

Construct validity and reliability of the Concussion Knowledge Assessment Tool (CKAT)

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Objective: *To evaluate the test-retest reliability and construct validity of the concussion knowledge assessment tool (CKAT) as a measure of knowledge of concussion and its management among chiropractic subgroups and to compare these properties for two scoring strategies for the CKAT.*

Methods: *Three chiropractic subgroups (first year students, interns and sports chiropractors) completed the CKAT via SurveyMonkey with a second administration two to six weeks later for a subset of respondents. Scatter plots and Intraclass Correlation Coefficients (ICC) were used for test-retest reliability. A priori hypotheses regarding the relationship of CKAT scores across known subgroups, and with concussion knowledge self-rankings were established prior to data collection. Distributions of CKAT scores were compared across the subgroups*

Objectif : *Évaluer la fiabilité du test-retest et interpréter la validité du Concussion Knowledge Assessment Tool (CKAT)) servant à évaluer les connaissances sur la commotion cérébrale et sa prise en charge par des sous-groupes de chiropraticiens et comparer ces propriétés pour deux stratégies de cotation du CKAT.*

Méthodologie : *On a demandé à trois sous-groupes de chiropraticiens (étudiants de première année, internes et chiropraticiens du sport) de remplir le questionnaire CKAT par SurveyMonkey et de deux à six semaines plus tard, on l'a utilisé une deuxième fois auprès d'un sous-ensemble de répondants. Des diagrammes de dispersion et des coefficients de corrélation intraclasse (CCI) ont été utilisés pour évaluer la fiabilité du test-retest. Des hypothèses a priori sur le rapport des scores CKAT dans les sous-groupes connus et les auto-évaluations des connaissances sur la commotion cérébrale ont été établis avant la collecte des données. On a comparé les*

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using boxplots and ANOVA for known groups validity, and correlation of CKAT scores with concussion knowledge self-ranking was examined.

Results: Test-retest ICC for the revised scoring was 0.68 (95%CI 0.51-0.80). First year students had a mean revised CKAT (out of 49) of 36.9 (SD= 4.7), interns 39.9 (SD=3.0) and sports chiropractors 41.8 (SD=3.2) which are significantly different ($F_{2,125}=17.54$; $p<0.0001$).

Conclusions: The CKAT distinguished between chiropractic subgroups expected to have different levels of knowledge, supporting construct validity, however, it did not achieve adequate test-retest reliability.

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KEY WORDS : assessment, concussion, knowledge, management, tool

Introduction

There has been increasing interest and focus on sport-related concussion (SRC) in the scientific literature and popular media in recent years. SRC is an immediate and transient display of traumatic brain injury (TBI) symptomatology as defined by the 2017 Concussion in Sport Group (CISG).¹ Symptoms are variable, and can be somatic, cognitive, and/or emotional in nature and may include: headaches, feeling like in a fog, lability, loss of consciousness, amnesia, neurological deficit, gait unsteadiness, irritability, slowed reaction times, and drowsiness.¹ Concussion has a favorable natural history with 80 to 90% of concussions resolving on their own within seven to 10 days.² Factors associated with slower recovery from concussion symptoms include: increased severity of initial symptoms, pre-existing and/or subacute development of migraine headaches or depression, particularly in young adults, adolescents and children.¹

The literature regarding concussion education for athletes has grown at a much faster pace than the literature on instructing healthcare practitioners about concussion

répartitions des scores CKAT entre les sous-groupes à l'aide de diagrammes de dispersion et ANOVA pour la validité des groupes connus et la corrélation des scores CKAT et on a examiné les auto-évaluations des connaissances sur la commotion cérébrale.

Résultats : Les CCI du test-retest pour le score révisé était de 0,68 (IC à 95 % : 0,51-0,8). Pour Les étudiants de première année, le score révisé moyen CKAT (sur 49) était de 36,9 (ÉT = 4,7), pour les internes de 39,9 (ÉT = 3) et pour les chiropraticiens du sport de 41,8 (ÉT = 3,2) ce qui constitue d'importantes différences ($F_{2,125}=17,54$; $p < 0,0001$).

Conclusions : Le score CKAT variait entre les sous-groupes de chiropraticiens qui sont censés avoir de différents degrés de connaissances, ce qui prouve la validité de l'interprétation. Cependant, le degré de fiabilité du test-retest n'est pas suffisant.

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MOTS CLÉS : évaluation, commotion cérébrale, connaissances, prise en charge, outil

management.³ This is especially of concern for those practitioners who work in sports health care settings and primary contact practices that frequently come into contact with the condition.³ As a result, concussion management can be challenging for health care practitioners, and assessing health care practitioners' knowledge of concussion and its management is of interest.

Boggild and Tator⁴ developed a concussion knowledge assessment tool (CKAT) for clinicians based on a literature review (including the 2008 Zurich consensus statement on concussion in sport⁵), expert review, and pilot testing. They then used the tool to assess concussion knowledge in graduating medical students and neurology/neurosurgery residents.⁴ Since that initial publication, the CKAT has been administered to other healthcare practitioner groups to assess their knowledge of concussion and its management, including physician trainees^{3,4,6}, chiropractors⁷, chiropractic trainees⁷, and sports chiropractors⁸. Although the distribution of CKAT scores across these different samples were comparable, all of these studies concluded that more education is required to fill know-

ledge gaps, which would likely require changes in the education curricula of these respective professions.

However, to our knowledge, the measurement properties of the CKAT, such as test-retest reliability and construct validity, have not been evaluated. Test-retest reliability is the degree to which a test score is able to be repeated on a second administration given the trait being measured has not changed.⁹ Construct validity is the extent to which a test measures what it claims to be measuring, capturing the construct of interest. In other words, for the CKAT, construct validity is the degree to which it measures the knowledge of concussion and its management.⁹ As such, the aim of this study is to investigate the test-retest reliability and construct validity of the CKAT among chiropractic trainees and practitioners. We also set out to investigate an alternative scoring method (as described in the methods) for the CKAT to determine whether it would have better measurement properties than the originally proposed scoring method. The original scoring has a nine-point scoring scale which possibly limits its resolution making it more difficult to discriminate between groups with different levels of knowledge. We hypothesized a priori that if the CKAT (with either scoring) is a valid tool to assess concussion knowledge and management, then it should be able to distinguish between groups of healthcare providers at different stages of training, it should correlate moderately with a self-ranking of concussion knowledge, and it would demonstrate adequate test-retest reliability.

Methods

Study design

Validity and reliability study with survey administration and short-term follow-up and re-administration for a subset of respondents.

Participants, recruitment and survey administration

A convenience sample of three groups of participants were targeted for the study, first-year chiropractic students (first year students), fourth-year chiropractic interns (interns) (both from the Canadian Memorial Chiropractic College (CMCC)) and Fellows from the Royal College of Chiropractic Sports Sciences Canada (RCCSS(C) (sports chiropractors)). First year students and interns were recruited from CMCC via class and/or clinic announcements, and

word-of-mouth in July and August of 2017. Students were given a SurveyMonkey¹⁰ link on a piece of paper either after a laboratory session, at the beginning of class, or during clinical rounds and were asked to complete the survey without the help of any external sources. Paper copies of the survey were made available for sports chiropractors at an RCCSS(C) annual general meeting and conference in Toronto, ON in November 2017. Additionally, email addresses for a complete list of sports chiropractors were obtained from the RCCSS(C) (n=117) and these sports chiropractors were invited to complete the survey via an emailed SurveyMonkey¹⁰ link in December of 2017. All participants from each of the three groups who completed the survey were emailed two to six weeks after initial submission with a SurveyMonkey¹⁰ link directing them to an identical copy of the survey for a re-test. There are no standard rules for determining the time interval between repeated measures for test-retest reliability. However, a common time frame of two weeks has been suggested in the literature.⁹ A time interval of two to six weeks between measures was used here, with the belief that this was long enough to avoid recall of the first administration, and short enough for changes in knowledge of concussion and its management to be unlikely. There was no blinding. Analysts weren't blinded to the responses, nor were the responders blinded to the purpose of the study.

Measures

The 26-item CKAT survey, originally created by Boggild and Tator⁴ and modified for chiropractors by Kazemi *et al.*^{7,8}, was entered into SurveyMonkey¹⁰. The original survey consisted of three sections: 1) questions about demographics, participation in sport, and history of concussion, 2) questions about knowledge of concussion and its management (the CKAT), and 3) questions about learning needs regarding concussion. The modified version of the CKAT implemented in this study is presented in Appendix 1.

Modifications to the original survey by Kazemi *et al.*^{7,8} altered language used in questions that was specifically aimed at physicians to wording more appropriate for chiropractic respondents. For instance, question 2 was changed from "What medical school..." to "What chiropractic college...". Three further modifications were implemented for the current study. For question 15 in part 2 "What is the appropriate management of concussion?

Select all that apply”, the response option “Every concussed individual should see a physician”, was changed to “Every concussed individual should see a healthcare professional”. For question 16, “What are some “red flags” that may predict the potential for more prolonged symptoms and may influence your investigation and management of concussion? Select all that apply”, the response option “age” was changed to “younger age” to remove ambiguity. The last modification was made to the version administered to the sports chiropractors, with the addition of an open-ended question asking whether there are changes they would recommend to the assessment tool, as a result of newer research.

The primary measure from the survey of interest in this study comes from the questions in section 2 measuring knowledge of concussion and its management – the CKAT. Boggild and Tator⁴ proposed a scoring scheme for this tool with a range of scores from 0 to 9 with each of questions 9 through 17 of the survey contributing one possible point to the overall score. Questions 12, 15, 16, and 17 are compound questions requiring the respondent to indicate all response options that apply and not indicate any options that do not apply. For instance, for question 17, “*What are the long-term consequences of repetitive concussive injury? Select all that apply*”, there are ten possible responses offered, with eight being correct choices and two being incorrect choices. To get one point for these questions in the original scoring, the respondent must have selected all the appropriate responses, *and not selected* the inappropriate responses. For the current study, we considered an alternative scoring method that allowed for one possible point for each of the compound question responses – either correctly endorsed, or correctly not endorsed. This scoring gives a potential range of scores from 0 to 49. We entertained this option as we thought these scores might be more dispersed and therefore have higher reliability and better discrimination. Kazemi *et al.*⁸ also considered an alternative scoring method utilizing the individual response options.

Other measures from the survey used in this study (see Appendix 1, ‘Modified Survey with CKAT’) included question 21, asking the respondent to self-rank their knowledge of concussions on a 1 to 10 scale anchored by Inadequate (1) and Completely Adequate (10).

Analysis

Descriptive statistics (counts and percentages for categorical variables, means and SD for continuous variables) were used to describe the participants.

Reliability

Test-retest reliability was assessed using scatterplots of retest versus test scores and intraclass correlation coefficients with 95% CI, specifically ICC(2,1) based on the taxonomy of Shrout and Fleiss.¹¹ Adequate test-retest reliability would be indicated by an ICC of 0.70 or greater.¹²

Validity

Construct validity is typically approached by posing hypotheses of how a measure should behave if it is a valid measure of the construct under study.⁹ We hypothesized that knowledge of concussion and its management should be highest among sports chiropractors who not only gain extra practical training throughout their two-year sports sciences residency, but they also frequently manage athletic injuries including SRC. We also hypothesized that interns in their fourth-year of education would have less knowledge than sports chiropractors, but would have some content related to concussion studied in years 1 through 3, followed by first-year chiropractic students, expected to have the lowest levels of knowledge.³ This approach is referred to as known groups validity or discriminative validity.⁹ We examined the distributions of scores across these three groups using boxplots to assess overlap of distribution, computing means and 95% CI for each subgroup and comparing mean subgroup levels of knowledge using one-way Analysis of Variance (ANOVA). Furthermore, for construct validity, we hypothesized that the CKAT scores should correlate at least moderately ($r \sim 0.5$) with the participants’ self-ranking of concussion knowledge, and this was investigated using scatterplots and Pearson correlation coefficients (r) with 95% CI.

Statistical software

The graphical analysis for this study was generated using R¹³ and the R package “psych”¹⁴ with remaining analysis generated using SAS software v9.4. (Copyright © 2012–2018, SAS Institute Inc., Cary, NC, USA. SAS and all other SAS Institute Inc. product or service names are registered trademarks or trademarks of SAS Institute Inc., Cary, NC, USA.)

Table 1.
Study participants.

| | First year students n=46 | Interns n=45 | Sports chiropractors n=37 | Total n=128 |
|---|-----------------------------|-----------------|------------------------------|----------------|
| Gender <i>n</i> (%) | | | | |
| Female | 26 (56.5%) | 22 (48.9%) | 9 (24.3%) | 57 (44.5%) |
| Male | 20 (43.5%) | 23 (51.1%) | 28 (75.7%) | 71 (55.5%) |
| CMCC student/graduate | 46 (100%) | 45 (100%) | 30 (81.1%) | 121 (94.5%) |
| Experienced concussion <i>n</i> (%) | 17 (37.0%) | 23 (51.1%) | 15 (40.5%) | 55 (43.0%) |
| Completed paper copy <i>n</i> (%) | N/A | N/A | 17 (45.9%) | |
| Retest completed <i>n</i> (%) | 15 (32.6%) | 21 (46.7%) | 22 (59.5%) | 58 (45.3%) |
| Self-Rank Concussion Knowledge 1-10 <i>Mean (SD)</i> | 5.0 (2.0) | 5.5 (1.5) | 7.4 (1.6) | 5.9 (2.0) |
| Time taken minutes <i>Mean (SD)</i> | 8.5 (4.7) | 13.4 (10.2) | 11.4 (13.0) | 11.1 (9.9) |

Sample size

The study protocol planned for at least 30 subjects per group (1st year, 4th year, sports chiropractors) for the original testing with retests completed by as many of each group as possible, targeting at least 50 retests overall distributed across the three groups. Streiner and Norman¹⁵ suggest that studies of test-retest reliability can be adequately conducted with 50 subjects. With at least 30 subjects per group for known groups validity, the sample size would be sufficient to detect between groups effect sizes of around 0.70¹⁶ with type 1 error $\alpha=0.05$ and power $1-\beta=0.80$. Effect sizes reported for comparisons made by Boggild and Tator⁴ and Kazemi *et al.*^{7,8} were considerably larger than 0.70.”

Ethics

The protocol for this study was reviewed and approved by the Research Ethics Board of the Canadian Memorial Chiropractic College (CMCC) (REB# 172008).

Results

Table 1 provides descriptive statistics of the participants in the study by study group. Overall there were 128 par-

ticipants completing the survey at least once, with 46 first year students (out of approximately 200 first year students), 45 interns (out of approximately 175 interns) and 37 sports chiropractors (out of 117) corresponding to 23%, 26% and 32% response rates respectively. Seventeen (46%) of the sports chiropractors completed paper copies of the survey at an annual conference hosted by the RCCSS in Toronto, Ontario. Fifty-six percent of the sample was male, although distribution by gender was fairly even for the two student groups, with the sports chiropractors being predominantly male. All of the students were affiliated with CMCC, while 81% of the sports chiropractors were CMCC graduates. Retests were completed by 33%, 47% and 60% of the first-year students, interns and sports chiropractors respectively. Retests occurred on average 25 days after the test ($SD=6.9$), with a minimum gap of 16 days and a maximum gap of 37 days. On average, mean time to complete the survey as recorded by SurveyMonkey was 11 minutes.

Reliability

Test-retest findings are presented in Figures 1(a) (original CKAT scoring) and 1(b) (revised CKAT scoring).

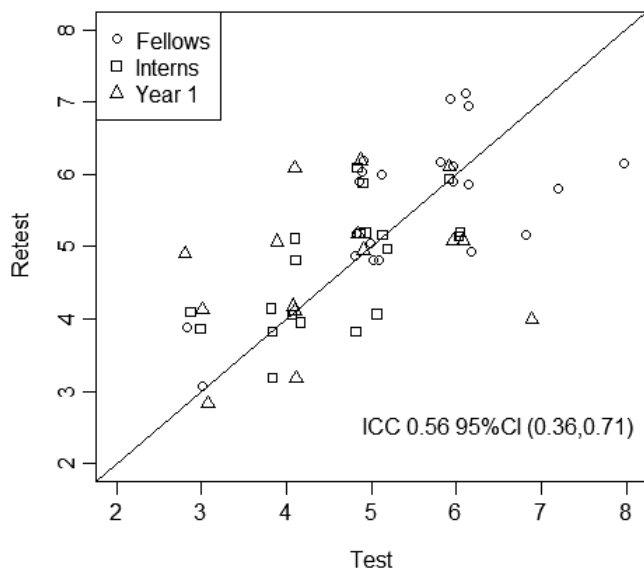


Figure 1(a).

Test-retest reliability with original scoring, scatterplot of retest versus test, with line $retest=test$ superimposed, and intraclass correlation coefficient with 95% confidence interval.

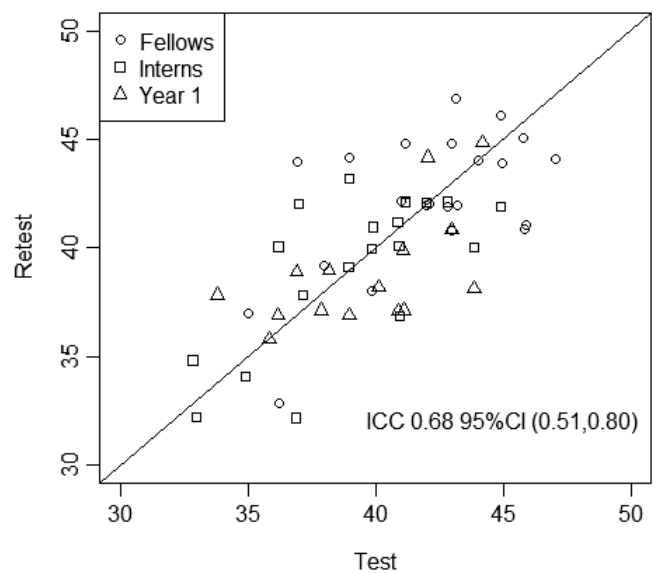


Figure 1(b).

Test-retest reliability with modified scoring, scatterplot of retest versus test, with line $retest=test$ superimposed, and intraclass correlation coefficient with 95% confidence interval.

Because there are a discrete number of scores that the CKAT can take on (0 to 9 for original scoring and 0 to 49 for revised scoring), the scatter plots were produced using the “jitter” function in R to add a small amount of noise to each coordinate to avoid multiple plotting points overlapping each other. There is some scatter in both plots – that is, they are loosely clustered around the line $y=x$,

and the intra-class correlation coefficients (ICC(2,1)) for test-retest reliability are 0.56 (95% CI 0.36-0.71) and 0.68 (95% CI 0.51-0.80) for the original and revised scoring respectively.

Validity

Table 2 shows descriptive statistics by group for the

Table 2. Comparing distribution of CKAT scores across known groups.

| | First year students n=46 | Interns n=45 | Sports chiropractors n=37 | ANOVA comparing means across groups |
|--|-----------------------------|-------------------|------------------------------|--|
| CKAT original scoring (possible range 0-9) | | | | |
| Mean (95%CI) | 3.98 (3.59, 4.37) | 4.53 (4.26, 4.81) | 5.49 (5.11, 5.86) | $F_{2,125}=18.44$ |
| SD | 1.31 | 0.92 | 1.12 | $P<0.0001$ |
| CKAT revised scoring (possible range 0-49) | | | | |
| Mean (95%CI) | 36.9 (35.5, 38.3) | 39.9 (39.0, 40.8) | 41.6 (40.6, 42.7) | $F_{2,125}=17.54$ |
| SD | 4.7 | 3.0 | 3.2 | $P<0.0001$ |

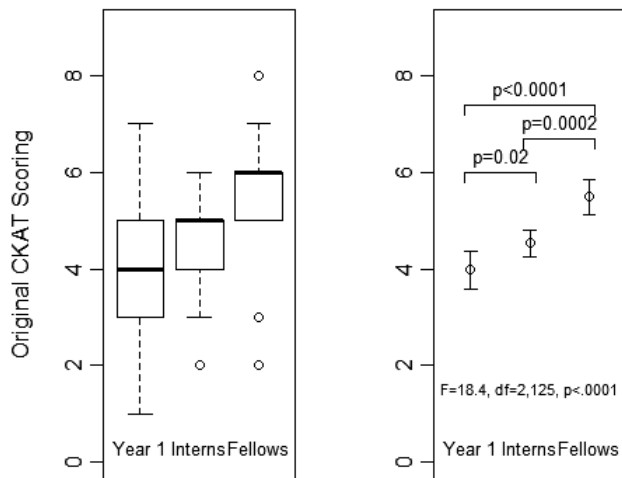


Figure 2(a).

Comparing distribution of CKAT across known groups using original scoring. The left-hand plot depicts boxplots for comparison of entire distribution of scores across the three groups. The right-hand plot depicts group means with 95% confidence intervals, and also shows the overall ANOVA F-test, and p-values for each pairwise comparison contrast.

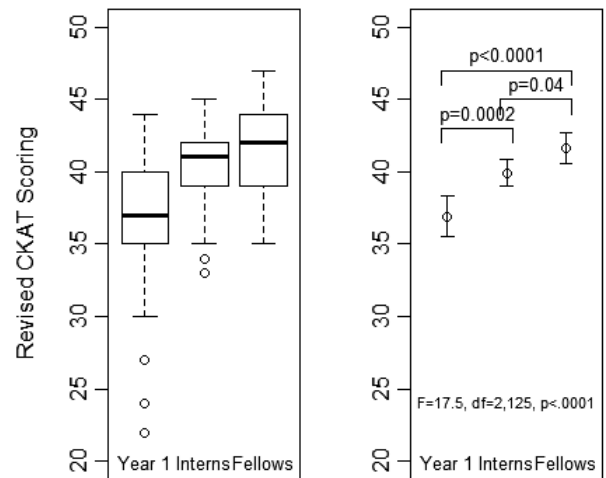


Figure 2(b).

Comparing Distribution of CKAT Across Known Groups – Revised Scoring. The left-hand plot depicts boxplots for comparison of entire distribution of scores across the three groups. The right-hand plot depicts group means with 95% confidence intervals, and also shows the overall ANOVA F-test, and p-values for each pairwise comparison contrast.

CKAT scores using both the original scoring method and the revised scoring method along with the test statistics from ANOVA. Figures 2(a) and 2(b) present graphical representations of the distributions of CKAT scores. For the original scoring of the CKAT (top rows of Table 2, Figure 2(a)), there is a gradient with mean scores increasing from 3.98 to 4.53 to 5.49 across first year students, interns and sports chiropractors. These means are significantly different with $F_{2,125}=18.44$ and $p<0.0001$, as were the means for each pairwise comparison of groups, p-values shown in the right-hand plot of Figure 2(a). These differences in means correspond to effect sizes of 0.49, 1.34 and 0.85 which are medium (0.49) and large (1.34, 0.85) using Cohen's classification¹⁶. In the boxplots (left-hand plot), there is some overlap of distribution between first year students and interns, although the majority of interns scored above the first-year student median score. There is almost no overlap in scores between the sports chiropractors and both the first-year students and interns. With the revised scoring, there is less overlap in distribution

as seen in the boxplots, between the first year and fourth year students, but more overlap in distribution between the fourth-year students and the sports chiropractors. Mean scores again show a gradient from 36.9 to 39.9 to 41.6 for first year, fourth year and sports chiropractors respectively and these means are significantly different with ANOVA test results of $F_{2,125}=17.54$ and $p<0.0001$, as are the means for each pairwise comparison of groups, p-values shown in the right-hand plot of Figure 2(b). These differences in means correspond to effect sizes of 0.80, 1.25 and 0.45 which are large (0.80, 1.25) and close to medium (0.45) using Cohen's classification¹⁶. Figures 3(a) and 3(b) show scatterplots (again using the jitter function) of the two versions of CKAT scoring against the participants' self-ranking of concussion knowledge. There was a moderately positive correlation between self-ranking of concussion knowledge and CKAT scores when using both the original and revised scoring respectively (Pearson Correlation Coefficients) ($r = 0.54$; 95% CI = 0.40, 0.65) and ($r = 0.48$; 95% CI = 0.33, 0.60) respectively. Self-

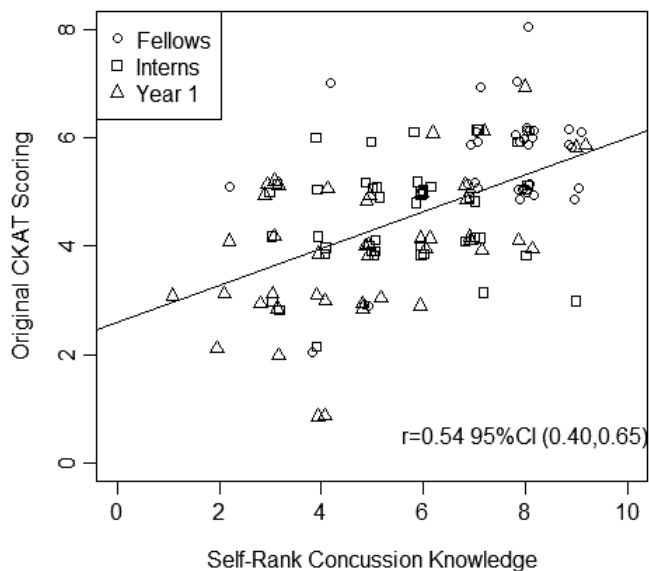


Figure 3(a).

Comparing CKAT scores using the original scoring and self-ranking of concussion knowledge using scatter plot and Pearson correlation coefficient with 95% confidence interval. The best fitting regression line is superimposed on the plot.

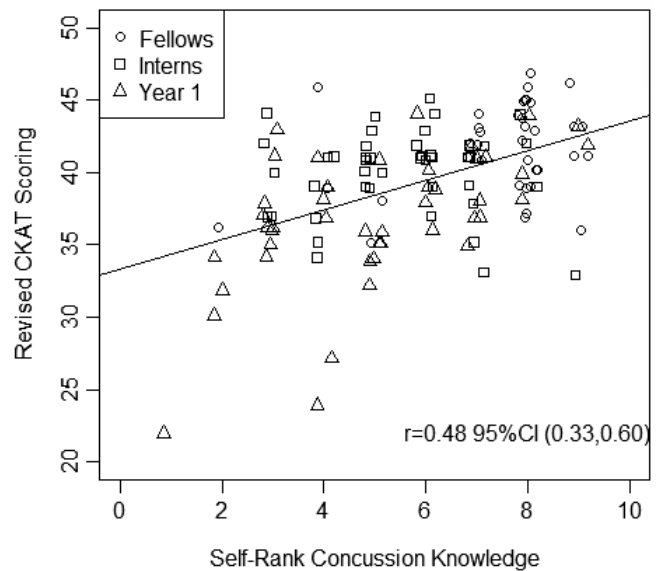


Figure 3(b).

Comparing CKAT scores using the revised scoring and self-ranking of concussion knowledge using scatter plot and Pearson correlation coefficient with 95% confidence interval. The best fitting regression line is superimposed on the plot.

ranked concussion knowledge on average increased with increasing training with means of 5.0, 5.5 and 7.4 for first year, fourth year and sports chiropractors respectively.

Discussion

We conducted a study to examine the psychometric properties of the CKAT, a tool developed to measure clinician knowledge of concussion and its management, and to compare two approaches to its scoring. The results show that both scoring versions of the CKAT were able to distinguish between the three groups of participants as hypothesized. There were moderate correlations of both versions with self-ranking as hypothesized a priori. Test-retest reliability was poor for the original scoring and fair for the revised scoring. Neither version achieved the criteria of 0.70 commonly considered adequate¹² although the revised scoring version came closer. Based on these findings, primarily the differences in test-retest reliability, the revised scoring of the CKAT performs more favorably.

We hypothesized a modest correlation ($r \sim 0.5$) between the CKAT scores and the self-ranking of concussion knowledge if the CKAT is a valid measure of concussion knowledge and management and found support for that hypothesis with correlations of $r=0.54$ and $r=0.48$ for the two scoring approaches. These are similar to correlations previously reported by Boggild and Tator⁴ ($r=0.44$), and Kazemi *et al.*⁷ ($r=0.40$), but not similar to the correlation of $r=0.07$ reported by Mann *et al.*⁶. It is unclear why the latter study had findings so different from the others, and the authors do not discuss this in their paper.

Comparability of our findings with other similar studies in the literature lends further support for the known groups validity component of the findings, with the ordering of scores (using the original scoring method) aligning with levels of education and specialty training. First-year chiropractic students examined in this study, and medical students⁴ have the lowest reported mean scores (4.0-4.2 respectively). Chiropractic interns examined both in this study and also in a different subset of respondents in

Kazemi *et al.*⁶, chiropractic residents⁶, and family medicine residents⁵ reported mid-range mean scores (4.5, 5.2, 5.3, 5.2 respectively). Lastly, in those with specialty training including sports chiropractors examined both in this study and in a different subset of respondents in Kazemi *et al.*⁷, along with neurology and neurosurgery residents⁴ obtained the highest overall mean scores (5.5, 5.6, 5.8 respectively). When comparing the most novice (first year chiropractic students) to the most trained (sports chiropractors) in our data set, we saw very large differences in CKAT scores using both scoring methods, with Cohen's effect sizes of 1.25 and 1.34. These effect sizes are larger than the effect size corresponding to the comparison of medical school students to neurology and neurosurgery residents which was 1.06, and much larger than the effect size (0.70) we used in our sample size planning.

Limitations

There are some limitations to this study. Concussion education curriculums can differ among educational programs/institutions between healthcare professions, and so the CKAT's psychometric properties may be different in other groups of healthcare professionals. Secondly, the CKAT was developed from the 2008 consensus statement released following a meeting in Zurich⁵, and since then subsequent consensus statements in Zurich 2012² and Berlin 2016¹ have been released. Although it does not appear that significant alterations to the CKAT questions are warranted based on the subsequent consensus statements, it would be a worthwhile exercise to scrutinize each question individually for content and face validity. Doing so may improve the psychometric properties of the test, which will provide a better representation of concussion knowledge in those tested. This study has demonstrated methods used to assess the validity and reliability of the CKAT, and as such, future CKAT versions can also have their psychometric properties assessed using the same approach. This is particularly important as newer guidelines are released.

We also could not prevent respondents from looking for answers in between test and retest. We aimed for a range of two to six weeks between trials to minimize recall of previous answers and limit the likelihood of change in concussion knowledge between administrations. Although the study's consent form stressed that our interest was in the investigation of the CKAT as a measurement

tool rather than individual respondents' scores, there is the possibility that some respondents may have felt that their knowledge was being evaluated, and it is possible that some individuals researched questions in between administrations. If a respondent is to study the content of the test in between test trials and change their responses, it would inevitably lead to an underestimation of true test retest reliability, biasing the results. Validity would not be affected by this since it is only based on the first test.

CKAT mean scores may not be representative of the populations from which our samples were recruited with response rates ranging from 23% to 32%, as perhaps only those with experience or interest in concussion diagnosis and management chose to participate. It is also inherent within every subgroup that there may be some variability in knowledge which could introduce bias. For example, some first year student respondents may have obtained concussion knowledge prior to their education at CMCC which may inflate the mean test score, which would not be representative of that group. Also, some of the sports chiropractor respondents are separated by decades of clinical experience which may also bias CKAT scores within that group. Lastly, it is not known whether respondents are able to accurately self-rank their level of concussion knowledge. In other words, respondents may over or underestimate their self-rank of knowledge which may not correlate as hypothesized with their CKAT score. Previous studies utilizing the tool have compared respondent self-rank to the CKAT score with an unwritten assumption that they should positively correlate, whereas we have stated this as an *a priori* hypothesis as another way to demonstrate construct validity.

Strengths

Target sample sizes were achieved which allowed for an adequate study sample size and power. The hypotheses for construct validity were established prior to collecting any data. We examined the psychometric properties using two different scoring methods. We are the first to assess test-retest reliability of this instrument.

Future considerations

We are able to measure concussion knowledge with more confidence now that the psychometric properties of the CKAT have been analyzed with favorable outcomes for validity, but not so favourable for reliability. Moving for-

ward, we highly recommend that each question of the CKAT be examined individually, especially in light of newer guidelines, in an attempt to improve the psychometric properties, particularly reliability. Identifying whether a statistical difference in mean scores between groups actually represents a clinically meaningful difference in actual knowledge also needs to be addressed. The validity and reliability findings from this study are limited to Canadian Doctors of Chiropractic and chiropractic students largely trained at CMCC, so establishing the psychometric properties in other populations would also be of importance as concussions are being managed by several different sport healthcare professions. Lastly, there seems to be a learning gap between concussion guidelines and practitioner/trainee knowledge which should be addressed through institutional curricula.

Conclusions

This study provided evidence to support construct validity of the CKAT by distinguishing chiropractic subgroups as hypothesized, and by moderately correlating with concussion knowledge self-rating. However, the CKAT was not able to achieve adequate test-retest reliability (0.70) using either scoring method, even though the revised scoring came close (0.68). In light of this and given there have been updates to the 2008 Zurich consensus statement on concussion in sport, we recommend a re-examination of the CKAT, item by item, to identify where improvements could be made to improve the psychometric properties of the instrument.

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Appendix 1.
Modified survey with CKAT (used for this study).

Part 1: ID questions and Sports and Recreation background:

1. What is your gender?
2. Which chiropractic college are you currently attending? If you have currently completed your chiropractic undergraduate degree, which college did you receive this at?
3. What residency program and year are you in? (question only in survey to residents)
4. Have you done any of the following in the past 2 years? Mark all that apply.
Thirty-one options of sports and activities given, including the option “other”
5. Last week, how many times did you participate in sports or physical activity?
Options for 1 time to 7 times given
6. About how much time did you spend on each occasion?
Options: 1 to 15 minutes, 16 to 30 minutes, 31 to 60 minutes, More than one hour
7. In the past, have you ever suffered a concussion? You may have been “knocked out”, knocked unconscious, confused, or had your “bell rung”. You may have felt lightheaded, not known where you were, etc.
Options: Yes – once, Yes – 1-5 times, Yes – more than 5 times, No
8. If you answered yes to the previous question, how did your concussion(s) occur? Please select all that apply.
Options: Work related, Motor Vehicle Crash, Sport or recreational activity, Fall, Other

Part 2 Knowledge questions about concussions (**Answers that were considered correct are bolded**):

9. What is the definition of concussion? Select the best answer.
 - a. Loss of consciousness for <5 mins after an impact to the head
 - b. A complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces**
 - c. A structural brain injury caused by mild traumatic force that transiently decreases cerebral blood flow
10. Is a concussion a brain injury? Select the best answer.
 - a. No, as there is no abnormality seen on standard structural neuroimaging
 - b. No, as symptoms are only psychological in nature
 - c. Yes, as there is a functional disturbance that cannot be seen on standard neuroimaging**
 - d. Yes, as there is structural abnormality seen on standard neuroimaging
11. Which one of the following is true?
 - a. A period of unconsciousness is necessary for the diagnosis of a concussion
 - b. Over 2/3 of all concussions involve loss of consciousness (LOC)
 - c. 1/3 to 2/3 of all concussions involve loss of consciousness (LOC)
 - d. Less than 1/3 of all concussions involve loss of consciousness (LOC)**
12. Which of the following is a sign or symptom of a concussion? Select all that apply.
Options: **Headache**, Hemiparesis, **Dizziness**, **Confusion**, Fixed dilated pupil, **Nausea and/or Vomiting**, **Vertigo**, **Amnesia**, **Tinnitus**, **Emotional or personality changes**, Papilledema, Intention tremor, **Fatigue**, **Temporary loss of consciousness**, Prolonged coma

13. How many symptoms of a concussion are required to diagnose a concussion?
Options: **One or more symptoms**, three or more symptoms, five or more symptoms
14. Which of the following is true regarding the mechanism of concussion?
- a. Direct physical contact to the head is necessary to sustain a concussion
 - b. Localized damage to the brainstem is the cause a concussion
 - c. Localized damage to the prefrontal cortex is the cause of a concussion
 - d. Localized damage to the hippocampus is the cause of a concussion
 - e. **A whiplash effect to the brain caused by an impact to any part of the body may cause a concussion**
15. What is the appropriate management of concussion? Select all that apply
- a. **Every concussed individual should see a healthcare professional**
 - b. A concussed player can return to play in the same game or practice if examined by a healthcare professional
 - c. **A stepwise increase in exercise and activity if symptomatic**
 - d. **Physical rest is always recommended after a concussion**
 - e. **Mental rest is always recommended after a concussion**
 - f. **Signs and symptoms should be monitored for increasing severity**
 - g. **Full neurological exam at initial assessment is recommended**
 - h. The standard mini mental status exam at initial assessment as an adequate cognitive test for concussion
 - i. MRI of the brain is mandatory
 - j. CT of the brain is mandatory
16. What are some “red flags” that may predict the potential for more prolonged symptoms and may influence your investigation and management of concussion? Select all that apply:
- a. Nose bleed
 - b. **Prolonged loss of consciousness**
 - c. **Number and duration of symptoms**
 - d. **Younger Age**
 - e. **Repeated concussions occurring with progressively less impact force**
 - f. **Slower recovery after each successive concussion**
 - g. **Repeated concussions over time**
 - h. **Concussions close together in time**
 - i. Being hit on the left side of the head
17. What are the long term consequences of repetitive concussive injury? Select all that apply.
- a. **Dementia**
 - b. **Depression**
 - c. **Headaches**
 - d. Increased risk of hemorrhagic stroke
 - e. **Death or disability with second concussion before recovery from a first concussion**
 - f. Increased risk of schizophrenia
 - g. **Prolonged fatigue**
 - h. **Impairment of concentration and memory**
 - i. **Parkinsonism**
 - j. **Chronic traumatic encephalopathy**

Part 3 Learning needs about concussions:

18. In your undergraduate chiropractic education, how did you learn about concussions? Select all that apply.
Options: Lecture, PBL (problem based learning), Seminar, Interest Group, Shadowing/Observership, Other, Never, I can't remember
19. In your residency to date, how did you learn about concussions? Select all that apply.
Options: Clinical experience, Self-study, Lecture, Never, I can't remember, Other
20. To date, have you seen a patient with:
 - concussion in the acute phase? Yes, No, I don't know (select one)
 - post-concussive syndrome? Yes, No, I don't know (select one)
21. How would you self-rank your knowledge about concussions?

| | |
|---|---------------------|
| Inadequate | Completely adequate |
| 1 2 3 4 5 6 7 8 9 10 | |
22. What resource would you most likely use to find information about concussions?
Options: Google, Wikipedia, Up-to-date, Textbook, Pubmed, an agency website, Thinkfirst.ca, other
23. Are concussions something you want to learn more about as part of your medical curriculum?

| | |
|---|-----------|
| Not at all | Very much |
| 1 2 3 4 5 6 7 8 9 10 | |
24. What is your preferred format for healthcare professional learning material?
Options: Pamphlet, letter, seminar or workshop, lecture, informational email
25. What challenges, if any, do you think healthcare professionals face when diagnosing and managing a concussion?
26. This concussion assessment tool was created from knowledge extracted from the 2008 Zurich Consensus Statement on Concussion. Given that there have been recent advances in concussion research since 2008, are there any changes you recommend to the assessment tool, as a result of newer research? (question asked to sports fellows only)