Precision of the Integrated Cognitive Assessment for the assessment of neurocognitive performance in athletes at risk of concussion

Daniel J. Glassbrook*[1¶], Paul L. Chazot[1¶], and Karen Hind[1¶]

[1]Wolfson Research Institute for Health and Wellbeing, Durham University, United Kingdom.

***Corresponding author**:

Email: daniel.glassbrook@durham.ac.uk (DG)

[¶] These authors contributed equally to this work.

Abstract

Choice reaction time tests are commonly used for the assessment of cognitive function, and may be useful to assess the effect of mild traumatic injuries or concussions. This study investigated the precision of the Integrated Cognitive Assessment (ICA; Cognetivity Neurosciences Ltd., Vancouver, Canada) test for the assessment of cognitive function in athletes. Thirty-one participants volunteered to take part in this study, from both contact (*n* = 22) and non-contact sports (*n* = 9). Participants performed the ICA test consecutively both before and after normal training session to simulate resting and post-sport conditions. Precision errors were calculated for three variables, ICA Index (overall information processing ability), ICA Speed (information processing speed) and ICA Accuracy (information processing accuracy). ICA precision errors [root mean squared-standard deviation, RMS-SD (coefficient of variation, %CV)] pre-sport were ICA Index: 5.18 (7.14%), ICA Speed: 3.98 (4.64%), and ICA Accuracy: 3.64 (5.00%); and post-sport were ICA Index: 3.96 (4.94%), ICA Speed: 2.14 (2.32%), and ICA Accuracy 3.40 (4.25%). The ICA test demonstrates high in-vivo precision with all variables, with all variables except ICA Index (7.14%) demonstrating an acceptable precision error of ≤5% %CV. The ICA test is suitable for the assessment of cognitive function pre- and post-sport.

Key words: Choice Reaction, Information Processing, Reaction Time, Simple Reaction Time, Concussion

Introduction

Cognitive decline is a troubling consequence of normal ageing, and evidence has demonstrated links between mild traumatic brain injuries (mTBI) and persistent cognitive decline and long-term neurodegeneration (1-3). A mTBI is commonly known as a concussion, and is the result of a sudden movement of the brain within the cranium, and can arise from rapid rotational or linear acceleration or deceleration of the head (4). People who play contact sports may be at a higher risk of sustaining a concussion due to the nature of these sports and associated collisions (5). In fact, sports-related concussion is one of the highest reported injuries in rugby union players in the United Kingdom (1). A person with a concussion can experience symptoms such as loss of consciousness, altered mental state, nausea, headaches, vertigo and amnesia (6). However, concussion is currently difficult to objectively assess.

One proposed method to assess the effects of concussion and cognitive function is via information processing and reaction time tests. An increase in reaction time (slower) is a commonly used indicator of cognitive change following concussion (7, 8). Additionally, information processing speed underpins several conditions of cognitive dysfunction, for example, multiple sclerosis (9, 10) and Alzheimer's disease (11). Two common types of reaction test include measurement of simple reaction time (SRT) or choice reaction time (CRT) (12). SRT is recorded when there is only one possible stimulus (signal) and one possible response (action), for example tapping anywhere on a screen when any image appears. In CRT tasks there are two or more possible stimuli, each of which requires a quite different response, for example, tapping on the left of the screen when an image of an object appears on the screen, and tapping on the right when an image of an animal appears on the screen.

The Integrated Cognitive Assessment (ICA; Cognetivity Neurosciences Ltd., Vancouver, Canada) (13, 14), is a newly developed method for the assessment of cognitive function, and may be applicable to the assessment of concussion in athletic populations. The ICA is a short computerised cognitive test of cognitive function via an assessment of information processing (CRT) speed based on a rapid categorisation task, and is independent of language (13, 15). The ICA test can be completed on a handheld device such as an iPad, and each test takes approximately five minutes. The ICA has been shown to accurately detect mild cognitive impairment and be moderately to highly correlated with other popular pen-and-paper cognitive tests such as the Montreal Cognitive Assessment (Pearsons r = 0.58) and Addenbrooke's Cognitive Examination (Pearsons r = 0.62) cognitive tests (13). There are no associated risks with completing the ICA, and the test provides three variables, ICA Speed; information processing speed, ICA Accuracy; information processing accuracy, and ICA Index; overall information processing ability, a combination of ICA Speed and ICA Accuracy. There is a speed-accuracy trade-off in reaction test performance, and often scoring higher in either speed or accuracy is achieved at the expense of the other capacity (16, 17). To combat the potential negative reflection on overall information processing ability from a poor speed or accuracy score, a common solution is the inverse efficiency score (18), whereby speed and accuracy are combined into a single score. In the case of the ICA, this concept is applied and manifests as the ICA Index variable.

The ICA has been shown to accurately measure cognitive impairment in patients in the early stages of dementia (13). However, to date, no known study has investigated the intra-day precision of the ICA test. Therefore, the purpose of this study was to determine the same-day, in-vivo precision of the ICA test to assess cognitive function.

Materials and Methods

Thirty-one participants volunteered to take part in this study. Participant characteristics are presented in Table 1. Participants were eligible for participation if they were a current contact sport or non-contact sport athletes (Table 2) aged 18-40 years, and healthy; having no underlying medical issues that affect participation in sport. Participants were excluded if they were injured, pregnant, or suffering from post-concussion syndrome. This study was approved by the Durham University Sport and Exercise Sciences Ethics Committee (reference: SPORT-2022-01-07T10_44_59-srhd22), and written informed consent was provided by each participant prior to participation.

Table 1: Participant Characteristics

	Age (Yr.)	Height (m)	Body Mass (kg)
Total (*n* = 31)	23.7 ± 5.7	1.78 ± 0.09	72.6 ± 8.3
Male (*n* = 16)	22.9 ± 4.7	1.82 ± 0.08	75.7 ± 7.4
Female (*n* = 15)	24.6 ± 6.6	1.71 ± 0.07	68.0 ± 9.9
Contact Sport (*n* = 22)	24.9 ± 6.3	1.80 ± 0.07	75.5 ± 6.0
Non-Contact Sport (*n* = 9)	20.6 ± 0.6	174.1 ± 8.3	77.2 ± 12.2

Data are presented as mean ± standard deviation. Yr., Years; m, Metres; kg, Kilograms; *n*, Number.

Table 2: Sports Breakdown

Contact Sports (*n* = 22)		Non-Contact Sports (*n* = 9)	
Rugby Union (*n* = 7)	Semi-professional, Amateur	Touch Rugby (*n* = 5)	Amateur
Boxing (*n* = 6)	Amateur	Athletics (*n* = 4)	Amateur
Muay Thai (Kickboxing) (*n* = 5)	Professional, Amateur		
Indoor Football (*n* = 4)	Amateur		

n, Number.

To simulate resting- and post-sport conditions, participants performed the ICA test (version 1.6.0 or 1.7.0) before and after a normal training session for their respective sports. Data collection was performed in a quiet room to minimise distractions. Prior to their sports training, participants completed two consecutive ICA tests. The participants then completed a normal training session and then two consecutive ICA tests again.

All data analysis was performed in Microsoft Excel (2016). Raw data for ICA Index, ICA Speed, and ICA Accuracy were extracted and exported to Microsoft Excel for analysis (19).

Precision of ICA scores and least significant change (LSC) were calculated at the 95% confidence level. Precision was determined as root mean square standard deviation (RMS-SD), coefficient of variation (CV), and percentage CV (%CV). RMS-SD represents the sample standard deviation of the differences between predicted values and observed values, and is calculated via the following formulae, where SD represents standard deviation and *n* represents the number of participants:

$$\sqrt{\left(\frac{\Sigma SD^2}{n}\right)}$$

The %CV expresses test variation relative to the mean of two tests and is corrected for small sample bias, and was defined as acceptable <5% (20). The LSC represents a true meaningful change was calculated from the precision errors (LSC = RMS-SD * 2.77).

Results

Results of the precision analysis for each ICA variable pre- and post-sport are presented in Table 3. All variables except for ICA Index pre-sport had a precision error of ≤5% %CV. LSC results are presented in Table 4.

Table 3: Precision Analysis Results

Variable	Precision (n = 31)		
	RMS-SD	CV	%CV
Pre			
ICA Index	5.18	0.07	7.14
ICA Speed	3.98	0.05	4.64
ICA Accuracy	3.64	0.05	5.00
Post			
ICA Index	3.96	0.05	4.94
ICA Speed	2.14	0.02	2.32
ICA Accuracy	3.40	0.04	4.25

n, Number; ICA, Integrated Cognitive Assessment; RMS-SD, Root Mean Square Standard Deviation; CV, Coefficient of Variation; %, Percentage.

Table 4: Least Significant Change Results

	LSC (n = 31)		
Variable	RMS-SD	CV	%CV
Pre			
ICA Index	14.36	0.20	19.78
ICA Speed	11.01	0.13	12.86
ICA Accuracy	10.09	0.14	13.9
Post			
ICA Index	10.96	0.14	13.7
ICA Speed	5.94	0.06	6.43
ICA Accuracy	9.43	0.12	11.78

LSC, Least Significant Change; n, Number; ICA, Integrated Cognitive Assessment; RMS-SD, Root Mean Square Standard Deviation; CV, Coefficient of Variation; %, Percentage.

Discussion

The purpose of this study was to determine on the same-day, in-vivo precision of the ICA test to assess cognitive function. The results of this study support the ICA as a tool with acceptable precision to measure changes in cognitive ability pre- and post-sport. All ICA variables in this study, except for ICA Index pre-sport demonstrated a precision error of ≤5% %CV.

The higher ICA Index precision score (7.14 %CV) pre-sport than post-sport (4.94 %CV) in this study may be explained by a large difference between test one and test two pre-sport, compared to a smaller difference in ICA scores between test three and test four post-sport. This is exemplified by a larger ICA Index RMS-SD pre-sport than post-sport, which indicates more variance in observed data around the mean. This result may be due to an increased level of comfort with the test from the first pre-sport ICA test to the subsequent test, and possibly a learning effect. However, this is in contrast to previous work which showed no learning effect for the ICA test in healthy participants and those diagnosed with dementia (13).

All variables showed greater precision post-sport compared to pre-sport. This may be due to the many positive physiological benefits that exercise has, such as an increase in blood flow to muscles and brain (21), structural and functional changes in the brain (22), and increases information processing ability (23). Indeed, improvements in cognitive function after a bout of exercise is supported by previous research (24, 25).

Previous research looking at precision in a similar cognitive test to the ICA, the CogSport choice reaction time test, has shown lower %CV for mean choice reaction time (speed) (1.4 %CV), and higher %CV for choice reaction time accuracy (11.4 %CV) (26). These results are interesting as the ICA is shown to be less precise in measuring reaction speed (2.32 - 4.64 %CV vs 1.4 %CV), however, the ICA test is shown to be more precise in terms of accuracy (4.25 – 5.00 %CV vs 11.4 %CV). These results may indicate that the test you adopt needs to be specific to the variable of interest (i.e., speed or accuracy), however, this should be negated in the case of the ICA via the ICA Index variable as an inverse efficiency score (18), whereby speed and accuracy are combined into a single score. The contrasting results between the present study and that of Straume-Naesheim, Andersen (26) may be due to the populations used; the CogSport test was used in elite football players only, whereas only a small percentage of the participants in the present study are practicing professionally (Table 2). Additionally, the present study recruited participants from a variety of sports, each with their own decision making and reaction characteristics, in comparison to only football.

In conclusion, the ICA is a practical test which can be used to measure cognitive function before and after sport participation. The results of this study support the ICA as a precise measure of information processing speed and information processing accuracy, and overall information processing ability. The ICA can be used for the assessment of cognitive function, and may be useful as a method to assess the effects of concussion.

References

1. Hume PA, Theadom A, Lewis GN, Quarrie KL, Brown SR, Hill R, et al. A Comparison of cognitive function in former rugby union players compared with former non-contact-sport players and the impact of concussion history. Sports Medicine. 2017;47(6):1209-20.

2. Johnson VE, Stewart W, Smith DH. Traumatic brain injury and amyloid-β pathology: a link to Alzheimer's disease? Nature Reviews Neuroscience. 2010;11(5):361-70.

3. McKee AC, Cantu RC, Nowinski CJ, Hedley-Whyte ET, Gavett BE, Budson AE, et al. Chronic Traumatic Encephalopathy in Athletes: Progressive Tauopathy After Repetitive Head Injury. Journal of Neuropathology & Experimental Neurology. 2009;68(7):709-35.

4. Jordan BD. The clinical spectrum of sport-related traumatic brain injury. Nature Reviews Neurology. 2013;9(4):222-30.

5. La Fountaine MF, Toda M, Testa AJ, Hill-Lombardi V. Autonomic nervous system responses to concussion: Arterial pulse contour analysis. Frontiers in Neurology. 2016;7.

6. Sharma A, Hind K, Hume P, Singh J, Neary JP. Neurovascular coupling by functional near infra-red spectroscopy and sport-related concussion in retired rugby players: The UK rugby health project. Frontiers in Human Neuroscience. 2020;14.

7. Collie A, Maruff P, Makdissi M, McCrory P, McStephen M, Darby D. CogSport: reliability and correlation with conventional cognitive tests used in postconcussion medical evaluations. Clinical Journal of Sport Medicine. 2003;13(1):28-32.

8. Erlanger D, Saliba E, Barth J, Almquist J, Webright W, Freeman J. Monitoring resolution of postconcussion symptoms in athletes: preliminary results of a web-based neuropsychological test protocol. Journal of Athletic Training. 2001;36(3):280.

9. Costa SL, Genova HM, DeLuca J, Chiaravalloti ND. Information processing speed in multiple sclerosis: Past, present, and future. Multiple Sclerosis Journal. 2016;23(6):772-89.

10. DeLuca J, Chelune GJ, Tulsky DS, Lengenfelder J, Chiaravalloti ND. Is speed of processing or working memory the primary information processing deficit in multiple sclerosis? Journal of Clinical and Experimental Neuropsychology. 2004;26(4):550-62.

11. Lu H, Chan SS, Lam LC. 'Two-level'measurements of processing speed as cognitive markers in the differential diagnosis of DSM-5 mild neurocognitive disorders (NCD). Scientific Reports. 2017;7(1):1-8.

12. Deary IJ, Liewald D, Nissan J. A free, easy-to-use, computer-based simple and four-choice reaction time programme: The Deary-Liewald reaction time task. Behavior Research Methods. 2011;43(1):258-68.

13. Kalafatis C, Modarres MH, Apostolou P, Marefat H, Khanbagi M, Karimi H, et al. Validity and cultural generalisability of a 5-minute ai-based, computerised cognitive assessment in mild cognitive impairment and Alzheimer's dementia. Frontiers in Psychiatry. 2021;12.

14. Khaligh-Razavi S, Habibi S. System for assessing mental health disorder. UK Intellect Prop Off. 2013.

15. Khaligh-Razavi S-M, Habibi S, Sadeghi M, Marefat H, Khanbagi M, Nabavi SM, et al. Integrated cognitive assessment: Speed and accuracy of visual processing as a reliable proxy to cognitive performance. Scientific Reports. 2019;9(1):1102.

16. Wickelgren WA. Speed-accuracy tradeoff and information processing dynamics. Acta psychologica. 1977;41(1):67-85.

17. Liesefeld HR, Janczyk M. Combining speed and accuracy to control for speed-accuracy trade-offs. Behavior Research Methods. 2019;51(1):40-60.

18. Townsend JT, Ashby FG. Stochastic Modeling of Elementary Psychological Processes. New York, NY: Cambridge University Press; 1983.

19. Glassbrook DJ, Chazot PL, Hind K. ICA Precision Raw Data.xlsx.: figshare; 2023.

20. Machin D, Campbell MJ, Walters SJ. Medical Statistics a Textbook for the Health Sciences: John Wiley & Sons, New York; 2007.

21. Poels MM, Ikram MA, Vernooij MW, Krestin GP, Hofman A, Messen WJ, et al. Total cerebral blood flow in relation to cognitive function: The Rotterdam Scan Study. Journal of Cerebral Blood Flow & Metabolism. 2008;28(10):1652-5.

22. Fernandes J, Arida RM, Gomez-Pinilla F. Physical exercise as an epigenetic modulator of brain plasticity and cognition. Neuroscience & Biobehavioral Reviews. 2017;80:443-56.

23. Davranche K, Audiffren M. Facilitating effects of exercise on information processing. Journal of Sports Sciences. 2004;22(5):419-28.

24. Lemmink KAPM, Visscher C. Effect of intermittent exercise on multiple-choice reaction times of soccer players. Perceptual and Motor Skills. 2005;100(1):85-95.

25. Niedermeier M, Weiss EM, Steidl-Müller L, Burtscher M, Kopp M. Acute effects of a short bout of physical activity on cognitive function in sport students. International Journal of Environmental Research and Public Health. 2020;17(10):3678.

26. Straume-Naesheim TM, Andersen TE, Bahr R. Reproducibility of computer based neuropsychological testing among Norwegian elite football players. British Journal of Sports Medicine. 2005;39(suppl 1):i64.