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Sex-Based Differences in Symptoms With Mouthguard Use After Pediatric Sport-Related Concussion

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Context: Current evidence regarding the protective effect of mouthguard use on symptom severity in children and adolescents who sustain sport-related concussions is insufficient to make clinical recommendations.

Objective: To compare the association between mouthguard use and symptoms stratified by sex in the first 4 weeks after pediatric sport-related concussion. We hypothesized that mouthguard use would be associated with less severe symptoms.

Design: Prospective cohort study.

Setting: Nine Canadian pediatric emergency departments (EDs).

Patients or Other Participants: Children aged 5 to 18 years who were assessed within 48 hours of concussions sustained during a collision or contact sport.

Main Outcome Measure(s): Injury characteristics were collected using the Acute Concussion Evaluation. The primary outcome measure was symptom score (range = 0–6), measured using age-appropriate versions (5–7, 8–12, or 13–18 years) of the Post-Concussion Symptom Inventory. The independent variable was time postconcussion (initial assessment and 1, 2, and 4 weeks).

Results: Of 1019 children (73% male; median [interquartile range] age = 13.43 years [11.01–15.27 years]), 42% wore a mouthguard at the time of injury. No significant group-by-sex-by-time interaction was present for symptoms ($\chi^2_3 = 0.27$; $P = .965$). Male mouthguard users reported similar symptom scores in the ED (difference in Post-Concussion Symptom Inventory Δ scores [diff] = –0.07; 95% CI = –0.23, 0.09) and at weeks 1 (diff = –0.02; 95% CI = –0.18, 0.14), 2 (diff = –0.03; 95% CI = –0.19, 0.13), and 4 (diff = –0.13; 95% CI = –0.29, 0.04) compared with males who did not wear a mouthguard. Female mouthguard users described minimally higher symptom scores at week 1 compared with non-mouthguard users (diff = 0.29; 95% CI = 0.01, 0.56). In the ED, symptom scores were not different for females who wore a mouthguard and those who did not (diff = 0.22; 95% CI = –0.04, 0.48) or at weeks 2 (diff = 0.22; 95% CI = –0.06, 0.51) or 4 (diff = 0.08; 95% CI = –0.20, 0.36).

Conclusions: Wearing a mouthguard at the time of injury was not associated with reduced acute or subacute symptoms after sport-related concussion in either males or females who were treated in the ED compared with those who did not wear a mouthguard. Athletes are still encouraged to wear mouthguards during sports because overwhelming evidence supports their use in preventing dental injuries.

Key Words: mild traumatic brain injuries, symptom change, children, adolescents, Post-Concussion Symptom Inventory

Key Points

- Mouthguard use did not protect against concussion symptoms in the first month after a sport-related concussion among children presenting to an emergency department.
- Males wore mouthguards more often than females did.
- Mouthguard use was not associated with sex-specific differences in postconcussion symptoms.

Sports are a leading cause of injury in youth, resulting in 1 to 2 million sport- and recreation-related concussions and accounting for roughly one-quarter of a million concussion-related visits to US emergency departments (EDs) every year.[1,2] Several US and Canadian sporting organizations (ie, football, ice hockey, lacrosse, field hockey, and boxing organizations) have mandated the use of mouthguards in an attempt to prevent injuries.[3] Although the ability of mouthguards to prevent dental injury has been well established,[4,5] it remains unclear whether mouthguards prevent concussion in contact sports and whether various mouthguard types may be more effective in reducing risk.[6–8]

The association between mouthguard use and the concussion-symptom burden after a sport-related concussion (SRC) is similarly ambiguous. Contradictory evidence[9,10] exists as to whether wearing a mouthguard reduces the number of practices and games missed by hockey and football players because of concussion. Although the researchers[9] of a large prospective study suggested that mean symptom severity may be less in professional hockey players who wear mouthguards, the authors[11] of a small retrospective study in adolescents found that mouthguards did not reduce acute symptoms after concussion.

Existing concussion-severity studies have been limited by factors including study quality (retrospective design, abstract only),[9,11] inconsistent definitions of concussion,[10,11] assessing game exposure only,[9] failure to report return-to-sport criteria,[9] adjusting for confounding variables,[9] and non–developmentally appropriate symptom scales.[11] Investigations have predominantly addressed male, elite, adolescent, collegiate, or professional athletes without sex-based reporting, making it difficult to apply the results to nonelite or female athletes. Ultimately, large prospective studies are needed to assess any protective effect against SRCs so that appropriate recommendations can be made regarding the use of mouthguards in youth.

Current evidence regarding the protective effect of mouthguard use on symptom severity in children and adolescents who sustained SRCs is insufficient to make clinical recommendations. Therefore, our primary objective was to compare the association between mouthguard use and symptom score stratified by sex at acute presentation and 1, 2, and 4 weeks after pediatric SRC. We hypothesized that symptom severity would be lower in children and adolescents who wore mouthguards at the time of concussion compared with those who did not but that no difference would be seen between males and females.

METHODS

Study Design and Setting

This work is a secondary analysis of the Predicting and Preventing Postconcussive Problems in Pediatrics (5P) study,[12,13] a prospective, multicenter cohort investigation. Participants were recruited between August 2013 and June 2015 from 9 Pediatric Emergency Research Canada Network (PERC) tertiary pediatric EDs. The research ethics committees at each participating institution approved the study.

Patients

We recruited patients aged 5 to 18 years who presented to the ED within 48 hours of head injury and were diagnosed with a concussion according to the Zurich Consensus Statement on Concussion in Sport.[14] Patients who sustained their concussion during a contact or collision sport- or recreation-related activity per the American Academy of Pediatrics classification[15] were included in this study. Although not cited in the original classification, rugby was added as a contact or collision sport because of the frequent and intentional contact with other players or the ground, intensity of impact, and risk of injury. Exclusion criteria were a Glasgow Coma Scale score of $\leq$13, abnormal neuroimaging, neurosurgical intervention, multisystem injuries, developmental delay, intoxication, absence of trauma as the primary event, or previous enrollment in the study.

Study Protocol

Recruitment. Details of the 5P study design have been published,[12] and are briefly summarized in the following paragraph. Eligible parents and patients provided written informed consent and assent as applicable before enrollment.

Standardized Assessment of Concussion. Trained research assistants collected participant data using a standardized assessment. Participants answered questions in electronic survey format in their first language (English or French) using a portable computer tablet. Parents and patients reported injury characteristics and risk factors for protracted recovery using the validated Acute Concussion Evaluation[16] to assist in the initial evaluation of concussion. Additionally, parents and patients provided information on the type of sport played and use of protective equipment. Symptoms were measured using the Post-Concussion Symptom Inventory (PCSI).[17] The PCSI is a self-reported measure of symptoms across the physical, cognitive, emotional, and sleep domains that has high internal consistency and interrater reliability.[17,18] Age-appropriate symptom scales measure the difference between current and preinjury symptoms in children aged 5 to 7 years (13 items, 3-point scale), 8 to 12 years (17 items, 3-point scale), and 13 to 18 years (20 items, 7-point scale) and in a parent-reported version (20 items, 7-point scale). All data were collected and managed using Research Electronic Data Capture.[19]

Follow-Up Questionnaires. Participants completed the age-appropriate PCSI at 1, 2, and 4 weeks after the initial ED visit via a web-based electronic survey or telephone interview. Research assistants telephoned nonresponders up to 5 times to minimize the loss to follow-up.

Outcome

The primary outcome was symptom score, operationalized as the item-averaged PCSI Δ score (difference between current and preinjury child-rated symptoms), with a possible score range from 0 to 6. To reconcile age-specific versions of the PCSI into a common metric, the following steps were undertaken: (1) when both the preinjury and postinjury scores were available for a constituent item, a Δ score was computed (postinjury score minus preinjury score) and then truncated to zero (if negative); (2) when a Δ score was available for at least 85% of constituent items, an average of all item Δ scores was computed; and finally, (3) this item-averaged Δ score for 5- to 7- and 8- to 12-year-old patients (original score range = 0–2) was multiplied by 3 to align with the original score range of 0 to 6 for adolescents (13–18-year-old patients).

Statistical Analysis

Baseline patient characteristics for each group were summarized using descriptive statistics. To estimate sex-specific relationships between mouthguard use and concussion symptoms at each of the 4 time points, we fitted a longitudinal, generalized least-squares multivariable model with the PCSI Δ score as the dependent variable and a 3-way interaction among mouthguard use, sex, and time (4 levels: initial assessment, 1 week, 2 weeks, and 4 weeks) as the main predictor of interest. We applied a continuous autoregressive (order 1) correlational structure to the model to account for within-participant measurements of the dependent variable and clustering by originating clinical site of study patient (9 levels). To minimize the potential for confounding bias, the model also featured comprehensive adjustment of covariates associated with clinical recovery. Covariates were chosen a priori based on recent systematic reviews,[20,21] consensus and medical position statements,[22,23] and clinical experience to adjust for preexisting factors and injury characteristics, including age, sex, symptom duration after previous concussion, family and personal history of migraine, history of anxiety, history of depression, history of sleep disorder, head

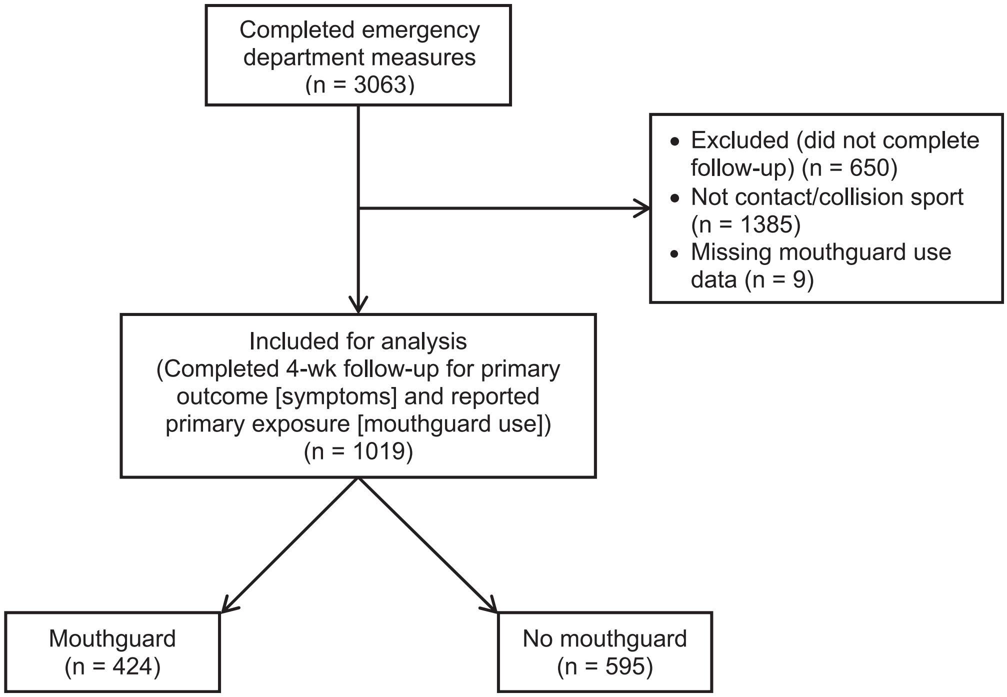

Figure 1. Participant flow diagram.

contact if the injury involved a fall, fall height, helmet use, type of sport, number of school days missed in the past 6 months, learning disability, attention-deficit/hyperactivity disorder, duration of loss of consciousness, postinjury seizure, and location of head contact. Missing data were dealt with using listwise deletion. Wald χ^2 statistics from initial model fitting were estimated to gain insights into the relative contribution of each independent variable to outcome prediction. To test our hypotheses, we performed a series of postmodel contrasts to formally quantify the adjusted comparisons of outcomes between mouthguard and non–mouthguard groups at each time point, stratified by sex (8 contrasts in total). These quantities represented the expected average difference in PCSI Δ score. Statistical analyses were performed using R (version 3.5.2; R Project for Statistical Computing).[24] Two-sided P values were considered statistically significant at $P < .05$.

RESULTS

Participant Characteristics

Of 3063 children who participated in the 5P study, 1019 (median [interquartile range] age = 13.43 years [11.01–15.27 years]) were included in this substudy (male n = 746, 73.2%; Figure 1). Baseline participant characteristics for statistical modeling and mouthguard use are presented in Table 1. Overall, 424 participants (41.6%) reported wearing a mouthguard at the time of the concussion, with the highest proportions in rugby (58 of 64, 90.6%), football (86 of 119, 72.2%), and hockey (237 of 460, 51.5%; Table 2). Mouthguard use was more common among males (344 of 746, 46.1%) than females (80 of 273, 29.3%), notably in football and hockey, for which mouthguard use is mandated.

Effect of Mouthguard Use on Symptoms

Mouthguard use was not a strong contributor to concussion symptoms ($\chi^2_8 = 9.08$, $P = .336$). Sex ($\chi^2_8 = 49.75$, $P < .001$) and time after concussion ($\chi^2_8 = 1825.54$, $P < .001$) were independently and significantly associated with symptoms; however, postmodel fitting revealed no significant group-by-sex-by-time interaction for symptoms ($\chi^2_3 = 0.27$; $P = .965$), reflecting little indication that the association between mouthguard use and symptom score varied between sexes or across time (Figure 2). The contributions of all model predictors to symptoms are shown in the Supplemental Table (available online at http://dx.doi.org/10.4085/1062-6050-0393.20.S1). The estimated effect of wearing a mouthguard on symptoms at each time point, stratified by sex, is presented in Table 3.

Emergency Department. Males who wore a mouthguard reported similar symptom scores in the ED compared with males who did not wear a mouthguard (difference [diff] = –0.07; 95% CI = –0.23, 0.09, $P = .389$). Similarly, symptom scores were not different between females who wore a mouthguard and those who did not (diff = 0.22; 95% CI = –0.04, 0.48; $P = .098$).

Week 1. No difference was present in symptom scores between males who did and those who did not wear a mouthguard (diff = –0.02; 95% CI = –0.18, 0.14; $P = .793$). In contrast, female mouthguard wearers reported higher symptom scores at week 1 compared with non–mouthguard users (diff = 0.29; 95% CI = 0.01, 0.56, $P = .039$).

Week 2. By the second week, no differences in symptom scores were observed in males who wore a mouthguard compared with those who did not (diff = –0.03; 95% CI = –0.19, 0.13, $P = .719$). Females who wore mouthguards described similar symptom scores as those who did not (diff = 0.22; 95% CI = –0.06, 0.51; $P = .128$).

Table 1. Baseline Characteristics of the 1019 Study Participants Who Sustained a Sport-Related Concussion Continued on Next Page

Variable[a]	Total No.	Contributed to Statistical Modeling[b] Excluded (n = 234)	Contributed to Statistical Modeling[b] Included (n = 785)	*P* Value	Mouthguard Use at Time of Concussion? Yes (n = 424)	Mouthguard Use at Time of Concussion? No (n = 595)
Participant characteristics						
Wore a mouthguard?	1019			.805		
Yes		99 (42)	325 (41)			
No		135 (58)	460 (59)			
Age, median (IQR)	1019	13.25 (10.63–15.13)	13.45 (11.12–15.32)	.210	13.97 (11.73–15.66)	12.95 (10.55–14.90)
Sex, No. (%)	1019			.021		
Male		185 (79)	561 (71)		344 (81)	402 (68)
Female		49 (21)	224 (29)		80 (19)	193 (32)
Maximum symptom duration after previous concussion, wk, No. (%)	1014			.780		
No previous concussion		165 (72)	539 (69)		281 (67)	423 (71)
<1		23 (10)	106 (14)		57 (14)	72 (12)
1–2		16 (7)	58 (7)		34 (8)	40 (7)
3–4		11 (5)	38 (5)		22 (5)	27 (5)
5–8		8 (3)	21 (3)		12 (3)	17 (3)
>8		6 (3)	23 (3)		16 (4)	13 (2)
Personal migraine history, No. (%)	1013	29 (13)	105 (13)	.797	54 (13)	80 (14)
Family migraine history, No. (%)	1002	100 (46)	361 (46)	.980	190 (45)	271 (46)
Depression, No. (%)	1018	9 (4)	20 (3)	.289	11 (3)	18 (3)
Anxiety, No. (%)	1015	24 (10)	45 (6)	.013	28 (7)	41 (7)
Sleep disturbance, No. (%)	1013	3 (1)	13 (2)	.717	8 (2)	8 (1)
Learning disability, No. (%)	1018	28 (12)	47 (6)	.002	31 (7)	44 (7)
ADD or ADHD, No. (%)	1016	33 (14)	59 (8)	.002	38 (9)	54 (9)
School days missed over past 6 mo for any reason, No. (%)	1015			.262		
0		47 (20)	129 (16)		85 (20)	91 (15)
1–2		70 (30)	249 (32)		126 (30)	193 (32)
3–6		78 (34)	251 (32)		127 (30)	202 (34)
7+		35 (15)	156 (20)		83 (20)	108 (18)
Helmet use, No. (%)	1019	121 (52)	444 (57)	.190	355 (84)	210 (35)
Injury characteristics						
Sport, No. (%)	1019			.796		
Combat sport[c]		3 (1)	17 (2)		10 (2)	10 (2)
Football		32 (14)	33 (6)		86 (20)	33 (6)
Hockey		97 (41)	363 (46)		237 (56)	223 (37)
Lacrosse		4 (2)	12 (2)		11 (3)	5 (1)
Ringette		7 (3)	27 (3)		16 (4)	18 (3)
Roller derby		0 (0)	2 (0)		1 (0)	1 (0)
Rugby		15 (6)	49 (6)		58 (14)	6 (1)
Soccer		70 (30)	215 (27)		2 (0)	283 (48)
Wrestling		6 (3)	13 (2)		3 (1)	16 (3)
Initial head contact during fall, No. (%)	1000			<.001		
Did not fall		68 (32)	449 (57)		221 (53)	296 (51)
No		37 (17)	81 (10)		48 (11)	70 (12)
Yes		110 (51)	255 (32)		150 (36)	215 (37)
Fall height, median (IQR)[d]	921	0.00 (0.00–0.00)	0.00 (0.00–0.00)	.027	0 (0–0)	0 (0–0)
Fall surface, No. (%)	1014			<.001		
Did not fall		68 (30)	449 (57)		221 (52)	296 (50)
Concrete		2 (1)	3 (0)		4 (1)	26 (4)
Grass		30 (13)	57 (7)		42 (10)	45 (8)
Ice		65 (28)	169 (22)		116 (27)	118 (20)
Steel		2 (1)	2 (0)		1 (0)	3 (1)
Other		48 (21)	89 (11)		39 (9)	98 (17)
Head impact location, No. (%)						
Face	1019	12 (5)	51 (6)	.445	20 (5)	43 (7)
Frontal	1019	59 (25)	208 (26)	.695	116 (27)	151 (25)
Mandible	1019	8 (3)	42 (5)	.230	25 (6)	25 (4)
Occipital	1019	57 (24)	175 (22)	.508	86 (20)	146 (25)
Parietal	1019	30 (13)	127 (16)	.212	66 (16)	91 (15)
Temporal	1019	49 (21)	160 (20)	.853	77 (18)	132 (22)

Table 1. Continued From Previous Page

Variable[a]	Total No.	Contributed to Statistical Modeling[b] Excluded (n = 234)	Included (n = 785)	P Value	Mouthguard Use at Time of Concussion? Yes (n = 424)	No (n = 595)
Loss of consciousness, min, median (IQR)[d]	925	0.00 (0.00–0.00)	0.00 (0.00–0.00)	.709	0 (0–0)	0 (0–0)
Postconcussive seizure	1013	7 (3)	14 (2)	.230	9 (2)	12 (2)

Abbreviations: ADD, attention-deficit disorder; ADHD, attention-deficit/hyperactivity disorder; IQR, interquartile range.

[a] Only prediagnostic participant characteristics were considered as covariates in the analysis.
[b] Complete data for at least 1 time point were required to contribute to statistical modeling.
[c] Karate, judo, taekwondo, mixed martial arts, boxing.
[d] To provide a summary statistic, all height and loss-of-consciousness data were coded to 0 if a fall or loss of consciousness did not occur.

Week 4. No difference was demonstrated in symptom scores between males who did and those who did not wear a mouthguard at 4 weeks (diff = –0.13; 95% CI = –0.29, 0.04, $P = .127$). Wearing a mouthguard had no effect on symptom scores among females compared with not wearing one (diff = 0.08; 95% CI = –0.20, 0.36; $P = .581$).

DISCUSSION

Regardless of sex, wearing a mouthguard at the time of concussion was not associated with reduced symptoms at baseline or 1, 2, or 4 weeks postinjury in children and adolescents compared with those who did not wear a mouthguard. Although a statistically observable difference was present in symptom severity between females who did and those who did not wear a mouthguard at 1 week after concussion, the estimated difference was small and deemed clinically nonrelevant. Our results did not support our hypothesis that mouthguards would be associated with reduced concussion symptoms, but they confirmed our hypothesis of no sex-specific differences.

More males wore mouthguards in sports for which their use was mandatory or recommended, yet the symptom scores were similar between sexes. Previous authors[25,26] have shown that high school females had a higher incidence of concussion and prolonged symptom recovery in sex-comparable sports; however, we are the first to examine whether differences in symptom recovery existed between sexes associated with mouthguard use. Whereas the finding that females reported worse symptoms at baseline may help explain differences in prolonged recovery,[25,26] our results suggested that wearing a mouthguard did not change the recovery pattern between sexes. High-quality, adequately powered studies are needed to examine sport-specific sex differences in mouthguard use and outcomes.

Our findings are consistent with those of a small number of authors[10,11] who identified no differences in the concussion burden associated with mouthguard use in an adolescent population. Limited evidence[11] indicated that mouthguard use was not associated with neurocognitive deficits or the degree of symptoms in adolescents within 3 days of concussion. Similarly, no differences in missed playing time due to concussion were found between high school football athletes who wore custom versus generic or specialized mouthguards.[10] Although our results support the finding that mouthguards did not play a role in symptom severity after SRC in youth, they stand in contrast to preliminary outcomes in an elite professional athlete population. Professional male ice hockey players who did not wear mouthguards reported greater symptom severity as measured by the modified McGill Acute Concussion Evaluation symptom scale than those who did wear mouthguards.[9] Possible explanations for the different findings include physiological differences between children and adults, higher impact forces in professional ice hockey, and differences in symptom scales. Because the protective effects of mouthguards might be more pronounced in collision sports compared with low-contact sports, sport-specific studies are needed to confirm our results.

Examining the effectiveness of mouthguards in preventing concussions lends support to the lack of a protective

Table 2. MouthGuard Use Reported by Sport, Stratified by Sex

Sport	Mouthguard Use at Time of Concussion? No. (%) Males (n = 746) Yes	No	Females (n = 273) Yes	No	Difference in Mouthguard Use Between Males and Females, % (95% CI)
Combat sports[a,b]	6 (46)	7 (54)	4 (57)	3 (43)	−11 (−46, 30)
Football[a]	85 (74)	30 (26)	1 (25)	3 (75)	49 (3, 71)
Hockey[a]	214 (55)	177 (45)	23 (33)	46 (67)	21 (9, 21)
Lacrosse[a]	9 (64)	5 (36)	2 (100)	0 (0)	–36 (–61, 33)
Ringette	0 (0)	1 (100)	16 (48)	17 (52)	–48 (–65, 32)
Roller derby	0 (0)	0 (0)	1 (50)	1 (50)	No value
Rugby[a]	26 (93)	2 (7)	32 (89)	4 (11)	4 (−13, 19)
Soccer	1 (1)	165 (99)	1 (1)	118 (99)	0 (−4, 3)
Wrestling[c]	3 (17)	15 (83)	0 (0)	1 (100)	17 (−63, 39)

[a] Mouthguard use is mandatory in Canadian sporting organizations.[25]
[b] Karate, judo, taekwondo, mixed martial arts, boxing.
[c] Mouthguard use is recommended by Canadian sporting organizations.[25]

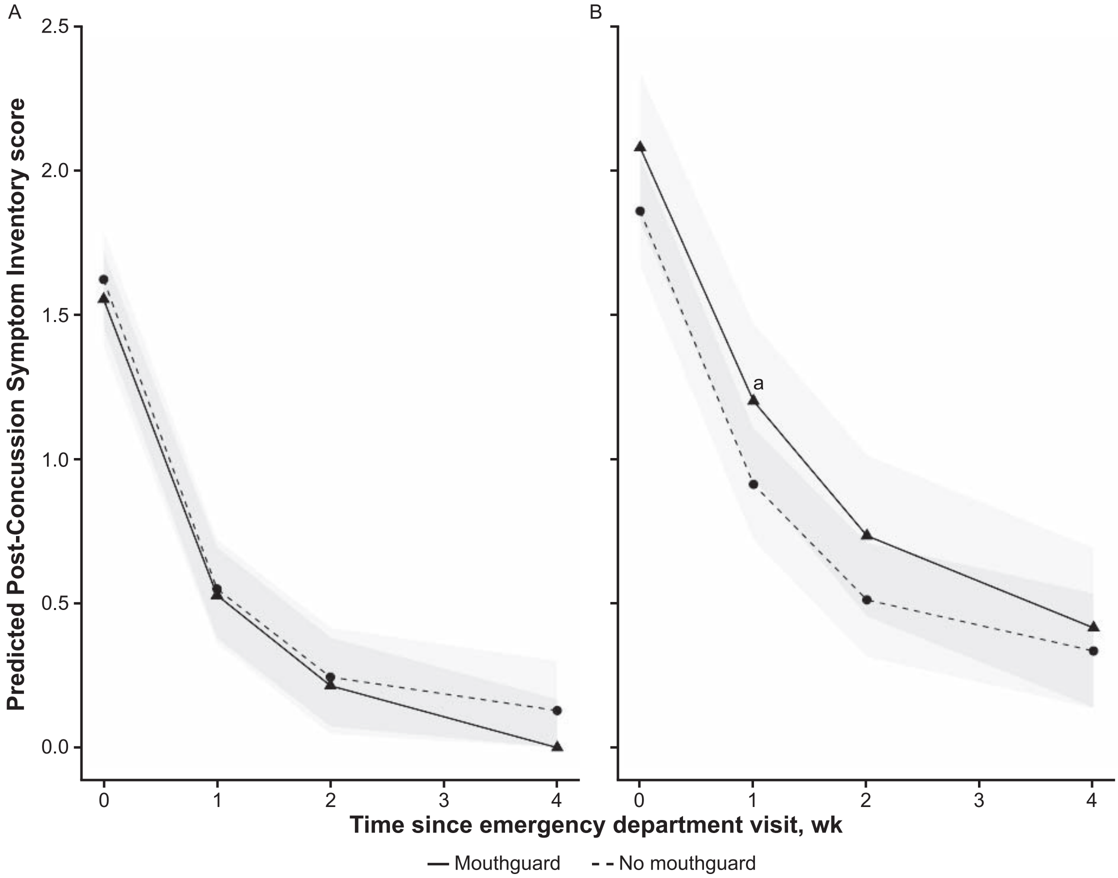

Figure 2. Sex-stratified comparison of mouthguard effect on symptom score on the Post-Concussion Symptom Inventory (PCSI) at initial presentation in the emergency department and at weeks 1, 2, and 4. Predicted PCSI represents the median symptom scores for those wearing a mouthguard and those not wearing a mouthguard. The difference between curves represents the adjusted effect of wearing a mouthguard. [a] Indicates a difference between groups ($P < .05$).

effect of mouthguards on concussion severity. Our findings are strengthened by recent systematic reviews and meta-analyses[6,7] that demonstrated an inconclusive association between mouthguard use and concussion incidence. It is also unclear whether wearing a custom mouthguard relative to a noncustom mouthguard confers any increased protection against concussion, although custom mouthguards have been associated with a predominantly negative effect, ranging from a 1% reduced to a 75% increased risk of concussion among university football players over a 15-week season.[27]

Overwhelming evidence supports the use of mouthguards to prevent dental injuries such as jaw fractures, dental trauma, and soft tissue injuries.[5] Authors of biomechanical studies[5,28] have suggested that mouthguards may reduce the incidence and severity of concussions by increasing the space within the temporomandibular joint and absorbing impact forces directed from the mandible to the base of the skull, thereby reducing the forces transmitted to the brain. It seems intuitive that mouthguards might offer protection from a direct blow to the maxilla or by buffering a forced occlusion during traumatic jaw closure. However, it is less convincing that mouthguards might offer protection against high levels of neuronal strain caused by rotational acceleration forces applied to the brain if an athlete is struck perpendicularly on the mandible with an open mouth or sustains an indirect blow.

Table 3. Estimated Effect (Est) of Wearing a Mouthguard on Symptoms at Wk 0, 1, 2, and 4, Stratified by Sex[a]

Time, wk[b]	Males		Females	
	Est (95% CI)	*P* Value	Est (95% CI)	*P* Value
0	−0.07 (−0.23, 0.09)	.389	0.22 (−0.04, 0.48)	.098
1	−0.02 (−0.18, 0.14)	.793	0.29 (0.01, 0.56)	.039
2	−0.03 (−0.19, 0.13)	.719	0.22 (−0.06, 0.51)	.128
4	−0.13 (−0.29, 0.04)	.127	0.08 (−0.20, 0.36)	.581

[a] Symptoms measured using the Post-Concussion Symptom Inventory (score = 0–6).

[b] Time from presentation in the emergency department within 48 hours of injury.

Clinical Relevance

Our results should not discourage athletes from wearing mouthguards during sport but rather should provide youths with a reasonable expectation as to their purpose and discourage the unjustified promotion or purchase of mouthguards to protect against concussion symptoms. Using mouthguards might give athletes a false sense of protection and encourage them to play more aggressively,[29] putting themselves at an increased risk for injury. Rather, efforts to reduce the number and severity of concussions through validated means such as eliminating body checking in youth ice hockey, rule changes, education, and fair play should be encouraged.[6]

This research had several strengths. First, existing population-based studies were often sport specific and focused on acute symptoms in adult males or elite athletes. We prospectively measured symptom scores in all youth with a sport- or recreation-related concussion who were seen within hours of injury at multiple pediatric hospitals across Canada and examined symptom recovery in the first month. Second, we supplied a novel contribution to the literature by providing a sex-based comparison. Third, we used validated and developmentally relevant symptom scales that were scaled appropriately to compare symptoms across a wide range of ages. We considered this important given the limited evidence of mouthguard use in younger children. By including children of all ages who participated in multiple sports, we ensured that our results can be generalized to a diverse range of recreational and competitive athletes across a variety of sports and not limited to contact sports such as football or hockey. Fourth, we controlled for multiple confounders associated with clinical recovery to strengthen the validity of our findings.

Our results are novel because we demonstrated that outcomes associated with mouthguards were not sex specific, even when controlling for symptom duration with previous concussion, medical history, and injury characteristics. Moreover, this study is unique in that we prospectively measured symptom change during the initial 4 weeks at 9 pediatric EDs across Canada using validated and developmentally appropriate symptom scales. By including youth who participated in more than 20 organized sports, we ensured that our results can be generalized to both recreational and competitive athletes across multiple sports and not limited to contact sports such as football or hockey. Additionally, our multivariable model included established risk factors for concussion recovery.

Limitations

Developmental differences across our participants regarding musculoskeletal strength may have influenced our results. Although neck strength is similar between sexes in younger children, sex differences exist among adolescents.[30] Sex differences in neck strength have been proposed as one possible explanation for the higher risk of concussion among females in sex-comparable sports.[21] There is growing interest in examining the association between neck strength and SRC given that an SRC may be caused by either a direct or indirect blow to the head or neck or elsewhere on the body.[22] The neck has a potential role in reducing the risk of concussion by stabilizing the head against large acceleration forces and absorbing the transfer of energy from the head to the brain.[31] Preliminary evidence[32] for the importance of neck strength in high school athletes suggests that greater isometric neck strength reduced the risk of concussion. Given that this study is a secondary analysis of a larger prospective, multicenter cohort investigation to derive and validate a clinical prediction rule for persistent postconcussive symptoms in children and adolescents that did not include measures of musculoskeletal strength,[13] we were unable to control for differences in neck strength in our analysis. We did, however, control for sex and sport type, both of which have been found to independently predict the risk of concussion in a univariate analysis.[32] We were unable to control directly for musculoskeletal strength, but we controlled for age, which may share similarities with developmental changes in neck strength as a covariate.

Several other possible limitations may have affected our study. Although it has been hypothesized that the improved fit, thickness, stiffness, tensile strength, and durability of custom-made mouthguards provide superior shock absorption and protection versus more commonly used boil-and-bite mouthguards,[11] this was a secondary analysis of a large data set that did not include detailed descriptions of mouthguard types worn at the time of injury, thereby precluding our ability to include this factor in the analysis. Children under the age of 13 may be more likely to wear less expensive, noncustom mouthguards because of the need to replace the device more frequently with changes in dentition and jaw sizes. It is possible that discriminating among mouthguard types would have produced different results, although the lack of difference in days lost among high school football players wearing custom versus generic mouthguards suggested otherwise.[10] To determine the effect of mouthguards as compared with the association of outcomes with their use would require a randomized controlled trial, yet ethical considerations constrain randomizing participants to a non–mouthguard group given the strong evidence for the dental protection of wearing a mouthguard. However, the large prospective cohort in this study helps to minimizes this limitation in that the sample size was adequately powered to control for known confounders. Additionally, 30% to 40% of concussions sustained by adolescent athletes are not reported,[33] and only 12% of patients aged 0 to 17 years have been shown to access the ED for concussion care.[34] Even though concussion patients seeking care in the ED may present with more severe injuries than those who do not report their injuries, higher rates of persistent symptoms have been shown in patients assessed in sport medicine and specialty clinics.[35,36] Further research is required to assess the effect of mouthguard use in patients recruited from different medical settings and sport types. Also, we truncated symptom differences to zero under the assumption that negative scores would most likely indicate a patient response error for a preinjury item, as a return to baseline level is far more realistic. Although this may have introduced some error, it is unlikely to have affected the overall results. Finally, because no objective biomarkers exist for concussion diagnosis or recovery, our study was limited to patient self-reports to measure symptom persistence.

CONCLUSIONS

Wearing a mouthguard at the time of concussion did not reduce symptoms in the first month after SRC among either males or females who were treated in the ED compared with not wearing a mouthguard. Nonetheless, we endorse international dental association and consensus statement recommendations to wear a mouthguard in sport,[37,38] as overwhelming evidence exists to support the use of mouthguards in preventing dental injuries.

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