ORIGINAL ARTICLE

The Montreal Cognitive Assessment as a Cognitive Screening Tool in Athletes

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ABSTRACT: ***Background:*** The Montreal Cognitive Assessment (MoCA) is a cognitive screening tool known to accurately measure mild cognitive impairment (MCI) in many different neurological populations. ***Objective:*** We aimed to determine whether a sport-related concussion (SRC) history and other concussion modifiers influence global cognitive function in high-performance athletes. ***Methods:*** A cross-sectional study of 326 varsity and national team athletes aged 18–36 years was completed at the University of Calgary Sports Medicine Clinic, Calgary, Alberta, Canada. Logistic regression analysis was used to examine the association between the total MoCA score, MoCA subscales, and number of previous SRC, adjusting for age, sex, sport participation (SP), and concussion modifiers. ***Results:*** Athletes with a history of three or more SRC were 5.36 times more likely to score less than 26/30 on the MoCA (the cutoff for MCI) compared to athletes with two or less SRC ($p = 0.02$). Males were 2.23 times more likely to have MCI than females ($p = 0.0004$). There was a significant relationship between the number of previous concussions and the MoCA subscales of attention ($p = 0.05$) and abstraction ($p = 0.003$). Age, SP, and concussion modifiers (migraine, depression, anxiety, and attention deficit and hyperactivity disorder) did not influence the relationship between MoCA and previous concussion history. ***Conclusion:*** In the appropriate clinical context, cognitive screening with the MoCA may benefit clinical care in athletes with multiple previous SRC, but should not replace a full neuropsychological assessment. Thus, further research is needed to compare the MoCA to full neuropsychological assessments in this population.

RÉSUMÉ: L'évaluation cognitive de Montréal comme outil de dépistage pour les athlètes. ***Contexte***: L'évaluation cognitive de Montréal (MoCA en anglais) constitue un outil de dépistage cognitif réputé pour mesurer de façon précise des troubles légers de la cognition (TLC) parmi divers segments de la population. ***Objectif***: Nous avons cherché à déterminer dans quelle mesure des commotions cérébrales antérieures liées au sport ainsi que des facteurs modificateurs produits par ces mêmes commotions peuvent avoir un impact sur les fonctions cognitives globales d'athlètes de haut niveau. ***Méthodes***: Une étude de prévalence incluant 326 athlètes universitaires et membres d'équipes nationales âgés entre 18 et 36 ans a été complétée à la Clinique de médecine sportive de l'Université de Calgary (Canada). Pour ce faire, nous avons fait appel à l'analyse de régression logistique pour examiner l'association pouvant exister entre les scores totaux au MoCA, les sous-échelles du MoCA et le nombre de commotions cérébrales liées à la pratique d'un sport, et ce, après contrôle de l'âge, du sexe, du taux de participation sportive et des facteurs modificateurs liés à ces mêmes commotions. ***Résultats***: Les athlètes victimes de trois commotions cérébrales ou plus en lien avec la pratique d'un sport étaient 5,36 fois plus susceptibles d'obtenir un score de moins de 26/30 au MoCA (la valeur seuil d'un TLC) en comparaison avec des athlètes ayant subi deux commotions ou moins ($p = 0{,}02$). Les hommes étaient par ailleurs 2,23 fois plus susceptibles que les femmes de souffrir de TLC ($p = 0{,}0004$). De plus, on a noté une relation notable entre le nombre de commotions cérébrales antérieures et les sous-échelles de l'attention ($p = 0{,}05$) et de l'abstraction ($p = 0{,}003$) du MoCA. L'âge, le taux de participation sportive et les facteurs modificateurs induits par les commotions cérébrales (migraine, dépression, anxiété, TDAH) n'ont pas eu d'incidence sur la relation entre les scores au MoCA et des antécédents de commotions cérébrales. ***Conclusion***: Dans un contexte clinique approprié, le dépistage cognitif au moyen du MoCA pourrait améliorer les soins cliniques prodigués aux athlètes victimes de nombreuses commotions cérébrales. Il ne devrait toutefois pas remplacer une évaluation neuropsychologique complète si cela est nécessaire. De ce point de vue, des recherches plus approfondies sont nécessaires afin de comparer le MoCA à une évaluation neuropsychologique complète dans le cas de ce segment de la population.

Keywords: Concussion, Montreal Cognitive Assessment, Cognitive assessment tool, Athletes, Sport-related concussion

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Introduction

Cognitive testing has been a cornerstone of concussion management for many years. Recent studies have explored the effects of multiple factors that may influence the results of cognitive testing in athletes, including a past medical history of learning disabilities (LDs), poor sleep, history of playing contact sport,[1–3] and previous concussion.[4–8] Previous concussion history has been inconsistently related to cognitive function, with some studies finding no correlation and other findings a dose–response relationship, with two or more concussions correlating with poorer cognitive performance.[8–12]

Historically, the assessment of neurocognitive performance in athletes has been done using computerized tests. However, computerized testing has been shown to have only moderate sensitivity[13] in detecting post-concussive cognitive deficits, requires a subscription that can be cost prohibitive, and is not readily available to some coaches, athletic therapists, or family physicians.[13] As well, previous studies using standardized neurocognitive testing in athletes have shown that sport participation (SP)[1,3] and a past medical history of migraine,[14] attention deficit and hyperactivity disorder (ADHD),[5] depression,[15] or anxiety[16] may influence pre-injury assessments. The Sport Concussion Assessment Tool 3 and 5 (SCAT3 and 5)[17–20] has a brief cognitive component, based on the Standardized Assessment of Concussion[18] and can be administered by qualified health-care providers. However, the SCAT has limited norms and provides a restricted assessment of an athlete's cognition, as it only assesses delayed recall, orientation, and language. Additionally, at the International Conference on Concussion in Sport held in Berlin, 2016, the SCAT was deemed most appropriate for use as a post-sport-related concussion (SRC) tool; pre-season or random baseline testing with the SCAT was not considered necessary. To date, the neurocognitive tests most frequently used in athletic populations were developed to evaluate altered cognition in the acute phase following SRC. Other than traditional neuropsychological assessments, no global cognitive screening tool has been studied in athletic populations.

The Montreal Cognitive Assessment (MoCA) is a global cognitive assessment tool originally developed to screen for mild cognitive impairment (MCI) in the elderly.[21] It is now used worldwide as a standard in clinical care, in multiple different languages, in different age groups, and in a variety of illnesses,[22] as a measure of general cognition. It takes approximately 10 min to complete and is cost-free. The MoCA yields a maximum score of 30 points from 7 domains: visuospatial abilities/executive functions, short-term memory, language, attention, concentration, working memory, and temporal and spatial orientation. Originally, normative data for the MoCA were based on 90 Canadian controls (mean age: 72.84 years and mean education: 13.33 years).[21] From these data, a suggested normal cutoff was determined to be >26 on a 30-point scale. This value provided a sensitivity of 90% and a specificity of 100% for MCI.[21] Since then, other studies have established normative data for the MoCA in other ethnic populations, ages (18–90 years), sex, and education levels.[21,23–29] Most recently, three studies have administered the MoCA to patients with mild traumatic brain injury/concussion and found there was a relationship between severity of injury and lower scores on the MoCA.[30–32] The authors concluded that the MoCA was a useful cognitive screening tool for patients with mild to severe traumatic brain injury (TBI).

Although the MoCA has the potential to serve as a brief, cost-free, comprehensive cognitive screening tool for athletic populations, it has yet to be examined for this purpose. Thus, the objectives of this study were to screen global cognitive function using the MoCA in high-performance athletes and to explore whether a previous concussion history influences cognition. We hypothesized that athletes with more self-reported SRC would score lower on the MoCA than those with none or fewer SRC. A second objective was to determine whether other factors, such as age, sex, type of SP, past medical history of migraine, depression, anxiety, and ADHD, would be associated with outcomes on the MoCA.

Methods

Study Population

University of Calgary varsity athletes and Canadian national athletes in Calgary, Alberta, Canada, were asked to participate in this observational cross-sectional cohort study from August 2011 to May 2013. Inclusion criteria included the ability to speak and comprehend English and having greater than grade 12 (i.e., completed high school) years of education. Exclusion criteria included being aged less than 18 years and having previous history of neurological issues, such as stroke, seizure, or known congenital intracranial abnormalities.

Material and Procedures

Biographical information and medical history were obtained from each subject prior to the start of the athletic season. Medical history included previous self-reported SRC history, other previous medical issues including concussion modifiers (migraines, ADHD,[2,5] anxiety,[15] and depression[15]), and varsity or Canadian national team SP. To collect data on concussion modifiers, the athletes were asked if they were ever diagnosed previously with migraine, ADHD, anxiety, or depression by a treating clinician.

Clinical assessments took approximately 30 min to complete. Each subject underwent standardized physical assessment by a sport medicine physician or physiatrist, including history, neurological examination, and SCAT3.[18] The MoCA[21] was administered by a trained research assistant, athletic therapist, or physiatrist.

Statistical Analysis

Logistic regression was used to examine the relationship between MoCA subscale domains and concussion history. For analysis of the total MoCA score, athletes were divided into two different categories based on total MoCA scores: (1) MoCA scores ≥ 26 (signifying normal cognition) and (2) MoCA scores < 26 (signifying MCI). Logistic regression was used to examine the association between MoCA (<26 and ≥ 26) and concussion history, adjusting for age, sex, SP, and medical history (migraine, ADHD, depression, and anxiety). Current SP was stratified into no/limited contact sports and contact/collision sports based on the recommendation of the American Medical Society for Sports Medicine position statement: Concussion in Sport[4] and a paper by Rice documenting classifications of sport according to level of contact.[34] Based on their recommendations, American football, ice hockey, rugby, wrestling, soccer, winter sports with contact, and basketball were considered contact/collision sports. Adjusted

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Table 1: Participant characteristics

Participant description	Number of athletes
Males	203 (62%)
Average age ($m \pm$ SD)	26.8 ± 3.4
Right handed (n, %)	325 (97%)
Medical history	
History of migraines	31 (9%)
Family history of migraines	43 (12%)
History of ADHD	9 (2%)
History of anxiety	8 (2%)
History of depression	11 (3%)
History of neck pain	15 (4%)

odds ratio and 95% confidence intervals were calculated. Results were considered significant at $p < 0.05$. All statistical analyses were performed using SAS 9.4.

Ethical Considerations

This study was approved by the University of Calgary Conjoint Health Research Ethics Board (Ethics ID 23963). This study was a study embedded within a larger study which assessed the utility of robotic assessments for motor impairment following SRC in varsity and national team athletes. All subjects provided informed consent prior to participation.

Results

Participant Characteristics

A cross-sectional sample of 345 varsity and Canadian national athletes were recruited to complete the study. Of these, 326 athletes met inclusion criteria for this study. Athletes excluded were 9 subjects that were less than 18 years of age and had not completed grade-12 education and 10 that did not complete the MoCA or past medical history questionnaire. There were 203 males (age 26.9 ± 2.8) and 123 females (age 26.5 ± 2.1) in the study. Two hundred ninety-one (65% male) athletes participated in contact/collision sports and 35 (37% male) in no/limited contact sports. Descriptive information regarding participants and average MoCA scores for each sport and sex are presented in Tables 1 and 2, respectively.

Influence of SRC History on MoCA Scores

Among the 326 athletes, 85 (26%) scored less than 26 on the MoCA; of these, 64 (73%) were male. Athletes who reported a history of three or more previous concussions were 5.36 times (Table 3) more likely to have a score in the MCI range (less than 26/30 on the MoCA) (47%) than athletes who reported a history of two or less previous concussions (24%) ($p = 0.02$) (Table 4). Age, previous history of migraine, anxiety, depression, or ADHD, and sport type (contact/collision vs. no/limited contact) were not significantly associated with total MoCA scores. However, sex (male) was a significant predictor of MCI, with higher odds among males (see Table 3), with males 2.23 times more likely to have MCI than females ($p = 0.0004$). Of the 326 athletes assessed, only 9 reported a history of ADHD. It is not known whether they were on a neurostimulant at the time of testing. Further analysis of MoCA subscales revealed there was a significant relationship between the domains of attention ($p = 0.05$) and abstraction ($p = 0.003$) and previous concussion history, but not visuospatial/executive, naming, language, delayed recall, or orientation (Table 5). Finally, sex significantly influenced the relationship between the MoCA subscales of visuospatial ($p = 0.018$), attention ($p = 0.003$), and abstraction ($p = 0.0001$), but not naming, delayed recall, language, or orientation. Age did not influence the relationship between previous concussion and any MoCA subscales.

Table 2: Average MoCA for each sport and sex

Contact/ collision sports	Sex	Number of athletes	Average MoCA ± SD	Number (%) with MoCA < 26
Football	Male	93	26.0 ± 2.1	32 (34%)
Hockey	Male	36	25.6 ± 2.0	14 (38%)
	Female	31	26.5 ± 2.2	8 (25%)
Rugby	Female	13	26.6 ± 2.9	4 (30%)
Soccer	Male	13	27.3 ± 2.0	2 (15%)
	Female	13	27.6 ± 1.9	2 (15%)
Basketball	Male	9	26.0 ± 2.1	3 (33%)
	Female	11	25.5 ± 2.5	4 (36%)
Wresting	Male	10	27.3 ± 2.4	3 (30%)
	Female	8	27.8 ± 1.9	1 (12%)
Alpine	Male	10	28.6 ± 1.3	0
	Female	6	27.7 ± 1.9	1 (17%)
Bobsled	Male	10	27.0 ± 1.2	1 (10%)
	Female	10	28.1 ± 1.5	1 (10%)
Skeleton	Male	7	26.7 ± 1.6	0
	Female	6	27.6 ± 2.3	1 (17%)
Luge	Male	2	26.0 ± 1.0	1 (50%)
	Female	3	25.5 ± 2.4	0
No/limited contact sports				
Field hockey	Female	15	27.2 ± 1.8	0
Volleyball	Male	11	26.5 ± 2.1	3 (27%)
	Female	5	27.4 ± 1.9	1 (20%)
Speed skating	Male	2	27.5 ± 3.5	1 (50%)
	Female	1	28.5 ± 2.1	0
Track and field	Female	1	28.0 ± 0.0	0

MoCA = Montreal Cognitive Assessment; MCI = mild cognitive impairment.

Discussion

Influence of SRC History on MoCA Scores

We found that athletes who self-report a history of three or more SRC were significantly more likely to show MCI on the MoCA total score compared to athletes with two or less SRC. Further, we found that the MoCA subscales of attention and

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Table 3: Comparison of concussion history and MoCA adjusted for age, sex, SP, and past medical history

	MCI vs. normalor (95% CI)	*p*-value
Number of previous concussions		
≤1 vs. ≥2	2.68 (0.76–9.51)	0.13
≤2 vs. ≥3	5.36 (1.19–24.20)	0.02*
Sport		
No/limited contact sport vs. contact/collision sport	1.08 (0.37–3.11)	0.89
Age	0.94 (0.86–1.02)	0.15
Male vs. female	2.05 (1.16–3.62)	0.0004*
Previous history of ADHD	1.57 (0.39–6.34)	0.53
Previous history of anxiety	0.19 (0.03–1.35)	0.10
Previous history of depression	0.59 (0.12–2.84)	0.51
Previous history of migraine	0.76 (0.70–0.82)	0.93

Adjusted odds ratios (95% CI) of predictors for differences between evidence of MCI (MoCA score < 26) and normal (MoCA ≥ 26) in the athletics population.
*Significance is based on $p < 0.05$.

abstraction were significantly related to a greater number of previous concussions. The existing literature shows mixed results when analyzing the influence of previous concussion on cognitive performance in athletes. Plancher et al.[35] found lacrosse players with a history of concussion had significantly worse verbal memory on computerized cognitive testing compared to those without a history of concussion.[35] Likewise, Covassin et al. and Collins et al. found a dose–response relationship between the number of previous concussions and computerized cognitive testing,[8,36] such that participants with a previous history of two or more concussions had poorer cognitive outcomes than athletes with one or no previous concussion. In contrast, Brooks et al. and Tshushima et al. found adolescent athletes with one or more previous concussions showed similar cognitive test performance as athletes with no previous concussion.[10,37] Furthermore, Brown et al. and Bruce and Echemendia found no difference on computerized testing in collegiate athletes with history of concussion versus those without.[38,39] The reasons for such variable results are difficult to determine. Different types of neurocognitive testing were done in each of these studies, making comparison difficult. For example, our study used the MoCA, a global cognitive screening tool, whereas other studies used computerized neurocognitive testing or a full neuropsychological assessment. When comparing our studies to those above, we found similar results to the studies of Covassin et al.[8] and Collins et al.[36] in which the computerized testing focused on frontal lobe dysfunction reflecting impairment in attention, executive function, working memory, and processing speed, and reflecting our

Table 4: Number of previous concussion, percentage of MCI, and average MoCA scores

Number of previous SRC	Total number of athletes	Number of athletes with MCI on MoCA (percentage of MCI)	Average MoCA score
0	183	44 (24%)	26.8 ± 2.0
1	92	28 (30%)	26.2 ± 2.3
2	28	3 (10%)	27.2 ± 1.8
3	12	4 (33%)	26.7 ± 2.5
4	6	4 (66%)	25.3 ± 2.3
5	4	1 (25%)	25.5 ± 2.5
6	1	1 (100%)	24.0 ± 0.0

findings of significantly lower scores on attention and abstraction in relation to a greater number of previous concussions. Additionally, we controlled for past medical history of migraine, depression, anxiety, or ADHD, and type of SP (contact/collision vs. no/limited contact), whereas some of the other studies did not. Finally, many of the previous studies, as well as ours, used self-report to determine concussion history, raising the possibility of recall bias.

We did not find a significant difference in total MoCA scores in athletes with two or less concussions. This most likely reflects the ceiling effect of the MoCA total score. Following concussion processing speed, memory, executive function, and attention are most often affected. The MoCA tests these domains with Trails B portion, attention, abstraction, delayed recall, and verbal fluency. However, we would not expect the other cognitive domains tested (language, visual spatial perception) to be impaired. Therefore, we would expect to see a ceiling effect and only those athletes with more concussions or greater cognitive impairment would have deficits on the overall MoCA score. This was evident when the MoCA subscales were analyzed and worse scores on attention and abstraction were related to a greater number of previous concussions. This suggests that screening tools that are more sensitive to impairments in frontal lobe dysfunction may be the most appropriate tools for those with fewer concussions or less severe concussion, compared to a global screening tool.

Comparison of SP, Age, Migraine, ADHD, Anxiety, and Depression

We found no significant difference in MoCA scores in athletes currently involved in contact/collision sports compared to those involved in no/limited contact sports. In contrast, other studies have found contact-sport athletes to be at a greater risk of cognitive impairment compared to control subjects. For example, Killam et al. found non-concussed collegiate athletes in contact sports scored worse on immediate memory, delayed memory, and overall score of the Repeatable Battery for the Assessment of Neuropsychological Status (RBANS) compared to controls.[1] Similarly, McAllister et al. found collegiate football and ice hockey players performed worse on computerized cognitive

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Table 5: Relationship between subscale of MoCA and previous concussion history

MoCA subscale (total number)	Mean ± SD	Relationship between MoCA subscale & previous concussion history or (95% CI)	*p*-value
Visuospatial/executive function (5)	4.71 ± 0.61	4.72 (4.64–4.80)	0.464
Naming (3)	2.96 ± 0.19	2.96 (2.93–2.98)	0.861
Delayed recall (5)	3.18 ± 1.38	3.18 (3.00–3.36)	0.972
Attention (6)	5.46 ± 0.87	5.52 (5.41–5.64)	**0.050***
Language (3)	2.53 ± 0.63	2.54 (2.46–2.63)	0.787
Abstraction (2)	1.78 ± 0.46	1.83 (1.77–1.89)	**0.003***
Orientation (6)	5.96 ± 0.20	5.96 (5.93–5.99)	0.585

Relationship between the subscales on the MoCA and previous concussion history.
*p-value ≥ 0.05 signifies a significant relationship between attention and abstract thinking and increasing number of previous concussion.

testing compared to non-contact athletes post-season, despite not reporting a concussion during their season.[2] More recently, Alexander et al. examined school-age male rugby players with and without a history of concussion and compared them to controls. They found both groups of rugby players scored significantly lower on WISC-III Coding Immediate Recall subtest compared to controls.[3]

The studies by Alexander et al., McAllister et al., and Killam et al. compared athletes who had experienced many previous years of contact/collision sports to non-contact athletes and controls. Our study examined elite varsity and national athletes who had been involved in a specific contact/collision sport for many years and found no difference among those involved in no/limited contact sports. We used a cognitive screening tool rather than a neuropsychological battery of tests. The MoCA may not be as sensitive a tool for assessing cognitive function as a neuropsychological battery of tests. Adding a cognitive screening tool, such as the MoCA, would be especially prudent in demographic areas where access to a full neuropsychological battery is extremely limited. If an athlete scores poorly on the MoCA, has a past medical history of multiple concussion, and is struggling in their daily functioning with cognitive demands, this may warrant further investigation with a full neuropsychological battery of test.

We found no significant difference in MoCA scores or MoCA subscales based on the age of the athlete. Previous studies have shown less influence of age on neurocognitive testing in the athletic population over the age of 18 years (post-high school) but a significant influence on the pre-teenage/teenage years[40,41] and post-SRC.[6,15,42,43] Similar to previous research, athletes in this study were between the age of 18 and 36 years, so fall in the age range where age differences are less common.

Finally, we found no significant difference in MoCA scores when controlling for a past medical history of migraine, ADHD, depression, or anxiety. As well, athletes with three or more SRC did not appear to have a greater incidence of a past medical history of one of these medical issues. Others have found a history of ADHD or LD can influence computerized neurocognitive testing in athletes.[5] Zuckerman et al.[5] found athletes with ADHD or LD did significantly worse on visual memory, verbal memory, and visual motor processing speed compared to athletes without ADHD or LD.[5] Similarly, Covassin et al.[15] showed athletes scoring in the severe depressive range on the Beck Depression Inventory II did significantly worse on visual memory tasks than athletes scoring in the minimally depressed range.[15] Further, previous studies have shown psychological distress,[44] and a history of anxiety[16] can influence neurocognitive testing in athletes, specifically effecting visual memory.[16] The reason why we did not find that a history of depression, anxiety, or ADHD influenced MoCA scores is unclear. Only 9% of athletes had a history of migraines, 2% a history of ADHD or anxiety, and 3% had a history of depression. These are small numbers, making it hard to detect any difference between groups. Regardless, based on previous research, a thorough medical history is important to obtain as it may influence neurocognitive results.

Sex Difference in MoCA Scores

Our study found males were significantly more likely to score in the MCI range on the total MoCA score and the MoCA subscales of visuospatial, attention, and abstraction compared to females. There is conflicting evidence in the literature regarding the impact of sex differences on neurocognitive testing in athletes. Covassin et al.[15] found that male athletes with a previous history of concussion (two or more) performed worse on computerized neurocognitive testing than females.[15] They also found that males performed worse on motor processing speed and reaction time compared to females whether they reported a previous concussion or not. In contrast, Zuckerman et al. found no significant differences between male and female athletes on computerized neurocognitive testing at baseline prior to or following SRC.[45] Additionally, testing using the MoCA in other patient populations has not shown a sex difference.[23,24,30,46] In our study, an equal proportion of males (45%) and females (46%) had a history of one or more concussions, and males were not more likely to have three or more of SRC. When comparing male athletes only, no significant difference was found between contact/collision sports and no/limited contact sport athletes (26.4 ± 2.1 vs. 26.8 ± 2.1; $p = 0.49$), and a previous medical history of migraine, ADHD, anxiety, and depression did not influence the results. The reason for the current sex difference is unclear. However, based on other studies, male athletes may perform worse in some domains, such as processing speed and reaction time, compared to female athletes,[40] and we found a sex difference in visuospatial, attention, and abstraction. The current results suggest a need for future studies that explore sex difference in neurocognitive functioning in athletes.

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Advantages and Limitations of the MoCA as a Global Cognitive Screening Tool in Athletic Populations

The MoCA has many potential advantages as a screening tool for global cognition in athletes. Administration of the MoCA does not require access to a computer-based program. The test is publicly available and free of charge. A clinician or therapist can easily administer it in only 10 min, and it has well-established cutoff scores to reflect MCI across ages.[23,24] However, the MoCA also has limitations suggesting that it may not be an appropriate tool for screening global cognition in athletes. First, the MoCA has no embedded tests of effort to help detect athletes who are giving sub-maximal performance, and this may be important in this patient population.[33] Second, the total MoCA score provides a single number that reflects multiple domains of cognitive function, and clinicians often only focus on the total score not exploring the scores of the subscales. Athletes with concussions often present with deficits in processing speed, memory, sustained attention, and executive function. The MoCA only tests for a portion of this and thus the test will be subject to a ceiling effect in athletes with one or two concussions and you may see a small change in those with multiple concussions. Third, interpreting a global cognitive screening test is risky in the absence of additional information about functional impairment or clinical corroboration, given the risk of false positives in healthy individuals.[47] Finally, the study group is a young and relatively health population that has a lower prevalence of the past medical history of migraine, anxiety, and depression making the results of this study less generalizable to general public; however, previous studies have shown the MoCA to be a beneficial tool in patients with mild traumatic brain injury due to all causes.[31,32,48] Using a cognitive screening tool such as the MoCA should likely be considered in athletes with other symptoms and functional impairments, not in asymptomatic athletes or those with two or fewer concussions, and should not replace a full neuropsychological assessment if required.

Conclusion

This study is the first to administer the MoCA to athletes as a global cognitive screening tool. Using the MoCA, we found athletes with a self-reported history of three or more SRC were more likely to score less than 26, suggesting the presence of MCI. Similar to other studies assessing baseline cognition in athletes, males were more likely to score lower on the total MoCA score and MoCA subscales of visuospatial, attention, and abstraction than females. In contrast, age, current type of SP (contact/collision vs. limit/non-contact), and a past medical history of migraine, anxiety, depression, and ADHD were not associated with MoCA performance.

Previous studies have shown the MoCA to be a valid cognitive screening tool in different ethnicities, ages, sexes, and disease states including acute mild traumatic brain injury/concussion due to all causes for the purpose of determining MCI. The findings of this study suggest administering a cognitive screening tool, specifically focusing on impairments in working memory, attention, processing speed, and executive function, may be more appropriate in individuals with two or less concussions as the total MoCA score most likely has a ceiling effect. However, the MoCA can be administered in individuals with persistent cognitive and function symptoms and three or more concussions to screen for global cognitive impairment, but should not replace a formal neuropsychological assessment if deemed necessary. Further studies are required to compare the MoCA to full neuropsychological assessments in individuals with both acute SRC and persistent cognitive deficits following multiple concussions to better understand the utility of this cognitive screening tool in this population.

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Conflict of Interest

No authors of this paper have a conflict of interest.

Statement of Authorship

CTD - MD, MSc – Primary researcher, wrote manuscript.
JS - MD – Aided in collection data and editing manuscript.
TS - PhD – Data analysis.
MW - MSc – Data analysis.
KK - PhD – Data collection and editing manuscript.
BWB - MD, PhD – Co-PI of larger Own the Podium study and editing manuscript.
KY - PhD – Data analysis and editing manuscript.
SPD - MD, PhD – Data analysis and editing manuscript.

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