Concussion Incidence, Duration, and Return to School and Sport in 5- to 14-Year-Old American Football Athletes

Sara P. D. Chrisman, MD, MPH[1,2,3], Sarah Lowry, PhD, MPH[1,4], Stanley A. Herring, MD[3,5], Emily Kroshus, ScD, MPH[1,2], Teah R. Hoopes, MPH[1], Shannon K. Higgins, BS[1], and Frederick P. Rivara, MD, MPH[1,2,3]

Objective To collect prospective data on concussion incidence, risk factors, duration of symptoms, and return to school and sport in 5- to 14-year-old American football participants.

Study design We conducted a prospective cohort study over 2 years collecting data during two 10-week fall seasons. Youth with concussion were followed to determine time to return to school, sport, and baseline level of symptoms. Logistic regression was used to estimate the risk of sustaining a concussion associated with baseline demographic factors. Time to return to school, sport, and baseline symptoms were analyzed using Kaplan-Meier survival curves.

Results Of 863 youth followed (996 player-seasons), 51 sustained a football-related concussion, for an athlete-level incidence of 5.1% per season. Youth with history of concussion had a 2-fold increased risk for sustaining an incident concussion (OR, 2.2; 95% CI, 1.1-4.8). Youth with depression had a 5-fold increased risk of concussion (OR, 5.6; 95% CI, 1.7-18.8). After a concussion, 50% of athletes returned to school by 3 days, 50% returned to sport by 13 days, and 50% returned to a baseline level of symptoms by 3 weeks.

Conclusions Concussion rates in this study were slightly higher than previously reported, with 5 of every 100 youth sustaining a football-related concussion each season. One-half of youth were still symptomatic 3 weeks after injury. Further research is needed to address the risk of concussion in youth football. *(J Pediatr 2019;207:176-84).*

Approximately 45.7 million US youth 6-17 years old play organized sports annually.[1] Sports involvement provides opportunities for social interaction and physical activity, and may decrease the risk of obesity, diabetes, and osteoporosis.[2] However, sports are not without risk, and concussion is a growing concern.[3] Estimates suggest sports and recreation-related concussions affect up to 1.9 million youth each year.[4] Although studies have examined concussion in high school-aged youth,[5-11] there is scant research on the incidence and natural history of concussion in elementary and middle school aged youth.[12-15] Youth in these younger age groups are undergoing rapid brain development including axonal myelination, yielding concern that brain injuries could have long-term outcomes.[16]

Youth football is of particular concern, given both the contact involved in routine play and the possible risk of concussion, suggested by the high rates of concussion in high school and college.[5-7] There are currently 2.8 million football players younger than high school,[17] yet little is known about the risk of concussion in younger youth. Even though a few studies have measured the concussion incidence in football earlier than high school,[12-15] these studies did not examine symptom duration. Studies measuring concussion symptom duration in youth have used clinical populations, and unfortunately not all athletes with concussion seek care.[18-20] Given the barriers to seeking medical care, concussed youth who present to the medical setting either have greater severity of injury or greater distress, both of which can affect symptom duration.[21] We undertook the current study to measure more accurately both the incidence of concussion in youth football and the duration of symptoms. We used a prospective design with athletic trainers on the sidelines as injury reporters and contacted youth who sustained a concussion weekly to determine recovery. Prior studies have also suggested potential risk factors for concussion in youth, such as older age,[22] prior concussion,[22-26] attention deficit hyperactivity disorder,[23] and migraine,[23,27] and we examined the relationship between these risk factors at baseline and prospectively measured incident concussion.

Methods

Youth (5-14 years old) and parents were recruited via email from a Seattle-area youth football league in 2016 and 2017. Interested participants completed consent

HBI Health Behavior Inventory

From the [1]Center for Child Health, Behavior and Development, Seattle Children's Research Institute; [2]Department of Pediatrics, University of Washington; [3]Harborview Injury Prevention and Research Center; [4]Department of Epidemiology; and [5]Department of Rehabilitation Medicine, Orthopedics and Sports Medicine, and Neurological Surgery, University of Washington, Seattle, WA

Funded by the Seattle Pediatric Concussion Research Collaborative and the University of Washington Sports Health and Safety Institute. S.H. was previously chair of the medical advisory committee, a member of the board of directors for USA Football, and a member of the medical advisory committee for Pop Warner Little Scholars. He is currently one of the team physicians for the Seattle Seahawks. The other authors declare no conflicts of interest.

Portions of this study were presented as a poster at the annual meeting for the American College of Sports Medicine, May 29 - June 2, 2018, Minneapolis, MN.

https://doi.org10.1016/j.jpeds.2018.11.003

and parent permission forms online, and were then directed to baseline surveys. Email reminders were sent 4 times to each participant. Recruitment was also achieved by attending team and league meetings before the start of the season. Lotteries of football experiences (tickets to professional football games or practices) were used as incentives. All procedures were approved by the Seattle Children's Institutional Review Board.

Baseline Data Collection

Parents and youth athletes completed online surveys in REDCap regarding (1) demographics (age, sex, race/ethnicity, and responding parent education), (2) years of football participation, (3) history of prior diagnosed concussion, and (4) mental health history (history of diagnosed depression, anxiety, and/or attention deficit disorder).

Injury Identification

Study-employed athletic trainers attended all games during the two 10-week seasons and notified the study team if one of the athletes sustained a potential concussion. Concussion was defined based on the Zurich concussion consensus documents.[28] Parents and coaches were also asked to contact study staff if a youth sustained a possible concussion during a practice or game. Athletes with suspected concussion were called to obtain additional information, including mechanism of injury, name of clinician seen, and any diagnoses of concussion. Information regarding these potential concussions was reviewed by an independent clinician overseeing the study to make a determination of confirmed or not confirmed. Athletes with confirmed concussion (and their parents) completed surveys weekly regarding concussive symptoms, return to school, and return to sport. Symptom surveys were continued until symptoms resolved. Symptom resolution was defined as no more than 3 symptoms greater than preinjury baseline by both child and parent report, given data suggesting variation in symptoms in absence of injury.[29] Surveys regarding returning to school and sport were continued until the athlete returned to school and sport, or up to 12 weeks after injury. Of note, parents provided an exact date of when their child returned to school and sport, but time to return to baseline symptoms was calculated based on parent and child report of concussive symptoms, which was only measured weekly. Both football seasons began in August, and thus some concussions (n = 11) occurred before the school year began and time to return to school was not a useful metric for these concussions. These individuals were thus excluded from the return to school analysis. Some individuals might not have had the opportunity to return to sport if their injury was at the end of the season. Return to sport time was censored in mid-November, when the season was complete.

Concussive Symptom Measurement

Health Behavior Inventory (for Subjects 5-12 Years Old). The Health Behavior Inventory (HBI) is contained in the Sport Concussion Assessment Tool-3 Child Version,[30] and is a 20-item, 4-point Likert instrument measuring postconcussive symptoms. The HBI has demonstrated validity and reliability among adolescents and individuals with mild traumatic brain injury (Cronbach alpha = 0.85-0.94).[31-35]

Symptom Checklist from the Sport Concussion Assessment Tool-3 (for Subjects 13-14 Years Old). The Sport Concussion Assessment Tool-3 symptom checklist was adapted from the Post Concussion Symptom Scale and is a 22-item, 6-point Likert scale survey of concussive symptoms[36] with established internal consistency (Cronbach alpha = 0.88-94) and test-retest reliability (Spearman $r = 0.55$).[36-39]

Statistical Analyses

Descriptive analyses of baseline characteristics and missing data were summarized using baseline data from each participant's first year of enrollment in the study, because some participants were enrolled in multiple years (**Table I**). Logistic regression was used to estimate ORs and 95% CI of sustaining a concussion during the season, including the following covariates: age, sex, ethnicity, race, responding parent education, number of years participating in youth football (including current year), and child's history of concussion, attentional problems (either diagnosis of attention deficit hyperactivity disorder/attention deficit disorder or the use of medications for attention), depression, and headache. For each player-season, the exposures of interest were baseline characteristics reported at the beginning of that particular season, and the outcome was whether a concussion was sustained during that season. The unit of analysis was the player-season, or each season played by a participant, and thus participants enrolled both years were included twice. Clustering by individual was accounted for using a modified sandwich robust variance estimator for cluster-correlated data. Player-seasons with confirmed football-related concussions were compared with player-seasons with no concussion. Player-seasons with suspected-only concussions were excluded from primary analyses given our inability to confirm concussion status of these individuals. Owing to the small numbers of concussed players with a prior history of depression, analyses were presented both with and without adjustment for depression.

Kaplan-Meier recovery curves were plotted to assess time to recovery among confirmed sport-related concussions with 3 recovery outcomes: return to school, return to sport, and return to baseline level of concussion symptoms (by both parent and youth report). Censoring owing to attrition or study end was indicated visually. For return to school, only concussions occurring on or after the first day of school were included. Censoring owing to the end of the season (mid-November) was also indicated visually. All analyses were conducted using Stata version 14.2 (StataCorp LP, College Station, Texas).

Results

Of the 2466 families, 9 had no emails on file and 26 had emails that were either inaccurate or had been closed. Of the remaining 2431, 863 (35%) chose to participate (**Figure 1**). Of these 863 athletes, 133 were followed for 2 seasons, yielding a total of 996 player-seasons. During the two 10-week fall seasons,

Table I. Demographics of 5- to 14-year-old Seattle youth football athletes who sustained a confirmed or suspected football-related concussion during the 2016-2017 or 2017-2018 seasons*

	All	Confirmed concussion	Suspected but not confirmed or nonfootball concussion	Nonconcussed
	(n = 863)	(n = 51)	(n = 62)	(n = 750)
Child age (y)				
5-7	96 (11.1)	2 (3.9)	8 (12.9)	86 (11.5)
8-10	300 (34.8)	18 (35.3)	32 (51.6)	250 (33.3)
11-12	311 (36.0)	20 (39.2)	16 (25.8)	275 (36.7)
13-14	156 (18.1)	11 (21.6)	6 (9.7)	139 (18.5)
Child sex				
Male	854 (99.0)	50 (98.0)	62 (100.0)	742 (98.9)
Female	9 (1.0)	1 (2.0)	0 (0.0)	8 (1.1)
Parental education				
Less than high school	7 (0.8)	0 (0.0)	0 (0.0)	7 (0.9)
High school/General Educational Development	75 (8.7)	4 (7.8)	6 (9.7)	65 (8.7)
Some college, no degree	183 (21.2)	13 (25.5)	19 (30.6)	151 (20.1)
College degree	410 (47.5)	28 (54.9)	26 (41.9)	356 (47.5)
Masters' degree	115 (13.3)	4 (7.8)	5 (8.1)	106 (14.1)
Professional degree	50 (5.8)	1 (2.0)	4 (6.5)	45 (6.0)
Prefer not to answer	23 (2.7)	1 (2.0)	2 (3.2)	20 (2.7)
Child ethnicity				
Hispanic or Latino	81 (9.4)	5 (9.8)	1 (1.6)	75 (10.0)
Not Hispanic or Latino	708 (82.0)	39 (76.5)	58 (93.5)	611 (81.5)
Missing	74 (8.6)	7 (13.7)	3 (4.8)	64 (8.5)
Child race				
American Indian or Alaska Native	11 (1.3)	0 (0.0)	0 (0.0)	11 (1.5)
Black or African American	63 (7.3)	3 (5.9)	3 (4.8)	57 (7.6)
White	598 (69.3)	41 (80.4)	37 (59.7)	520 (69.3)
Asian	45 (5.2)	3 (5.9)	6 (9.7)	36 (4.8)
Native Hawaiian or Pacific Islander	30 (3.5)	1 (2.0)	4 (6.5)	25 (3.3)
Two or more races	51 (5.9)	0 (0.0)	8 (12.9)	43 (5.7)
Prefer not to answer	65 (7.5)	3 (5.9)	4 (6.5)	58 (7.7)
Years of football participation				
1	315 (36.5)	24 (47.1)	26 (41.9)	265 (35.3)
2	174 (20.2)	9 (17.6)	11 (17.7)	154 (20.5)
3	129 (14.9)	8 (15.7)	10 (16.1)	111 (14.8)
4	79 (9.2)	5 (9.8)	4 (6.5)	70 (9.3)
5	31 (3.6)	2 (3.9)	1 (1.6)	28 (3.7)
6	15 (1.7)	1 (2.0)	1 (1.6)	13 (1.7)
7	8 (0.9)	0 (0.0)	1 (1.6)	7 (0.9)
Prefer not to answer	12 (1.4)	0 (0.0)	1 (1.6)	11 (1.5)
Missing	100 (11.6)	2 (3.9)	7 (11.3)	91 (12.1)
History of prior concussion				
Yes	115 (13.3)	13 (25.5)	8 (12.9)	94 (12.5)
Missing	3 (0.3)	0 (0.0)	0 (0.0)	3 (0.4)
Diagnosis of ADD/ADHD or use of medications for attention problems				
Yes	97 (11.2)	3 (5.9)	5 (8.1)	89 (11.9)
History of headache				
Yes	143 (16.6)	13 (25.5)	10 (16.1)	120 (16.0)
Missing	4 (0.5)	0 (0.0)	0 (0.0)	4 (0.5)
History of depression				
Yes	16 (1.9)	4 (7.8)	1 (1.6)	12 (1.6)
History of anxiety				
Yes	49 (5.7)	2 (3.9)	3 (4.8)	44 (5.9)
Year of confirmed football-related concussion†				
None	812 (94.1)	0 (0.0)	62 (100.0)	750 (100.0)
Year 1 only (2016)	35 (4.1)	35 (68.6)	0 (0.0)	0 (0.0)
Year 2 only (2017)	16 (1.9)	16 (31.4)	0 (0.0)	0 (0.0)
Study participation				
Year 1 only (2016)	464 (53.8)	33 (64.7)	21 (33.9)	410 (54.7)
Year 2 only (2017)	266 (30.8)	8 (15.7)	22 (35.5)	236 (31.5)
Both	133 (15.4)	10 (19.6)	19 (30.6)	104 (13.9)

ADD/ADHD, attention deficit hyperactivity disorder/attention deficit disorder.
Values are number (%).
*No participants sustained multiple confirmed sport-related concussions during the study.
†Participants were classified as having a suspected but not confirmed, and/or nonsport concussion, only if they were not confirmed to have a sport-related concussion during enrollment in the study.

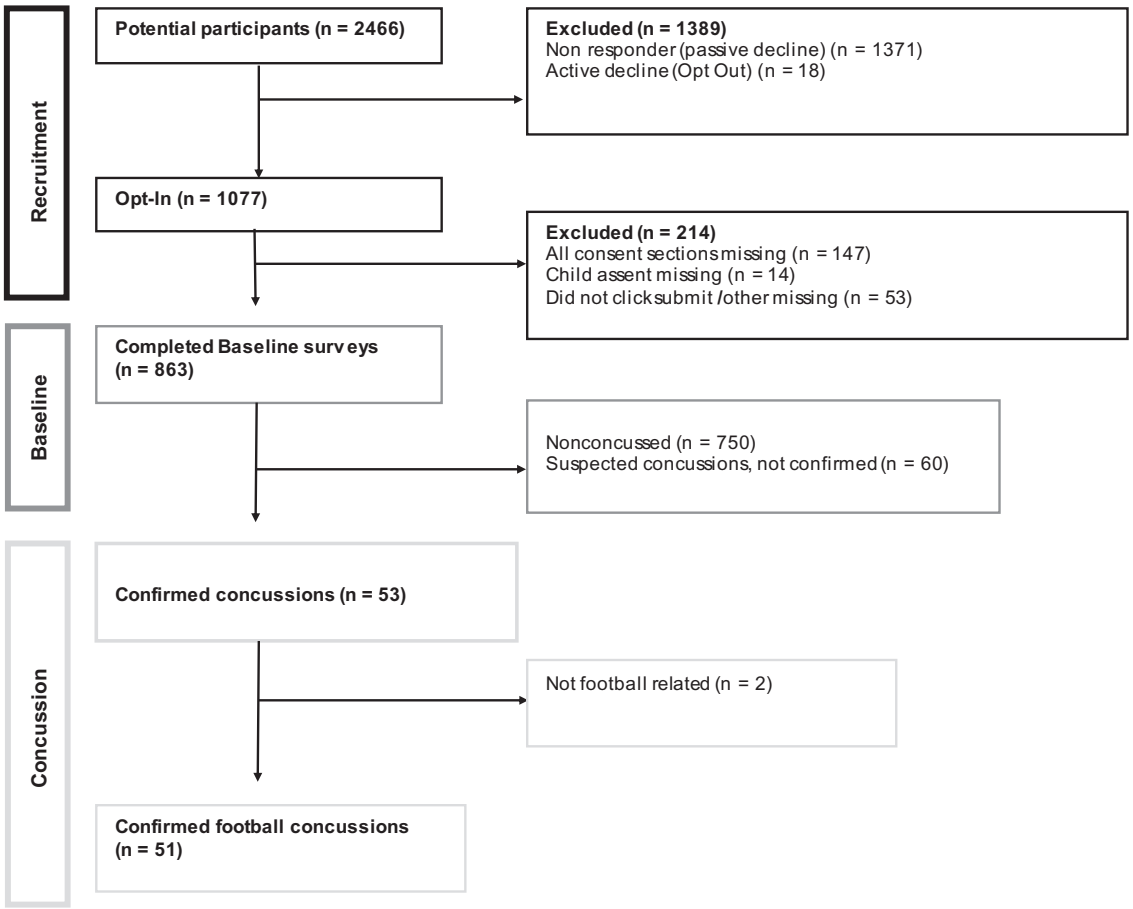

Figure 1. CONSORT diagram for youth football study, Seattle, Washington, 2016-18.

athletic trainers and study staff identified 113 potential concussions, 53 of which were clinician confirmed, and 2 of which occurred outside of football and thus were not counted in the incidence rate, yielding a per-season incidence rate of 5.1% (51 confirmed football-related concussions/996 player-seasons). The 2 individuals with non-football-related concussions (one from skateboarding and the other from a fall) were not included in further analyses. Individuals with suspected but not confirmed concussions were also not included in any further analyses.

Characteristics of the initial youth cohort and the concussed subset are shown in **Table I**. Multivariable logistic regression analysis (**Table II**) suggested that youth with a prior concussion were significantly more likely to sustain an incident concussion (OR, 2.2; 95% CI, 1.1-4.8; $P = .04$). Concussed and nonconcussed athletes did not differ regarding history of attention problems, anxiety, or headaches. History of depression was significantly associated with risk of concussion (OR, 5.6; 95% CI,1.7-18.8), but we presented analyses both with and without this factor because the number of youth with a history of depression was small (**Table III**; available at www.jpeds.com).

Information regarding mechanism was obtained on all 51 of the football-related concussions (see **Table III** for further details). Two-thirds occurred during a game and one-third during practice, and almost one-half (47%) were due to head to head collisions. Nearly two-thirds (59%) of youth with concussion were removed from play immediately, 24% later the same game or practice, and 14% (7 athletes) were not removed from that game/practice. Six of the 7 athletes who were not removed did not experience symptoms until after the game (not uncommon for individuals with sport-related concussion). One initially felt symptomatic during the game, but then had symptoms resolve so did not report until after the game. The most common concussion symptoms were headache, fatigue, and difficulty concentrating. A small proportion of concussed youth (8%) experienced a loss of consciousness.

Time to return to school, sport, and baseline symptoms are shown in **Figure 2**. Nearly all youth (90%) returned to school by 9 days (mean, 6.7 days; median, 3.0 days; IQR, 2-6 days). Several youth (n = 11) sustained a concussion in the summer before the start of school and thus were not included in the return to school analysis. Returning to sport took longer, with 90% back by 1 month (mean, 19.3 days; median, 13.0 days; IQR, 9-20 days). One youth was concussed near the end of the season and thus return to sport was censored. Returning to baseline level of symptoms took the longest, with 90% back to baseline by 2 months. Of note, youth were not considered to have returned to baseline level of symptoms unless both

Table II. Odds of confirmed football-related concussion vs no concussion during 1 football season associated with each baseline factor, adjusted for all factors indicated, accounting for clustering by individual (Seattle, 2016-2018)*,†

	OR‡	(95% CI)	OR§	(95% CI)
Child age (y)				
5-7	1.0	Referent	1.0	Referent
8-10	2.91	(0.66-12.95)	2.85	(0.65-12.49)
11-12	2.12	(0.46-9.69)	2.10	(0.47-9.37)
13-14	2.88	(0.57-14.45)	2.78	(0.57-13.48)
Sex				
Male	1.0	Referent	1.0	Referent
Female	1.95	(0.26-14.63)	2.25	(0.30-16.79)
Responding parent education				
High school or less than high school	1.0	Referent	1.0	Referent
Some college, no degree	1.42	(0.36-5.56)	1.34	(0.35-5.12)
College degree	1.22	(0.37-4.06)	1.19	(0.36-3.90)
Masters or professional degree	0.47	(0.10-2.15)	0.47	(0.10-2.17)
Ethnicity				
Not Hispanic or Latino	1.0	Referent	1.0	Referent
Hispanic or Latino	1.80	(0.66-4.90)	1.67	(0.66-4.23)
Race				
White	1.0	Referent	1.0	Referent
Black or African-American	0.25	(0.03-1.96)	0.27	(0.03-2.14)
Asian	0.86	(0.20-3.68)	0.71	(0.18-2.86)
American Indian, Alaskan Native, Native Hawaiian or Other Pacific Islander, or >1 race	0.19	(0.02-1.5)	0.18	(0.02-1.51)
History of prior concussion	**2.24**	**(1.05-4.75)**	1.98	(0.93-4.21)
History of depression	—		**5.59**	**(1.66-18.77)**
History of attention problems	0.99	(0.35-2.77)	0.83	(0.30-2.34)
History of headaches/migraines	1.52	(0.70-3.32)	1.40	(0.61-3.17)
Years playing football (including current year)				
1	1.35	(0.63-2.87)	1.32	(0.62-2.8)
2	1.12	(0.48-2.66)	1.10	(0.46-2.61)
≥3	1.0	Referent	1.0	Referent

Bold values refer to those Odds Ratios which are significant at $P < .05$.
*Children with suspected but not confirmed concussion were excluded from all analyses.
†The unit of analysis was the player-season; thus, players enrolled both years were included twice. Clustering by individual was accounted for in all analyses.
‡Covariates include all factors shown except for history of depression.
§Covariates include all factors shown.

parent report of child symptoms and child self-report had returned to baseline levels. About one-third of athletes (n = 16) returned to sport before return to baseline level of symptoms, using both child and parent report. However, for one-half of these subjects either the parent or child reported low levels of symptoms at time of return to sport (HBI total of 10 or less, consistent with normative levels).[40] Therefore, only 3 athletes returned to sport while clearly symptomatic from both athlete and parent perspective (2%), two within 1 week of concussion and one 29 days after injury.

Discussion

We report a higher incidence of concussion in this youth football sample (5.1%); the reported rate in prior studies ranged from 0.9%[12,14] to 4.4%.[13] These differences seem to be explained by data collection methods. Peterson et al relied on team managers to provide injury reports, resulting in a very low reported concussion incidence of 0.9% per season.[14] Dompier et al analyzed data from the Youth Football Surveillance System, which used athletic trainer report, and they described concussion rates for 5- to 14-year old youth of 3.1%-3.5% annually.[12] Kontos et al collected data on 8- to 12-year-old youth using research coordinators present at games and coach contact weekly, and reported concussion rates more similar to ours (4.4%).[13] For the current study, we provided athletic trainers for all games and asked parents and coaches to report concussions that occurred in practice to ensure adequate injury surveillance. It is likely that our estimates were higher than previous studies[14] not due to increased risk, but to greater identification of injuries given a higher level of medical surveillance. This finding is consistent with prior work showing that schools with athletic trainers have higher reported rates of concussion,[41] and supports recommendations from the American Academy of Pediatrics recommending athletic trainer coverage as a standard for youth football.[42] In the absence of any medical presence, it is likely that some youth with concussion are not diagnosed, resulting in youth playing while experiencing concussive symptoms and risking greater injury and prolonged recovery.[43-47] The higher concussion rates found in our study may also be due to the combination of concussion legislation and media attention that has resulted in greater numbers of concussions being diagnosed.[48,49]

We also examined risk factors for football-related concussion in this sample of youth athletes, finding that both history of prior concussion and history of depression were associated with greater risk for incident concussion. History of prior concussion has been reported as a risk factor for concussion in multiple prior studies,[23-26] likely owing to its function as a marker of risk. In other words, a prior history of concussion suggests a greater propensity to concussion, whether owing to genetic factors or environmental exposure (such as style of play or position). To our knowledge, depression history has not previously been reported as a risk factor for concussion in a prospective manner. Studies have reported an association between depression and concussion,[50] as well as increases in risk of depression after either a single or multiple concussions.[51-53] In addition, there is evidence for a relationship between depression and persistent symptoms of concussion,[54] and treatments for depression (such as cognitive-behavioral therapy and medication) have been found to be beneficial for treating youth with persistent concussion symptoms.[55] In sum, the relationship between depression and concussion is complex and this study adds important data on younger players. It is possible that athletes with a history of depression are more sensitive to their own symptoms and thus more likely to report them and be diagnosed with a concussion. It is also possible that a history of depression is in some manner linked to a greater susceptibility for concussion, perhaps owing to the increased risk taking associated with depression.[56,57] However, the estimates regarding depression in the current study were based on small numbers, and further research is needed to confirm and understand this relationship. Prior studies have reported that history of headaches[23,27] and attention problems[23] were risk

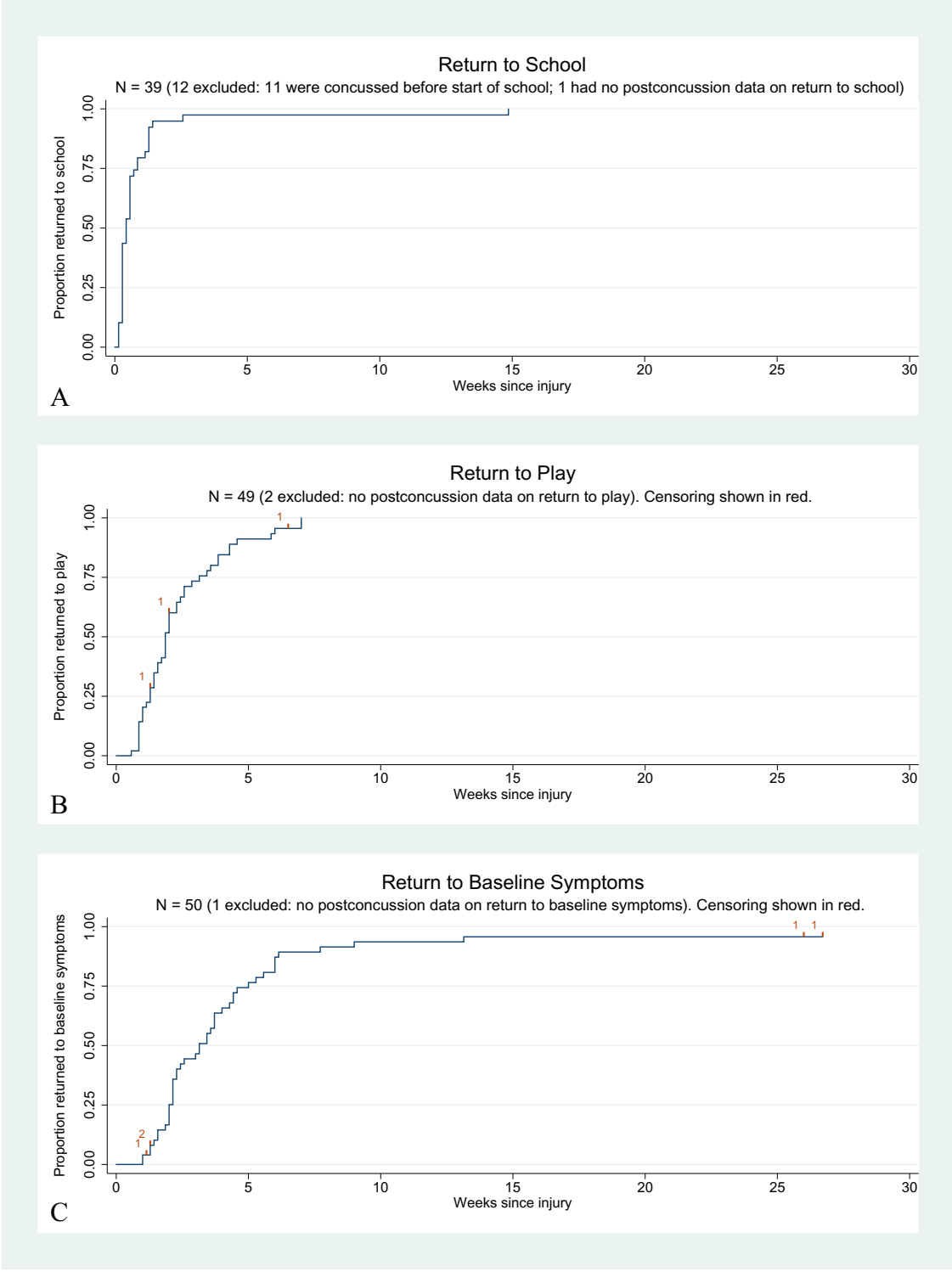

Figure 2. Kaplan-Meier survival curves illustrating **A,** time to return to school full-time **B,** time to return to sport and **C,** time to return to baseline level of symptoms following concussion in Seattle youth football players, 2016-18.

factors for incident concussion, but they were not significant risk factors in this study.

There is currently a dearth of studies regarding natural history of concussive symptoms and return to school and sport in youth younger than high school. Kerr et al reported 16% of concussed youth 5-14 years old returned to sport in more than 1 month, similar to the levels we report here (10% waited longer than 1 month).[58] Studies in clinical populations have reported more prolonged durations of symptoms, likely because individuals who seek care for concussion either have more

severe injury or greater distress, both of which increase the likelihood of prolonged symptoms.[59,60] Thomas et al reported that 21% of youth 10-12 years old and 53% of those 13-15 years old were still symptomatic 28 days after injury.[18] We believe our estimates are likely more representative of the true natural history in this age group given that we are sampling directly from sports teams, but further research is needed in this area.

Three youth in this study were confirmed to have returned to sport before complete resolution of symptoms, which was not in line with the Zurich consensus guidelines used at the time.[61] It is possible that additional youth might have minimized symptoms, and thus the true number returning while symptomatic may be greater. Although the return of these youth was not excessively rapid, with 2 returning 7 days after injury (an adequate amount of time to complete a graduated return to sport) and the other 29 days after injury, it is still concerning that they may have played while not fully recovered, which would place them at risk for more severe injury.[62] When managing extremity injuries such as fractures and strains, time since injury is used in combination with clinical examination and symptom report to determine readiness to return to sport,[63] and perhaps a similar strategy should be used for concussion. Further research is also needed to develop and refine objective measures that would allow us the ability to determine readiness to return to sport without relying on symptom report.

This study was limited by a moderate participation rate (35%), which increases susceptibility to bias, because more conscientious athletes and parents might have chosen to participate. However, the group that participated was large (>900 player-seasons), and we were able to obtain follow-up measures on all individuals in the sample who sustained a concussion. An additional limitation arose from the moderate number of concussed athletes.[51] Although we followed a large number of athletes, concussion is rare and this limited the final sample size of injured athletes. Given the dearth of studies in the literature examining concussion in youth football, the methodologic limitations of those studies, and the complexity of completing prospective cohort studies on relatively rare injuries, we believe this study adds significantly to the evidence base regarding football-related concussion in youth.

Further longitudinal research is needed with larger samples to affirm these findings, better understand the appropriate timing of return to school and sport, and explore potential means for prevention of both head impact exposure and concussion for youth football athletes. ■

Submitted for publication Jul 19, 2018; last revision received Oct 18, 2018; accepted Nov 2, 2018

Reprint requests: Sara P. D. Chrisman, MD, MPH, Center for Child Health, Behavior and Development, Seattle Children's Research Institute, PO Box 5371, CW 8/6, Seattle, WA 98145. E-mail: sara.chrisman@seattlechildrens.org

References

1. Langhorst P. Youth sports participation statistics and trends. Engage Sports 2016;http://www.engagesports.com/blog/post/1488/youth-sports-participation-statistics-and-trends. Accessed August 4, 2017. [Internet].
2. Smith JJ, Eather N, Morgan PJ, Plotnikoff RC, Faigenbaum AD, Lubans DR. The health benefits of muscular fitness for children and adolescents: a systematic review and meta-analysis. Sports Med 2014;44:1209-23. [Internet].
3. Leopold SS, Dobbs MB. Editorial: orthopaedic surgeons should recommend that children and young adults not play tackle football. Clin Orthop Relat Res 2016;474:1533-7. [Internet].
4. Bryan MA, Rowhani-Rahbar A, Comstock RD, Rivara F, Seattle Sports Concussion Research Collaborative. Sports- and recreation-related concussions in US youth. Pediatrics 2016;138:http://www.ncbi.nlm.nih.gov/pubmed/27325635. Accessed September 19, 2016. [Internet].
5. Marar M, McIlvain NM, Fields SK, Comstock RD. Epidemiology of concussions among United States high school athletes in 20 sports. Am J Sports Med 2012;40:747-55. [Internet].
6. Marshall SW, Guskiewicz KM, Shankar V, McCrea M, Cantu RC. Epidemiology of sports-related concussion in seven US high school and collegiate sports. Inj Epidemiol 2015;2:13. [Internet].
7. O'Connor KL, Baker MM, Dalton SL, Dompier TP, Broglio SP, Kerr ZY. Epidemiology of sport-related concussions in high school athletes: National Athletic Treatment, Injury and Outcomes Network (NATION), 2011-2012 through 2013-2014. J Athl Train 2017;52:175-85. [Internet].
8. Castile L, Collins CL, McIlvain NM, Comstock RD. The epidemiology of new versus recurrent sports concussions among high school athletes, 2005-2010. Br J Sports Med 2012;46:603-10. [Internet], 2011/12/07.
9. Gessel LM, Fields SK, Collins CL, Dick RW, Comstock RD. Concussions among United States high school and collegiate athletes. J Athl Train 2007;42:495-503. [Internet], 2008/01/05.
10. Rosenthal JA, Foraker RE, Collins CL, Comstock RD. National high school athlete concussion rates from 2005-2006 to 2011-2012. Am J Sports Med 2014;42:1710-5. [Internet].
11. Meehan WP, d'Hemecourt P, Comstock RD. High school concussions in the 2008-2009 academic year: mechanism, symptoms, and management. Am J Sports Med 2010;38:2405-9. [Internet].
12. Dompier TP, Kerr ZY, Marshall SW, Hainline B, Snook EM, Hayden R, et al. Incidence of concussion during practice and games in youth, high school, and collegiate American football players. JAMA Pediatr 2015;169:659. [Internet].
13. Kontos AP, Elbin RJJ, Fazio-Sumrock VC, Burkhart S, Swindell H, Maroon J, et al. Incidence of sports-related concussion among youth football players aged 8-12 years. J Pediatr 2013;163:717-20. [Internet].
14. Peterson AR, Kruse AJ, Meester SM, Olson TS, Riedle BN, Slayman TG, et al. Youth football injuries: a prospective cohort. Orthop J Sports Med 2017;5:232596711668678. [Internet].
15. Kerr ZY, Cortes N, Caswell AM, Ambegaonkar JP, Hallsmith KR, Milbert AF, et al. Concussion rates in U.S. middle school athletes, 2015-2016 school year. Am J Prev Med 2017;53:914-8. [Internet].
16. Babikian T, Merkley T, Savage RC, Giza CC, Levin H. Chronic aspects of pediatric traumatic brain injury: review of the literature. J Neurotrauma 2015;32:1849-60. [Internet].
17. Alic S. Participation for tackle and flag football increases in 2015 [Internet]. USA Football Blog. https://web.usafootball.com/blogs/steve-alic/post/11740/participation-for-tackle-and-flag-football-increases-in-2015. Accessed April 8, 2017. 2016.
18. Thomas DJ, Coxe K, Li H, Pommering TL, Young JA, Smith GA, et al. Length of recovery from sports-related concussions in pediatric patients treated at concussion clinics. Clin J Sport Med 2017;1:http://www.ncbi.nlm.nih.gov/pubmed/28085687. Accessed May 4, 2017. [Internet].
19. Zemek RL, Farion KJ, Sampson M, McGahern C. Prognosticators of persistent symptoms following pediatric concussion: a systematic review. JAMA Pediatr 2013;167:259-65. [Internet].
20. Meehan WP, Mannix RC, O'Brien MJ, Collins MW. The prevalence of undiagnosed concussions in athletes. Clin J Sport Med 2013;23:339-42. [Internet].
21. Fehr SD, Nelson LD, Scharer KR, Traudt EA, Veenstra JM, Tarima SS, et al. Risk factors for prolonged symptoms of mild traumatic brain injury. Clin J Sport Med 2017;1:http://www.ncbi.nlm.nih.gov/pubmed/29084034. Accessed July 18, 2018. [Internet].

22. Tsushima WT, Siu AM, Ahn HJ, Chang BL, Murata NM. Incidence and risk of concussions in youth athletes: comparisons of age, sex, concussion history, sport, and football position. Arch Clin Neuropsychol 2018;http://www.ncbi.nlm.nih.gov/pubmed/29554189. Accessed April 4, 2018. [Internet].
23. Brett BL, Kuhn AW, Yengo-Kahn AM, Solomon GS, Zuckerman SL. Risk factors associated with sustaining a sport-related concussion: an initial synthesis study of 12,320 student-athletes. Arch Clin Neuropsychol 2018;http://www.ncbi.nlm.nih.gov/pubmed/29471410. Accessed April 24, 2018. [Internet].
24. Burman E, Lysholm J, Shahim P, Malm C, Tegner Y. Concussed athletes are more prone to injury both before and after their index concussion: a data base analysis of 699 concussed contact sports athletes. BMJ Open Sport Exerc Med 2016;2:e000092. [Internet].
25. Hides JA, Franettovich Smith MM, Mendis MD, Treleaven J, Rotstein AH, Sexton CT, et al. Self-reported concussion history and sensorimotor tests predict head/neck injuries. Med Sci Sports Exerc 2017;1:http://www.ncbi.nlm.nih.gov/pubmed/28708701. Accessed August 16, 2017. [Internet].
26. Yeung A, Munjal V, Virji-Babul N. Development of the Sports Organization Concussion Risk Assessment Tool (SOCRAT). Brain Inj 2017;31:542-9. [Internet].
27. Terry DP, Wojtowicz M, Cook NE, Maxwell BA, Zafonte R, Seifert T, et al. Factors associated with self-reported concussion history in middle school athletes. Clin J Sport Med 2018;1:http://www.ncbi.nlm.nih.gov/pubmed/29601349. Accessed July 18, 2018. [Internet].
28. McCrory P, Meeuwisse WH, Aubry M, Cantu RC, Dvořák J, Echemendia RJ, et al. Consensus statement on concussion in sport: the 4th International Conference on Concussion in Sport, Zurich, November 2012. J Athl Train 2014;48:554-75. [Internet].
29. Hänninen T, Parkkari J, Tuominen M, Iverson GL, Öhman J, Vartiainen M, et al. Interpreting change on the SCAT3 in professional ice hockey players. J Sci Med Sport 2017;20:424-31. [Internet].
30. Davis GA, Purcell L, Schneider KJ, Yeates KO, Gioia GA, Anderson V, et al. The Child Sport Concussion Assessment Tool 5th edition (Child SCAT5). Br J Sports Med 2017;http://www.ncbi.nlm.nih.gov/pubmed/28446452. Accessed May 2, 2017. [Internet], bjsports-2017-097492.
31. Ayr LK, Yeates KO, Taylor HG, Browne M. Dimensions of postconcussive symptoms in children with mild traumatic brain injuries. J Int Neuropsychol Soc 2009;15:19-30. [Internet].
32. Taylor HG, Dietrich A, Nuss K, Wright M, Rusin J, Bangert B, et al. Post-concussive symptoms in children with mild traumatic brain injury. Neuropsychology 2010;24:148-59. [Internet].
33. Moran L. Do postconcussive symptoms discriminate injury severity in pediatric mild traumatic brain injury? Changes 2012;29:997-1003.
34. Fay TB, Yeates KO, Taylor HG, Bangert B, Dietrich A, Nuss KE, et al. Cognitive reserve as a moderator of postconcussive symptoms in children with complicated and uncomplicated mild traumatic brain injury. J Int Neuropsychol Soc 2010;16:94-105. [Internet].
35. Hajek CA, Yeates KO, Taylor HG, Bangert B, Dietrich A, Nuss KE, et al. Agreement between parents and children on ratings of post-concussive symptoms following mild traumatic brain injury. Child Neuropsychol 2011;17:17-33. [Internet].
36. Lovell MR, Iverson GL, Collins MW, Podell K, Johnston KM, Pardini D, et al. Measurement of symptoms following sports-related concussion: reliability and normative data for the post-concussion scale. Appl Neuropsychol 2006;13:166-74. [Internet], 2007/03/17.
37. Kontos AP, Elbin RJ, Schatz P, Covassin T, Henry L, Pardini J, et al. A revised factor structure for the post-concussion symptom scale: baseline and postconcussion factors. Am J Sports Med 2012;40:2375-84. [Internet].
38. McLeod TCV, Leach C. Psychometric properties of self-report concussion scales and checklists. J Athl Train 2012;47:221-3.
39. Chin EY, Nelson LD, Barr WB, McCrory P, McCrea MA. Reliability and validity of the Sport Concussion Assessment Tool-3 (SCAT3) in high school and collegiate athletes. Am J Sports Med 2016;http://www.ncbi.nlm.nih.gov/pubmed/27281276. Accessed June 29, 2016. [Internet].
40. Brooks MA, Snedden TR, Mixis B, Hetzel S, McGuine TA. Establishing baseline normative values for the child sport concussion assessment tool. JAMA Pediat,2017;171:670. American Medical Association. [Internet].
41. Kroshus E, Rivara FP, Whitlock KB, Herring SA, Chrisman SPD. Disparities in athletic trainer staffing in secondary school sport: implications for concussion identification. Clin J Sport Med 2017.
42. Council on Sports Medicine and Fitness. Tackling in youth football. Pediatrics 2015;136:e1419-30. [Internet].
43. Asken BM, McCrea MA, Clugston JR, Snyder AR, Houck ZM, Bauer RM. "Playing through it": delayed reporting and removal from athletic activity after concussion predicts prolonged recovery. J Athl Train 2016;51:329-35. [Internet].
44. Elbin RJ, Sufrinko A, Schatz P, French J, Henry L, Burkhart S, et al. Removal from play after concussion and recovery time. Pediatrics 2016;138:e20160910. [Internet].
45. Heyer GL, Schaffer CE, Rose SC, Young JA, McNally KA, Fischer AN. Specific factors influence postconcussion symptom duration among youth referred to a sports concussion clinic. J Pediatr 2016l;174:33.e2-38.e2. [Internet].
46. Asken BM, Bauer RM, Guskiewicz KM, McCrea MA, Schmidt JD, Giza CC, et al. Immediate removal from activity after sport-related concussion is associated with shorter clinical recovery and less severe symptoms in collegiate student-athletes. Am J Sports Med 2018;46.
47. Howell DR, O'Brien MJ, Fraser J, Meehan WP. Continuing play, symptom severity, and symptom duration after concussion in youth athletes. Clin J Sport Med 2018;1:http://www.ncbi.nlm.nih.gov/pubmed/29337721. Accessed September 28, 2018. [Internet].
48. Gibson TB, Herring SA, Kutcher JS, Broglio SP. Analyzing the effect of state legislation on health care utilization for children with concussion. JAMA Pediatr 2015;169:163-8. [Internet].
49. Zhang AL, Sing DC, Rugg CM, Feeley BT, Senter C. The rise of concussions in the adolescent population. Orthop J Sports Med 2016;4:232596711666245. [Internet].
50. Chrisman SPD, Richardson LP. Prevalence of diagnosed depression in adolescents with history of concussion. J Adolesc Health 2014;54.
51. Didehbani N, Munro Cullum C, Mansinghani S, Conover H, Hart J. Depressive symptoms and concussions in aging retired NFL players. Arch Clin Neuropsychol 2013;28:418-24. [Internet].
52. Stazyk K, DeMatteo C, Moll S, Missiuna C. Depression in youth recovering from concussion: correlates and predictors. Brain Inj 2017;31:631-8. [Internet].
53. Vargas G, Rabinowitz A, Meyer J, Arnett PA. Predictors and prevalence of postconcussion depression symptoms in collegiate athletes. J Athl Train 2015;50:150219105224004. [Internet].
54. Iverson GL, Gardner AJ, Terry DP, Ponsford JL, Sills AK, Broshek DK, et al. Predictors of clinical recovery from concussion: a systematic review. Br J Sports Med 2017;51:941-8. [Internet].
55. McCarty CA, Zatzick D, Stein E, Wang J, Hilt R, Rivara FP, et al. Collaborative care for adolescents with persistent postconcussive symptoms: a randomized trial. Pediatrics 2016;http://www.ncbi.nlm.nih.gov/pubmed/27624513. Accessed September 19, 2016. [Internet].
56. Rice SM, Kealy D, Oliffe JL, Ogrodniczuk JS. Externalizing depression symptoms among Canadian males with recent suicidal ideation: a focus on young men. Early Interv Psychiatry 2018;http://www.ncbi.nlm.nih.gov/pubmed/29708308. Accessed July 18, 2018. [Internet].
57. Reyna VF, Farley F. Risk and rationality in adolescent decision making: implications for theory, practice, and public policy. Psychol Sci Public Interest 2006;7:1-44. [Internet], Reyna, Valerie F., Department of Human Development, Cornell University, B44 MVR Hall, Ithaca, NY, US, 14853.
58. Kerr ZY, Zuckerman SL, Wasserman EB, Covassin T, Djoko A, Dompier TP. Concussion symptoms and return to play time in youth, high school, and college American football athletes. JAMA Pediatr 2016;170:647. [Internet].

59. Chrisman SPSP, Quitiquit C, Rivara FPFP. Qualitative study of barriers to concussive symptom reporting in high school athletics. J Adolesc Health 2013;52:330.e3-335.e3. [Internet].
60. Kroshus E, Garnett B, Hawrilenko M, Baugh CM, Calzo JP. Concussion under-reporting and pressure from coaches, teammates, fans, and parents. Soc Sci Med 2015;134:66-75. [Internet].
61. McCrory P, Meeuwisse WH, Aubry M, Cantu B, Dvorak J, Echemendia RJ, et al. Consensus statement on concussion in sport: the 4th International Conference on Concussion in Sport held in Zurich, November 2012. Br J Sports Med 2013;47:250-8. [Internet], 2013/03/13.
62. Choe M, Barlow KM. Pediatric traumatic brain injury and concussion. Continuum (Minneap Minn) 2018;24:300-11. [Internet], Child Neurology.
63. Myklebust G, Bahr R. Return to play guidelines after anterior cruciate ligament surgery. Br J Sports Med 2005;39:127-31. [Internet].

50 Years Ago in *The Journal of Pediatrics*

Sensory Isolation Therapy of Autistic Children

Schechter MD, Shurley JT, Toussieng PW, Maier WJ. J Pediatr 1969;74:564-9.

Children with autism can have sensory symptoms including hyporesponsiveness, hyperresponsiveness, and sensory seeking.[1] Fifty years ago, it was perceived that children with autism are disturbed by these sensory experiences and develop defensiveness. This theory of sensory deprivation in autism formed the basis for sensory isolation therapy. Schecter et al reported their experiences with sensory isolation therapy in 3 autistic boys. The subjects were kept in a closed hospital room with a single mattress and a toilet for 40-74 days, provided food throughout the day, and their activities were viewed through an observation window. Authors observed that they became more sociable and more interested in people after isolation, which improved interaction with their parents. Later, Schopler and Reicher also explored the sensory deprivation theory to devise their sensory modulation therapies for children with autism.[2] This form of isolation experiment invited ethical concerns, there was no further research beyond the 1970s.

In last 50 years, we have moved far away from the theories of sensory deprivation and "refrigerator mother" to theories of altered neural connectivity, neuroinflammation, and synaptopathies in the pathogenesis of autism.[3] Early intensive, structured behavioral intervention remains the mainstay of treatment for addressing the core symptoms of autism spectrum disorder. Sensory symptoms are handled with sensory integration therapies rather than sensory isolation strategies. If enhanced sensations are provided to the child with a just right challenge, adaptive response takes place at the level of a synapse leading to a change in behavior.[4] Sensory integration therapies are often used in conjunction with other treatments to help a child with sensory problem experience an optimal level of arousal and regulation. Currently approved behavioral strategies also include applied behavior analysis, the treatment and education of autistic and communication related handicapped children (TEACCH) model of structured teaching, and other sensory integration therapies including sensory diet.

Jaya Shankar Kaushik, MD, DNB, DM
Department of Pediatrics
Pt B D Sharma PGIMS
Rohtak, Haryana, India

Piyush Gupta, MD, FAMS
Department of Pediatrics
University College of Medical Sciences
Delhi, India

References

1. Posar A, Visconti P. Sensory abnormalities in children with autism spectrum disorder. J Pediatr (Rio J) 2018;94:342-50.
2. Schopler E, Reichler RJ. Parents as co-therapists in the treatment of psychotic children. J Autism Child Schizophr 1971;1:87-102.
3. Watts TJ. The pathogenesis of autism. Clin Med Pathol 2008;1:99-103.
4. Kashefimehr B, Kayihan H, Huri M. The effect of sensory integration therapy on occupational performance in children with autism. Occup Particip Health 2017;38:75-83.

Table III. Characteristics of football-related concussions in a Seattle youth league, 2016-2018

	n	(%)
Location		
Game	33	(64.7)
Practice	18	(35.3)
Mechanism of injury		
Head to head	24	(47.0)
Head to ground	19	(37.3)
Head to body	7	(13.7)
Missing	1	(2.0)
Removed from play		
Immediately	30	(58.8)
Later that game/practice	12	(23.5)
Not removed during game/practice	7	(13.7)
Missing	2	(4.0)
Loss of consciousness		
No	46	(90.2)
Yes	4	(7.8)
Missing	1	(2.0)
Grade in school		
2	1	(2.0)
3	4	(7.8)
4	7	(13.7)
5	9	(17.6)
6	7	(13.7)
7	9	(17.6)
8	14	(27.4)