ACRM AMERICAN CONGRESS OF REHABILITATION MEDICINE

Archives of Physical Medicine and Rehabilitation

journal homepage: www.archives-pmr.org

Archives of Physical Medicine and Rehabilitation 2025;106: 1073−80

ORIGINAL RESEARCH

5P Risk Classification Predicts Performance on Self-reported but Not Objective Clinical Outcomes at 4 Weeks Postconcussion in Children

Elizabeth Teel, PhD,[a] Marie Brossard-Racine, OT, PhD,[b,c,d] Laurie-Ann Corbin-Berrigan, PhD, CAT,[e] Isabelle Gagnon, pht, PhD[b,f]

From the [a]Department of Health, Kinesiology, & Applied Physiology, Concordia University, Montreal, Quebec, Canada; [b]School of Physical and Occupational Therapy, McGill University, Montreal, Quebec, Canada; [c]Division of Neonatology, Department of Pediatrics, Montreal Children's Hospital, McGill University Health Centre, Montreal, Quebec, Canada; [d]Department of Neurology and Neurosurgery, Montreal Children's Hospital, McGill University Health Centre, Montreal, Quebec, Canada; [e]Département des Sciences de l'Activité Physique, Université du Quebec à Trois-Rivières, Trois-Rivières, Quebec, Canada; and [f]Division of Pediatric Emergency Medicine, Department of Pediatrics, Montreal Children's Hospital, McGill University Health Centre, Montreal, QC, Canada.

Abstract

Objective: To determine if performance on symptom, cognitive, balance, fatigue, physical activity, and quality of life outcomes at 4 weeks postinjury in children with concussion differs based on acute Predicting and Preventing Postconcussive Problems in Pediatrics (5P) risk classification.

Design: Prospective cohort.

Setting: Laboratory.

Participants: Sixty-two children (age: 13.27±2.50y; 29 [46.7%] women) with diagnosed concussion.

Interventions: Not applicable.

Main Outcome Measures: Patient demographics and postinjury assessments were completed within 72 hours of concussion and used to classify patients as "high," "moderate," or "low" persistent postconcussion symptoms risk. Children then completed a multimodal assessment battery at 4 weeks postconcussion. Kruskal−Wallis assessments analyzed whether study outcomes differed between 5P risk groups.

Results: Significant group differences were observed in symptom ($\chi^2(2)=9.76$, $P=.008$), fatigue ($\chi^2(2)=14.60$, $P<.001$), physical activity ($\chi^2(2)=15.76$, $P<.001$), and quality of life ($\chi^2(2)=7.82$, $P=.02$) outcomes. The low-risk group had fewer symptoms and less fatigue but increased physical activity levels and quality of life compared with the high-risk group. No significant differences in cognitive or balance outcomes were observed ($P>.05$).

Conclusions: The 5P rule provides clinicians with valuable prognostic information related to persistent postconcussion symptoms and self-reported outcomes 4 weeks postconcussion, but not objective cognitive or balance outcomes. This information may help clinicians prioritize treatment resources to children most at risk of prolonged concussion recovery.

Archives of Physical Medicine and Rehabilitation 2025;106:1073−80

Concussion results in numerous postinjury problems, including increased symptoms[1] and fatigue[2] and reduced cognition,[3] balance,[4] and physical activity levels.[5] Children and adolescents typically experience large improvements in concussion symptoms over the first 2 weeks after injury,[1] with most children recovering by 1 month postconcussion.[6] However, nearly 30% of pediatric patients have persistent postconcussion symptoms (PPCS), defined as 3 or more new or worsening symptoms at 4 weeks postinjury.[6]

Supported by a 2016 RI-MUHC Merck Sharp & Dohme Corp Grant Opportunities for Applications in Biomedical Research to IG and MBR.

Disclosures: This study was supported by a 2016 RI-MUHC Merck Sharp & Dohme Corp Grant Opportunities for Applications in Biomedical Research to Isabelle Gagnon and Marie Brossard-Racine. The other authors have nothing to disclose. The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

https://doi.org/10.1016/j.apmr.2025.02.008

PPCS is related to negative outcomes in children, including more days of missed school,[7] mental health disturbances,[8] and reduced quality of life.[9] Acutely identifying which children will go on to experience PPCS is limited, as few prognostic indicators of pediatric concussion have been developed.

One clinical prediction rule for children and adolescents with concussion is the Predicting and Preventing Postconcussive Problems in Pediatrics (5P) clinical risk score (http://www.5pconcussion.com). The 5P risk score uses patient demographics and acute postinjury presentation to classify children as low, moderate, or high risk of PPCS.[6] The 5P clinical risk score has moderate discrimination ability and is better at predicting which children will go on to experience PPCS than physician judgment alone.[6] Although the original 5P clinical risk score was derived and validated in an emergency room setting within 48 hours of injury,[6] 1 study observed similar classification accuracy when applied up to 10 days postconcussion in an outpatient clinic.[10]

The 5P rule was solely designed to predict PPCS. Current best practice recommends a comprehensive assessment battery to aid in concussion diagnosis and management decisions.[11] Furthermore, clinical presentation after concussion is highly variable, with rehabilitation interventions often tailored to specific deficits.[11] For example, vestibular therapy is effective for children with postural instability and dizziness after concussion,[12] whereas cognitive behavioral therapy can reduce mood/emotional problems and improve quality of life.[13] Acute prognostic information that predicts objective deficits in clinical functioning can assist health care providers by allowing for earlier enrollment into more targeted treatment interventions, which may improve rehabilitation outcomes and reduce recovery times.[14] However, it remains unknown if the 5P clinical risk score can detect clinical deficits beyond symptom resolution.

Therefore, our primary purpose was to determine whether symptom, cognitive, balance, fatigue, physical activity, and quality of life outcomes at 4weeks postinjury significantly differ based upon 5P risk classification in children and adolescents with concussion. A secondary purpose was to validate the discriminant ability of the 5P rule using parent and child-reported symptom outcomes. We hypothesized that individuals at high-risk of PPCS will have worse clinical outcomes and that both parent and child-reported symptom scores can be used to discriminate children with PPCS at 4 weeks postinjury.

Methods

This is a secondary analysis of a previously completed study. Originally, a parallel, 3-arm, randomized controlled trial was designed to investigate the effect of a 3-dimensional multiple object tracking intervention on clinical concussion recovery in children (Clinicaltrials.gov registration number: NCT03213730). The intervention had no meaningful effect, with the full study details published elsewhere.[15] In the present study, participants were classified into low-, moderate-, or high-risk groups using the 5P risk classification rule. This study was approved by the McGill University Research Ethics Board.

List of abbreviations:

5P	**Predicting and Preventing Postconcussive Problems in Pediatrics study**
BESS	**Balance Error Scoring System**
CI	**confidence interval**
ImPACT	**Immediate Postconcussion Assessment and Cognitive Test**
PAQ	**Physical Activity Questionnaire**
PCSI	**Postconcussion Symptom Inventory**
PedsQL	**Pediatric Quality of Life**
PPCS	**persistent postconcussion symptoms**

Participants

Children aged 6-17 years presenting to the Montreal Children's Hospital Pediatric Emergency Department who were diagnosed with a concussion were included in this study.[11] Because of the high proportion of both anglophone and francophone speakers in our local community, participants were eligible if they spoke English or French and assessments were provided in the language of the participant's preference. Children and adolescents were excluded if they had (1) a previous concussion within the past 6 months or any previous concussion with unresolved symptoms or deficits; (2) other injuries, comorbidities, or diagnoses that would prevent the completion of any outcome measure.

Procedures

Patient demographics along with the Acute Concussion Evaluation, Balance Error Scoring System (BESS), and Post-Concussion Symptom Inventory (PCSI) assessments were completed within 72 hours of injury. These variables were used to calculate the 5P clinical risk score (table 1), which classified children as low (0-3), moderate (4-8), or high (9-12) risk of PPCS according to established guidelines.[6] Participants returned 4 weeks after their concussion and completed a battery of clinical assessments administered by a trained research assistant.

Outcome measures

PCSI: The PCSI is a set of developmentally appropriate symptom scales for children aged 5-7 (5 items, 0-2 Guttman scale), 8-12 (17 items, 0-2 Guttman scale), 13-18 (21 items, 0-6 Guttman scale), and their parents (20 items, 0-6 Guttman scale). Scores from the 5-7 and 8-12 version (0-2 Guttman scale) were multiplied by 3 to align them with the 13-18 and parent versions (0-6 Guttman scale). The total PCSI change score (summation of postinjury minus preinjury scores) from both the child and parent versions were analyzed, with higher scores indicating more frequent and severe symptoms postconcussion.

PPCS: PPCS was defined as 3 new or worse symptoms at 4 weeks postinjury compared to preinjury levels. This is consistent with the *International Statistical Classification of Diseases and Related Health Problems, Tenth Revision* definition of postconcussion syndrome[16] and has been used previously.[6] Presence of PPCS was evaluated using both child- and parent-reported symptom scores from the PCSI.

Immediate Post-Concussion Assessment and Cognitive Test: Immediate Post-Concussion Assessment and Cognitive Test (ImPACT) is a 30-minute, computerized neurocognitive assessment, which evaluates memory, executive function, attention, and processing speed. ImPACT uses stimuli randomization to reduce practice effects, and on-screen instructions and short practice orientations are provided. We evaluated percentile scores for verbal memory, visual memory, visual motor speed, reaction time, and

Table 1 Variables and risk points used to calculate the overall 5P clinical risk score as described in Zemek et al[6]

Assessment	Variable		PPCS Risk Points
Demographics	Age group (y)	5-7	0
		8-12	1
		13-18	2
	Sex	Male	0
		Female	2
	Concussion history	No history or symptom duration<1wk	0
		Prior history with symptom duration≥1wk	1
	Physician-diagnosed migraines	No	0
		Yes	1
Acute concussion evaluation	Answers questions slowly	No	0
		Yes	1
Balance error scoring system	Tandem stance	0-3 errors	0
		≥4 errors	1
Post-Concussion Symptom Inventory	Headache	No	0
		Yes	1
	Sensitivity to noise	No	0
		Yes	1
	Fatigue	No	0
		Yes	2

Abbreviations: 5P, Preventing Postconcussive Problems in Pediatrics; PPCS, persistent postconcussion symptoms.

cognitive efficiency, with higher scores indicating better performance.

BESS: The BESS uses 3 stances (2-leg, 1-leg, and tandem) over 2 support conditions (firm and foam). Each 20-s trial is done with eyes closed. Errors include (a) removing hands from hips; (b) opening eyes; (c) step, stumble, fall; (d) hip abduction/flexion >30°; (e) lifting the forefoot/heel off the testing surface; and (f) out of position >5 seconds. The primary outcome for the BESS was the total number of errors committed, with lower scores indicating better performance.

Tandem gait: Participants walk barefoot with an alternating heel-to-toe gait along a 3-m-long piece of sports tape, make a 180-degree turn, and return to the original starting point as quickly as possible. Time (in seconds) of the fastest trial (4 total trials performed) was the outcome of interest, with lower scores indicating better performance.

Pediatric Quality of Life Scale: The Pediatric Quality of Life Scale (PedsQL) is a 23-question survey which evaluates health, emotional, social, and school-related domains. Children rate each scenario from 0 (never) to 4 (almost always). The PedsQL was converted into a total score out of 100, with higher scores indicating better quality of life.

Pediatric Quality of Life- Multidimensional Fatigue Scale: The Pediatric Quality of Life- Multidimensional Fatigue Scale (PedsQL Fatigue) is an 18-question survey, which gathers information related to general, sleep, and cognitive fatigue. Participants rate each scenario from 0 (never) to 4 (almost always). The PedsQL Fatigue was converted into a total score out of 100, with higher scores indicating less fatigue.

Physical Activity Questionnaire: The Physical Activity Questionnaire (PAQ) is a recall questionnaire, which assesses physical activity levels in children over the preceding week. The PAQ lists several physical activity options (eg, running, biking, etc.) and participants select the number of times they participated in that activity over the past 7 days, from 1 (not at all) to 5 (7+ times). The average score across all activities was used, with higher scores representing increased levels of physical activity.

Statistical analysis

All statistical analyses were completed in SAS (version 9.4; SAS Institute, Inc). Descriptive statistics were used to characterize the sample and study outcomes. Given the large number of clinical outcomes analyzed in this study, a more conservative alpha level of $P<.01$ was selected for all analyses to reduce the risk of type I error. Kruskal–Wallis tests were conducted to see if symptom, cognitive, balance, fatigue, physical activity, and quality of life scores differed between 5P risk classification groups, as all clinical outcomes were nonnormally distributed. Post hoc analyses were conducted using Dunn's test for any main effect reaching statistical significance. Spearman's rank correlations were performed to evaluate relationships between clinical outcomes, whereas receiver operating curve analyses determined the ability of the 5P rule to accurately classify the presence of PPCS at 4 weeks postconcussion. Chi-square tests were used to determine differences in the proportion of children with PPCS at 4 weeks postinjury based on 5P risk classification.

Results

A total of 62 children enrolled in the study, with 13 (21.0%) classified as low risk, 33 (53.2%) as moderate risk and 16 (25.8%) as high risk for PPCS at time of presentation to the emergency department. Groups significantly differed by age and sex (table 2), with the high-risk group being older and having a larger proportion of women. However, this was expected as age and sex are components in the 5P risk classification criteria.

Self-reported outcomes significantly differ between low- and high-risk 5P groups

Descriptive statistics for all outcomes can be found in table 3 and mean differences with 95% confidence intervals (CIs) between high versus low-/moderate-risk groups can be visualized in

Table 2 Demographic variables for all patients analyzed in the study

Category	Variable Name	Levels	Low Risk of PPCS (n=13)	Moderate Risk of PPCS (n=33)	High Risk of PPCS (n=16)	*P* Value
Patient characteristics	Age (y)	-	11.47±1.52	13.17±2.76	14.92±1.31	**.001**
	Sex	Male	11	21	1	**.001**
		Female	2	12	15	
	Height (cm)	-	151.34±13.20	161.72± 16.05	160.52±7.71	.09
	Weight (kg)	-	41.57±10.82	57.62±25.81	59.86±15.99	.05
Injury characteristics	Previous concussions	-	0.30±0.63	0.81±1.09	1.00±1.59	.27
	Loss of consciousness	No	11	30	15	.43
		Yes	1	3	0	
		Unknown	1	0	1	
	Retrograde amnesia	No	10	28	13	.75
		Yes	2	4	1	
		Unknown	1	1	2	
	Anterograde amnesia	No	12	28	13	.41
		Yes	0	4	1	
		Unknown	1	1	2	
	Mechanism of injury	Sport	10	30	14	.46
		Fall	1	2	0	
		Other	2	1	2	
Premorbid conditions	Migraine history	No	11	28	11	.38
		Yes	2	5	5	
	Learning disability	No	12	31	14	.74
		Yes	1	2	2	
	ADHD	No	11	29	13	.82
		Yes	2	4	3	
	Developmental disorder	No	13	32	13	.06
		Yes	0	1	3	
	Anxiety	No	11	32	11	.02
		Yes	2	1	5	
	Depression	No	12	32	15	.77
		Yes	1	1	1	
	Sleep disorder	No	13	32	16	.64
		Yes	0	1	0	

Abbreviation: ADHD, attention deficit hyperactivity disorder; PPCS, persistent postconcussion symptoms.

figure 1. Significant group differences in child-reported symptom scores at 4 weeks postconcussion were present ($\chi^2(2)=9.76$, $P=.008$). Post hoc tests revealed that the low-risk group had significantly fewer symptoms than the high-risk group ($z=2.99$, $P=.008$), but no significant differences between low and moderate-risk or moderate and high-risk groups were observed. Using

Table 3 Median (interquartile range) or frequencies (percentage) are presented for all outcomes. PCSI scores (rated by the injured child) and quality of life outcomes were significantly better in the low-risk group

Category	Levels	Low Risk of PPCS (n=13)	Moderate Risk of PPCS (n=33)	High Risk of PPCS (n=16)	*P* Value
Symptoms	PCSI Δ (child)	0 (0,0)	3 (0-15)	8 (1-13)	**.008**
	PCSI Δ (parent)	0 (−1.5-1)	0.5 (0-4)	4 (0-7.5)	.17
	Yes PPCS (child)	11 (73.3%)	12 (46.1%)	1 (7.7%)	**.002**
	Yes PPCS (parent)	10 (62.5%)	8 (32.0%)	2 (16.7%)	.03
Cognition	Verbal memory	74 (21-93)	60.5 (44-94)	62.5 (24.5-79.5)	.65
	Visual memory	16 (2-31)	60.5 (25-88)	56 (33-78.5)	.11
	Visual motor speed	19 (6-54)	32.5 (16-51)	20.5 (13.5-55)	.87
	Reaction time	19 (6-42)	40.5 (7-46)	21 (13.5-29.5)	.77
	Cognitive efficiency	0.22 (0.14-0.30)	0.28 (0.21-0.39)	0.37 (0.28-0.40)	.07
Balance	BESS total errors	23 (17-32.5)	22 (14-31)	21 (13.5-29.5)	.60
	Tandem gait (s)	17.1 (10.9-19.0)	17.3 (14.5-23.9)	16.7 (14.1-20.7)	.79
Quality of life	PedsQL	96.7 (90.2-100)	90.2 (75-97.8)	76.1 (73.6-91.7)	.02
	PedsQL fatigue	90.3 (80.6-94.4)	78.5 (61.1-90.3)	52.8 (43.1-72.2)	**<.001**
	Physical activity	2.82 (2.11-3.33)	1.93 (1.55-2.52)	1.31 (1.09-1.91)	**<.001**

Abbreviations: PCSI, Post-Concussion Symptom Inventory; PPCS, persistent postconcussion symptoms.

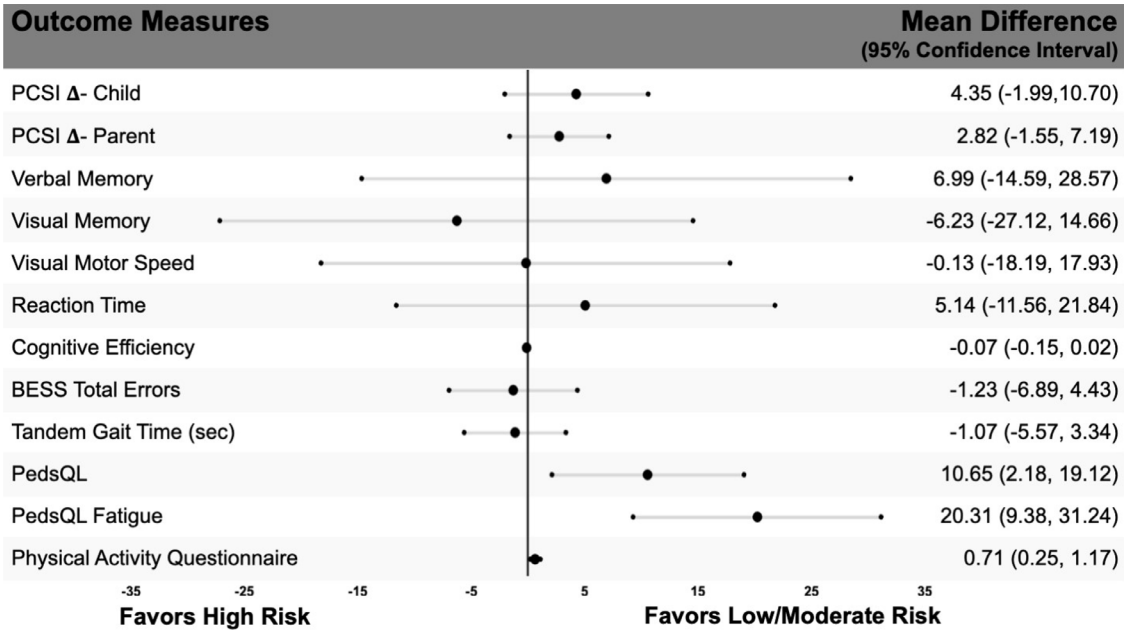

Fig 1 Visual representation of group differences observed in the study. Results are presented between high-risk versus combined low-/moderate-risk group. Mean differences between groups and 95% confidence intervals are provided.

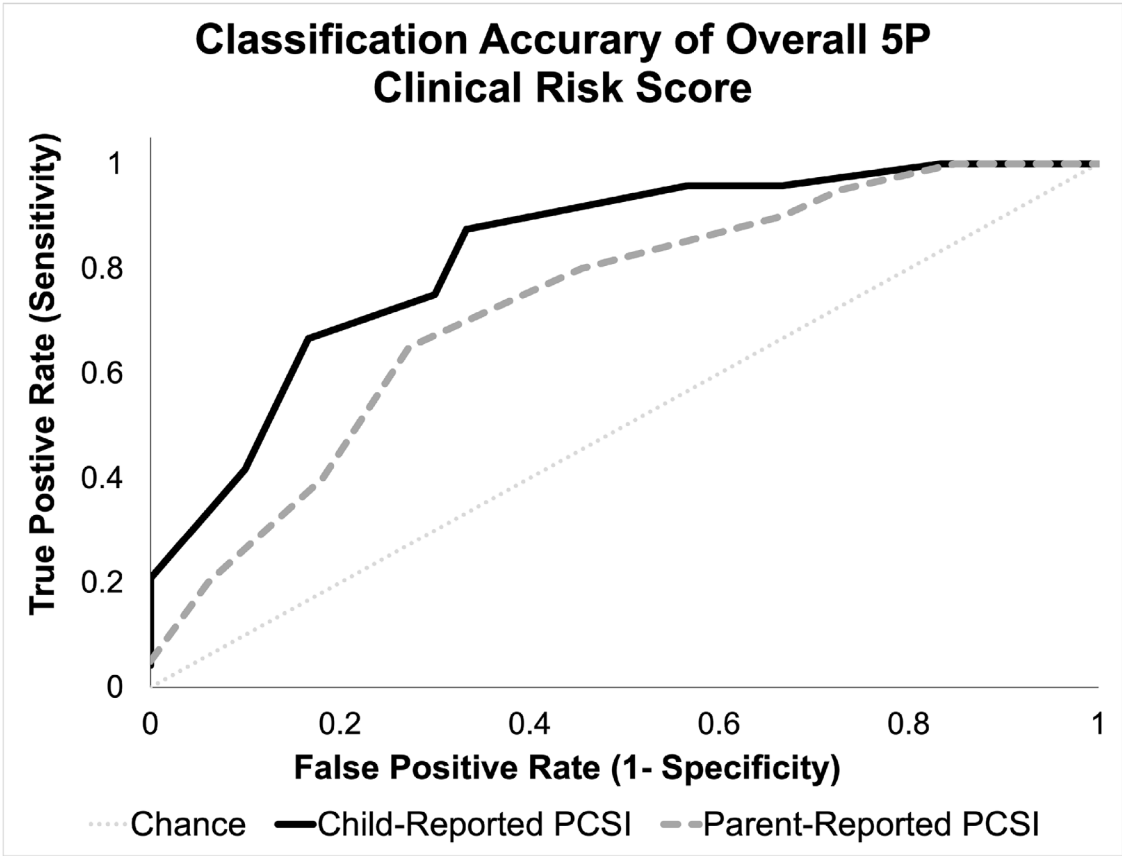

Fig 2 Results from the receiver operating curve analysis looking at the ability of the overall 5P risk score (0-12) to accurately classify participants who went on to experience PPCS at 4 weeks postinjury using both the child and parent-reported PCSI.

the parent-reported symptoms scores, no significant group differences were observed ($\chi^2(2)=3.58$, $P=.17$).

PedsQL Fatigue scores ($\chi^2(2)=14.60$, $P<.001$) and general physical activity levels ($\chi^2(2)=15.76$, $P<.001$) were also significantly different between 5P risk classification groups. The low-risk group reported significantly less fatigue (z=3.79, $P<.001$) and engaged in significantly higher levels of physical activity (z=3.96, $P<.001$) than the high-risk group. Overall quality of life scores were not significantly different between 5P risk classification groups ($\chi^2(2)=7.82$, $P=.02$).

Relationships between self-reported outcomes were observed. More specifically, child-reported symptoms were significantly correlated to overall quality of life ($r=-0.54$, $P<.001$) and fatigue ($r=-0.62$, $P<.001$) levels. Parent-reported symptom scores were not significantly related to any other outcomes ($P>.07$).

Objective outcomes do not significantly differ between low- and high-risk 5P groups

The 5P risk classification groups were not significantly different on any cognitive outcome generated from ImPACT. This includes verbal memory ($\chi^2(2)=0.85$, $P=.65$), visual memory ($\chi^2(2)=4.40$, $P=.11$), visual motor speed ($\chi^2(2)=0.28$, $P=.87$), reaction time ($\chi^2(2)=0.53$, $P=.77$), and cognitive efficiency ($\chi^2(2)=5.20$, $P=.07$) outcomes. BESS ($\chi^2(2)=1.01$, $P=.60$) and tandem gait ($\chi^2(2)=0.47$, $P=.79$) outcomes at 4 weeks postconcussion were also not significantly different between 5P risk classification groups.

Validation of the 5P risk score discriminant ability

An overall 5P clinical risk score (0-12) of 6 points maximally classified participants who went on to experience PPCS using the child-reported symptom scores (area under the curve [AUC], 0.83, 95% CI, 0.72-0.94; sensitivity=0.875; specificity=0.667; $P<.001$). For the parent-reported symptom scores, an overall 5P clinical risk score of 4 points best classified children who went on to experience PPCS (AUC, 0.69, 95% CI, 0.56-0.83; sensitivity=0.650; specificity=0.727; $P=.045$). The classification accuracy between child and parent-reported symptom scores were not significantly different ($\chi^2(1)=1.24$, $P=.27$; fig 2). Additionally, a significantly higher proportion of children acutely classified as high risk went on to experience PPCS using the child reports ($\chi^2(2)=12.21$, $P=.002$), but results did not reach significance using parent-reported symptom scores ($\chi^2(2)=6.79$, $P=.03$). Using the child reports, 11 (73.3%) children in the high-risk group met the study definition of PPCS, compared with 12 (46.1%) in the moderate-risk group and 1 (7.7%) in the low-risk group. Using the parent-reports, 10 (62.5%) high-risk children, 8 (32.0%) moderate-risk children, and 2 (16.7%) low-risk children experienced PPCS at 4 weeks postinjury.

Discussion

Significant differences in self-reported outcomes (symptoms, fatigue, and physical activity levels) were observed between 5P risk classification groups. This aligns with previous literature suggesting that individuals with persistent symptoms have increased fatigue[17] and lower levels of physical activity.[18] Additionally, child-reported symptom scores were related to other self-reported measures, with higher symptoms related to worse quality of life and more fatigue in our study. Prior research suggests an inverse relationship between quality of life and postinjury symptom scores,[19,20] in agreement with our findings. Interestingly, the correlations between clinical outcomes were not observed for parent-reported symptom scores, suggesting there are distinct differences between parent and child reports.

No significant differences in cognitive or balance outcomes were observed between 5P risk classification groups, contrary to our original hypothesis. However, the sensitivity of these assessments to concussion drops dramatically after the first few days to weeks after injury. The BESS loses its sensitivity to concussion by 5 days postinjury,[21] whereas ImPACT[22] and tandem gait[23] outcomes typically return to normal within 2 weeks. Therefore, it is unknown if the failure to observe differences in cognitive and balance outcomes speaks to the inability of the 5P rule to ascertain these disparities, or if the selected assessments were not sensitive enough to detect the subtler deficits patients may be experiencing further out from injury. Future studies should investigate whether the 5P rule can detect chronic cognitive or balance deficits using assessments that have established sensitivity 4 or more weeks postinjury.

Our results provide further validation that the 5P clinical risk score can accurately predict which children and adolescents will experience PPCS at 4 weeks postinjury. The classification accuracy reported in our study aligns with the previous literature[6,10] and supports previous work indicating that 5P risk classification accuracy is not significantly altered if child-reported symptom scores are used in place of parent-reported scores.[24] However, when investigating the total symptom score as opposed to the presence of persistent symptoms, differences between child and parent-reports were observed and this finding speaks to growing evidence of variable parent-child agreement on postconcussion symptoms.[24-27] Using the child-reported symptoms, children in the low-risk group had significantly fewer symptoms than the high-risk group, but no group differences were observed with parent-reported symptoms.

Strengths

This study is the first to investigate the ability of the 5P rule to detect clinical concussion deficits beyond the presence of PPCS at 4 weeks postinjury. Apart from the ImPACT test, all the assessments used in this study are developed specifically for and validated in children and adolescent populations. A pediatric version of the ImPACT test is available, but its validity and reliability are not established at the levels required for clinical care or research.[28,29] Therefore, the adult version was selected for this study and has been used in adolescents with concussion previously.[30] Finally, our broad inclusion criteria allowed us recruit a heterogenous sample of participants, which permits broader and more generalizable conclusions.

Limitations

This study is limited by its small sample size. Our findings and participant demographics are similar to previously published findings.[6,10,17] Additionally, several subjective outcomes reached significance in our study, whereas few objective findings were close to this threshold. Therefore, we expect the general pattern of our findings would be maintained with larger sample sizes. The 5P clinical risk score is calculated based on patient demographics and acute injury characteristics. This led to several significant

differences between groups, notably in sex and age. Univariate analyses revealed that sex and age were related to some, but not all, self-reported outcomes at lower levels of statistical significance. Therefore, although sex and age alone may contribute to significant findings, the 5P risk classification provides insight above and beyond these factors alone. Pre-existing health conditions (eg, attention deficit hyperactivity disorder, anxiety, etc) were determined on patient self-report and current medication status was not obtained. However, pre-existing conditions were generally rare in our sample and largely similar across groups; thus, this is unlikely to have a major effect on the reported results. The PCSI is limited by the lack of equivalence among the different child versions. Creating equivalency between versions assumes a 1-point discrepancy on the 0-2 scale is equal to a 3-point discrepancy on a 0-6 scale, which may not be an appropriate assumption. The objective assessments chosen for this study are widely used in clinical practice, but they generally lose their sensitivity to concussion within 2 weeks postinjury. This prevents us from making strong conclusions regarding the lack of differences in cognitive and balance outcomes observed between 5P risk classification groups. This limitation is a broader criticism of clinical concussion assessment tools, which lack sensitivity to more subtle, chronic deficits.

Clinical significance

Our results suggest that the 5P clinical prediction rule can help clinicians acutely identify which children are at high risk of experiencing PPCS and worse subjective outcomes 1 month after concussion. This can help clinicians prioritize resources to pediatric concussion patients who are most likely to benefit from intervention, including earlier enrollment into treatment. Whereas the lack of significant findings on objective assessments may preclude early enrollment into more targeted rehabilitation pathways (eg, vestibular therapy, neuropsychological intervention, etc), more generalized postconcussion treatment options such as aerobic exercise are still highly effective in improving clinical outcomes.[14,31] Differences between child and parent-reported outcomes were observed in our study. This aligns with prior literature suggesting that parent-child agreement on postconcussion symptoms is fair overall but is lower with younger patients and for emotional symptoms.[24-26] Child-reported symptom scores appear superior to parent-reported scores and may more accurately reflect the patient's subjective experience, particularly for older children/adolescents and for mood-related symptoms that are not easily observable to parents or guardians. Thus, clinicians should obtain patient-reported outcomes whenever possible, but for younger children who are preverbal or may struggle to understand and appraise complex and abstract concussion symptoms, parent-reported outcomes should be obtained to supplement or replace child-reported outcomes as appropriate.

Conclusions

The 5P risk classification calculated acutely postconcussion provides valuable prognostic information related to PPCS and self-reported clinical outcomes at 4 weeks postinjury. No significant differences in objective cognitive or balance outcomes were observed between 5P risk classification groups; however, this may be because of a lack of sensitivity to long-term concussion deficits in the assessments deployed. Clinicians can use the 5P rule to acutely identify children and adolescents with concussion most likely to experience prolonged recovery and prioritize resources to these patients, which may improve recovery outcomes through earlier enrollment into concussion rehabilitation programs.

Keywords

Adolescents; Brain injury (traumatic); Children; Fatigue; Prognosis; Rehabilitation

Corresponding author

Elizabeth Teel, Department of Health, Kinesiology, & Applied Physiology, Concordia University, Montreal, 7141 Sherbrooke St. West, Science Pavilion Room 165.39, Montreal (Quebec) H4B 1R6. *E-mail address:* elizabeth.teel@concordia.ca.

References

1. Ledoux A-A, Tang K, Yeates KO, et al. Natural progression of symptom change and recovery from concussion in a pediatric population. JAMA Pediatr 2019;173:e183820.
2. Norrie J, Heitger M, Leathem J, Anderson T, Jones R, Flett R. Mild traumatic brain injury and fatigue: a prospective longitudinal study. Brain Inj 2010;24:1528–38.
3. Tanveer S, Zecavati N, Delasobera EB, Oyegbile TO. Gender differences in concussion and postinjury cognitive findings in an older and younger pediatric population. Pediatr Neurol 2017;70:44–9.
4. Howell DR, Osternig LR, Chou L-S. Adolescents demonstrate greater gait balance control deficits after concussion than young adults. Am J Sports Med 2015;43:625–32.
5. Huber DL, Thomas DG, Danduran M, Meier TB, McCrea MA, Nelson LD. Quantifying activity levels after sport-related concussion using actigraph and mobile (mHealth) technologies. J Athl Train 2019;54:929–38.
6. Zemek R, Barrowman N, Freedman SB, et al. Clinical risk score for persistent postconcussion symptoms among children with acute concussion in the ED. JAMA 2016;315:1014–25.
7. Grubenhoff JA, Deakyne SJ, Comstock RD, Kirkwood MW, Bajaj L. Outpatient follow-up and return to school after emergency department evaluation among children with persistent post-concussion symptoms. Brain Inj 2015;29:1186–91.
8. Ponsford J, Nguyen S, Downing M, et al. Factors associated with persistent post-concussion symptoms following mild traumatic brain injury in adults. J Rehabil Med 2019;51:32–9.
9. Novak Z, Aglipay M, Barrowman N, et al. Association of persistent postconcussion symptoms with pediatric quality of life. JAMA Pediatr 2016;170:e162900.
10. Howell DR, Zemek R, Brilliant AN, Mannix RC, Master CL, Meehan III WP. Identifying persistent postconcussion symptom risk in a pediatric sports medicine clinic. Am J Sports Med 2018;46:3254–61.
11. McCrory P, Meeuwisse W, Dvorak J, et al. Consensus statement on concussion in sport—the 5th international conference on concussion in sport held in Berlin, October 2016. Br J Sports Med 2017;51:838–47.
12. Schneider KJ, Meeuwisse WH, Nettel-Aguirre A, et al. Cervicovestibular rehabilitation in sport-related concussion: a randomised controlled trial. Br J Sports Med 2014;48:1294–8.
13. McNally KA, Patrick KE, LaFleur JE, Dykstra JB, Monahan K, Hoskinson KR. Brief cognitive behavioral intervention for children and adolescents with persistent post-concussive symptoms: a pilot study. Child Neuropsychol 2018;24:396–412.
14. Leddy JJ, Haider MN, Ellis MJ, et al. Early subthreshold aerobic exercise for sport-related concussion: a randomized clinical trial. JAMA Pediatr 2019;173:319–25.

15. Teel E, Brossard-Racine M, Corbin-Berrigan L-A, Gagnon I. Perceptual cognitive training does not improve clinical outcomes at 4 and 12 weeks following concussion in children and adolescents: a randomized controlled trial. J Head Trauma Rehabil 2021;36:E97–107.
16. Steindel SJ. International classification of diseases, clinical modification and procedure coding system: descriptive overview of the next generation HIPAA code sets. J Am Med Inform Assoc 2010;17:274–82.
17. Pearce AJ, Tommerdahl M, King DA. Neurophysiological abnormalities in individuals with persistent post-concussion symptoms. Neuroscience 2019;408:272–81.
18. Mercier LJ, Kowalski K, Fung TS, Joyce JM, Yeates KO, Debert CT. Characterizing physical activity and sedentary behavior in adults with persistent postconcussive symptoms after mild traumatic brain injury. Arch Phys Med Rehabil 2021;102:1918–1925.e1911.
19. Boisgontier MP, Cheval B, Schmidt J. Daily life physical activity and concussion symptoms in adolescents. Can J Occup Ther 2020;87:364–71.
20. Emanuelson I, Andersson Holmkvist E, Björklund R, Stålhammar D. Quality of life and post-concussion symptoms in adults after mild traumatic brain injury: a population-based study in western Sweden. Acta Neurol Scand 2003;108:332–8.
21. McCrea M, Guskiewicz KM, Marshall SW, et al. Acute effects and recovery time following concussion in collegiate football players: the NCAA Concussion Study. JAMA 2003;290:2556–63.
22. McClincy MP, Lovell MR, Pardini J, Collins MW, Spore MK. Recovery from sports concussion in high school and collegiate athletes. Brain Inj 2006;20:33–9.
23. Howell DR, Osternig LR, Chou L-S. Single-task and dual-task tandem gait test performance after concussion. J Sci Med Sport 2017;20:622–6.
24. Gagnon I, Teel E, Gioia G, et al. Parent-child agreement on postconcussion symptoms in the acute postinjury period. Pediatrics 2020;146:e20192317.
25. Sady MD, Vaughan CG, Gioia GA. Psychometric characteristics of the postconcussion symptom inventory in children and adolescents. Arch Clin Neuropsychol 2014;29:348–63.
26. Hajek CA, Yeates KO, Taylor HG, et al. Agreement between parents and children on ratings of post-concussive symptoms following mild traumatic brain injury. Child Neuropsychol 2010;17:17–33.
27. Patsimas T, Howell DR, Potter MN, Provance AJ, Kirkwood MW, Wilson JC. Concussion-symptom rating correlation between pediatric patients and their parents. J Athl Train 2020;55:1020–6.
28. Newman JB, Reesman JH, Vaughan CG, Gioia GA. Assessment of processing speed in children with mild TBI: A “first look” at the validity of pediatric ImPACT. Clin Neuropsychol 2013;27:779–93.
29. LaFevor ME. Examining concurrent validity, reliability, and sex and age normative values of the Impact Quick Test-pediatric version [dissertation]. East Lansing: Michigan State University; 2017.
30. Schatz P, Sandel N. Sensitivity and specificity of the online version of ImPACT in high school and collegiate athletes. Am J Sports Med 2013;41:321–6.
31. Gagnon I, Grilli L, Friedman D, Iverson G. A pilot study of active rehabilitation for adolescents who are slow to recover from sport-related concussion. Scand J Med Sci Sports 2016;26:299–306.