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Research Article

Psychometric Properties of a Concussion Evaluation Tool in College Athletes

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Abstract

Sport concussion has emerged as significant concern especially for youth playing contact sports. Diagnosis of concussion continues to be a clinical decision that should be guided by use of sideline assessment tools. The Sport Concussion Assessment Tool (SCAT) was developed by the International Consensus Group, and continues to be refined with subsequent revisions. With these revisions, there is a need to evaluate the psychometric properties of the various components of the SCAT that measure balance, cognition, and symptom report. The current study sought to evaluate the reliability of SCAT in 165 college athletes who played collision sports at a university in Canada. Data was obtained across two competitive seasons by team Athletic Therapists during baseline medical evaluations prior to the start of competitive seasons. Twenty-two athletes suffered concussions were diagnosed by team physicians during the competitive season and data from these individuals was evaluated for changes at the next baseline evaluation. The main outcome measures included intracass coefficients and paired sample t-tests. The intraclass reliability coefficients for demographic variables ranged from moderate to good (0.66 to 0.94). The reliability of the cognitive test results and balance error scoring system (BESS) was rated as good (0.83 and 0.88 respectively). Total symptom report and symptom severity report was moderate, with significant differences noted between males and females. History of concussion did not significantly impact reliability coefficients. Among the 22 athletes who suffered concussions during a competitive season, the reliability of the core components of the SCAT remained high. The reliability of the SCAT is classified as good although symptom report is more variable. Future revisions should include improved methods for measuring symptom report.

Keywords: *Concussion; Sport Concussion Assessment Tool; Psychometric Properties*

Abbreviations

SCAT: Sport Concussion Assessment Tool; MTBI: Mild Traumatic Brain Injury; SAC: Standardized Assessment of Concussions; BESS: Balance Error Scoring System; ICC: Interclass Correlations

Introduction

Sport related concussion has become a priority within the field of sports medicine. By definition, a mild traumatic brain injury (MTBI) is the consequence of a biomechanical collision between the brain and skull resulting in pathophysiological changes to the brain [1-3]. Typically, a sport concussion is viewed as a milder subset of MTBI in which rapid improvement in most individuals is anticipated, however; there is a concern that sustaining multiple concussions will lead to significant effects on brain functioning [4-6]. There has been a substantial increase in research dedicated to standardizing a valuable assessment tool for sport concussions. Among these, The Sport Concussion Assessment Tool, third edition (SCAT3) was released following the Fourth International Conference on Concussion in Sport in

2012, and the newest version is to be released 2017 [3]. This tool was adapted from its previous version with the purpose of increasing clinical utility and providing increased psychometric properties [7].

The SCAT3 is comparable to the SCAT2, with minor refinements [3,7]. Specifically, both include the Glasgow Coma Scale; a Maddocks scale; a subjective symptom report; a cognitive assessment entailing orientation, concentration and memory (immediate and delayed); a coordination assessment; and a balance component. The standardized assessment of concussions (SAC) total score is derived from adding the orientation, immediate memory, concentration and delayed recall scores together. The balance error scoring system (BESS) total score is derived from the total number of errors observed during the balance component. SCAT3 sections are in an alternate order compared with the SCAT2, wording has been enhanced, and the SCAT3 now incorporates a neck examination, has added the tandem gait assessment to the balance component, and added background health questions the examiner must ask the athlete [3].

Various studies have provided normative data for the SCAT and SCAT2. In college populations, select studies found that demographic and injury variables affect various components of SCAT2 scores. For instance, McLeod., *et al*. [8] noted that baseline values (scores out of 100) of 1134 adolescent athletes on the SCAT2 differ by sex, age, and concussion history. Males scored significantly lower on the SAC and BESS components but no differences were noted in symptom report [8]. In contrast, a recent meta-analysis showed that females reported greater total symptom scores in comparison to males on the SCAT2 [9]. However, the researchers explained that this may not be a reliable difference between sexes, as female's menstrual cycles were not accounted for [8]. A study by Putukian., *et al*. [10] found that the SCAT2 demonstrated clinical utility in post-concussion assessments among college athletes such that concussed individuals had statistically significant scores on the SCAT2 in comparison to non-concussed individuals.

Schneider., *et al*. [11] examined a large cohort of adolescent hockey players (n = 4193) and found differences in normative values compared to collegiate populations. Specifically, age and gender significantly affected SCAT scores, and there was a trend for higher symptom report among those with concussions. Jinguji., *et al*. [12] also demonstrated that a collegiate athlete sample endorsed fewer symptoms (1.75) than did the high school sample (2.25) leading to evidence of developmental variables (age) contributing to SCAT2 performance. The above findings were contrasted by Zimmer., *et al*. [13] who found little to no difference in total scores due to sex, sport type or concussion history. However, in their study female participants in collision sports reported significantly fewer symptoms than did female or male participants in non-collision sports. In addition, female participants were observed to perform significantly better than males on the SAC portion [13]. Given that Putukian., *et al*. [10] found that the SCAT2 demonstrated clinical utility in post-concussion assessments among college athletes, the differences found in the above studies between adolescent and collegiate populations, highlights the need for more specific college-aged normative information.

In spite of its widespread use, there have been few studies measuring the reliability of the SCAT from season to season. Valovich., *et al*. [14] reported test-retest indices to be poor for the SAC portion and good for the Balance (BESS) portion in a sample of 50 youth (ages 9 - 14). Chan., *et al*. [15] found that the total intra class correlations (ICC) scores for the total SCAT2 in elementary children was poor, with a slight improvement observed on the individual components of the SCAT2 (SAC, GCS, Maddocks score, and BESS. The authors advised against using a change in scores from preseason to postseason for clinical decisions in a younger population.

The purpose of the current study was to examine test characteristics that occur when transitioning collegiate athletes from the SCAT2 to the more recent SCAT3 version. In addition, we sought to report changes in athletes who had suffered concussions during the previous competitive season. Overall, this study sought to evaluate the reliability and stability from a collegiate sample that underwent baseline testing with the SCAT2 and were then re-tested with the SCAT3.

Methods

One hundred and sixty-five student-athletes (127 male; 38 female) from a Canadian university in Western Canada completed the SCAT2 and SCAT3 as part of the preseason concussion management program over the course of 2 consecutive seasons. In addition, all athletes completed a detailed medical history questionnaire. Items from this questionnaire included items that matched the SCAT3 background questions (history of mood disorders, previous medical imaging, etc). All participants were between the ages of 18 and 25, (mean age = 21.26 years). Table 1 displays the demographic information. A participant was considered previously concussed (PC) if they self-reported ever having a previous concussion on their preseason SCAT and this was verified by the physician who undertook the pre-season medical evaluation with that participant. Inclusion criteria were: (1) individuals on the active roster for varsity wrestling, hockey, football, soccer or basketball over the course of consecutive seasons; (2) consent form completion; (3) completion of a SCAT2 and pre-season questionnaire in the previous year; and (4) completion of a SCAT3. Twenty-two athletes suffered a concussion during the 2012-2013 competitive season and were diagnosed by the University Athletics medical staff and underwent the university's return to play protocol.

Demographic Variables	N = 165	Concussion in past year (N = 22)
Gender		
Male	127	19
Female	38	3
Sport		
Soccer	27	4
Football	68	8
Hockey	42	3
Basketball	18	4
Wrestling	10	3
Handedness		
Left	11	2
Right	154	20

Table 1: *Demographic Variables.*

The SCAT2 and SCAT3 include four primary indexes: (a) a symptom inventory, (b) the SAC, (c) the BESS balance test, and (d) the co-ordination examination. The symptom inventory includes 22 commonly reported concussion symptoms similar to the Post-concussion Symptom Inventory [16]. The symptom score is derived from the number of symptoms reported by the athlete (range of 0 - 22). The symptom severity score is calculated by adding all the scores in the table (on a scale of 0 = none to 6 = severe; range of 0 - 122). The severity score was included in the comparison analysis regardless if the athlete had a previous concussion (on the revised SCAT3 the severity symptom score is included). In addition, the SCAT3 has an optional tandem gait measure. Because the objective of this study was to compare SCAT2 with SCAT3 we omitted the tandem gait measure (not part of the SCAT2). These changes as described by Zimmer., et al. [13] are minor and the SCAT3 does not differ in assessment protocol from the SCAT2. Another supplemental questionnaire measuring athlete attitudes towards concussions was administered during the 2012 season. The results from that questionnaire were not part of the purpose of this study, but background variables (for instance being previously diagnosed with headaches/migraine, learning disabilities, etc.) were used for the purpose of this study.

One subject reported taking a stimulant medication, but did not self-identify as having a learning difficulty, dyslexia or ADHD (from the SCAT3 background section). This individual was included as having an attentional disorder.

All participants were involved in contact or collision sports according to criterion proposed by Zimmer., et al [13]. All SCAT's were administered with verbatim instructions outlined by the SCAT2/3 by team athletic therapists who had undergone training under the supervision of the university's Head Athletic Therapist. Approval was obtained from the Health Ethics Research Board at the University of Alberta. Consent was attained at the time of each athlete's yearly physical.

Data Analysis

Descriptive statistics described the sample population. Separate paired-samples t tests were performed to analyze whether significant differences existed between the initial test and the retest. We calculated a 2-way random effects analysis of variance ICC (2,1) and Pearson product correlation to estimate the test-retest reliability of each variable (symptom score, symptom severity, SAC total and BESS). Portney and Watkins [17] suggested that ICCs less than 0.50 were considered to indicate poor reliability, coefficients measuring 0.50 to 0.75 indicated moderate reliability; and coefficients measuring greater than 0.75 represent good reliability. Randolph., *et al*. [18] argued that the test-retest reliability must be greater than 0.90 to make decisions regarding an athlete's cognitive status after concussion. All data analyses were conducted using SPSS (version 21.0; SPSS Inc., Chicago, IL), and statistical significance was set at $\alpha = 0.05$.

Results

The majority of participants reported reliable demographic information (Table 2) from year to year. Thirteen participants did not record a previous history of concussion on the 2012 form, and were eliminated from the analysis. There was no other missing data from participants. A consistent change was used to describe individuals who correctly noted a change in their status from 2012 to 2013. For instance, an athlete who reported having no concussion prior to 2012, who then sustained a concussion that year and reported this in 2013, represented a consistent change. An inconsistent change was used to identify participants who had differing information from year to year (for instance indicating no history of a mood disorder one year, but not the next without confirmation of a medical diagnosis). The test/retests reliabilities for most variables were good with the exception of mood disorders which fell in the moderate range. Reliability of concussion history report was moderate. Six of the 22 participants did not report having sustained a concussion the year prior in spite of this being verified by physicians during the 2012 - 2013 season.

Frequency	Consistent change (percent)	Inconsistent change (percent)	Same	Intraclass Correlation (2,1)	Pearson r
Previous Concussion	12.6	5.0	82.4	. 66	.66
Hospitalization	0	1.3	98.7	.94	.94
Migraines	0	1.8	98.2	.86	.86
Learning Disorder	0	1.3	98.7	.93	.93
Mood Disorder	0.6	4.2	95.2	.62	.71
Family Diagnosis	0	1.3	98.7	.93	.96
Medications	0	0	100	1.00	1.00

Table 2: *Changes from SCAT2 to SCAT3 Demographic Variables (Y/N).*

Raw scores across the various domains of the SCAT at test-retest intervals are reported in Table 3. There were no significant changes measured by the paired t-tests on the various domains of the SCAT. There was a trend for males to report an increased number of symptoms and total symptoms but the results were not significant. Females, in contrast, demonstrated the reverse trend but again results did not reach statistical significance.

	Initial Session (2012)		Retest (2013)		Test-retest	
Frequency	**Mean**	**SD**	**Mean**	**SD**	**t**	**P**
Number of Symptoms						
Males	1.4	2.6	1.9	3.8		
Females	2.2	3.1	1.9	1.8	1.6	0.12
Total Symptom Score						
Males	2.3	4.9	2.9	6.1		
Females	3.4	5.7	3.2	2.9	0.87	0.31
Orientation						
Males	4.9	0.17	4.9	0.21		
Females	4.9	0.16	4.9	0.27	1.13	0.26
SAC Memory						
Males	14.6	1.1	14.6	1.3		
Females	14.6	1.6	14.6	1.6	1.5	0.13
SAC Delay*						
Males	3.7	1.1	3.8	1.1		
Females	4.2	0.9	4.1	1.3	0.14	0.89
Concentration						
Males	3.9	0.9	3.9	1.0		
Females	3.9	0.8	3.9	0.9	0.00	1.0
Balance errors*						
Males	2.8	2.6	2.9	3.0		
Females	1.7	2.0	1.3	1.7	0.33	0.74
Coordination						
Males	0.96	0.19	0.97	0.18		
Females	0.95	0.23	0.95	0.24	0.25	0.82

Table 3: *Changes from SCAT2 to SCAT3 Domains.*

**Note: Significant differences between females and males at both time intervals ($p < 0.05$)*

While there was a trend for females to report more symptoms and a higher total symptom score compared to males, results did not research statistical significance. Other studies have found significant differences in number and total symptom report between males and females at baseline [13,14,19]. In contrast, independent t-tests reached significance with females scoring higher than males on SAC delay and errors measured by the BESS at both 2012 and 2013 intervals.

Table 4 presents the test-retest reliability results on the 4 core domains measured by the SCAT. Results suggested poor reliability of symptom report and total symptoms for females and scores falling in the moderate range for males. A significant proportion of females endorsed more symptoms and increased severity at the second-time interval even though the mean group scores decreased slightly. While males demonstrated a similar trend, reliability of scores was moderate. In contrast, reliability coefficients on the BESS and SAC total score were good for both genders.

Frequency	Improve (%)	Worse (%)	Same (%)	Intraclass Correlation (2,1)	Pearson r
Symptom Total				0.63	0.65
Male	15.0	29.9	55.1	0.70	0.75
Female	23.7	47.4	28.9	0.29	0.32
Symptom Severity				0.67	0.61
Male	17.3	36.2	46.5	0.60	0.68
Female	21.1	55.3	23.7	0.24	0.30
Balance				0.87	0.88
Male	26.0	20.5	53.5	0.89	0.94
Female	34.2	18.4	47.4	0.75	0.91
SAC Total				0.83	0.83
Male	17.3	18.1	64.6	0.82	0.77
Female	23.7	18.4	57.9	0.92	0.92

Table 4: *Stability of SCAT Variables.*

As noted above, thirteen athletes did not report a concussion history on their 2012 forms and were excluded from the analysis. Conversations with athletic therapists indicated that it was likely that some athletes were unsure about their concussion history and for that reason left this information blank. Among the remaining 152 athletes, 67 reported a history of a previous concussion (PC) and 85 had no history of (NC). No significant differences existed between the two groups on the 4 domains of the SCAT. An interesting trend emerged in which the PC group reported more symptoms and higher symptom severity total in 2012 compared to the NC group. Yet the next year, a reversal of symptom report was noted in which the PC group reported fewer and a lower symptom severity total than the NC group. Overall, test-retest reliability coefficients were good and slightly higher compared to the overall sample. One noticeable difference was that concussed athletes were more likely to either increase or decrease their balance scores from year to year in comparison with the non-concussed group.

	Improve (%)	Worse (%)	Same (%)	Intraclass Correlation (2,1)	Pearson r
Frequency					
History of Concussion (n = 67)					
Symptom Total	22.9	25.3	51.8	0.68	0.69
Severity Total	25.3	28.9	45.8	0.70	0.67
Balance Total	32.5	50.6	16.9	0.88	0.87
SAC Total	18.1	15.7	66.3	0.77	0.89
No History of Concussion (n = 85)					
Symptom Total	11.0	42.7	46.3	0.60	0.66
Severity Total	11.0	52.4	36.6	0.55	0.60
Balance Total	23.2	23.2	53.7	0.84	0.91
SAC Total	19.5	20.7	59.8	0.78	0.91

Table 5: *Individuals with a history of concussion.*

There were 22 athletes who suffered a concussion during the 2012 - 2013 competitive season (3 females and 19 males). None of the participants suffered more than 1 concussion during the course of the competitive season and all returned to play within that competitive season. All athletes were diagnosed by university athletics sports medicine physicians and followed the return to play protocol monitored by athletic therapists. As noted above, 6 of the 22 athletes did not report an increased number of concussions on their 2013 SCAT3 report form. Test-retest reliabilities coefficients were mostly classified as good (Table 6), with the exception of total symptom score that was moderate. There were no significant changes from season to season as measured by paired sample t-tests although there was a trend for an increased number of symptom reported and a higher symptom score the next year.

	Initial Season (2012)		Retest (2013)		Test-retest data		Intraclass
Frequency	**Mean**	**SD**	**Mean**	**SD**	**t**	**p**	**Correlation (2,1)**
Number of Symptoms	1.3	2.1	1.6	2.5	0.74	0.47	0.81
Total Symptom Score	2.2	4.2	3.2	5.4	1.15	0.26	0.68
Orientation	5.0	0.0	5.0	0.0	n/a	n/a	n/a
SAC Memory	14.6	0.8	14.4	0.66	1.00	0.33	0.96
SAC Delay	4.4	0.7	4.6	0.67	1.13	0.26	0.87
Concentration	3.7	0.8	3.6	1.2	0.62	0.54	0.78
Balance Errors	2.2	2.5	2.5	2.4	1.25	0.22	0.89
Coordination	1.0	0.0	1.0	0.0	n/a	n/a	n/a

Table 6: *Changes from SCAT2 to SCAT3 Domains for twenty-two players with concussion.*

Discussion

The revisions of the SCAT2 to the SCAT3 were a product of growing empirical evidence and revised following the most recent CISG in 2013 [7]. While normative data have been published for youth and collegiate athletes, there is limited research published surrounding the reliability and consistency of the SCAT2 and SCAT3. The current study sought to evaluate the reliability and consistency of the various domains of the SCAT in a college sample.

Overall, the reliability of demographic information reported by participants was good although report of previous concussions and mood disorders was less reliable. Athletes may not have accurate recall of their concussion history especially recalling information from their remote medical history. A significant proportion (6/22) of our sample who experienced a concussion during a competitive season incorrectly reported this information the next year. Our results suggested accurate recording of mental health and concussion history is essential and use of developing technology systems that track this information may be helpful.

Reliability coefficients for both balance and SAC totals were good and provide corroborating evidence of strong psychometric properties of the SCAT. In spite of the challenges of the subjectivity of rating errors on the BESS, the reliability of scores remained good. Concerns with inter-rater reliability of BESS scores have been noted in other studies and were not part of the purpose of this study, however, this may contribute to poorer reliability [20]. In contrast, our results noted poor reliability in symptom totals and symptom severity report, especially among our female participants, although the small sample size may have contributed to these findings. A sizable proportion (approximately 50% or higher) of athletes either reported improved (decreased) or worsened (increased) symptoms totals and symptom severity from year to year although the overall "net change" did not reach statistical significance. This underscores the importance of evaluating individual differences each year and we believe our results support yearly SCAT testing.

While our results did not demonstrate significant improvements on the SAC from year to year, it is possible that athletes have learned what to expect during on cognitive testing. Some participants asked athletic therapists if they could repeat words prior to instructions.

This may impact performance over multiple years and artificially augment reliability coefficients. Alternative versions of word list are provided but for athletes who undergo multiple assessments, familiarity with the process may inflate scores. In conclusion, the results from this study can inform practice through accurate baseline testing, diagnosis and concussion management.

Like all studies, this one was not without its limitations. Information regarding an athlete's history (e.g. previous diagnosed learning disability, attention disorder, mental health history) was based upon self-report which is limited by the subject's recall of that information. For the sample of the 22 athletes who were concussed in year one, 6 individuals (27%) did not correctly endorse having sustained another concussion during the preceding year at the next baseline evaluation. Thus, verifying clinical information is important. Second, the SCAT was administered by clinicians, the rapport between athlete and clinician may influence the athlete's willingness to disclose symptoms. Third, the demands of collegiate athletics are unique and therefore our results may not generalize to other athlete populations or settings.

Future research should build upon existing findings related to sideline assessments. The SCAT5 was recently published by the International Consensus Group and although most components were kept the same as its predecessor, there were some changes [21]. Establishing psychometric properties with the SCAT5 will be important to ensure valid and reliable outcomes. In addition, individuals with learning disabilities and attention disorders demonstrate unique outcomes on cognitive measures used in concussion evaluations, a factor that is important to understand when interpreting clinical data [22]. In addition, as technology develops there may be consideration for other sideline assessment tools that can provide a "value added" when measuring balance.

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Bibliography

1. Halstead Mark E and Kevin D Walter. "Sport-related concussion in children and adolescents". *Pediatrics* 126.3 (2010): 597-615.

2. Iverson Grant L., *et al*. "Cumulative effects of concussion in amateur athletes". *Brain Injury* 18.5 (2004): 433-443.

3. McCrory Paul., *et al*. "Consensus statement on concussion in sport: the 4th International Conference on Concussion in Sport held in Zurich, November 2012". *British Journal of Sports Medicine* 47.5 (2013): 250-258.

4. Chen Jen-Kai., *et al*. "Neural substrates of symptoms of depression following concussion in male athletes with persisting post-concussion symptoms". *Archives of General Psychiatry* 65.1 (2008): 81-89.

5. Guskiewicz Kevin M., *et al*. "Recurrent concussion and risk of depression in retired professional football players". *Medicine and Science in Sports and Exercise* 39.6 (2007): 903-909.

6. Kerr Zachary Y., *et al*. "Nine-year risk of depression diagnosis increases with increasing self-reported concussions in retired professional football players". *The American Journal of Sports Medicine* 40.10 (2012): 2206-2212.

7. Guskiewicz Kevin M., *et al*. "Evidence-based approach to revising the SCAT2: introducing the SCAT3". *British Journal of Sports Medicine* 47.5 (2013): 289-293.

8. Valovich McLeod., *et al*. "Representative baseline values on the Sport Concussion Assessment Tool 2 (SCAT2) in adolescent athletes vary by gender, grade, and concussion history". *The American Journal of Sports Medicine* 40.4 (2012): 927-933.

9. Brown Dana A., *et al*. "Differences in symptom reporting between males and females at baseline and after a sports-related concussion: a systematic review and meta-analysis". *Sports Medicine* 45.7 (2015): 1027-1040.

10. Putukian Margot., *et al*. "Prospective clinical assessment using Sideline Concussion Assessment Tool-2 testing in the evaluation of sport-related concussion in college athletes". *Clinical Journal of Sport Medicine* 25.1 (2015): 36-42.

11. Schneider Kathryn J., *et al*. "Preseason reports of neck pain, dizziness, and headache as risk factors for concussion in male youth ice hockey players". *Clinical Journal of Sport Medicine* 23.4 (2013): 267-272.

12. Jinguji Thomas M., *et al*. "Sport Concussion Assessment Tool–2: Baseline values for high school athletes". *British Journal of Sports Medicine* 46.5 (2012): 365-370.

13. Zimmer Adam., *et al*. "Normative values of major SCAT2 and SCAT3 components for a college athlete population". *Applied Neuropsychology: Adult* 22.2 (2015): 132-140.

14. McLeod Tamara C Valovich., *et al*. "Psychometric and measurement properties of concussion assessment tools in youth sports". *Journal of Athletic Training* 41.4 (2006): 399-408.

15. Chan Monica., *et al*. "Test-retest reliability of the sport concussion assessment tool 2 (SCAT2) for uninjured children and young adults". *British Journal of Sports Medicine* 47.5 (2013): e1.

16. Ponsford Jennie., *et al*. "Predictors of post-concussive symptoms 3 months after mild traumatic brain injury". *Neuropsychology* 26.3 (2012): 304-313.

17. Portney Leslie Gross and Mary P Watkins. "Foundations of clinical research: applications to practice". Upper Saddle River, NJ: Prentice Hall 3(2009).

18. Randolph Christopher. "Implementation of neuropsychological testing models for high school, collegiate, and professional sport settings". *Journal of Athletic Training* 36.3 (2001): 288-296.

19. Shehata Nadia., *et al*. "Sport concussion assessment tool: baseline values for varsity collision sport athletes". *British Journal of Sports Medicine* 43.10 (2009): 730-734.

20. Bell David R., *et al*. "Systematic review of the balance error scoring system". *Sports Health: A Multidisciplinary Approach* 3.3 (2011): 287-295.

21. Elbin RJ., *et al*. "Individual and combined effects of LD and ADHD on computerized neurocognitive concussion test performance: evidence for separate norms". *Archives of Clinical Neuropsychology* 28.5 (2013): 476-484.

22. Echemendia Ruben J., *et al*. "The Sport Concussion Assessment Tool 5th Edition (SCAT5)". *British Journal of Sports Medicine* (2017).

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