



Citation for published version:

McKay, C, Schneider, K, Brooks, B, Mrazik, M & Emery, CA 2014, 'Baseline evaluation in youth ice hockey players: Comparing methods for documenting prior concussions and attention or learning disorders', *Journal of Orthopaedic & Sports Physical Therapy*, vol. 44, no. 5, pp. 329-335. <https://doi.org/10.2519/jospt.2014.5053>

DOI:

[10.2519/jospt.2014.5053](https://doi.org/10.2519/jospt.2014.5053)

Publication date:

2014

Document Version

Peer reviewed version

[Link to publication](#)

University of Bath

Alternative formats

If you require this document in an alternative format, please contact:
openaccess@bath.ac.uk

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

Take down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Baseline evaluation in youth ice hockey players: Comparing methods for documenting prior concussions and attention or learning disorders

Carly D McKay, PhD: *Sport Injury Prevention Research Centre, Sport Medicine Centre, University of Calgary, Calgary, Alberta, Canada*

Kathryn J Schneider, PT PhD: *Sport Injury Prevention Research Centre, Sport Medicine Centre, University of Calgary, Calgary, Alberta, Canada*

Brian L Brooks, PhD: *Alberta Children's Hospital, Alberta Children's Hospital Research Institute, and University of Calgary, Calgary, Alberta; Alberta Children's Hospital Research Institute for Child & Maternal Health, Faculty of Medicine, University of Calgary, Calgary, Alberta*

Martin Mrazik, PhD: *University of Alberta, Edmonton, Alberta, Canada*

Carolyn A. Emery, PT PhD: *Sport Injury Prevention Research Centre, Sport Medicine Centre, University of Calgary, Calgary, Alberta, Canada; Alberta Children's Hospital Research Institute for Child & Maternal Health, Faculty of Medicine, University of Calgary, Calgary, Alberta, Canada; Community Health Sciences, Faculty of Medicine, University of Calgary, Calgary, Alberta, Canada*

Funding sources: The Sport Injury Prevention Research Centre is one of the International Research Centres for Prevention of Injury and Protection of Athlete Health supported by the International Olympic Committee. We acknowledge the funding from the McCarthy Tetrault Award (BLB), Alberta Innovates Health Solutions, Max Bell Foundation and the Alberta Children's Hospital Research

Institute for Child & Maternal Health.

Institutional Review: This study was approved by the Conjoint Health Research Ethics Board at the University of Calgary and the Health Research Ethics Board at the University of Edmonton.

Corresponding author: Carly D McKay, Sport Injury Prevention Research Centre, University of Calgary, 2500 University Drive NW, Calgary, AB, Canada, T2N 1N4 [email: cdmckay@ucalgary.ca].

Financial Disclosure and Conflict of Interest: The authors affirm that they have no financial interest in any matter included in this manuscript. Dr. Brooks receives funding from a test publisher (Psychological Assessment Resources, Inc.), book royalties from Oxford University Press, and in-kind test credits for research from another computerized test publisher (CNS Vital Signs). The remaining authors declare no conflict of interest.

2 **Study Design:** Cross-sectional.

3 **Objective:** To examine differences in concussion history and attention or
4 learning disorders reported by elite youth ice hockey players using a
5 questionnaire that allows parental input compared to a clinic-based test battery
6 that does not.

7 **Background:** A history of previous concussion and the presence of attention or
8 learning disorders can affect concussion management decisions; however, youth
9 athletes may not accurately report their medical history because they do not
10 know or recall important details.

11 **Methods:** The sample included 714 (601 male, 113 female) Bantam (ages 12-
12 14) and Midget (ages 15-17) ice hockey players from the most elite divisions of
13 play (AA, AAA). Players completed a take-home preseason questionnaire (PSQ)
14 with the input of a parent/guardian, then independently completed a baseline
15 Immediate Post-Concussion Assessment and Cognitive Test (ImPACT) at the
16 beginning of the 2011-2012 hockey season.

17 **Results:** In 21.1% (95% CI: 18.1, 24.1) of cases there was disagreement
18 between PSQ and ImPACT in the number of previous concussions reported. For
19 those reporting an attention disorder on the PSQ, 85.7% also reported it on
20 ImPACT. Only 9.5% of those who reported a learning disorder on the PSQ also
21 reported it on ImPACT.

22 **Conclusion:** For 1 in 5 players, reported concussion history differed between
23 PSQ and ImPACT, and there was substantial disagreement between instruments

24 for those reporting learning disorders. The method of obtaining medical history
25 may therefore affect baseline and post-concussion evaluations.

26 **Key Words:** Baseline testing; medical history; youth sport

27

28

29

30

31

32

33

34

35

36

37

38

39

40

41

42

43

44

45

46

Pre-publication

47

48 Concussion is a common injury among youth athletes, with the highest
49 rates reported in contact sports such as ice hockey.^{1,11,13,21,23} Defined as a
50 complex pathophysiological process affecting the brain induced by traumatic
51 biomechanical forces,²⁸⁻²⁹ concussion is an evolving heterogeneous injury.
52 Clinical findings of this multifaceted injury may include somatic and/or emotional
53 symptoms, physical signs, behavioral changes, cognitive impairment, and/or
54 sleep disturbances.²⁸⁻²⁹ Baseline evaluations may enhance a clinician's ability to
55 diagnose, manage, and monitor the trajectory of recovery for athletes following
56 concussion.

57 Baseline evaluations commonly include a demographic and injury history
58 section, along with assessments of neurocognitive function, motor function,
59 and/or symptoms.^{5,13,19} Traditionally, baseline medical information has been
60 recorded using paper and pencil methods and, for youth athletes, parental input
61 is often permitted during questionnaire completion.^{11,13} Importantly, medical
62 history may not be known, recalled, or understood by youth, resulting in an
63 under-representation of conditions that can influence clinical evaluations when
64 the athlete does not have the benefit of parental oversight. This is of particular
65 concern with the increasing popularity of computerized testing, which does not
66 allow for parental assistance (i.e., the athlete completes this information on
67 his/her own just prior to participating in the testing). Thus, depending on the
68 setting and nature of data collection, there may be variability in the information
69 collected from youth athletes.

70 The Immediate Post-Concussion Assessment and Cognitive Test
71 (ImPACT) is a popular web-based, computer-administered neuropsychological
72 test battery used for baseline and post-concussion evaluation.^{18-19,24,35} A
73 demographic information portion is completed at the start of each test, and
74 includes items such as age, previous history of concussion, number of previous
75 concussions, and previous diagnosis of an attention or learning disorder.
76 Research has shown that the results of baseline cognitive tests can be affected
77 by a history of learning and attention disorders.^{6,26} Specifically, results from tests
78 of verbal learning, working memory, complex attention, and processing speed
79 are most sensitive to these conditions.^{6,26} The accuracy of baseline information,
80 particularly related to medical history, is therefore essential when interpreting test
81 results and for the validity of clinical assessments.

82 It is necessary to consider, however, that children and adolescents may
83 be more sensitive to the mode of questionnaire administration than adults.⁴⁰ For
84 example, the current literature suggests that mode of symptom reporting has
85 been found to affect the number and intensity of concussion symptoms reported
86 by athletes.²² The issue of social desirability bias must also be considered when
87 discussing self-report of attention deficits or learning disabilities. Youth athletes
88 may under report these conditions to avoid embarrassment or to project a more
89 favorable image to others.³ This issue may be particularly salient when athletes
90 are being tested in a team setting,³² although its effect on responses to the
91 ImPACT demographic questions is unknown.

92 Moreover, there is considerable evidence that concussions are under-
93 reported by young athletes.^{27,38-39} This has largely been attributed to poor
94 understanding of the signs, symptoms, and potential long-term sequelae of
95 concussion or deferring medical history knowledge to parents, and has been
96 combatted with education-based interventions.^{9,34,37-38} Because a previous
97 concussion is one of the strongest predictors of future concussions,¹²⁻¹³ it is
98 possible that athletes will under-report previous concussions to avoid being
99 labeled as “high risk” or being advised to discontinue sport participation.

100 The extent to which self-report of previous history of concussion, attention
101 disorders, or learning disorders may differ between a paper baseline
102 questionnaire and the ImPACT background history section is unknown.
103 Therefore, the primary objective of this study was to examine the differences in
104 concussion history, attention disorders, and learning disorders reported by elite
105 youth ice hockey players using a paper-based questionnaire that allows parental
106 input compared to ImPACT, which does not allow parental input. The secondary
107 objective was to determine the effect of age group and sex on agreement
108 between the 2 methods.

109

110 **METHODS**

111

112 **Study design and participants**

113 This validation study used cross-sectional data that were collected during
114 the baseline assessment phase of a larger prospective cohort study conducted in

115 the 2011-2012 ice hockey season.⁴ The study population was Bantam (ages 13-
116 14) and Midget (ages 15-17) ice hockey players competing in the most elite
117 divisions (AA, AAA) in Calgary and Edmonton, Canada. Players were required to
118 be 13-17 years at the end of the calendar year to participate on a team in 1 of
119 these age groups, but some Bantam players were 12 years of age at the time of
120 baseline assessment. Similarly, some Midget players were 14 years of age at
121 baseline. Inclusion criteria were the following: male or female players; aged 12-
122 17 through the season of play; written informed consent to participate (player and
123 1 parent or guardian); players registered with Hockey Calgary, Girls Hockey
124 Calgary, Edmonton Minor Hockey Association, or the Edge School (Calgary);
125 players participating in the Bantam or Midget age groups only; players in elite
126 divisions of play (AA, AAA); agreement of the player's head coach to participate
127 in the study; and agreement of the team therapist to collect information about
128 individual player participation and injury throughout the season as part of the
129 larger cohort study. Players were excluded if they had sustained a previous injury
130 or chronic illness that prevented full participation in hockey at the beginning of
131 the 2011-2012 season.

132 Approval for this study was granted by the research ethics boards at the
133 University of Calgary and the University of Alberta.

134

135 **Data collection**

136 Consent forms and Preseason Questionnaires were distributed to all
137 participants 2-3 weeks prior to baseline testing. These were completed at home,

138 with instructions that the questionnaire was to be completed with the assistance
139 of a parent or guardian, and submitted at the baseline testing session. Baseline
140 testing was conducted, by team, at the University of Calgary Sport Medicine
141 Centre, the Glen Sather Sport Medicine Clinic in Edmonton, or LifeMark
142 Physiotherapy at the Edge School. At these sessions, players completed
143 ImPACT on individual laptop computers with an external mouse under the
144 supervision of a research assistant. Up to 10 players completed ImPACT
145 simultaneously, and the testing environment was kept as quiet and free from
146 distractions as possible.

147

148 **Outcome measures**

149 The Preseason Questionnaire (PSQ) is part of a previously validated
150 injury surveillance system,^{11,13} and was designed to pre-screen athletes at
151 baseline for medical, mental health, or behavioral conditions. It is a paper-and-
152 pencil instrument that collects information regarding participant demographics (ie:
153 age, sex, height, weight), current sport participation, protective equipment worn
154 during hockey participation, and previous medical history (ie: injury history,
155 surgical history, diagnosed medical conditions). The questionnaire asks
156 specifically about previous concussions (“Have you ever had a concussion or
157 been ‘knocked out’ or had your ‘bell rung’?”) as well as attention deficits and
158 learning disabilities (“Have you ever been formally diagnosed by a health care
159 professional (physician, psychologist, etc.) as having an attention or learning

160 issue?”). The PSQ was sent home with the study consent form, with instructions
161 that it was to be completed with parental input.

162 The ImPACT battery is a web-based computer-administered
163 neuropsychological test.^{18-19,24,35} It was developed for the acute assessment of
164 sports-related concussion in youth, collegiate, and professional athletes, and was
165 designed to minimize practice effects through the use of several alternating
166 forms. ImPACT yields 5 composite scores for visual memory, verbal memory,
167 visual motor processing speed, reaction time, and impulse control, and also
168 provides a total symptom score from the post-concussion symptom inventory.
169 Prior to starting the cognitive testing with ImPACT, the athlete completes a
170 number of sport- and health-related questions, including questions that ask the
171 athlete to identify the number of prior concussions they have experienced (i.e.,
172 “Indicate number of times diagnosed with a concussion”) and whether they have
173 any attention or learning disorders (“Check if the following apply: diagnosed
174 attention deficit disorder or hyperactivity; diagnosed learning disability”). The
175 ImPACT battery takes approximately 30 minutes to complete, including the
176 background questions, and the athlete completes it without parental input.

177 Although the PSQ and ImPACT have been used in previous injury
178 surveillance studies,^{11,13,18-19,24,35} the validity and reliability of their demographic
179 and medical history questions have not been previously established in the
180 literature.

181

182 **Analysis**

183 Stata version 12.0 was used for all statistical analyses. Descriptive
184 statistics are reported as frequencies, proportions with 95% confidence intervals,
185 or medians with ranges. Agreement in the number of concussions and the
186 presence of attention or learning disorders reported using the PSQ and the
187 ImPACT test was examined using intraclass correlation coefficients (ICC).
188 Models [ICC(3,1)] were fit using a repeated measures design to account for
189 multiple scores given from individual raters. A multivariable logistic regression
190 model, adjusted for cluster by team, was fit to assess the effect of age group
191 (Bantam or Midget) and sex (male or female) on agreement (yes/no) in
192 concussion history between the PSQ and ImPACT.

193

194 **RESULTS**

195

196 Of the 742 participants who were recruited for the larger cohort study, 714
197 (96.2%) completed both the PSQ and baseline ImPACT testing and are therefore
198 included in the present analysis. Baseline characteristics of included players are
199 presented in **TABLE 1**.

200

201 The proportion of players reporting a concussion, attention disorder, or
202 learning disorder using the PSQ and ImPACT are reported in **TABLE 2**. Overall
203 agreement between PSQ and ImPACT for history of any prior concussion was
204 moderate (ICC = 0.69), but it was substantially poorer for those reporting 1
205 previous concussion (ICC = 0.53). Agreement for reported attention disorders

206 (ICC = 0.95) and learning disorders (ICC = 0.94) across the entire sample was
207 very good.

208

209 Prevalence rates for disagreement in the number of previous concussions
210 reported on the PSQ compared to ImPACT is shown in **TABLE 3**. Overall, there
211 was disagreement between PSQ and ImPACT in 21.1% (95% CI: 18.1, 24.1) of
212 cases. Compared to the PSQ, ImPACT indicated fewer concussions in 9.6%
213 (95% CI: 7.4, 11.8) of cases and more concussions in 11.4% (95% CI: 9.1, 13.8)
214 of cases. Disagreement was highest for those reporting 1 (41.3%) or 2 (38.7%)
215 previous concussions.

216

217 When examining self-reported history of previous concussions, Bantam
218 players were less likely to have agreement (odds ratio [OR] = 0.53; 95% CI: 0.35,
219 0.80) between the PSQ and ImPACT than Midget players, adjusting for cluster by
220 team. There was no trend in favor of either instrument for the Bantam players.
221 There was no association between sex and agreement (males compared to
222 females: OR = 0.85; 95% CI: 0.45, 1.59).

223

224 Congruence between the PSQ and ImPACT regarding reported attention
225 and learning disorders is presented in **TABLE 4**. Overall, there was agreement
226 between PSQ and ImPACT in the vast majority (96.0%) of cases, with most
227 players reporting no attention or learning problems on either instrument. Of those
228 reporting an attention disorder on the PSQ (n = 14), 85.7% also reported a

229 problem on ImPACT. However, 90.5% of those who reported a learning disorder
230 on the PSQ (n = 21) did not report it on ImPACT.

231

232 **DISCUSSION**

233

234 In our comparison of the PSQ and ImPACT, we found notable
235 disagreement in self-reported learning problems and concussion history.
236 Although our results may reflect differences that existed due to the amount of
237 parental input given when completing the PSQ, it is likely that few players
238 completed the PSQ independently, given their age and the detailed nature of the
239 questions. As per the instructions, the majority of players likely had at least some
240 parental input or the parents completed the PSQ on behalf of the player.
241 Interpretation of the results is therefore framed to reflect PSQ responses that
242 included parental input.

243 The largest disagreements in concussion history existed for those
244 reporting 1 or 2 previous concussions, and more of those players reported fewer
245 concussions on ImPACT compared to the PSQ. It is possible that parental input
246 may have resulted in a more sensitive self-reported history, particularly for those
247 with a small number of previous concussions. Parents may have more precise
248 recollection or record of previous injuries, or they may consider some injuries to
249 be concussions while players do not. For example, parents may use a broader
250 definition of concussion and include incidents where the player was not medically
251 diagnosed but had observable symptoms, whereas players may not believe that

252 these events constitute a concussion.¹⁴ Considering the high number of players
253 who had a larger estimate of their concussion history on ImPACT compared to
254 the PSQ, however, it is equally probable that players included on-ice events that
255 their parents were unaware of because they were not formally diagnosed as
256 concussions. There is some evidence that children and parents have only low-to-
257 moderate agreement in symptom reporting following concussion,¹⁴ congruent
258 with studies in the domains of psychology and quality of life research suggesting
259 that children often report more somatic symptoms^{11,16} while parents report more
260 cognitive or behavioral symptoms.^{11,16} This may have influenced whether parents
261 or athletes considered a particular event to be a concussion. These alternative
262 explanations may indicate important differences in the level of concussion
263 awareness among elite youth ice hockey players and their parents, which
264 warrant further research and player/parent education considerations.

265 Moreover, there is evidence that the wording of questions can influence
266 the quality of information elicited from respondents. Using very specific items and
267 providing comprehensive response options has been shown to stimulate recall
268 for health-related events.⁸ Because the PSQ provides a broader range of terms
269 used to identify concussion (i.e.: “Have you ever had a concussion or been
270 ‘knocked out’ or had your ‘bell rung’?”) than ImPACT, which specifically asks
271 about the number of times an individual has been *diagnosed* with a concussion,
272 responses to the PSQ would likely capture a more sensitive picture of previous
273 concussion events. This has implications in terms of the type of concussion
274 history obtained through ImPACT (e.g., “diagnosed” concussions only), and may

275 indicate the need to collect a more comprehensive injury history during baseline
276 and post-concussion evaluations.

277 Under circumstances where there is particular public attention to a health
278 issue, recall can be more accurate for the condition of concern than other related
279 health matters.¹⁷ Considering recent publicity and awareness campaigns directed
280 at sport concussion, it is likely that parents and players demonstrated enhanced
281 recall for concussion events in the present study. It is assumed that parents and
282 players completed the PSQ together, as instructed. Differential recall between
283 PSQ and ImPACT is therefore unlikely, given the short time frame between
284 administration of the 2 questionnaires, unless parents completed the PSQ
285 without player input. Discrepancies between the PSQ and ImPACT may
286 therefore be attributed to other sources of error, such as recall bias related to the
287 timing of concussion events, or even differences in the medium in which
288 questions were presented (computer versus pencil and paper).

289 Although all self-report measures are vulnerable to recall bias, concussion
290 history may be particularly sensitive to the length of the recall period. In a
291 seminal study, Harel and colleagues¹⁵ found that parents have diminishing recall
292 of their children's injuries over time, particularly those injuries that did not require
293 medical attention or result in time loss from school. In the present study,
294 concussions occurring months or years previously may therefore have been
295 underreported, especially if medical attention was not sought. Harel et al¹⁵ also
296 demonstrated that recall for injuries sustained by adolescent (age 14-17 years)
297 boys appears to have a sharper decrease over time than for adolescent girls, for

298 whom recall remains relatively stable. For children 13 years and younger, they
299 reported a similar steady decrease in recall over time for both sexes.¹⁵ This
300 supports our finding that Bantam players were more likely to have disagreement
301 in their concussion history than Midget players, though we were unable to
302 replicate sex-specific differences. Due to the relatively small sample of female
303 players in our study we may have been underpowered to detect this relationship,
304 or elite level female athletes may demonstrate similar sport-specific injury recall
305 to their male counterparts and therefore have equivalent discrepancies in self-
306 reported concussion history.

307 Social desirability bias is another potential source of error between PSQ
308 and ImPACT. It has been suggested that youth athletes may under-report
309 medical conditions to project a more favorable image to others, particularly in a
310 team setting.^{3,32} The high proportion of athletes reporting more concussions on
311 ImPACT compared to the PSQ indicates that this did not affect concussion
312 reporting in this sample. With changing attitudes in the sport community, there is
313 decreasing stigma associated with having sustained a concussion and, as a
314 result, athletes are likely more willing to be transparent about their concussion
315 history.

316 Similarly, with increased public acceptance of attention problems such as
317 Attention Deficit Hyperactivity Disorder (ADHD),³⁰ adolescents may be more
318 willing to report being diagnosed with one of these conditions. The congruence
319 between PSQ and ImPACT reports of attention disorders support this, although it
320 is interesting that a small proportion (1.5%) of players did not report an attention

321 disorder on PSQ but reported one on ImPACT. This suggests that not only are
322 these players comfortable reporting attention problems in team settings, they
323 may report problems that have not been formally diagnosed or that they are
324 unwilling to report using a take-home questionnaire. Although these findings
325 pertain to a very small proportion of our sample, it may point to a valuable area
326 for future research.

327 The proportion of athletes who did not report a learning difficulty on
328 ImPACT despite a positive response on the PSQ, however, may be evidence of
329 social desirability bias. Although only a small percentage (3.2%) of our total
330 sample reported a learning difficulty on PSQ, 90.5% of those players did not
331 report it on ImPACT. The stigma associated with learning difficulties,³⁶
332 particularly in school-aged children, may have influenced responses on ImPACT
333 because it was administered in a group setting.^{7,20,25,31} As learning difficulties
334 have the potential to affect tests of cognitive ability, the method by which
335 adolescents are asked to report their disabilities should be carefully considered,
336 given these results.^{6,26}

337 From a clinical perspective, the importance of an accurate concussion
338 history during neurocognitive testing can be debated. Studies have ranged from
339 finding no residual cognitive deficits in children and adolescents following
340 concussion^{2,4} to reporting significant lingering effects of prior concussion.³³ Minor
341 discrepancies between a paper-and-pencil medical questionnaire and ImPACT
342 may therefore be negligible in terms of concussion management. Yet, for the
343 roughly 13% of players in this study who reported no history of concussion using

344 one instrument and at least 1 concussion on the other, there may be implications
345 for injury prevention. Because having 1 concussion is a significant predictor of
346 future concussions,¹²⁻¹³ it is important for baseline evaluations to be accurate to
347 allow for the most accurate baseline concussion risk assessment.

348 From a clinical standpoint, individuals with a history of multiple
349 concussions may be managed in a more conservative nature than an athlete with
350 a history of 1 concussion. Additionally, clinical monitoring for concussion may be
351 greater in individuals with a greater number of reported previous concussions
352 and result in more conservative management in the event of a suspected
353 concussion. In this study, disagreement in reported number of concussions was
354 greatest for individuals reporting 1 or 2 previous concussions. Thus, depending
355 on the methods of reporting concussions an individual may be monitored more or
356 less closely for future concussion. Future studies to compare the number of
357 concussions reported on the PSQ and ImPACT compared with a clinical
358 interview would be of benefit.

359 Differences in self-reported learning difficulties also have the potential to
360 significantly affect baseline and post-concussion evaluations.^{6,26} As such, the
361 PSQ or a similar take-home background questionnaire may be preferable to the
362 medical history portion of ImPACT.

363

364 **Limitations**

365 Although standardized forms were used to collect the preseason baseline
366 data, it is not known how much input parents had when completing the PSQ. In

367 some cases, parents may have completed the majority of the questionnaire and
368 may have a more accurate recollection/record of the medical history of their child.
369 Individuals who completed the questionnaire with limited parental input may have
370 been more likely to report the same score on repeat questioning. Alternatively,
371 the participants whose parents completed the entire questionnaire may have not
372 known the parental answers to some of the questions, resulting in interrater
373 variability rather than intrarater variability, as well as unknown measurement
374 bias.

375

376 **Future directions**

377 Considering the potential clinical implications of previous concussion
378 history, attention disorders, and learning disorders, it will be important to
379 determine the most valid method of collecting medical history information during
380 concussion assessment. Future studies examining the validity of both paper and
381 computerized self-report approaches are necessary to advance best practice
382 standards in concussion management.

383

384 **CONCLUSION**

385 There are sizable discrepancies in self-reported concussion history and
386 learning disorders between the take-home PSQ and the computerized ImPACT
387 test, which may be due to the amount of parental input permitted using the PSQ
388 method. Although differences in how concussion history is documented do not
389 appear to systematically over- or under-estimate the number of previous

390 concussions, there is a tendency to report fewer learning disorders on ImPACT.
391 Clearly, *how* an athlete is asked to document his or her past history makes a
392 difference on the answers obtained. Researchers and clinicians should account
393 for these differences when evaluating youth athletes, but future studies are
394 needed to determine the validity of both paper and computerized methods of
395 obtaining medical history information.

397 **KEY POINTS**

398 **Findings:** Youth ice hockey players reported their concussion history and
399 learning disorders differently using a take-home medical questionnaire compared
400 to ImPACT. The number of previous concussions did not appear to be
401 systematically higher or lower using either reporting method, but there was a bias
402 toward underreporting learning difficulties on ImPACT.

403 **Implications:** The interpretation of post-concussion assessments may be
404 influenced by the method of obtaining medical history. Researchers and
405 clinicians should consider parental input when assessing youth athletes, and
406 must be aware of potential biases in self-reported learning disorders.

407 **Caution:** It is unclear whether a take-home questionnaire that allows parental
408 input is more accurate than the ImPACT demographic questions. The validity of
409 both of these methods compared to medical records is unknown.

410

Acknowledgements: The authors acknowledge Andrea Jubinville, Tracy Blake,
Kirsten Taylor, and Nicole Lemke for their assistance with data collection. We

would also like to thank the players, parents, and coaches of the hockey associations who participated in this research.

411

Pre-publication

412

413 **REFERENCES**

- 414 1. Bakhos LL, Lockhart GR, Myers R, Linakis JG. Emergency department
415 visits for concussion in young child athletes. *Pediatrics*. 2010; 126:e550-
416 e556.
- 417 2. Bijur PE, Haslum M, Golding J. Cognitive outcomes of multiple head injuries
418 in children. *J Dev Behav Pediatr*. 1996;17(3):143-148.
- 419 3. Brener ND, Billy JOG, Grady W. Assessment of factors affecting the validity
420 of self-reported health-risk behavior among adolescents: evidence from the
421 scientific literature. *J Adolescent Health*. 2003;33:436-457.
- 422 4. Brooks BL, Mrazik M, McKay C, et al. Subjective, but not objective, lingering
423 effects of multiple past concussions in adolescents. *J Neurotrauma*.
424 2013;30:1469-1475.
- 425 5. Collie A, Maruff P, Makdissi M, et al. CogSport: reliability and correlation
426 with conventional cognitive tests used in postconcussion medical
427 evaluations. *Clin J Sport Med*. 2003;13(1):28-32.
- 428 6. Collins MW, Lovell, MR, & Mckeag, DB. Current issues in managing sports-
429 related concussion. *JAMA*. 1999; 282(24), 2283-2285.
- 430 7. Cooney, G., Jahoda, A., Gumley, A., & Knott, F. (2006). Young people with
431 learning disabilities attending mainstream and segregated schooling:
432 Perceived stigma, social comparisons and future aspirations. *Journal of*
433 *Intellect Disabil Res*. 2006;50:432-445.
- 434 8. Coughlin S. Recall bias in epidemiologic studies. *J Clin Epidemiol*.

- 435 1990;43(1):87-91.
- 436 9. Echlin PS, Johnson AM, Riverin S, et al. A prospective study of concussion
437 education in 3 junior ice hockey teams: implications for sports concussion
438 education. *Neurosurg Focus*. 2010;29:E6.
- 439 10. Eiser C, Morse R. Can parents rate their child's health-related quality of
440 life? Results of a systematic review. *Qual Life Res*. 2001;10:347-357.
- 441 11. Emery CA, Meeuwisse WH. Injury rates, risk factors, and mechanisms of
442 injury in minor hockey. *Am J Sports Med*. Dec 2006;34(12):1960-1969.
- 443 12. Emery, CA. Risk factors for injury in child and adolescent sport: a
444 systematic review of the literature. *Clin J Sport Med*. 2003;13(4):256-268.
- 445 13. Emery CA, Kang J, Shrier I, et al. Risk of injury associated with body
446 checking among youth ice hockey players. *JAMA*. Jun 9
447 2010;303(22):2265-2272.
- 448 14. Hajek CA, Yeates KO, Taylor HG, Bangert B, Dietrich A, Nuss KE, et al.
449 Agreement between parents and children on ratings of post-concussive
450 symptoms following mild traumatic brain injury. *Child Neuropsychol*.
451 2011;17:17-33.
- 452 15. Harel Y, Overpeck MD, Jones DH, Scheidt PC, Bijur PE, Trumble AC,
453 Anderson J. The effects of recall on estimating annual nonfatal injury rates
454 for children and adolescents. *Am J Public Health*. 1994;84(4):599-605.
- 455 16. Herjanic B, Reich W. Development of a structured psychiatric interview for
456 children: Agreement between child and parent on individual symptoms. *J*
457 *Abnorm Child Psychol*. 1982;10(3):307-324.

- 458 17. Infante-Rivard C, Jacques L. Empirical study of parental recall bias. *Am J*
459 *Epidemiol.* 2000;152(5):480-486.
- 460 18. Iverson GL, Lovell MR, Collins MW. Interpreting change on ImPACT
461 following sport concussion. *Clin Neuropsychol.* 2003;17(4):460-467
- 462 19. Iverson GL, Brooks BL, Collins MW, Lovell MR. Tracking
463 neuropsychological recovery following concussion in sport. *Brain Inj.* Mar
464 2006;20(3):245-252.
- 465 20. Jahoda A, Wilson A, Stalker K, Cairney A. Living with stigma and the self-
466 perceptions of people with mild intellectual disabilities. *J Social Issues.*
467 2010;66(3):521-534.
- 468 21. Koh JO, Cassidy D, Watkinson EJ. Incidence of concussion in contact
469 sports: a systematic review of the evidence. *Brain Inj.* 2003; 17(10):901-
470 917.
- 471 22. Krol AL, Mrazik M, Naidu D, Brooks BL, Iverson GL. Assessment of
472 symptoms in a concussion management programme: method influences
473 outcome. *Brain Inj.* 2011;25(13-14):1300-5
- 474 23. Lincoln AE, Caswell SV, Almquist JL, Dunn RE, Norris JB, Hinton RY.
475 Trends in concussion incidence in high school sports: A prospective 11-year
476 study. *Am J Sports Med.* 2011;doi:10.1177/0363546510392326.
- 477 24. Maroon JC, Lovell MR, Norwig J, Podell K, Powell JW, Hartl R. Cerebral
478 concussion in athletes: evaluation and neuropsychological testing.
479 *Neurosurgery.* 2000;47(3):659-669; discussion 669-672.

- 480 25. Martinez RS, Semrud-Clikerman M. Emotional adjustment and school
481 functioning of young adolescents with multiple versus single learning
482 disabilities. *J Learn Disabil.* 2004;37:411-420.
- 483 26. Mayers LB, Redick, TS, Chiffrieller SH, Simone AN, Terraforte KR. Working
484 memory capacity among collegiate student athletes: Effects of sport-related
485 head contacts, concussions, and working memory demands. *J Clin Exp*
486 *Neuropsychol.* 2011; 33: 532-537.
- 487 27. McCrea M, Hammeke T, Olsen G, et al. Unreported concussion in high
488 school football players: implications for prevention. *Clin J Sport Med.*
489 2004;14:13-17.
- 490 28. McCrory P, Meeuwisse W, Johnston K, et al. Consensus Statement on
491 Concussion in Sport 3rd International Conference on Concussion in Sport
492 Held in Zurich, November 2008. *Clin J Sport Med.* 2009;19:185-200.
- 493 29. McCrory P, Johnston K, Meeuwisse W, et al. Summary and agreement
494 statement of the 2nd International Conference on Concussion in Sport,
495 Prague 2004. *Br J Sports Med.* 2005;39(4):196-204.
- 496 30. McLeod JD, Fettes DL, Jensen PS, Pescosolido BA, Martin JK. Public
497 knowledge, beliefs, and treatment preferences concerning Attention-Deficit
498 Hyperactivity Disorder. *Psychiatr Serv.* 2007;58(5):626-631.
- 499 31. Minsha F. Learning disabilities and bullying: Double jeopardy. *J Learn*
500 *Disabil.* 2003;61:335-372.

- 501 32. Moser RS, Schatz P, Neidzwski K, Ott SD. Group versus individual
502 administration affects baseline neurocognitive test performance. *Am J*
503 *Sports Med.* 2011; 39: 2325-2330.
- 504 33. Moser RS, Schatz P, Jordan BD. Prolonged effects of concussion in high
505 school athletes. *Neurosurgery.* 2005;57(2):300-306.
- 506 34. Providenza CF, Johnston KM. Knowledge transfer principles as applied to
507 sport concussion education. *Br J Sports Med.* 2009;43:168-175.
- 508 35. Schatz P. Long-term test-retest reliability of baseline cognitive assessments
509 using ImPACT. *Am J Sports Med.* 2010;38(1):47-53.
- 510 36. Scior, K. Public awareness, attitudes and beliefs regarding intellectual
511 disability: A systematic review. *Res Dev Disabil.* 2011;32:2164-2182.
- 512 37. Silver JM. Effort, exaggeration, and malingering after concussion. *J Neurol*
513 *Neurosurg Psychiatry.* 2012; 83: 836-841.
- 514 38. Sye G, Sullivan SJ, McCrory P. High school rugby players' understanding of
515 concussion and return to play guidelines. *Br J Sports Med.* 2006;40:1003-
516 1005.
- 517 39. Williamson IJS, Goodman D. Converging evidence for the under-reporting
518 of concussions in youth ice hockey. *Br J Sports Med.* 2006;40:128-132.
- 519 40. Wright D, Aquilina W, Supple A. A comparison of computer-assisted and
520 paper-and-pencil self-administered questionnaires in a survey on smoking,
521 alcohol and drug use. *Public Opin Quart.* 1998;62:331-353

522
523
524
525

526

	Males (n = 601) Frequency (%) or Median (range)	Females (n = 113) Frequency (%) or Median (range)
Age	15 (12-17)	15 (13-17)
Age group		
<i>Bantam (ages 12-14)</i>	166 (27.6)	50 (44.3)
<i>Midget (ages 14-17)</i>	435 (72.4)	63 (55.8)
Competitive level		
AAA	339 (56.4)	113 (100.0)
AA	262 (43.6)	-

527

528

529

Table 1. Participant characteristics.

Pre-publication

530
531

	PSQ (95% CI)	ImPACT (95% CI)	ICC (95% CI)
Percentage reporting a previous concussion (yes/no)	41.2 (37.6, 44.8)	36.4 (32.9, 39.9)	0.69 (0.10, 1.00)
1 previous concussion	32.9 (29.5, 36.4)	23.7 (20.6, 26.8)	0.53 (0, 1.00)
2 previous concussions	6.2 (4.4, 7.9)	9.2 (7.1, 11.4)	0.70 (0.11, 1.00)
3 or more previous concussions	1.3 (0.4, 2.1)	3.5 (2.2, 4.9)	0.76 (0.26, 1.00)
Proportion missing	0.8 (0.2, 1.5)	-	-
Percentage reporting attention problems	2.0 (0.9, 3.0)	3.2 (1.9, 4.5)	0.95 (0.82, 1.00)
Proportion missing	0.3 (0, 0.7)	2.1 (1.1, 3.2)	-
Percentage reporting learning difficulties	2.9 (1.7, 4.2)	0.3 (0, 0.7)	0.94 (0.78, 1.00)
Proportion missing	4.9 (3.3, 6.5)	2.9 (1.7, 4.2)	-

532
533
534
535

Table 2. Players reporting previous concussion, attention problem, or learning difficulty at baseline.

Pre-publication

536

	PSQ concussions (Frequency)			
ImPACT concussions (Frequency)	0	1	2	3 or more
0	387	57	4	1
1	25	138	5	1
2	5	33	27	-
3 or more	3	7	8	7

537

538

539

540

Table 3. Disagreement in PSQ and ImPACT report by number of previous concussions.

Pre-publication

541

ImPACT (Frequency)	PSQ (Frequency)	
	No	Yes
Attention problem		
No	672	2
Yes	11	12
Learning difficulty		
No	644	19
Yes	0	2

542

543

544

Table 4. Comparison between PSQ and ImPACT reports of attention problems and learning difficulties.

Pre-publication