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A Comparison of Sideline Versus Clinical Cognitive Test Performance in Collegiate Athletes

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Objective: To test whether performance on 5 cognitive tests administered in a controlled clinical environment differed compared with administration in an uncontrolled sideline environment. Additionally, we investigated the effect of testing environment order on the learning effect for each cognitive test.

Design and Setting: Athletes were assessed on 2 test occasions (8 ± 2 days apart), once in a sports medicine research laboratory and once on a lacrosse practice field site.

Subjects: A total of 59 Division I collegiate student-athletes participated in this study.

Measurements: Normative data were collected on 5 cognitive tests (Stroop Test, Trail-Making Test part A, Trail-Making Test part B, Wechsler Digit-Span Forward Test, and Digit-Span Backward Test).

Results: An independent-samples *t* test for environment difference on test day 1 revealed no significant differences between tests performed in the controlled environment and those performed in the uncontrolled environment. A repeated-measures analysis of variance test revealed a significant learning effect for all 5 tests, as subjects tended to improve approximately 11 points on the Stroop Test, 3 seconds on the Trail-Making A Test, 7 seconds on the Trail-Making B Test, and 1 point each on the Wechsler Digit Span Forward and Backward Tests. A paired-samples *t* test using delta scores (first test minus second test), sorted by order of testing environment, revealed a significant difference for the Stroop Test, but not for the remaining cognitive tests.

Conclusions: There appears to be no difference in cognitive testing performance completed in a controlled clinical environment versus that performed in an uncontrolled sideline environment. This finding suggests that clinicians can administer cognitive tests to athletes with mild head injuries in uncontrolled sideline environments and expect valid results. Thus, clinicians can more thoroughly evaluate mildly head-injured athletes during the most crucial period after injury so that a safe return-to-play decision can be based on quantifiable, objective data.

Key Words: concussion, mild head injury, neuropsychological testing

Athletic trainers and other sports medicine personnel are constantly faced with the challenge of deciding when an injured athlete should return to competition, and perhaps the toughest situation involves an athlete with a mild head injury (MHI). The incidence of repeated concussions and the long-term sequelae that follow have been topics of considerable debate in the sports medicine literature.[1–6] The National Athletic Trainers' Association studies[1,5] of high schools in 1986–1988 and 1995–1997 revealed national estimates of approximately 40 000 concussions in football players annually, while another study[6] of the incidence of MHI in collegiate and high school football showed a 5.1% incidence rate and a 14.7% recurrence rate in the same seasons. However, these statistics do not include the number of head injuries that go unrecognized or unreported; thus, the clinician performing the initial evaluation must always be aware that an individual may have had a previous MHI that went undetected, resulting in increased susceptibility to serious complications from MHI.[7]

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MHI assessment presents a unique situation because of the difficulty in gathering quantifiable, objective information during an immediate sideline evaluation. The sideline management of mild head injuries has long relied on subjective information such as headache, dizziness, and blurred vision. Unfortunately, these symptoms are often not reported by the athlete; therefore, this method of evaluation has been criticized for lacking objectivity. The use of neuropsychological cognitive testing to objectively assess an athlete with MHI has recently come to the forefront, yet the focus of this testing has been on the follow-up evaluation for return to competition, ie, 1 day, 1 week, or 1 month postinjury.[3,8–22]

The typical sideline evaluation consists of assessing orientation to time, place, person, situation, and simple memory and concentration tests.[7–9,17–19] The fact that normative baselines may not be established for each individual athlete or for entire groups of athletes makes rating difficult. Deciding when an athlete who has possibly sustained an MHI should return to competition is normally a judgment decision made by sports medicine personnel. If normative cognitive baselines are established for individuals and groups of athletes, a more objective decision can be made, and athletes can be returned safely to competition.

Baseline neuropsychological testing is becoming increasingly popular among high school, collegiate, and professional sports medicine personnel.[20–22] This type of preseason quantifiable data may aid the clinician in making return-to-play decisions after MHI. Yet neuropsychological tests are normally given in a quiet, controlled, clinical environment, while the typical MHI evaluation occurs on the sideline, during an athletic practice or contest. The need for normative sideline neuropsychological baselines may be imperative because the effects of fatigue, motivation to return to competition, noise, and other distractions may alter an athlete's neuropsychological test performance. The comparison of sideline scores to clinical scores may result in a normal individual's being labeled as deficient in cognitive capacity, which may be the result of testing environment conflicts rather than actual cognitive impairment. Thus, it is important to investigate the effect of environment on normative baseline neuropsychological testing so that the certified athletic trainer and team physician can use this information in making a sideline decision regarding immediate return to play.

The main purpose of our study was to investigate if there was a significant difference between the scores of cognitive tests administered to subjects in a controlled clinical environment to scores administered in an uncontrolled sideline environment. We assessed the need to establish different normative baseline values to be used for clinical testing (controlled environments) versus sideline testing (uncontrolled environments). Additionally, we looked at the effect of testing environment order on the learning effect for each cognitive test.

METHODS

A total of 59 Division I college student-athletes from the University of North Carolina at Chapel Hill were recruited from the men's and women's lacrosse teams: 39 men (age = 19.80 $\pm$ 1.20 years) and 23 women (age = 19.30 $\pm$ 1.29 years). Student-athletes who had sustained a head injury within the last 6 months were excluded from this study. Also, any athlete who had undergone any type of neuropsychological testing within the last 6 months or had a known learning disability, color-vision disorder, or color blindness was excluded from this study. We obtained advance permission from each of the team's head coaches and thoroughly discussed the procedures for the clinical and sideline evaluations. All subjects were informed of the testing procedures and were asked to sign an informed consent form in accordance with the Human Subjects Committee at the University of North Carolina at Chapel Hill. The study was approved by the Academic Affairs Institutional Review Board at the University.

Half the subjects on each team were randomly placed in group 1 (controlled clinical environment first), while the other half were placed in group 2 (uncontrolled sideline environment first). Subjects scheduled a time to take the test battery and were tested first according to the group in which they were assigned, then retested 8 $\pm$ 2 days later in the other environment. The controlled clinical environment tests were performed in the Sports Medicine Research Laboratory, with only the researcher and the subject present in the room. All outside noises, distractions, and interferences were kept to a minimum. The uncontrolled sideline environment involved testing subjects on the sideline during practice; no attempt was made to control for noises, distractions, or interferences.

During each test session, subjects were asked to complete 1 trial each of 5 neuropsychological tests, lasting approximately 10 minutes total. The tests were administered in a set order to minimize the effects of testing fatigue on the individual: Stroop Test (cognitive flexibility and attention span)[14,23–25]; Trail-Making Tests A and B (orientation, concentration, visual-spatial capacity, and problem-solving abilities)[14,26–28]; Wechsler Digit-Span Forward and Backward Tests (WDSFT and WDSBT, respectively; attention span, concentration, distractibility, and immediate memory recall).[13,14,19] Scoring for the Trail-Making Tests A and B was modified slightly. This test is traditionally scored by recording the total time taken to complete each test, and separate time totals and error totals are then calculated. We added 1 second per error (eg, not touching the circled item or connecting the wrong sequence).[14] The purpose of this modification was to combat the extreme competitiveness of the athletes, who tended to finish quickly and to disregard the directions to properly touch the circled items or to carry on a wrong sequence to achieve a better time.

DESIGN AND ANALYSIS

Mean test scores, standard deviations, and ranges were calculated for all 5 tests on each of the testing sessions. An independent-samples *t* test was performed with scores for all tests taken during the controlled clinical environment and the uncontrolled sideline environment to evaluate for a significant difference between testing environments. We performed a repeated-measures analysis of variance for each test to detect any significant differences between the learning effects for the 2 groups. Additionally, a paired-samples *t* test using delta scores (first test minus second test), sorted by order of testing environment, was performed to determine if a significant change in the learning effect occurred as a result of the environment order. Data were organized and analyzed with SPSS for Windows, version 6.1 (SPSS Inc, Chicago, IL).

RESULTS

Mean values and standard deviations were calculated for each of the 5 cognitive tests when sorted by testing order (Table 1) and by test day (Table 2). An independent-samples *t* test for environment difference on test day 1, with an a priori alpha level of 0.05, was carried out. None of the analyses revealed significant differences between the tests performed in the controlled environment versus those performed in the uncontrolled environment ($P > .05$). T2

A repeated-measures analysis of variance revealed a significant learning effect ($P < .05$) for all 5 scores: subjects tended to improve approximately 11 points on the Stroop Test, 3 seconds on the Trail-Making Test A, 7 seconds on the Trail-Making Test B, and 1 point each on the WDSFT and WDSBT (Table 3). T3

We performed an additional analysis to determine if a change in the learning effect occurred as a result of the environment order. A paired-samples *t* test using delta scores revealed a significant difference only for the Stroop Test ($P < .05$) (Table 4). No significant differences were seen with any of the other cognitive tests. As for the Stroop Test, subjects tested first in the controlled environment demonstrated a significant difference in improvement between tests compared with subjects tested first in the uncontrolled environment (Figure). F1

Table 1. Mean Test Scores (SDs) for the 5 Cognitive Tests on Test Days 1 and 2 Sorted by Group

		Test				
Group	Day	Stroop*	Trail A†	Trail B†	WDSFT‡	WDSBT‡
Controlled	1	236.15 (27.99)	23.42 (5.12)	47.85 (12.35)	9.73 (1.48)	7.77 (1.99)
Clinical Environment First	2	256.35 (30.40)	19.57 (4.49)	42.64 (12.47)	10.38 (1.36)	8.12 (2.10)
	Delta	20.19 (12.17)	3.85 (5.51)	5.21 (13.17)	0.65 (1.44)	0.35 (2.02)
Uncontrolled	1	247.52 (26.85)	21.91 (5.03)	51.10 (17.69)	9.48 (1.52)	7.42 (1.89)
Sideline Environment First	2	250.79 (33.71)	20.02 (5.08)	42.34 (15.06)	10.03 (1.63)	8.70 (2.11)
	Delta	3.27 (16.25)	1.89 (3.60)	8.76 (10.90)	0.55 (1.42)	1.28 (1.74)

* Mean represents the total number of correct responses in 3 45-second trials.
† Mean represents the total number of seconds to complete the task.
‡ Mean represents the total number of correct sequences of digits recalled.

Table 2. Mean Test Scores (SDs) for the 5 Cognitive Tests on Test Days 1 and 2 Sorted by Day (Environments Combined)

	Test				
Test Day	Stroop*	Trail A†	Trail B†	WDSFT‡	WDSBT‡
Day 1	242.51 (27.71)	22.57 (5.09)	49.67 (15.53)	9.59 (1.50)	7.58 (1.92)
Day 2	253.24 (32.15)	19.82 (4.79)	42.47 (13.86)	10.19 (1.51)	8.44 (2.11)

* Mean represents the total number of correct responses in 3 45-second trials.
† Mean represents the total number of seconds to complete the task.
‡ Mean represents the total number of correct sequences of digits recalled.

Table 3. Repeated-Measures Analysis of Variance *F* Values Indicating Significant Learning Effects Between Test Days

Test	$F_{1,58}$ Value	*P* Value
Stroop	24.14	0.000*
Trail-Making A	21.09	0.000*
Trail-Making B	21.33	0.000*
WDSFT	10.36	0.002*
WDSBT	12.12	0.001*

* Values of $P < 0.05$ were considered significant.

Table 4. Paired-Samples *t* Tests for Delta Scores* Between Test Days as a Result of Environment Order

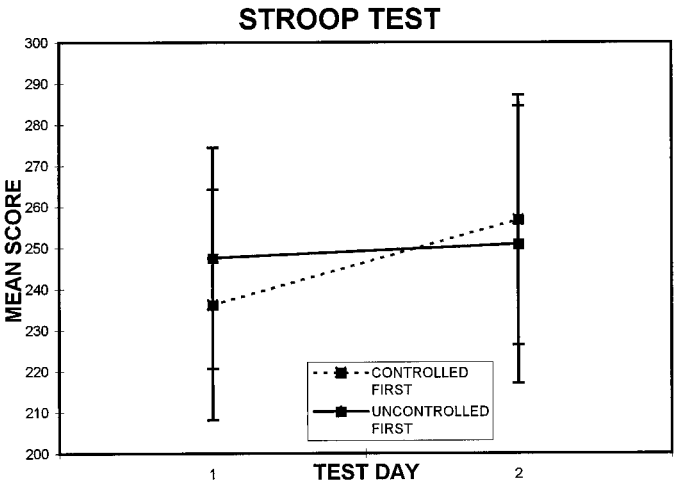
Test	*t* Value	*P* Value
Stroop	−4.14	0.000†
Trail-Making A	−1.94	0.105
Trail-Making B	−3.64	0.262
WDSFT	−4.88	0.773
WDSBT	−2.89	0.063

* First test minus second test.
† Values of $P < 0.05$ are considered significant.

DISCUSSION

The return-to-play decision after an MHI is one of the most difficult decisions for a certified athletic trainer or team physician. Sports neuropsychological testing has come to the forefront of MHI research in terms of looking at preseason baseline normative values to quantifiably compare data, yet the results may be skewed in an on-the-field sideline evaluation situation due to testing environment circumstances.[14] The purpose of our study was to determine whether scores on 5 neuropsychological tests (Stroop Test, Trail-Making Tests A and B, and Wechsler Digit-Span Forward and Backward Tests) administered in a controlled clinical environment differed when compared with tests administered in an uncontrolled sideline environment. Our most important finding was that there appears to be no significant difference in cognitive testing performance completed in a controlled clinical environment versus that performed in an uncontrolled sideline environment. This finding may be invaluable for future MHI evaluation, since we found no adverse effect of environment on cognitive testing abilities, which may allow clinicians to administer cognitive tests (traditionally administered in controlled laboratory environments) in uncontrolled sideline environments with more confidence.

The establishment of preseason baseline data for each athlete is needed to make a sound judgment regarding cognitive status, since people often vary in cognitive abilities.[14,29] The establishment of preseason data allows clinicians to have quantifiable baselines as reference points so that sound judgments can be made during the return-to-play decision-making process. We found no differences in 5 cognitive tests performed in controlled clinical situations as opposed to uncontrolled sideline situations; thus, there is no apparent need to establish



Stroop test scores for days 1 and 2 (paired-samples *t* test for delta scores).

separate baseline scores for cognitive testing during different environmental conditions. We can also speculate that other commonly used preseason cognitive tests would not be affected by administration in uncontrolled sideline environment conditions, yet further studies using various cognitive tests in the different environments must be undertaken before this speculation is validated.

Sideline evaluation using various cognitive tests has been recommended by several authors (M. McCrea, personal communication, October 12, 1999).[7,9,14,16,18,19,29–35] Our finding of no effect on cognitive performance on these 5 tests caused by noise and other distractions associated with the athletic environment suggests that clinicians can use either type of baseline cognitive test scores in making immediate on-field MHI cognitive evaluations. The use of cognitive tests to ascertain an athlete's mental status (attention span, concentration, memory, and information processing) has been previously established.[14,16–22,29–35] Thus, this finding allows the sideline clinician the opportunity to safely infer that scores noted immediately after injury on the playing field should correspond with preseason baseline scores established in either type of testing environment in ascertaining an athlete's mental status.

An additional note concerning our findings is that these subjects were not mildly head injured at the time of testing, and perhaps the task of a normally functioning brain is to screen out distracting stimuli. The screening of distracting stimuli task may be compromised by trauma and therefore result in a testing difference between clinical and sideline testing environments. As such, sideline cognitive testing may be a significant detector of MHI if it imposes a more difficult task on a concussed individual.

AQ: A

The recent addition of sports neuropsychological testing to the field of sports medicine has led to various modifications in the administration of standardized cognitive tests. This type of testing is designed for use by clinicians with little or no previous experience in psychomotor testing, ie, certified athletic trainers and team physicians. It is not intended to substitute for formal cognitive testing conducted by a licensed neuropsychologist, but rather can provide objective, quantifiable measurements for use during the acute phase of recovery from MHI (M. McCrea, personal communication, October 12, 1999).

Universal agreement is lacking on the best neuropsychological tests for assessing MHI in athletes. Clinicians should be aware that different tests assess various components of cognitive function and that an attempt should be made to assess as many of those components as possible in the time allotted. The use of all 5 cognitive tests performed in this test battery may not be feasible due to time constraints; therefore, the battery of tests may need to be modified. Modifications to some of the standard neuropsychological tests and test batteries are becoming more accepted given the time constraints involved in the athletic setting. Thus, the Trail-Making Test A and the WDSFT could be eliminated if necessary. The higher degree of difficulty of the Trail-Making Test B could offer the clinician a valuable, time-saving option for the assessment of orientation, concentration, visual-spatial capacity, and problem-solving abilities. Additionally, the more challenging WDSBT test can be used to assess attention span, concentration, distractability, and immediate memory recall in place of using both the forward and backward tests (M. McCrea, personal communication, October 12, 1999).

Another finding of this study was the occurrence of a significant learning effect for each of the 5 cognitive tests across test days. A repeated-measures analysis of variance revealed a significant ($P < 0.05$) learning effect 8 days later for all 5 scores, as subjects tended to improve approximately 11 points on the Stroop Test, 3 seconds on the Trail-Making Test A, 7 seconds on the Trail-Making Test B, and 1 point each on the WDSFT and WDSBT. This finding, which is consistent with previously reported research,[14] offers valuable information, since MHI assessment requires constant re-evaluation. This finding allows clinicians who use cognitive testing to assess normal function to expect learning or improvement during follow-up assessment. The question still remains as to how much time between tests would negate this learning effect. Clinicians should suspect lingering pathology if there is no improvement following initial testing.[14,35]

We performed further analysis on the learning effect to determine if a change had occurred as a result of the testing environment order. A paired-samples *t* test using delta scores (first test minus second test), sorted by order of testing environment, revealed a significant difference ($P < 0.05$) only for the Stroop Test. The learning effect for the Stroop Test remained normal for the subjects tested first in the controlled clinical environment, yet there was less of an observed learning effect for those subjects tested first in the uncontrolled sideline environment. Table 1 reveals that the Stroop Test for day 1 scores for both groups are comparable with those found in Oliaro et al,[14] but a comparison of day 2 scores revealed a significantly lower comparison than in Oliaro et al's study, which was performed on a similar population group in a controlled clinical environment only. Oliaro et al[14] reported that an improvement of approximately 20 points can be expected from day 1 to day 2 scoring on the Stroop Test, consistent with our group that tested first in the controlled clinical environment. However, the group that tested first in the uncontrolled sideline environment revealed only a 3-point average improvement on the Stroop Test. We found that a learning effect is still present 8 ± 2 days later, but that effect may be significantly decreased on the Stroop Test if subjects are tested first in an uncontrolled sideline environment. A possible explanation for this is that the learning effect in the uncontrolled environment may not be as drastic as that in the controlled environment for the Stroop Test because of possible deleterious effects caused by the environment when first taking the test in a distraction-based situation. A better learning strategy for the Stroop Test most likely occurs in the controlled clinical environment that allows the athlete first tested in the controlled environment to perform subsequent follow-up tests better than the athlete first tested in the uncontrolled environment. Perhaps this is due to the fact that environmental distractions may cause a difference in the Stroop Test learning strategy. This additional finding regarding environment testing order concerning the Stroop Test may result in caution when evaluating the learning effect of the Stroop Test when first performed in an uncontrolled sideline situation or a controlled clinical situation. Future testing should focus on the Stroop Test and whether this environment learning phenomenon occurs consistently.

AQ: B

Future research should also be directed at collecting data on a larger number of collegiate athletes in the preseason and then comparing established baselines with those in athletes with recent MHI episodes. The use of cognitive

tests in preseason screening has already been established by numerous organizations, yet there is a substantial need for additional studies comparing baseline and immediate post-MHI evaluation.[19–22,36] Baseline return-to-play criteria may be established using normal and MHI subjects, thus allowing clinicians the opportunity to review normative versus MHI data. The collection of future data involving collegiate athletes, high school athletes, and professional athletes may allow us to establish general normative baselines for each level of play and each individual sporting event. As stated previously, though, cognitive baselines often vary among individuals; thus, the establishment of performance trends and preseason baselines for individual athletes at risk of MHI is much more useful than overall group normative baseline scores. Ideally, all athletes would have a preseason baseline screening, but this will not always be the case. Therefore, the establishment of some normative data will at least provide comparison scores to make immediate, objective return-to-play decisions. Additionally, this study relied on practice conditions only. It may be helpful to investigate whether game conditions are significantly more distracting than practice conditions, with a resultant impact on cognitive testing performance.

CONCLUSIONS

Our most important finding was no apparent difference in cognitive testing performance in a controlled clinical environment versus performance in an uncontrolled sideline environment for 5 specific cognitive tests. The sole significant difference was that of the testing environment order learning effect for the Stroop Test. This finding may be beneficial for future MHI evaluation; we found no adverse effects for environmental differences on various cognitive testing abilities. Of more importance is the suggestion that clinicians can administer 5 specific cognitive tests in a setting that does not have to be highly controlled, with a note of caution about the variation in the learning effect for testing environment order for the Stroop Test. This finding will allow easier administration of cognitive tests during an acute, initial, uncontrolled sideline environment situation without worry over whether the scores are skewed due to testing environment situations. This investigation on cognitive test performance in varied environments should permit clinicians the opportunity to more confidently evaluate athletes with MHI during the most crucial period after injury. The use of quantifiable objective data should result in safer return-to-play decisions.

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