLICATIONS FOR RETURN TO PLAY

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Introduction: Management of sports-related concussion is an area of great interest, particularly regarding recovery and return-to-play decisions. Athletes may not display concussion symptoms or may minimise symptoms. Prematurely cleared athletes risk sustaining cumulative neuropsychological damage or second impact syndrome.

Objective: Evaluate the symptom reporting patterns of concussed athletes. Examine cognitive performances of symptom-free athletes 1–3 days post-concussion.

Method: In one study, symptoms of concussed athletes having pre-season baseline testing were evaluated 2, 5, 8, and 10 days post-injury. Scores were compared to a control group. In a second study, the symptoms and cognitive function of symptomatic (SC) and asymptomatic concussed (AC) athletes and control athletes were tested.

Results: In study one, at 10 days post-injury, the concussed group reported significantly fewer symptoms than at baseline, while symptom reporting in the control group remained relatively stable. In study two, AC and SC groups were more impaired on all ImpACT composite scores (visual memory, verbal memory, visual motor speed, reaction time) versus controls. AC athletes demonstrated higher scores than SC athletes on visual memory, visual motor speed, and reaction time.

Conclusions: Return-to-play decisions should not be based entirely on symptom presentation. Neuropsychological test results should also be considered so as not to return a still-concussed athlete back to play.

029 SEX DIFFERENCES IN ACUTE RECOVERY FOLLOWING CONCUSSION IN ATHLETES

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Objective: The objective of this study was to evaluate sex differences in recovery from concussion. This study compares the neurocognitive test performance of male and female concussed athletes two days post-injury to a group of healthy control athletes.

Methods: A sample of 109 male and female high school and college athletes was evaluated two days post-injury using a computerized neurocognitive test battery (ImpACT) that is now in use by over 500 high school, college, and professional sports teams. Male and female concussed athletes were compared to a sample of non-concussed (control) athletes using Multi-Variate Analysis of Variance (MANOVA) with sex (male vs. female) and concussion status (concussed vs. control) serving as independent variables and the memory, reaction time, and processing speed composite scores from ImpACT serving as dependent variables. The concussed and control athletes participated primarily in American football, soccer, or ice hockey.

Results: The MANOVA yielded a main effect for concussion status (Rao's $R = 4.92$, $df = 3, 130$, $p = 0.002$) indicating overall neurocognitive dysfunction in the concussed group compared to the control group. Differences between concussed and control athletes were observed on the memory ($F = 7.67$, $p = 0.006$), reaction time ($F = 9.67$, $p = 0.002$), and processing speed ($F = 6.22$, $p = 0.01$) composite measures of ImpACT. Both males and females performed equally poorly on post-concussive testing compared to non-injured controls.

Conclusions: Concussed male and female athletes performed comparatively poorly on a computerized neurocognitive test battery at 2 days post-injury. The effect of sex was not significant, indicating no differences between male and female athletes in acute recovery from concussion.

030 SENSITIVITY AND SPECIFICITY OF THE IMPACT TEST BATTERY IN ATHLETES' CONCUSSION STATUS

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Introduction: A recent consensus statement by the Concussion in Sport (CIS) group recommends assessment of both post-concussion symptom status and neuropsychological testing as integral parts of proper concussion management. ImpACT is a computerized battery of neuropsychological tests that can detect neurocognitive difficulties by assessing memory, reaction time, and processing speed. This study will determine the efficacy of ImpACT in discriminating concussed from nonconcussed athletes.

Method and Results: A group of concussed athletes ($n = 76$) was compared to a control group ($n = 71$). All were tested using ImpACT, which yields five composite scores. A post-concussion symptom inventory was also evaluated. A stepwise function analysis using factors of symptom, processing speed, verbal memory, and impulse control scores correctly classified 85% of cases (79% concussed, 92% nonconcussed). The eigenvalue (0.776) suggests high discriminating power with a canonical correlation of 0.661.

Conclusions: ImpACT scores along with postconcussion symptoms, provide an accurate way to discriminate concussed and nonconcussed athletes. The study supports using ImpACT in the diagnosis and treatment of concussion as well as in the decision-making process regarding return-to-play following concussion.

031 POSTTRAUMATIC MIGRAINE FOLLOWING SPORTS-RELATED MILD TRAUMATIC BRAIN INJURY

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Objective: To compare symptom status and neurocognitive functioning of concussed non-headache (non-HA) athletes, concussed athletes complaining of headache (HA), and concussed athletes with characteristics of posttraumatic migraine (PTM).

Method: Neurocognitive testing data was collected from 262 participants (16.37 ± 2.60 years). Athletes were separated into the three groups described above. ImpACT summary scores for verbal and visual memory, visual motor speed, reaction time, and total symptom scores were analysed.

Results: Significant differences existed between the three groups for all outcome measures. The PTM group demonstrated significantly greater cognitive deficits as compared to the HA and the non-HA group. The PTM group also exhibited the greatest amount of departure from baseline scores.

Discussion: Observed data suggest that PTM characteristics triggered by sports-related concussion are related to increased neurocognitive dysfunction. All athletes suffering concussion should be assessed for symptom status and neurocognitive function to better determine recovery. Given increased impairments observed in the PTM group, clinicians should exercise increased caution in the management and return to play decision-making process in this population.

032 THE POST-CONCUSSION SYMPTOM SCALE (PCSS): A FACTOR ANALYSIS

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Introduction: The PCSS is a commonly used symptom inventory in clinical subjective assessment of concussed athletes. A factor analysis of the PCSS was conducted on a sample of 327 recently concussed athletes to delineate potential core symptom clusters within the first week of recovery.

Methods/Analysis/Results: The 21-items on the PCSS were submitted to an exploratory factor analysis using the 327 concussed athletes who completed all items within 7 days of their injury. Factors were extracted using principle components analysis with an oblique rotation (oblimin), which allows for correlated factors. Results suggest a four-factor solution containing a 7-item Cognitive problems and slowing factor, a 2-item Sleep Problems factor, a 4-item Emotionality factor, and an 8-item Somatic Symptoms factor. The internal consistency values were acceptable for items making up the cognitive problems/slowing ($\alpha = 0.89$), sleep problems ($\alpha = 0.79$), emotionality ($\alpha = 0.78$), and somatic symptoms ($\alpha = 0.87$) scales.

Conclusions: Factor structure of the PCSS suggests several core symptom dimensions that may reflect different subtypes of concussion.

Also, the identification of symptom dimensions through factor analysis is only the first step in determining measurement validity.

033 FUNCTIONAL NEUROIMAGING AND NEUROCOGNITIVE RECOVERY AFTER SPORTS-RELATED CONCUSSION

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Introduction: The Concussion in Sport (CIS) group assembled in Austria in 2001 to formulate recommendations for the managing of athletic concussions as well as to elucidate the current state of concussion research and knowledge. This group suggested that neuropsychological testing become a "cornerstone" for concussion management. The group also encouraged further exploration of the pathophysiology of concussion through use of functional neuroimaging and other techniques, as many aspects of the physiology of the injury are poorly understood. The current poster represents early findings from the NIH funded "fMRI and Sport-Related Concussion" study currently being implemented by the UPMC Sports Medicine Concussion Program. The purpose of the larger study is to understand through both functional neuroimaging and cognitive functioning (measured by the ImPACT computerized test battery) the effects of concussion and the process of concussion recovery in athletes aged 13–25.

Method: Most subjects in the project have received baseline neurocognitive evaluations on ImPACT through their school or sport organisation. Once concussed, these athletes are retested on ImPACT weekly until their scores return to baseline and they are symptom free at rest and exertion (as recommended by the CIS group). Within 7 days of concussion, the athletes also complete a functional MRI protocol, whereby they complete several cognitive tasks within an fMRI scanner. Once recovered, they again complete the fMRI protocol.

Results: Examination of three case studies provide early evidence of differences in activation in key cortical areas occurring with concussion that is not present in control subjects. The presentation will provide ImPACT scores reflecting changes in cognitive functioning in the concussed subjects from baseline to recovery, as well as several MRI slices for each case with functional overlays to demonstrate activation in a control subject (2 scans) a concussed athlete with no prior concussion history (concussed and recovered scans), and a concussed athlete with a prior history of three concussions (concussed and recovered scans).

Discussion: Early results suggest differences in activation seen in concussed subjects with or without prior history of concussion that are not seen in controls. Once recovered, these differences in activation appear to resolve, as demonstrated by MRI with functional overlays. The utilisation of functional or physiological neuroimaging following concussion may provide an objective and physiological means to manage concussion in athletes. Furthermore, such technology may help validate the abnormalities commonly seen with neurocognitive testing.

034 DIFFERENTIAL SENSITIVITY OF SYMPTOMS AND NEUROPSYCHOLOGICAL TESTING FOLLOWING SPORT-RELATED CONCUSSION

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Introduction: Neuropsychological testing was endorsed as the "cornerstone" of concussion management by the Vienna Concussion in Sports Group (CIS). Cognitive testing is particularly important because athletes often underreport post-concussive symptoms. This study evaluated individual and combined sensitivity of symptom report and neuropsychological testing.

Method: 201 high school and college athletes who had suffered concussion while participating in sports were evaluated. All athletes had previously undergone baseline testing using the ImPACT computerized test battery, and were then tested within 1 week of injury. "Abnormal" performance was determined by use of reliable change index scores (RCIs).

Results: 65% of concussed athletes reported significant increases in symptoms compared to baseline. 82% of the concussed sample demonstrated significantly poorer results on ImPACT. Addition of neuropsychological testing resulted in increased sensitivity of 17%. Combined sensitivity of symptom report and cognitive testing was 88%.

Discussion: Reliance on player reported symptoms could result in poor diagnostic sensitivity and premature return-to-play. Addition of a

neuropsychological protocol increases diagnostic sensitivity. Careful evaluation of both player symptoms and cognitive performance represents the most useful approach to concussion management.

035 CONCUSSION IN SPORTS: RELATIONSHIP OF ACTIVITY LEVEL AFTER CONCUSSION TO POST-CONCUSSIVE SYMPTOMS AND NEUROCOGNITIVE PERFORMANCE

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Objective: This retrospective pilot study examines the correlation between post-concussive symptoms, neurocognitive performance and the level of exertion after concussion.

Methods: Activity level in the first week after concussion was retrospectively reviewed in 51 cases (15.57 ± 2.12 years old) from a sports concussion clinic. The number of on-field symptoms was recorded. Summary composite scores from the ImPACT computerized test battery were utilised. These data were used to compare immediate symptoms reported; intensity of activity between concussion and time of initial evaluation, and performance on neurocognitive tests.

Results: A significant correlation was found between the number of immediate symptoms and the intensity of activity after concussion. Those athletes with fewer immediate symptoms had a significantly higher activity level and better performance on visual memory. The data demonstrated significant differences ($p=0.0431$) in the number of immediate symptoms between activity intensity groups.

Discussion: We theorise that those athletes with a greater number of immediate symptoms are less likely to engage in high levels of exertion after concussion due to a disruption in cerebral metabolism that is worsened by exertion. Cortisol may play a key role in this destructive process as it has been shown to reduce cerebral glucose uptake and glutamate clearance, exacerbate declines in ATP after injury, and it increases in a dose dependent manner with activity.

Conclusion: Further research is required to examine the role of post-concussive exertion to formulate an evidenced-based approach in returning athletes to activity following concussion.

036 COGNITIVE RECOVERY PATTERNS FOLLOWING SPORTS-RELATED CONCUSSION

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Introduction: Neuropsychological testing is a valuable tool in concussion diagnosis and management. ImPACT, a computerized neuropsychological testing program, consists of 8 cognitive tasks and a 21-item symptom inventory.

Method: ImPACT was used to examine the cognitive performance of 104 concussed athletes at baseline, 2, 7, and 14 days post-injury. Dependent measures included composite scores from the ImPACT computerized test battery, as well as a total symptom score from the Post-Concussion Symptom Scale.

Results: Differences between baseline and day 2 post-injury scores were observed for all ImPACT composites (Verbal memory-VERM, visual memory-VISM, processing speed-PROC, and reaction time-RT) as well as in total symptom score (SX). At day 7, concussed athletes continued to perform significantly poorer on VERM, VISM, RT, and SX. At day 14, only VERM scores were significantly different from baseline.

Conclusions: Cognitive performance deficits in concussed athletes may persist to 7 and even to 14 days in some cases. In addition to symptom status, the athlete's post-concussion cognitive functioning should be considered when making return-to-play decisions.

037 NEUROPSYCHOLOGICAL PERFORMANCE AMONG NORWEGIAN FOOTBALLERS—REPRODUCIBILITY AND EFFECT OF HEADING EXPOSURE AND PREVIOUS CONCUSSIONS

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Background: Cross-sectional studies have indicated that neurocognitive performance may be impaired among football players. Heading the ball has been suggested as the cause, but recent reviews state that the reported deficits are more likely to be the result of accidental head impacts that occur during the course of matches.

Main objective: To assess the reliability of a computerized neuropsychological test battery (CogSport™) and examine the association between previous concussions and heading exposure with test performance among Norwegian professional football players.

Methods: All players in the Norwegian professional football league (Tippeligaen) performed two consecutive baseline CogSport™ tests prior to the 2004 season (90.1% participation) and completed a questionnaire assessing previous concussions, match heading exposure (self-reported number of heading actions per match), player career, etc. CogSport™ is a computer based neuropsychological test which consists of seven different subtasks: Simple Reaction Time (SRT), Choice Reaction Time (ChRT), Congruent Reaction Time (CgRT), Monitoring Task (MON), One-Back Task (OBK), Matching Task (Match) and Learning Task (Learn).

Results: There was a small, but significant improvement from repeated testing for all seven subtasks (SRT: 1.3%, ChRT: 0.3%, CgRT: 1.1%, MON: 0.8%, OBK: 2.1%, Match: 2.0%, Learn: 1.0%). The method error was 2.8% for SRT, 1.5% for ChRT, 1.5% for CgRT, 2.9% for MON, 1.9% for OBK, 1.9% for Match and 1.3% for Learn. Thus, the variance decreased with increasing complexity of the task performed. Neither match nor lifetime heading exposure was associated with CogSport™ test performance. The number of previous concussions was positively associated with match heading exposure, but there was no relationship between previous concussions and test performance.

Conclusion: Computerized neuropsychological testing revealed no evidence of neurocognitive impairment due to heading exposure or previous concussions in a cohort of Norwegian professional football players.

038 CONCUSSION IN SPORT. ARE RECOMMENDATIONS BEING FOLLOWED?

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Objective: To determine if current concussion recommendations¹ for pitch side assistance and return to play practices are being followed.

Design: A retrospective postal questionnaire.

Setting: Sports casualties in accident and emergency.

Method: Patients who had presented with signs and symptoms of concussion, and/ or, a head, neck, chest or thigh injury, had a response rate of 58% (n = 104/186).

Results: All respondents received a poor standard of pitch side first aid. Among the 26 concussed respondents, 11 were aware of guidelines used for safe return to play, however 7 admitted to evading injury detection, and 12 to ignoring guidelines or advice when returning to play, (6 to both and 13 to either). While 8 received a medical examination before returning to play, only 7 did so in a stepwise fashion, which was significantly less than respondents without concussion injury (n = 63) (p < 0.005). No concussed respondents had neurocognitive assessments.

Conclusion: In keeping with the finding of other studies² pitch side first aid needs to be improved to an acceptable standard. Objective measures are justified in supervision of safe return to play following concussive injury.

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039 UNDERSTANDING THE RELATIONSHIP BETWEEN HEADING A SOCCER BALL AND NEUROPSYCHOLOGICAL PERFORMANCE IN GIRLS INTERSCHOLASTIC SOCCER

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Participation in girls' interscholastic soccer has increased dramatically over the last 5 years, due in part to the success of the women's US National program. Heading a soccer ball is one aspect of the game that has become a target in the popular press as being dangerous and detrimental to brain function. The purpose of this study was to determine if a relationship exists between soccer heading and neuropsychological performance before and after a competitive soccer season in a group of female high school players. A total of 100 interscholastic soccer players (age = 16.1 ± 1.2 years; ht. = 164.5 ± 6.5 cm; mass = 59.4 ± 9.3 kg)

with an average of 5+ years of playing experience, were tested before and immediately after one competitive soccer season. The Automated Neuropsychological Assessment Metrics (ANAM) computer program was used to assess neuropsychological performance. Throughput scores for Matching to Sample (MTS) and Sternberg Memory (STN) were analyzed. Throughput scores combine accuracy and speed, therefore the higher the score, the better. Headers were tabulated during each sanctioned match using a simple tally system. The Pearson Product Moment Correlation Coefficient was employed to analyze the relationship between the number of headers per game and total headers, and pre/post-season scores on these two measures of neuropsychological performance. The average number of total headers for the season was 20.2, while the average headers/game was 1.0. There were no significant correlations between total headers (pre MTS r = 0.06, post MTS r = 0.14, pre STN r = -0.04, post STN r = -0.03) or headers/game (pre MTS r = 0.03, post MTS r = 0.13, pre STN r = -0.04, post STN r = 0.01) and the two neuropsychological tests. The STN and MTS sequences of the ANAM are designed to test working and visual memory respectively. The results of this study indicate that there is no relationship between total headers and headers/game and these measures of brain function. The implications of these findings point to the fact that heading a soccer ball, if performed properly by skilled players, is not related to any deficits in memory function as measured in this study. Interestingly, it appears that over the course of an entire season, interscholastic female soccer players on average do very little heading of the soccer ball in sanctioned matches. Additional research is needed to get a better understanding of the relationship between neuropsychological performance and soccer heading over the long-term. (This study was funded in part by a grant from the Mid-America Athletic Trainers' Association).

040 INJURY REGISTRATION FOR CONCUSSION PREVENTION

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The Swedish Elite Ice Hockey uses a computerized injury registration system (International Sports Injury System-ISIS) since the season 2002/2003. The intent of this program is to make it possible to continuously monitor the injury pattern, detect changes and evaluate the effect of different injury preventive programs. The system can also detect effects of rule changes, playing schedule and, for example, changes in arena design. Since the system combines presence and injuries, we can calculate the incidence and use it instead of number of injuries, which is the correct way to register epidemiological data in sports.

During these two seasons, there were 12 teams in the Swedish elite league. The compliance for using the system was initially not too good but increased during the two studied years and during the second season nine used the system fully and the other used it partially.

Forty-six concussions appeared in games during these two seasons. We found that these concussions were evenly distributed over the three periods. When we made deeper analyses we could see that these concussions appeared mainly in the first period during the first season and mainly in the third period for the second. For the two seasons there were also variances in incidence between the teams and between the studied years. One team reported many concussions the first year and only half the second year while other teams doubled their number of concussion from one year to the other.

In order to reduce the incidence of concussions and perform the correct preventive measures to we need data from different teams over many years and probably from different leagues. These data must include different factors in order to make it possible to draw valid conclusions. It is also of utmost importance that the exposure time is shown as the incidence of concussion is depending on the number of exposures. The injury registration system that now is in use in Sweden gives the opportunity to perform these studies

041 CONCUSSION IN SWEDISH ELITE ICE HOCKEY. A 20 YEAR EXPERIENCE

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The awareness of the seriousness of concussion in ice hockey has increased over the last two decades. In the beginning of the 80-ies

very few physicians engaged in ice hockey was aware of the significance of this injury. In 1985 a Swedish symposium was arranged in order to classify concussion and to establish norms for treatment of this injury. At these symposia it was suggested that the term concussion should be abandoned and the term mild head injury should be used instead.

Since 1984 the author has registered all injuries occurring in one Swedish elite ice hockey team. Since 1987/88 the definition of a concussion used has been the same—transient confusional period with or without amnesia/loss of consciousness and since 1997/98 the management of concussion have, with a slight modification, followed the recommendations by American Academy of Neurology.

During these 20 years 85 concussions were registered. 71 of the concussions appeared during game play. The incidence during normal

league games was 57/1000 games and during play off the incidence was nearly doubled 110/1000 games. Most of these concussions were minor (grade 1) and a grade 3 concussion with prolonged loss of consciousness was rare. There was a tendency for an increase in the incidence of concussions up to 2003 and during the last season a decrease was noted.

153 players were playing for this elite team over the years and of these players 48 sustained a concussion. One player has had 6 concussions registered during this period and another player stopped to play due to sequelae after multiple concussions.

Concussion is a serious injury with a risk for long term sequelae. There is a need for continuous registration in order to early be able to detect a change of incidence in order to perform appropriate measurements.