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Original Article

Tracking postural stability of children and adolescents after a concussion: sport-related versus non-sport-related concussion

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ABSTRACT

Background. Although postural impairments have long been reported following a concussion in the pediatric population, we still know very little about who is more at risk of presenting those balance problems and how the mechanism of injury (sport vs non-sport) could influence balance problems after concussions.

The purpose of this study was to compare balance function in children having sustained a sport-related (SRC) or non-sport-related (NSRC) concussion, to that of children with an orthopedic injury (OI) and to non-injured (NI), over a one-year period.

Methods. One-hundred and twelve participants were included in this study. Among them, 38 were concussed, with 27 having sustained a SRC; and 11 an NSRC, as well as 38 NI, and 36 OI. Balance function was evaluated at 2 weeks, 3 months, 6 months, and 12 months after a concussion, and at the same time intervals for the control groups. The balance subtest of the Bruininks-Oseretsky Test of Motor Proficiency (BOT2) and Timed Foam Test was used to measure postural instability. Concussion related symptoms were measured by the Post Concussion Symptom Scale (PCSS).

Results. There was an improvement in tandem standing on the balance beam (P=.02) and in single-leg standing (SL) on foam surface (P=.02) for all groups over a year. At the 2nd week, NSRC had more postural instability than NI during SL on the balance beam when eyes were closed (P =.01), and performed significantly worse than SRC (P =.01) and NI (P =.01) during SL on the foam surface. NSRC also reported more symptoms than SRC on PCSS (P <0.001). In the 3rd month, NSRC still had lower performance than SRC in SL on foam surface (P =.01).

Conclusions. Children sustaining a concussion outside of a sport seem to have higher levels of postural instability up to 3 months post-injury when compared to those injured in sport.

Key words: mild traumatic brain injury, balance, sport related concussion, non-sport related concussion.

Concussion is a growing public health concern affecting more than 1.2 million people in the USA annually.[1] The reported incidence rate has increased fourfold among high school students between 2000 and 2011 due to public awareness and increased attention to injury.[2] Concussion, also referred to as mild traumatic brain injury (mTBI), results from acceleration and deceleration movement of the brain within the skull through external forces acting on the body.[3] The most common causes of concussions in youth are from falls, collisions or sport related contact impacts.[2] In fact, 53.4 % of the concussions occur in children between the ages 10-14 and concussions account for 9-12% of all injuries in high school athletes.[1] Regardless of age, individuals mainly complain of headaches, fatigue, confusion, dizziness as initial symptoms after sustaining a concussion.[2,3] Moreover, a significant number of people also experience cognitive and motor dysfunctions

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such as attention deficit, reduced concentration, balance deficit, and gait dysfunction.[4,5] Various measurement methods are used for the assessment of balance in concussion such as patient reported outcomes, measurement scales, and laboratory analysis systems in both adult and pediatric population.[6,7] Using motion analysis systems (MAS), balance dysfunction, such as abnormal body sway, was reported to occur in adults even nine month after the injury[8] and it was reported up to one month in adolescents.[9] Indeed, available studies using MAS did not measure balance deficit in long term in concussed adolescents. Moreover, there is no study measuring postural instability by MAS in children with mTBI. On the other hand, performance based measures evaluating both static and dynamic postural stability have been frequently used in the pediatric population. Such a study showed persistent balance deficit up to three months post-concussion,[10] and it was reported by another study continuing up to six months post-injury.[6] However, the evidence supporting the time to recovery from balance deficit among concussed children still remains inconclusive.

The recovery of post-concussion symptoms has been associated with the mechanism of injury.[7] Many concussions are sustained during a sport activity, and much has been done in the way of prevention, evaluation and management programs of sport-related concussions (SRC).[1,2] However, a significant proportion of pediatric injuries also occurs outside of sports, mainly resulting from falls, assaults, motor vehicle or bicycle collisions.[11] Even though SRC is getting much attention in both clinical and research communities, the severity of symptoms for the non-sport related concussion (NSRC) also needs to be characterized. There might exist some differences in outcome, as athletes may be more aware of the risk of concussions, and informed on how to be react with resilience to a concussive injury. In addition, athletes may have better endurance and body strength owing to their training habits, and may recover differently from the impairments brought upon by the brain injury. Nonetheless, persistence of postural instability could be a potential risk factor for sustaining a second injury both for children with SRC and NSRC. To achieve a better understanding of the recovery of balance deficits we saw a need to measure balance symptoms over the course of one-year post-concussion and examine whether recovery occurred in a similar manner between children with SRC and NSRC and when compared to children without concussions.

This study therefore aimed to estimate the extent to which concussed children and adolescents experience balance deficits up to one year following the injury, when compared to orthopedically-injured and non-injured peers; as well as to uncover the extent to which performance in balance function in NSRC may differ from that in SRC. We hypothesized that children and adolescents having sustained a concussion in a sport event would tend to show faster recovery from imbalance as they may have higher skills when considering that they are under a training program before the injury.

Material and Methods

Participants

We recruited 38 subjects with a concussion presenting consecutively to the Concussion Clinic of the Trauma Programs at Montreal Children's Hospital of the McGill University Health Center in Montreal, Canada as per the following definition: Glasgow Coma Scale of 13-15 score after 30 minutes post-injury or later upon presentation for the healthcare provider; and presenting with at least one of the following signs : confusion or disorientation, loss of consciousness for 30 minutes or less, post-traumatic amnesia for less than 24 hours, and/or other transient neurological abnormalities such as focal signs, seizure, and intracranial lesion not requiring surgery.[12] We excluded children if they had a history of concussion in the previous year. Children within the concussion group were separated into two groups, on the basis of the mechanism of their injury; SRC and NSRC.

As controls, we included 38 non-injured (NI) children and 36 children with a minor upper extremity injury (OI) such as shoulder dislocation, wrist sprain, and finger fracture that would restrict physical activities but not interfere with testing. Controls were matched as much as possible to the concussed children based on the Activity Rating Scale (ARS), a tool developed to assess general level of participation in physical activity in the context of epidemiological studies.[13] We excluded participants if they did not speak in French or English, or had a pre-morbid medical diagnosis of learning disabilities, attention-deficit, and hyperactivity disorder or behavior problems.

Outcome Measures

We measured the balance of the participants with the Bruininks- Oseretsky Test of Motor Proficiency, Second Edition (BOT2) balance subscale[14], a Timed Foam Test[15] and using selected items from Post-Concussion Symptom Scale (PCSS).[16] The BOT2 is a reliable and valid assessment tool for the fine and gross motor skill of children and youth between the age of 4 and 21 years and has eight subtests including a scale for balance function.[14] The balance subtest comprises nine items, and evaluates both dynamic and static balance skills such as tandem walking on a line or tandem standing on a beam.[17] Because the items of the BOT2 vary in difficulty levels, we chose two most difficult items for individual analysis; item 8 (single leg standing on balance beam) and item 9 (heel-to-toe standing on balance beam).

The Timed Foam Test is a reliable, practical and cost-effective way to assess postural stability on an unstable surface.[15] Participants were instructed to stand on a foam pad (Airex balance pad) with their hands on their hips in three different foot positions when eyes were closed: Double-leg stance with feet together (FT), single leg stance (SL) and heel-to-toe stance (HT). Participants were asked to maintain stability in these positions for a maximum of 20 seconds with their eyes closed conditions.[15] The performance was recorded as the number of seconds the positions could be held without moving out of the position.

Self-reported post-concussion symptoms were assessed using the PCSS. The PCSS is composed of 22 items scored using a Likert scale ranging from 0 (no difficulty) to 6 (severe difficulty). The reliability and validity of the PCSS are well-documented.[16,18] For the purpose of this study, along with PCSS total score, we also analyzed the "balance problems" item individually.

Procedure

Approval for this study was obtained from the Research Ethics Board of the McGill University Health Center (12-190-PED). Assessments of children meeting inclusion criteria were performed at the Trauma Center of The Montreal Children's Hospital. Children and their parents were informed about the test procedures, and informed consent was signed before the data collection. All assessments were completed by a pediatric physical therapist who was blind to the group status of the child. Assessments were performed within 2 weeks of injury, and then again 12 weeks, 6months and 12 months post-injury for concussed children and adolescents, and at corresponding time intervals for controls.

Data Analyses

The primary outcome of this study was balance as measured using BOT2-balance scale, Foam test and PCSS-balance score, and the secondary outcome was post concussion symptoms on PCSS. The predictor variable was the type of group (concussed group vs controls). Differences in participant socio-demographic and clinical information (e.g., age, gender, dominant foot, Physical Activity Level, Parent Educational Level) between the experimental and control groups were examined using Chi-Square Test and One Way ANOVA Test. The data was examined for normality using Shapiro-Wilk test. A two-way ANOVA with repeated measures was used to examine main time and group effects, as well as time x group interactions for all outcome measures. When

applicable, pairwise comparisons were used to determine group and time differences. The level of significance was set at $p < 0.05$ for all analyses. All analyses were done using IBM SPSS Statistics version 23.

Results

A total of 112 (mean age 11.86 ± 2.97 years) participants were enrolled in the study with males being slightly overrepresented across all groups (63.39 %). Among concussed children, 71.01 % had sustained a sport-related concussion (n=27), while others experienced falls or motor vehicle collisions (n=11). There were no differences in gender, dominant foot, physical activity level and parent educational level among the four groups ($p > 0.05$). The only difference was in age ($p=0.003$) where participants with OI and NSRC were slightly younger than those in the NI and SRC groups. Majority of concussed children complained of headache (86.84 %) and dizziness (60.53 %) at the time of injury (Table I). The performance of children on outcome measures at three time points were presented in Table II.

Table I. Demographic and clinical characteristics by group.

Characteristic	Concussed Group		NI Group	OI Group	p
	SRC (n= 27)	NSRC (n= 11)	(n= 38)	(n= 26)	
	(Mean±Sd)	(Mean±Sd)	(Mean±Sd)	(Mean±Sd)	
Age	13.19±3.1	10.45±2.7	12.31±2.99	10.81±2.47	0.03
	Number (%)	Number (%)	Number (%)	Number (%)	
Gender					
Female	10 (37.04)	5(45.45)	14 (36.84)	12 (33.33)	0.91
Male	17 (62.96)	6(54.55)	24 (63.16)	24 (66.66)	
Physical activity level					
Much more than others	14 (51.85)	2 (18.18)	9 (23.68)	6 (16.66)	0.07
More than others	7 (25.92)	3 (27.27)	12 (31.58)	15 (41.66)	
Same as others	4 (14.81)	6 (54.54)	16 (42.11)	13 (36.11)	
Less than others	2 (7.41)	0(0.0)	1 (2.63)	2 (5.55)	
Parent educational level					
Not identified	4 (14.81)	0 (0.00)	0 (0.00)	1 (2.78)	0.39
High school	7 (25.93)	4 (36.36)	6 (15.79)	3 (8.33)	
College	6 (22.22)	3 (27.27)	9 (23.68)	13 (36.11)	
University	3 (11.11)	5 (45.45)	21 (55.26)	19 (52.78)	
Dominant foot					
Right	24 (88.89)	9 (81.82)	36 (94.73)	31 (86.11)	0.53
Left	3 (11.11)	2 (18.18)	2 (5.26)	5 (13.88)	
Initial symptoms					
Confused	9 (33.33)	4 (36.36)			0.57
Vomit	6 (22.22)	5 (45.45)			0.15
Headache	23 (85.19)	10 (90.90)			0.54
Dizziness	17 (62.96)	6 (54.54)			0.45
LOC					
No LOS	19 (70.37)	10 (90.91)			0.17
0-10 mi	8 (29.63)	1 (9.09)			

SRC: sport-related concussion, NSRC: non-sport related concussion, NI: non-injured group, OI: orthopedically-injured, LOS: loss of consciousness

Table II. Analysis of mean and standard deviation for findings on outcome measures (Mean±Sd).

Variable	Groups	2 weeks	12 week	6 months	12 months
BOT Score (n=109)					
Balance subtest	Concussed group	15.05±4.14	14.84±3.81	16.73±3.59	15.92±4.27
	SRC	15.48±3.5	15.52±4.10	17.41±3.57	16.15±4.25
	NSRC	13.90±5.6	13.00±2.10	14.90±3.10	15.30±4.49
	NI group	15.46±3.73	15.81±5.07	15.76±3.92	15.86±3.30
	OI group	14.26±4.54	14.34±3.46	13.86±4.41	15.54±4.05
Item 8	Concussed group	3.68±0.66	3.86±0.41	3.89±0.38	3.95±0.22
	SRC	3.77±0.84	3.93±0.26	3.96±0.19	3.96±0.19
	NSRC	3.40±0.84	3.70±0.67	3.70±0.67	3.90±0.31
	NI group	3.89±0.38	3.86±0.41	3.89±0.38	3.97±0.16
	OI group	3.74±0.55	3.74±0.55	3.66±0.63	3.83±0.51
Item 9	Concussed group	2.89±1.10	2.62±1.10	3.30±1.05	3.14±1.35
	SR	3.00±1.07	2.78±1.12	3.44±1.12	3.30±1.29
	NSR	2.60±1.17	2.20±1.03	2.90±0.73	2.70±1.49
	NI group	2.76±1.23	2.78±1.25	2.78±1.22	2.86±1.14
	OI group	2.54±1.31	2.46±0.95	2.54±1.14	2.83±1.29
TFT (n=103)					
Foot Together	Concussed group	18.73±3.66	20.00±0.00	20.00±0.00	19.89±0.58
	SRC	18.24±5.26	20.00±0.00	20.00±0.00	20.00±0.00
	NSRC	18.89±3.04	20.00±0.00	20.00±0.00	19.85±0.67
	NI group	19.68±1.72	20.00±0.00	19.86±0.82	20.00±0.00
	OI group	19.66±2.47	20.00±0.00	19.91±0.56	19.61±1.62
Single Leg	Concussed group	4.43±2.93	6.43 ±5.08	5.87±3.86	6.10±4.11
	SRC	5.05±3.13	7.33±5.56	6.26±4.00	6.00±3.73
	NSRC	2.63±0.95	3.79 ±1.48	4.74±3.34	6.36±5.29
	NI group	5.03±3.22	4.87±3.46	5.05±2.77	5.36±4.24
	OI group	3.78±1.58	4.51±2.73	3.93±1.91	3.78±1.86
Heel-to-toe	Concussed group	8.60±5.96	8.32±5.67	8.91±5.17	9.17±6.10
	SRC	9.44±5.96	8.27±5.30	9.12±5.32	10.30±6.41
	NSRC	6.14±5.54	8.44±6.98	8.30±4.96	5.05±2.67
	NI group	9.28±5.05	9.62±5.07	8.84±5.15	8.55±4.87
	OI group	6.12±4.16	6.57±4.39	7.94±4.39	7.54±3.98
PCSS (n=97)					
Total score	Concussed group	9.16±15.40	3.16±6.47	4.16±10.95	1.50±3.81
	SRC	6.15±7.97	3.35±6.91	2.58±4.30	3.50±7.63
	NSRC	22.17±30.0	2.33±4.41	11.00±24.13	1.04±2.27
	NI group	1.67±2.16	1.91±4.18	1.61± 2.89	1.52± 3.75
	OI group	2.16±6.01	1.13±2.74	1.09±3.70	0.81±3.05
Balance item	Concussed group	0.28±0.88	0.13 ±0.70	0.00 ±0.00	0.00 ±0.00
	SRC	0.00±0.00	0.15±0.784	0.00±0.00	0.00±0.00
	NSRC	1.50 ±1.64	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00
	NI group	0.03±0.17	0.00 ±0.00	0.06± 0.34	0.00 ±0.00
	OI group	0.03±0.18	0.06 ±0.35	0.00 ±0.00	0.00 ±0.00

BOT: bruininks- oseretsky test of motor proficiency-second edition, TFT: timed foam test, PCSS: post-concussion symptom scale, SRC: sport-related concussion, NSRC: non-sport related concussion, NI: non-injured group, OI: orthopedically-injured

Comparison of the Concussed group with NI and OI groups

BOT2 -Balance subtest

Repeated-measures ANOVA of the performances on the BOT2-balance scale showed no significant group x time interaction (p= 0.10, η^2_p =0.049), and the main effects for time (p=0.226, η^2_p =0.041) or group (p=0.17, η^2_p=0.033) were not significant. Analysis of two most difficult items (item 8 and item 9) of the balance subscale did not reveal any significant group x time interactions (p=0.44, η^2_p =0.027; p= 0.37, η^2_p = 0.031 respectively) and no main effects of group (p= 0.10, η^2_p=0.042; p=0.145,η^2_p=0.036 respectively). There was, however, a significant effect of time for item 8 (p=0.020, η^2_p=0. 75), illustrating an overall increase in performance of heel-to-toe standing on balance beam during the testing period for all groups (Fig. 1).

Timed FOAM Test

The ANOVA results revealed no significant group x time interactions for FT, SL and HT eyes closed standing positions (p=0.19, η^2_p=0.042; p=0.160, η^2_p =0.046; p=0.39, η^2_p= 0.031 respectively). However, there was a main effect of time (p=0.027, η^2_p = 0.89) for FT position without a significant group effect (p=0.44 η^2_p =0.016), indicating improvements in the performance on FT position over the time in all groups. There was no main effect of time for SL position (p= 0.60, η^2_p = 0.073), however group effect was significant (p=0.017, η^2_p = 0.07), indicating significant differences between the concussed and OI groups. Multiple comparisons showed that the OI group had lower performance than the concussed group over the period (p=0.014). Yet, there were no main effect of group (p=0.081, η^2_p=0.049) and time (p=0.917, η^2_p=0.005) for HT position.

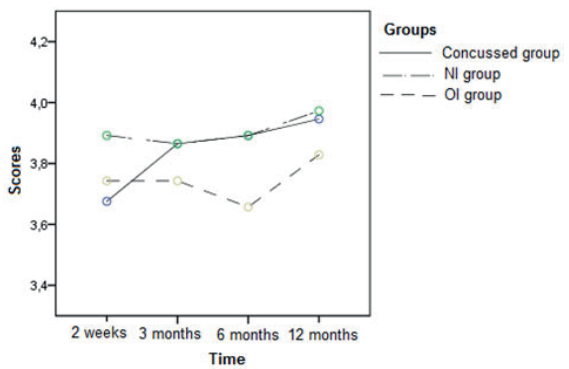

Fig. 1. The mean score of heel-to-toe standing position over the period by group.

PCSS

The ANOVA results performed on PCSS total score showed significant time x group interactions (p=0.033, η^2_p =0.71), as well as significant main effect of time (p= 0.05 η^2_p =0.128) and group (p=0.019, η^2_p= 0.081). Between-group comparisons revealed significant differences in total score at 2 weeks post-injury, where children in the concussed group had more severe symptoms than those of the NI and OI groups (p=0.002, p=0.005 respectively). There were significant improvements in total score after three (p=0.001), six (p=0.00) and 12 (p=0.00) months in the concussed group while no differences were observed in NI and OI groups (p>0.05). Further analysis for the specific "balance problems" item revealed no group x time interaction (p= 0.192, η^2_p=0.046) and no significant main effects for time (p=0.085, η^2_p=0.069) or group (p=0.149, η^2_p=0.040).

Comparison of the SRC and the NSRC with the NI and OI groups

The repeated measures ANOVA was performed again on all the outcomes after separating the concussed participants into two subgroups: SRC and NSRC groups.

BOT2 -Balance subtest

There were no significant group x time interactions (p=0.227, η^2_p=0.036; p=0.671, η^2_p=0.021) and no significant main effects of time (p=0.226, η^2_p=0.041; p=0.054; η^2_p= 0.071) or group (p=0.173, η^2_p=0.033; p=0.080, η^2_p=0.062) in the subtest total scale score or for item 9; however, there were main effects of time (p=0.003, η^2_p =0.127) and group (p=0.039, η^2_p=0.076) for item 8. Further analysis for item 8 showed that time was only significant for the NSRC group, where

children showed significant improvements over the 12-month period (p=0.003). Group comparisons also revealed that the NSRC group had poorer balance skills than the NI group (p=0.013) 2 weeks post-injury. At the third month, the SRC group showed better scores than the NI group (p=0.015) (Fig. 2).

Timed FOAM Test

There were no significant group x time interactions for FT, SL, and HT eyes closed positions (p=0.40, η^2_p=0.031; p=0.091, η^2_p=0.049; p=0.114, η^2_p=0.047). However, there were main effects of time (p=0.007, η^2_p=0.117) and group (p=0.009, η^2_p=0.111) for SL position, illustrating lower performance in NSRC group than the SRC at the 2nd (0.018) and the 12th week (p=0.018) (Fig. 3), and the NI groups at the 2nd week (p=0.016) despite overall improvement in all groups.

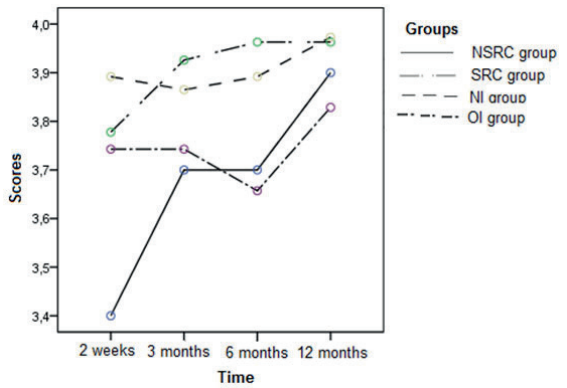

Fig. 2. The mean score of heel-to-toe standing on a balance beam (item 8) over the period by group.

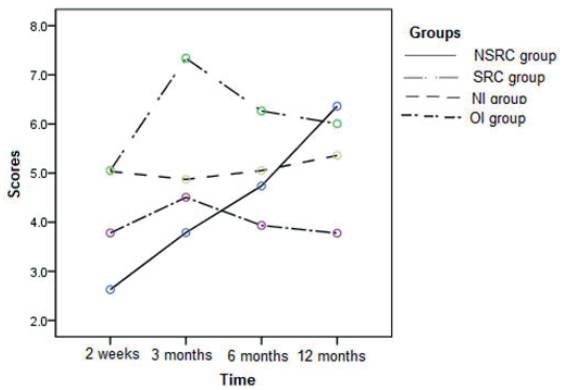

Fig. 3. The average durations of single leg standing on foam surface over the period by group.

There were no significant main effects of time (p=0.57, η^2_p = 0.020) or group (p=0.67, η^2_p=0.070) for HT position while there was a significant time effect (p=0.003, η^2_p=0.072) for FT position unlike group effect (p=0.614, η^2_p=0.018); demonstrating overall improvement in the HT position in all the groups.

PCSS

Time x group interactions were significant for total score and balance item (p=0.00, η^2_p =0.105; p=0.00, η^2_p=0.198 respectively) with significant main effects of time (p=0.00, η^2_p =0.279; p=0.00, η^2_p=0.383 respectively) and groups (p=0.00, η^2_p =0.166; p=0.00, η^2_p =0.665 respectively). There were significant decreases in total score for NSRC and SRC group after six (p= 0.00, p=0.015 respectively) and twelve months (p=0.00, p=0.002 respectively) contrary to NI and OI groups (p>0.05) (Fig. 4). There were significant improvements in only NSRC group in balance item after three (p=0.00), six (p=0.00) and twelve (p=0.00) months later. Group differences were reported only at 2nd week when NSRC had higher score as compared to SRC (p=0.00), NI (p=0.00), and OI (p=0.00) groups. There were no other group differences at any follow-up time (p>0.05).

Discussion

We aimed to investigate the long-term consequences of a concussion on balance

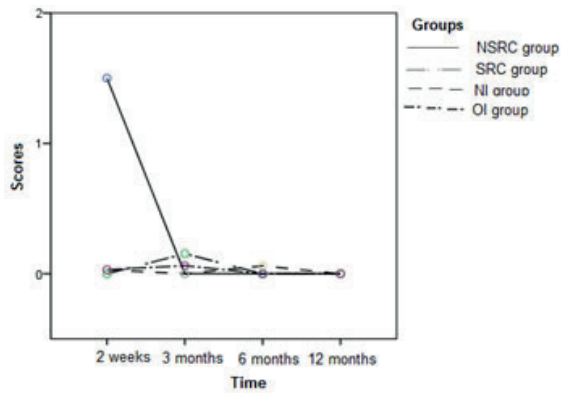

Fig. 4. PCSS –balance item scores over the period by group.

function in the pediatric population aged between 6-17 years, as well as to illustrate the potential differences in recovery between sport-related and non-sport-related concussions when compared with non-injured and orthopedically injured children. The results of this study revealed that concussed children improved their postural stability over a one-year period on some challenging activities; however, the improvements were comparable to those of OI and NI groups, for all measurements at each assessment time. On the other hand, children who sustained a concussion outside of sport had lower postural stability than healthy controls at the second week of injury. They also showed slower improvements in maintaining balance on unstable surfaces up to three months, as well as more post-concussion symptoms, particularly about imbalance at the second week when compared to NSRC group.

The BOT2 is one of the most commonly used tests for the assessment of motor proficiency in children after an injury.[10,19,20] Previous studies using the BOT2 test in the concussed population generally reported greater differences in the balance subtest between concussed and uninjured children.[6,10,19] For example, Dahl et al.6 reported reduced postural instability on the BOT2 balance subtest in concussed children three to six months after the injury. Similarly, Sambasivan et al.[20] demonstrated lower performance in concussed children on the BOT2-balance subtest, especially for the most difficult items which were tandem and single leg standing on a balance beam.[20] Our study reported similar findings only for children with NSRC who had lower performance on tandem standing on a balance beam at the second week. The NSRC group also showed higher postural instability on a foam surface while standing on single leg than healthy controls and that was found up to three months following the injury. Measuring balance on a foam surface is a component of the Balance Error Scoring System (BESS), which was originally designed for collegiate athletes to assess balance function, using a cost-effective equipment. It has since widely used in patients with mild TBI and became an important assessment tool for concussion. It was found a valid and reliable tool to detect the differences between concussed and healthy college athletes, especially within a week post-concussion. The BESS has six different positions including double-leg stance, single-leg stance, and tandem stance on 2 different support surfaces (firm and foam) with eyes were closed. In children and adolescent, two positions were highlighted to distinguish the differences between concussed and healthy individuals: single leg standing on firm and foam surfaces.[21] The results of the current study also supported this finding. We only detected postural instability in NSRC group when compared them with SRC group while standing on single-leg condition on the foam when eyes were closed. Moreover, differences were evident not only at the second week but also in the third month after post injury, where NSRC group had lower score than SRC. A previous study in young adults also illustrated that non-athletes had larger distance between the center of mass and center of pressure than the athletes during a one-month period post-concussion, illustrating higher body sway in the non-athletes.[7] However, the same study also reported that athletes had slower gait speed and faster body sway than non-athletes.[7] In fact, there are very few studies in the literature addressing the relationship between the cause of injury and the post-concussion symptoms, so it is not known whether the differences in the injury mechanism lead to diverse pathological changes, consequently various symptoms.

There is a great emphasis on athletes in the concussion literature since participation in a sport-related activity increases the risk of falling and contact head injury. A recent review concluded that athletes generally experience balance impairment lasting three to ten days following a concussion without a persisting deficit.[22] However, our study did not identify any balance deficit in the SRC group; rather they performed better than NSRC and controls in the single leg standing position on foam surface in

the given time frame. This may be because they had better physical fitness and body endurance as they had been training previously in some way to maintain their postural stability in a sport activity. This notion was elucidated from the finding of the review evaluating the balance function of athletes from different sport activities in comparison with non-athletes.[23] It showed that athletes were better than non-athletes to maintain the body in equilibrium, particularly those who were participating in soccer and gym.[23] There might be a relationship between physical activity level and balance ability which is evident in the current study; for example, more than a half of the children in the SRC group defined themselves as "much more active than the others" (52%) while it was much less in the NSRC (18%).

Another considerable difference between the SRC and the NSRC groups arose from PCSS score. The mean score of PCSS was more than twenty for the NSRC group at the second week, indicating "very high level" in severity classification of concussion, whereas SRC group scored less than seven which is "borderline".[16] Interestingly, NSRC group also showed an increase in the total symptom score in the sixth month after a reduction in the third month. It seems that recovery from the symptoms lasted a year in the NSRC group, yet imbalance was only higher at the second week than the other groups. To summarize, this current study did not support the existence of persistent balance deficits in the concussed children that are contrary findings to the previous studies.[6,10,24] This may be because of the inadequacy of the measurements to evaluate the complex balance function. More challenging activities like adding cognitive loads or modifying environmental demands may be more appropriate to measure postural stability in the concussed children and adolescents. This is because maintaining balance in a silent room without any visual interference is much easier than balancing your body outside in a crowded and noisy environment with many visual distractions. Future studies should evaluate balance function in a more dynamic environment or under a dual task condition to examine the real-life performance. Moreover, our current study suggests that non-sport related concussion, which is not emphasized as much as sport related concussion, was deemed a significant risk for postural instability; so, further investigations are needed to estimate the differences in balance function and post-concussion symptoms between the children having a concussion in and out of a sport activity. This study had a few limitations. Non-random sampling resulted in the differences in the age among the groups. The children having an orthopedic minor injury and sustaining a concussion outside of the sport activity were younger than the other groups, yet average ages in all groups were older than 10 years old. Since the maturation in balance and gait function is completed by the age of seven,[25,26] all groups are treated as equal. This study had also limited sample size for NSRC group. In order to generalize the findings for the balance deficits observed in NSRC, studies with a larger sample size are required.

Children having a concussion outside of sport had balance impairment up to three months compared to those getting injured in sport and non-injured subjects, but all concussed children gradually improved their function up to three months following concussion and performed better than non-injured group after a year.

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Author contribution

The authors confirm contribution to the paper as follows: study conception and design: Eda Çınar, Isabelle Gagnon, Lisa Grilli, Debbie Friedman; data collection: Isabelle Gagnon,Lisa Grilli, Debbie Friedman; analysis

and interpretation of results: Eda Çınar, Isabelle Gagnon, Lisa Grilli, Debbie Friedman; draft manuscript preparation: Eda Çınar, Isabelle Gagnon. All authors reviewed the results and approved the final version of the manuscript.

Ethical approval

Research Ethics Board of the McGill University Health Center (12-190-PED).

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Conflict of interest

The authors declare no conflict of interest.

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