Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT)

Normative Data

Version 2.0 Only

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Grant L. Iverson, Ph.D.
University of British Columbia & Riverview Hospital

Mark R. Lovell, Ph.D.
University of Pittsburgh Medical Center

Michael W. Collins, Ph.D.
University of Pittsburgh Medical Center

Address correspondence to: Mark Lovell, Ph.D., UPMC Sports Concussion Program; Department of Orthopaedic Surgery; Center for Sports Medicine; 3200 South Water Street, Pittsburgh, PA 15203.

Table of Contents

Chapter 1
Introduction

Purpose

The purpose of this handout is to provide normative data for ImPACT Version 2.0 (Immediate Post-Concussion Assessment and Cognitive Testing). ImPACT is a computerized neuropsychological test battery developed specifically for the evaluation of sports concussion.

Description of Test

ImPACT is a computer administered neuropsychological test battery that consists of 6 individual test modules that measure aspects of cognitive functioning including attention, memory, reaction time, and processing speed (see Table 1). Some of these test modules have two distinct subtests that measure different cognitive functions (e.g., working memory and processing speed).

Table 1. ImPACT Neuropsychological Test Modules.

Test Module	Ability Areas
Word Memory	Immediate and delayed memory for words
Design Memory	Immediate and delayed memory for designs
X's and O's	Attention, concentration, working memory, reaction time
Symbol Match	Visual processing speed, learning and memory
Color Match	Focused attention, response inhibition, reaction time
Three Letters	Attention, concentration, working memory, visual-motor speed

Results from above tests are computed into composite scores.

Computation of Composite Scores

Verbal Memory Composite Score
Average of these scores:

- Word Memory total percent correct (immediate + delay) / 2
- Symbol Match (hidden symbols)/9*100
- Three letters Total letters correct

Visual Memory Composite Score
Average of these scores:

- X's and 0's Total correct (memory)/12*100
- Design memory-total percent correct (immediate + delay) / 2

Reaction Time Composite Score
Average of these scores:

- X's and 0's average correct RT
- Symbol Match average correct RT/3
- Color Match average correct RT

Processing Speed Composite Score
Average of the following scores:

- X's and 0's-total correct (interference) total/4
- Three letters-average counted correctly*3

Impulse Control Composite Score (experimental; not normed yet)
Sum of the following scores:

- X's and 0's-total incorrect –interference
- Color match total commissions

Postconcussion Scale: Total Score

Conceptualizing Normative Scores

The profession of clinical neuropsychology has a long history of over-pathologizing test scores. The most obvious and pervasive example is the use of the term "impaired." It is extremely common for researchers to state that a specific group of patients has impaired cognitive abilities because, as a group, they had statistically lower scores than a group of control subjects. This often occurs when the effect sizes for these differences are small or modest. Moreover, it is frequently the case that the mean scores for the patient group on various neuropsychological tests, although lower than the control group, still fall in the average or low average classification range; thus, they represent a presumed lowering, decline, diminishment, or decrement in performance, but not an impairment.

Although it can be argued that the term impairment simply refers to a negative change in function, for most people the term carries much more serious connotations. This is a particularly important issue when working with people who have sustained mild injuries or disease processes that could have affected their brains. Neuropsychologists must guard against iatrogenesis (i.e., health care providers making the problem worse). It is quite possible that by over-pathologizing test scores, the health care provider can inadvertently make the patient worse. Focusing, dwelling, and worrying about symptoms and "brain damage" can magnify them and protract the recovery period. Having stated this, it is important to accurately detect change that has occurred, and to determine whether this is a statistically and clinically meaningful change.

A basic conceptualization of initial level of performance is provided below. Standardized tests yield scores that fall within certain classification ranges. The following classification ranges and their corresponding percentile rank ranges are commonly used, although not universally accepted: Mildly Impaired < 2^{nd} percentile; Borderline 3^{rd} – 9^{th} percentile; Low Average 10^{th} – 24^{th} percentile; Average 25^{th} – 75^{th} percentile; High Average 76^{th} – 90^{th} percentile; Superior 91^{st} – 98^{th}; Very Superior > 99^{th} percentile. Thus, if an individual obtained a score at the 42^{nd} percentile, this would mean that his performance would be greater than or equal to 42% of his same-aged peers in the general population, and that his score would fall in the Average classification range.

Different normative scores and their corresponding descriptors (i.e., their classification ranges) are illustrated in Table 2. It is important to note that there is not precise agreement in our profession as to where exactly the cutoffs should fall between certain classification ranges (e.g., some may call a percentile rank of 9 low average instead of borderline, because it corresponds to an IQ of 80). There is also disagreement as to the three "impaired" classification ranges. The system below is similar to the more traditional IQ classifications corresponding to mild, moderate, and severe mental retardation.

Table 2. Normative scores and classification ranges in neuropsychology

Descriptor / Classification Range	Scaled Scores M=10, SD=3	IQs/Index Scores M=100, SD=15	T-Score M=50, SD=10	Percentile Rank
Severely Impaired	<1	<55	<20	<.13
Moderately Impaired	1	55-59	20-23	.13 - .35
Mildly Impaired	2 – 4	60 – 69	24 – 29	.38 – 1.9
Borderline	5 – 6	70 – 79	30 – 36	2 - 9
Low Average	7	80 – 89	37 – 43	10 - 24
Average	8 – 12	90 - 109	44 – 56	25 - 75
High Average	13	110 - 119	57 - 63	76 - 90
Superior	14 - 15	120 - 129	64 - 69	91 - 97
Very Superior	16 - 19	130+	70+	98+

(M = Mean (average), SD = Standard deviation)

Chapter 2
Normative Data for High School Students

Initial analyses were based a sample of 545 adolescents between the ages of 13 and 18, inclusive. A portion of these subjects reported some history of education-related problems, such as reading, math, or spelling difficulty; special education placement; or attention-deficit disorder. Athletes with any self-reported history of this nature were compared to those without a self-report history. The groups differed on the Verbal Memory Composite ($p < .006$; $d = .32$), Visual Memory Composite ($p < .006$; $d = .31$), Processing Speed Composite ($p < .002$; $d = .37$), and Reaction Time Composite ($p < .045$; $d = .24$). Therefore, subjects with a self-reported history of one or more of these problems were dropped from the normative sample.

The remaining subjects were 341 boys and 83 girls. The girls performed better on the Verbal Memory Composite ($p < .01$, $d = .32$), and there was a trend toward better performance on the Processing Speed Composite ($p < .055$, $d = .24$). Therefore, the normative data needed to be presented by gender.

The sample of 424 subjects was analyzed for age effects. The breakdown of subjects by age was as follows: 13 = 23, 14 = 122, 15 = 87, 16 = 87, 17 = 61, and 18 = 44. There was a significant main effect for age on the Processing Speed Composite ($p < .00001$) and the Reaction Time Composite ($p < .03$). Tukey planned comparisons revealed significantly higher Processing Speed scores for 16, 17, and 18 year olds compared to 13 and 14 year olds. There were no other differences. Tukey planned comparisons revealed no pairwise differences on the Reaction Time Composite. Therefore, the distinction between 13-14 year olds and 16-18 year olds was meaningful.

The sample was sorted into two groups, those between the ages of 13 and 15 and those between the ages of 16 and 18. The 15 year olds were included with the 13-14 year olds because they did not differ from younger or older subjects. The sample was then sorted by gender, and age-group comparisons were run. For the boys, the older subjects (aged 16-18) performed better on the Processing Speed Composite ($p < .00001$, $d = .58$), Reaction Time Composite ($p < .0009$, $d = .37$), and the Impulse Control Composite ($p < .004$, $d = .32$). There were no differences attributable to age among the girls, although the sample sizes, and thus power, were much smaller.

The normative tables are based on 183 boys between the ages of 13 and 15, 158 boys between the ages of 16 and 18, and 83 girls between the ages of 13 and 18. Normative data are based on the natural distributions of scores within these two samples.

The distributions of scores within these groups were examined and exact percentile ranks corresponding to the natural distribution of scores were assigned. Thus, these could be considered uniform percentile ranks. The distributions were not force-normalized, nor were raw scores converted to standard scores.

Norms for Boys Ages 13 – 15 (N = 183)

Table 3. Approximate Classification Ranges for Index Scores: Boys Ages 13 – 15

	Verbal Memory	Visual Memory	Processing Speed	Reaction Time
Impaired	≤ 63	≤ 49	≤ 16.2	≥ .76
Borderline	64 – 73	50 – 60	16.3 – 24.2	.75 - .67
Low Average	74 – 79	61 – 68	24.3 – 30.1	.66 - .61
Average	80 – 92	69 – 86	30.2 – 37.8	.60 - .53
High Average	93 – 96	87 – 93	37.9 – 44.2	.52 - .49
Superior	97 – 99	94 – 97	44.3 – 50.2	.48 - .45
Very Superior	100	98 – 100	≥ 50.3	≤ .44

Sometimes it is useful to know if an athlete performs particularly poorly on a specific subtest. Cutoff scores for the 10th percentile and the 2nd percentiles for 11 scores derived from the 6 subtests are provided in Table 4. This table allows you to identify unusually and abnormally low subtest scores.

Table 4. Cutoff Scores for Specific Subtests: Boys Ages 13 – 15

Subtests Score	Unusually Low (≤ 10th Percentile)	Impaired (≤ 2nd Percentile)
Word Memory – Learning Percent Correct	≤ 92%	≤ 86%
Word Memory – Delayed Memory Percent Correct	≤ 79%	≤ 67%
Design Memory – Learning Percent Correct	≤ 67%	≤ 50%
Design Memory – Delayed Memory Percent Correct	≤ 58%	≤ 44%
X's and O's – Total Correct (Memory)	≤ 5	≤ 3
X's and O's – Avg. Correct RT (Interference)	≥ .48	≥ .68
Symbol Match – Total Correct (Symbols)	≤ 26	≤ 25
Symbol Match – Avg. Correct RT (Symbols)	≥ 1.70	≥ 2.05
Color Match – Avg. Correct RT	≥ .98	≥ 1.15
Three Letters – Percent of Total Letters Correct	≤ 76%	≤ 67%
Three Letters – Avg. Counted Correctly	≤ 7.7	≤ 2.6

Normative Table 5: Boys Ages 13 – 15 (N = 183)

Percentile Rank	Verbal Memory Composite	Visual Memory Composite	Processing Speed Composite	Reaction Time Composite	Percentile Rank	Verbal Memory Composite	Visual Memory Composite	Processing Speed Composite	Reaction Time Composite
1	62.88	42.68	14.63	0.810	51	88.00	78.00	34.09	0.570
2	64.00	49.40	16.33	0.753	52	88.00	78.00	34.16	0.570
3	67.52	52.52	17.92	0.730	53	88.00	79.00	34.25	0.565
4	69.00	53.36	21.48	0.706	54	88.00	79.00	34.33	0.560
5	70.00	55.20	22.35	0.698	55	88.00	79.00	34.53	0.560
6	71.00	57.00	22.51	0.690	56	88.04	79.04	34.58	0.560
7	71.88	57.88	22.81	0.681	57	89.00	80.00	34.70	0.560
8	72.72	59.00	23.85	0.673	58	89.00	80.00	35.09	0.560
9	73.00	60.00	24.23	0.670	59	89.00	80.00	35.32	0.560
10	73.00	60.40	25.36	0.660	60	89.00	81.00	35.53	0.560
11	74.00	61.00	26.04	0.658	61	89.24	81.00	35.57	0.558
12	74.08	61.16	26.69	0.649	62	90.00	81.00	35.66	0.550
13	75.00	63.00	26.82	0.640	63	90.00	81.00	35.83	0.550
14	76.00	64.00	27.19	0.640	64	90.00	82.00	35.87	0.550
15	76.00	65.00	27.39	0.634	65	90.00	82.00	35.93	0.550
16	76.44	65.00	27.56	0.630	66	91.00	82.44	36.03	0.540
17	77.00	65.28	27.79	0.630	67	91.00	83.00	36.56	0.540
18	77.12	66.00	28.06	0.620	68	91.00	83.00	36.70	0.540
19	78.96	66.00	28.30	0.620	69	91.96	83.00	36.93	0.540
20	79.00	66.80	29.20	0.620	70	92.00	84.00	37.07	0.540
21	79.00	67.00	29.59	0.610	71	92.00	84.00	37.27	0.534
22	79.00	67.00	29.69	0.610	72	92.00	85.00	37.49	0.530
23	79.00	67.00	29.93	0.610	73	92.00	85.32	37.53	0.530
24	80.00	68.00	30.02	0.608	74	92.00	86.00	37.56	0.530
25	80.00	69.00	30.23	0.600	**75**	93.00	86.00	37.78	0.530
26	80.00	69.00	30.28	0.600	76	93.00	88.00	37.98	0.520
27	80.00	69.00	30.34	0.600	77	93.00	88.00	38.12	0.520
28	80.00	69.00	30.43	0.600	78	93.00	88.00	38.81	0.520
29	81.00	69.00	30.57	0.600	79	93.00	88.00	39.13	0.520
30	81.00	69.00	30.63	0.600	80	93.20	88.20	39.42	0.518
31	81.00	70.00	30.70	0.590	81	94.00	89.00	39.60	0.510
32	81.88	70.88	30.79	0.590	82	94.00	89.00	40.27	0.510
33	82.00	71.00	31.48	0.590	83	94.00	90.00	40.39	0.510
34	82.00	71.56	31.80	0.590	84	95.00	90.56	40.58	0.504
35	82.00	72.00	31.93	0.590	85	96.00	91.00	40.69	0.500
36	83.00	72.24	32.13	0.590	86	96.00	91.24	40.99	0.500
37	83.00	73.00	32.33	0.590	87	96.00	92.00	41.88	0.500
38	83.00	73.00	32.53	0.590	88	96.00	92.00	42.53	0.500
39	84.00	73.00	32.57	0.582	89	96.00	92.00	43.49	0.492
40	84.00	73.00	32.63	0.580	90	96.00	92.60	44.21	0.490
41	85.00	73.00	32.74	0.580	**91**	96.44	94.00	44.52	0.480
42	85.00	74.00	33.01	0.580	92	97.28	94.00	44.81	0.480
43	85.00	74.00	33.27	0.580	93	98.12	94.12	45.21	0.479
44	85.00	74.00	33.43	0.580	94	99.00	95.96	45.42	0.470
45	85.00	74.80	33.47	0.570	95	99.00	96.00	46.42	0.470
46	86.00	75.64	33.57	0.570	96	99.00	96.64	46.98	0.464
47	86.48	76.00	33.64	0.570	**97**	99.00	97.00	50.19	0.445
48	87.00	77.00	33.70	0.570	98	100.00	98.00	51.93	0.437
49	87.00	77.16	33.73	0.570	99	100.00	98.16	52.55	0.355
50	87.00	78.00	33.95	0.570					

Norms for High School Boys Ages 16 – 18 (N = 158)

Table 6. Approximate Classification Ranges for Index Scores: Boys Ages 16 – 18

	Verbal Memory	Visual Memory	Processing Speed	Reaction Time
Impaired	≤ 68	≤ 51	≤ 26.4	≥ .74
Borderline	69 – 74	52 – 59	26.5 – 29.6	.73 - .64
Low Average	75 – 79	60 – 70	29.7 – 33.6	.63 - .59
Average	80 – 92	71 – 88	33.7 – 42.5	.58 - .50
High Average	93 – 98	89 – 93	42.6 – 47.7	.49 - .47
Superior	99	94 – 96	47.8 – 51.1	.46 - .43
Very Superior	100	97 – 100	≥ 51.2	≤ .42

Cutoff scores for the 10th percentile and the 2nd percentiles for 11 scores derived from the 6 subtests are provided in Table 7. This table allows you to identify unusually and abnormally low subtest scores.

Table 7. Cutoff Scores for Specific Subtests: Boys Ages 16 – 18

Subtests Score	Unusually Low (≤ 10th Percentile)	Impaired (≤ 2nd Percentile)
Word Memory – Learning Percent Correct	≤ 92%	≤ 83%
Word Memory – Delayed Memory Percent Correct	≤ 79%	≤ 63%
Design Memory – Learning Percent Correct	≤ 71%	≤ 55%
Design Memory – Delayed Memory Percent Correct	≤ 67%	≤ 54%
X's and O's – Total Correct (Memory)	≤ 5	≤ 3
X's and O's – Avg. Correct RT (Interference)	≥ .46	≥ .59
Symbol Match – Total Correct (Symbols)	---	≤ 25
Symbol Match – Avg. Correct RT (Symbols)	≥ 1.67	≥ 2.06
Color Match – Avg. Correct RT	≥ .94	≥ 1.12
Three Letters – Percent of Total Letters Correct	≤ 80%	≤ 67%
Three Letters – Avg. Counted Correctly	≤ 9.6	≤ 7.3

Symbol match total correct is a highly skewed distribution. A 10th percentile cutoff is not available.

Normative Table 8: High School Boys Ages 16 – 18 (N = 158)

Percentile Rank	Verbal Memory Composite	Visual Memory Composite	Processing Speed Composite	Reaction Time Composite	Percentile Rank	Verbal Memory Composite	Visual Memory Composite	Processing Speed Composite	Reaction Time Composite
1	65.36	47.36	19.18	0.764	51	86.00	79.00	37.91	0.530
2	68.18	51.36	26.47	0.738	52	86.00	79.68	38.10	0.530
3	69.00	53.00	26.71	0.730	53	86.00	80.00	38.31	0.530
4	71.00	56.00	27.24	0.696	54	86.86	80.86	38.51	0.530
5	71.00	56.95	27.60	0.690	55	87.00	81.00	38.73	0.526
6	72.54	58.00	27.84	0.674	56	88.00	81.00	38.88	0.520
7	74.00	58.13	28.06	0.650	57	88.00	81.63	38.91	0.520
8	74.00	59.00	28.52	0.643	58	88.00	82.00	39.01	0.520
9	75.00	60.00	29.57	0.640	59	88.81	82.00	39.18	0.520
10	75.00	60.00	29.65	0.640	60	89.00	82.00	39.28	0.520
11	75.49	63.00	30.01	0.630	61	89.99	82.99	39.35	0.520
12	76.00	65.08	30.25	0.630	62	90.00	83.00	39.42	0.510
13	76.00	66.00	30.61	0.630	63	90.00	83.00	39.51	0.510
14	76.00	66.00	31.57	0.627	64	90.76	83.00	39.62	0.510
15	76.00	66.00	31.80	0.620	65	91.00	84.00	40.13	0.510
16	77.00	66.00	31.84	0.620	66	91.00	84.00	40.24	0.510
17	77.03	67.03	32.06	0.610	67	91.00	84.00	40.45	0.505
18	78.00	68.00	32.41	0.610	68	91.00	84.12	40.75	0.500
19	78.00	68.00	32.51	0.610	69	91.00	85.00	40.85	0.500
20	78.80	68.00	32.63	0.610	70	91.00	85.30	41.04	0.500
21	79.00	69.00	32.85	0.606	71	91.00	87.78	41.42	0.500
22	79.00	69.00	32.93	0.600	72	92.00	88.00	41.84	0.500
23	79.00	69.57	33.23	0.594	73	92.00	88.00	42.11	0.499
24	79.00	70.00	33.41	0.590	74	92.00	88.00	42.31	0.490
25	79.75	70.00	33.69	0.583	**75**	92.25	89.00	42.58	0.490
26	80.00	70.34	33.85	0.580	76	93.00	89.00	42.60	0.490
27	80.00	71.00	33.99	0.580	77	93.00	89.00	42.72	0.490
28	81.00	71.52	34.32	0.575	78	94.00	89.00	43.20	0.490
29	81.00	72.11	34.51	0.570	79	94.00	89.61	43.23	0.490
30	81.70	73.00	34.59	0.570	80	94.00	90.00	43.56	0.490
31	82.00	73.00	34.87	0.570	81	94.79	90.00	43.68	0.490
32	82.00	73.00	35.21	0.570	82	95.38	91.00	44.40	0.486
33	82.00	74.00	35.41	0.560	83	96.00	91.97	44.65	0.480
34	82.06	74.06	35.48	0.560	84	96.00	92.00	45.12	0.480
35	83.00	75.00	35.51	0.560	85	96.00	92.00	45.61	0.480
36	83.00	76.00	35.84	0.560	86	96.00	92.00	46.10	0.480
37	83.00	76.00	36.03	0.560	87	97.00	93.00	46.72	0.470
38	84.00	76.00	36.06	0.556	88	97.00	93.00	46.95	0.470
39	84.00	77.00	36.10	0.550	89	97.51	93.00	47.23	0.470
40	84.00	77.00	36.28	0.550	90	98.10	93.00	47.46	0.469
41	84.00	77.19	36.48	0.550	**91**	99.00	93.69	47.79	0.460
42	84.00	78.00	36.54	0.550	92	99.00	94.28	48.23	0.460
43	84.37	78.00	36.65	0.550	93	99.00	95.00	48.88	0.460
44	85.00	78.00	36.87	0.550	94	99.00	95.46	49.31	0.455
45	85.00	78.00	37.10	0.550	95	100.00	96.00	50.21	0.450
46	85.00	78.14	37.24	0.540	96	100.00	96.00	50.60	0.444
47	85.00	79.00	37.34	0.540	**97**	100.00	97.00	50.75	0.435
48	85.00	79.00	37.44	0.540	98	100.00	97.00	51.21	0.420
49	85.91	79.00	37.55	0.540	99	100.00	97.41	51.59	0.359
50	86.00	79.00	37.78	0.530					

Norms for High School Girls Ages 13 – 18 (N = 83)

Table 9. Approximate Classification Ranges for Index Scores: Girls Ages 13 – 18

	Verbal Memory	Visual Memory	Processing Speed	Reaction Time
Impaired	≤ 68	≤ 49	≤ 18.9	≥ .75
Borderline	69 – 77	50 – 59	19.0 – 28.9	.74 - .67
Low Average	78 – 83	60 – 69	29.0 – 32.7	.66 - .61
Average	84 – 93	70 – 88	32.8 – 42.3	.60 - .51
High Average	94 – 98	89 – 92	42.4 – 47.0	.50 - .49
Superior	99 – 100	93 – 98	47.1 – 51.1	.48 - .45
Very Superior	--	99 – 100	≥ 51.2	≤ .44

Cutoff scores for the 10th percentile and the 2nd percentiles for 11 scores derived from the 6 subtests are provided in Table 10. This table allows you to identify unusually and abnormally low subtest scores.

Table 10. Cutoff Scores for Specific Subtests: High School Girls Ages 13 – 18

Subtests Score	Unusually Low (≤ 10th Percentile)	Impaired (≤ 2nd Percentile)
Word Memory – Learning Percent Correct	≤ 91%	≤ 87%
Word Memory – Delayed Memory Percent Correct	≤ 82%	≤ 78%
Design Memory – Learning Percent Correct	≤ 66%	≤ 54%
Design Memory – Delayed Memory Percent Correct	≤ 57%	≤ 50%
X's and O's – Total Correct (Memory)	≤ 5	≤ 3
X's and O's – Avg. Correct RT (Interference)	≥ .49	≥ .59
Symbol Match – Total Correct (Symbols)	≤ 25	≤ 23
Symbol Match – Avg. Correct RT (Symbols)	≥ 1.69	≥ 1.96
Color Match – Avg. Correct RT	≥ .96	≥ 1.18
Three Letters – Percent of Total Letters Correct	≤ 80%	≤ 67%
Three Letters – Avg. Counted Correctly	≤ 9.1	0

Normative Table 11: Girls Ages 13 – 18 (N = 83)

Percentile Rank	Verbal Memory Composite	Visual Memory Composite	Processing Speed Composite	Reaction Time Composite	Percentile Rank	Verbal Memory Composite	Visual Memory Composite	Processing Speed Composite	Reaction Time Composite
1	58.00	43.00	14.13	0.790	51	90.00	79.00	38.79	0.540
2	61.40	49.80	15.91	0.770	52	90.00	79.00	39.02	0.540
3	68.72	53.52	19.05	0.739	53	90.00	79.00	39.17	0.540
4	74.72	54.00	21.49	0.713	54	90.36	79.00	39.32	0.540
5	76.00	54.40	22.74	0.698	55	91.00	79.20	39.53	0.540
6	76.04	56.12	25.53	0.690	56	91.04	80.00	39.55	0.540
7	76.88	58.64	26.67	0.690	57	91.88	80.00	39.62	0.540
8	77.00	59.00	27.85	0.683	58	92.00	80.00	39.72	0.540
9	77.56	59.00	28.83	0.669	59	92.00	80.56	39.81	0.534
10	78.40	59.80	29.28	0.656	60	92.00	81.00	40.09	0.530
11	79.24	61.00	29.28	0.650	61	92.00	81.24	40.48	0.530
12	80.00	61.00	29.32	0.648	62	92.00	82.08	40.58	0.529
13	80.00	61.00	29.48	0.632	63	92.00	82.92	40.58	0.521
14	80.76	62.52	29.88	0.630	64	92.00	83.76	40.71	0.520
15	81.60	63.00	30.09	0.630	65	92.00	84.00	40.75	0.520
16	82.00	63.44	30.27	0.626	66	92.00	84.44	40.77	0.520
17	82.00	64.00	30.44	0.620	67	92.28	85.00	40.81	0.520
18	82.00	64.24	30.52	0.620	68	93.00	85.00	40.88	0.520
19	82.00	65.92	30.84	0.620	69	93.00	85.00	41.07	0.520
20	82.00	66.80	30.93	0.612	70	93.00	85.80	41.32	0.512
21	82.64	67.64	31.91	0.610	71	93.00	86.00	41.64	0.510
22	83.00	68.00	32.50	0.610	72	93.00	86.96	42.01	0.510
23	83.00	68.32	32.56	0.607	73	93.00	88.00	42.26	0.507
24	83.16	69.16	32.69	0.600	74	93.16	88.00	42.29	0.500
25	84.00	70.00	33.28	0.600	**75**	94.00	88.00	42.33	0.500
26	84.00	70.00	33.41	0.600	76	94.00	88.84	42.37	0.500
27	84.00	70.68	33.51	0.593	77	94.00	89.00	42.67	0.500
28	84.52	71.00	33.77	0.590	78	95.04	89.00	43.01	0.495
29	85.00	71.00	34.00	0.590	79	96.00	89.00	43.47	0.490
30	85.00	71.20	34.03	0.588	80	96.00	89.20	44.00	0.490
31	85.00	72.04	34.04	0.580	81	96.00	90.00	44.20	0.490
32	85.00	72.88	34.36	0.580	82	96.00	90.00	44.29	0.490
33	85.72	73.00	34.67	0.573	83	96.00	90.00	44.48	0.490
34	86.56	73.00	34.78	0.570	84	96.56	90.56	45.24	0.490
35	87.40	73.40	34.89	0.566	85	97.00	91.00	46.06	0.490
36	88.00	74.00	35.16	0.560	86	97.24	91.00	46.53	0.490
37	88.00	74.00	35.50	0.560	87	98.00	91.08	46.71	0.489
38	88.00	74.00	35.53	0.560	88	98.00	91.92	46.77	0.481
39	88.00	74.76	35.76	0.560	89	98.76	92.00	46.80	0.480
40	88.00	75.00	35.87	0.560	90	99.00	92.60	47.00	0.480
41	88.00	75.00	36.24	0.556	**91**	99.00	93.00	47.31	0.480
42	88.00	75.28	36.69	0.550	92	99.28	93.56	47.91	0.480
43	88.00	76.00	36.78	0.550	93	100.00	95.00	48.88	0.479
44	88.00	76.00	37.13	0.550	94	100.00	95.00	49.23	0.470
45	88.00	76.80	37.17	0.550	95	100.00	95.00	50.61	0.462
46	88.64	77.00	37.37	0.544	96	100.00	96.28	50.95	0.460
47	89.48	77.00	37.72	0.540	**97**	100.00	97.96	51.12	0.446
48	90.00	77.00	38.18	0.540	98	100.00	99.32	51.89	0.385
49	90.00	77.32	38.62	0.540	99	100.00	100.00	53.15	0.290
50	90.00	79.00	38.73	0.540					

Chapter 3
Normative Data for University Students

Within this college sample, there were no differences on the four composites that were attributable to year. There was a gender effect for the Verbal Memory Composite, but not for Visual Memory, Reaction Time, or Processing Speed. The final normative tables are based on 410 university men, and 97 university women. Normative data are based on the natural distributions of scores within these two samples.

The distributions of scores within these groups were examined and exact percentile ranks corresponding to the natural distribution of scores were assigned. Thus, these could be considered uniform percentile ranks. The distributions were not force-normalized, nor were raw scores converted to standard scores.

Table 12. Approximate Classification Ranges for Index Scores – University Men (N = 410).

	Verbal Memory	Visual Memory	Processing Speed	Reaction Time
Impaired	≤ 71	≤ 51	≤ 23.8	≥ .75
Borderline	72 – 77	52 – 60	23.9 – 28.3	.74 - .67
Low Average	78 – 82	61 – 68	28.4 – 32.4	.66 - .61
Average	83 – 94	69 – 94	32.5 – 42.0	.60 - .52
High Average	95 – 97	95 – 97	42.1 – 46.0	.51 - .48
Superior	98 – 99	98 – 99	46.1 – 50.0	.47 - .45
Very Superior	100	100	≥ 50.1	≤ .44

Sometimes it is useful to know if an athlete performs particularly poorly on a specific subtest. Cutoff scores for the 10th percentile and the 2nd percentiles for 11 scores derived from the 6 subtests are provided in Table 13. This table allows you to identify unusually and abnormally low subtest scores.

Table 13. Cutoff Scores for Specific Subtests

Subtests Score	Unusually Low (≤ 10th Percentile)	Impaired (≤ 2nd Percentile)
Word Memory – Learning Percent Correct	≤ 88%	≤ 83%
Word Memory – Delayed Memory Percent Correct	≤ 75%	≤ 63%
Design Memory – Learning Percent Correct	≤ 61%	≤ 50%
Design Memory – Delayed Memory Percent Correct	≤ 57%	≤ 45%
X's and O's – Total Correct (Memory)	≤ 5	≤ 3
X's and O's – Avg. Correct RT (Interference)	≥ .48	≥ .59
Symbol Match – Total Correct (Symbols)	---	≤ 25
Symbol Match – Avg. Correct RT (Symbols)	≥ 1.78	≥ 2.19
Color Match – Avg. Correct RT	≥ .95	≥ 1.12
Three Letters – Percent of Total Letters Correct	≤ 80%	≤ 67%
Three Letters – Avg. Counted Correctly	≤ 9.2	≤ 6.6

Symbol match total correct is a highly skewed distribution. A 10th percentile cutoff is not available.

Normative Table 14: Men, University, N = 410

Percentile Rank	Verbal Memory Composite	Visual Memory Composite	Processing Speed Composite	Reaction Time Composite	Percentile Rank	Verbal Memory Composite	Visual Memory Composite	Processing Speed Composite	Reaction Time Composite
1	68.00	45.99	19.41	0.813	51	88.96	77.78	37.28	0.552
2	71.49	51.39	23.90	0.748	52	89.03	77.78	37.46	0.550
3	72.01	51.39	24.46	0.703	53	89.24	77.78	37.75	0.547
4	73.00	53.39	25.61	0.690	54	89.58	79.17	37.87	0.546
5	74.07	55.56	26.01	0.685	55	89.58	79.17	38.08	0.544
6	75.05	55.56	26.60	0.678	56	90.00	79.17	38.34	0.543
7	75.85	58.33	27.62	0.672	57	90.00	80.56	38.56	0.542
8	76.70	59.72	28.13	0.665	58	90.28	80.56	38.71	0.540
9	76.88	59.72	28.33	0.661	59	90.31	80.56	38.86	0.539
10	77.31	61.11	28.62	0.657	60	90.63	81.94	38.99	0.537
11	77.88	61.11	29.11	0.650	61	90.69	81.94	39.03	0.536
12	78.19	61.56	29.38	0.641	62	91.17	81.94	39.13	0.536
13	78.82	62.50	29.54	0.640	63	91.32	81.94	39.30	0.534
14	79.00	63.25	29.65	0.635	64	91.67	81.94	39.55	0.532
15	79.17	65.28	30.02	0.630	65	92.07	82.15	39.73	0.530
16	79.86	65.28	30.26	0.629	66	92.36	83.33	40.01	0.528
17	80.63	65.28	30.71	0.625	67	92.73	83.33	40.16	0.527
18	81.24	66.64	30.92	0.618	68	92.78	84.00	40.26	0.526
19	81.41	66.67	31.40	0.615	69	93.40	84.72	40.43	0.524
20	81.79	66.67	31.66	0.610	70	93.40	84.72	40.55	0.520
21	82.08	68.06	31.88	0.608	71	93.40	84.72	40.65	0.518
22	82.36	68.06	32.03	0.606	72	93.40	84.72	40.75	0.517
23	82.99	68.06	32.18	0.605	73	93.48	84.72	41.08	0.516
24	83.03	69.44	32.37	0.602	74	94.11	86.11	41.59	0.515
25	83.18	69.44	32.55	0.600	**75**	94.44	86.11	41.96	0.515
26	83.33	69.44	32.68	0.599	76	94.47	86.11	42.09	0.513
27	83.47	70.83	32.77	0.596	77	94.55	86.11	42.46	0.511
28	83.68	70.83	33.20	0.595	78	94.79	86.92	42.68	0.509
29	83.92	70.83	33.44	0.594	79	94.94	87.50	42.78	0.507
30	84.05	70.83	33.76	0.592	80	95.14	87.50	43.00	0.505
31	84.44	71.40	33.86	0.588	81	95.14	87.50	43.22	0.503
32	84.51	72.22	34.05	0.587	82	95.56	88.89	43.55	0.502
33	84.72	72.22	34.34	0.586	83	96.18	88.89	43.82	0.500
34	85.07	72.22	34.44	0.583	84	96.18	88.89	44.17	0.497
35	85.48	72.22	34.53	0.578	85	96.42	88.89	44.32	0.494
36	85.76	73.61	34.70	0.574	86	96.88	90.28	44.74	0.491
37	86.11	73.61	34.90	0.574	87	97.22	90.28	45.03	0.489
38	86.25	73.61	34.98	0.572	88	97.22	90.28	45.15	0.487
39	86.46	75.00	35.33	0.570	89	97.22	90.28	45.42	0.485
40	86.60	75.00	35.51	0.569	90	97.28	91.67	45.94	0.483
41	86.81	75.00	35.73	0.565	**91**	97.92	91.67	46.55	0.480
42	86.88	75.00	35.83	0.564	92	97.92	91.67	47.49	0.472
43	87.12	75.00	35.98	0.562	93	98.33	91.99	47.86	0.468
44	87.35	76.39	36.12	0.561	94	98.96	93.06	48.39	0.464
45	87.50	76.39	36.23	0.560	95	98.96	93.06	48.77	0.460
46	87.85	76.39	36.45	0.560	96	98.96	94.44	49.30	0.458
47	87.85	76.39	36.56	0.558	**97**	99.66	94.44	50.03	0.450
48	88.29	76.78	36.76	0.557	98	100.00	95.83	51.25	0.429
49	88.54	77.78	37.03	0.555	99	100.00	98.46	52.00	0.343
50	88.82	77.78	37.23	0.553					

Table 15. Approximate Classification Ranges for Index Scores – University Women (N=97)

	Verbal Memory	Visual Memory	Processing Speed	Reaction Time
Impaired	≤ 70	≤ 48	≤ 23.3	≥ .70
Borderline	71 – 82	49 – 59	23.4 – 29.7	.69 - .64
Low Average	83 – 86	60 – 69	29.8 – 34.3	.63 - .60
Average	87 – 97	70 – 88	34.4 – 42.1	.59 - .52
High Average	98 – 100	89 – 93	42.2 – 46.3	.51 - .50
Superior	---	94 – 96	46.4 – 49.2	.49 - .48
Very Superior	---	97 – 100	≥ 49.3	≤ .47

Cutoff scores for the 10th percentile and the 2nd percentiles for 11 scores derived from the 6 subtests are provided in Table 16. This table allows you to identify unusually and abnormally low subtest scores.

Table 16. Cutoff Scores for Specific Subtests

Subtests Score	Unusually Low (≤ 10th Percentile)	Impaired (≤ 2nd Percentile)
Word Memory – Learning Percent Correct	≤ 94%	≤ 87%
Word Memory – Delayed Memory Percent Correct	≤ 82%	≤ 74%
Design Memory – Learning Percent Correct	≤ 62%	≤ 50%
Design Memory – Delayed Memory Percent Correct	≤ 57%	≤ 46%
X's and O's – Total Correct (Memory)	≤ 4	≤ 2
X's and O's – Avg. Correct RT (Interference)	≥ .44	≥ .49
Symbol Match – Total Correct (Symbols)	---	≤ 25
Symbol Match – Avg. Correct RT (Symbols)	≥ 1.66	≥ 1.94
Color Match – Avg. Correct RT	≥ .93	≥ 1.02
Three Letters – Percent of Total Letters Correct	≤ 86%	≤ 73%
Three Letters – Avg. Counted Correctly	≤ 9.5	≤ 7.2

Symbol match total correct is a highly skewed distribution. A 10th percentile cutoff is not available.

Normative Table 17: Females, University, N = 410

Percentile Rank	Verbal Memory Composite	Visual Memory Composite	Processing Speed Composite	Reaction Time Composite	Percentile Rank	Verbal Memory Composite	Visual Memory Composite	Processing Speed Composite	Reaction Time Composite
1	55.14	43.06	22.55	0.774	51	91.81	79.17	38.70	0.539
2	60.81	48.39	23.39	0.693	52	92.01	79.17	38.70	0.537
3	70.70	49.92	25.66	0.674	53	92.01	79.17	38.92	0.537
4	71.58	53.83	26.97	0.661	54	92.34	80.47	38.93	0.537
5	75.47	54.17	28.43	0.660	55	92.36	80.56	38.99	0.535
6	79.69	54.17	29.08	0.652	56	92.99	80.56	39.05	0.534
7	81.52	57.75	29.39	0.637	57	93.36	80.56	39.07	0.532
8	82.20	59.50	29.57	0.632	58	93.82	81.75	39.35	0.532
9	82.58	59.72	29.74	0.631	59	94.06	83.11	39.53	0.531
10	82.75	59.72	29.80	0.630	60	94.38	83.33	39.67	0.531
11	82.94	59.72	30.07	0.626	61	94.44	83.33	39.98	0.531
12	83.78	60.78	30.23	0.623	62	94.50	83.33	40.25	0.529
13	84.03	62.14	30.32	0.623	63	94.57	84.39	40.57	0.528
14	84.08	62.50	30.84	0.618	64	95.05	84.72	40.69	0.527
15	84.19	62.50	31.11	0.613	65	95.51	84.72	40.75	0.525
16	84.38	63.44	31.59	0.611	66	96.01	84.72	40.81	0.523
17	84.63	63.89	31.82	0.609	67	96.18	85.67	40.89	0.521
18	84.72	63.89	32.56	0.608	68	96.18	86.11	40.94	0.519
19	84.94	64.75	33.22	0.607	69	96.63	86.11	40.97	0.519
20	85.07	66.11	33.47	0.606	70	96.88	86.11	41.11	0.519
21	85.11	67.47	33.54	0.601	71	97.08	86.11	41.23	0.518
22	85.29	68.06	33.80	0.597	72	97.26	86.92	41.47	0.515
23	85.60	68.81	34.11	0.595	73	97.29	87.50	41.78	0.513
24	85.76	69.44	34.28	0.594	74	97.63	88.25	41.90	0.512
25	86.81	70.14	34.40	0.592	**75**	97.92	88.89	42.06	0.510
26	87.85	71.50	34.53	0.589	76	97.92	88.89	42.26	0.508
27	87.85	72.22	34.88	0.586	77	98.12	88.89	42.39	0.508
28	87.88	72.22	35.25	0.585	78	98.33	89.53	42.46	0.507
29	88.03	72.22	35.36	0.583	79	98.61	90.28	42.62	0.505
30	88.33	72.22	35.44	0.580	80	98.96	90.28	42.80	0.504
31	88.54	72.75	35.54	0.576	81	98.96	90.83	43.43	0.503
32	88.54	73.61	35.63	0.575	82	98.96	91.67	44.42	0.503
33	88.57	73.61	35.76	0.571	83	98.96	91.67	44.55	0.502
34	88.70	74.06	35.90	0.569	84	98.96	92.14	45.03	0.500
35	88.91	75.00	36.06	0.568	85	99.29	93.06	45.82	0.499
36	88.98	75.00	36.09	0.565	86	100.00	93.06	45.97	0.499
37	89.10	75.36	36.15	0.565	87	100.00	93.06	46.09	0.498
38	89.34	76.39	36.40	0.562	88	100.00	93.06	46.13	0.496
39	89.48	76.39	36.98	0.560	89	100.00	93.06	46.17	0.492
40	89.67	76.39	37.13	0.557	90	100.00	93.06	46.29	0.489
41	90.11	76.39	37.27	0.557	**91**	100.00	93.06	46.72	0.489
42	90.64	76.39	37.39	0.556	92	100.00	93.31	47.89	0.488
43	90.69	76.58	37.48	0.552	93	100.00	94.44	47.99	0.487
44	90.75	77.78	37.66	0.551	94	100.00	94.44	48.24	0.484
45	91.19	77.78	37.76	0.551	95	100.00	94.61	48.42	0.483
46	91.35	77.78	37.82	0.547	96	100.00	95.83	48.97	0.479
47	91.67	77.78	38.09	0.544	**97**	100.00	95.83	49.24	0.476
48	91.67	77.78	38.36	0.544	98	100.00	96.00	50.64	0.457
49	91.67	77.81	38.65	0.541	99	100.00	98.67	51.69	0.451
50	91.67	77.81	38.65	0.541					

Chapter 4
Normative Data for the Postconcussion Scale[1]

The Postconcussion Scale is a 22-item scale designed to measure the severity of symptoms in the acute phase of recovery from concussion (Lovell & Collins, 1998). An earlier version of this scale has been used with large samples of collegiate football players (Collins et al., 1999). The version of the scale used for this project is reprinted on page 17.

The Postconcussion Scale is essentially a "state" measure of perceived symptoms associated with concussion. That is, the athlete is asked to report his or her "current" experience of the symptoms. This allows tracking of symptoms over very short intervals, such as consecutive days or every few days.

Sample

A sample of 2,304 high school and university students was used for this project. The vast majority of subjects were healthy at the time of their evaluations (i.e., 894 high school students and 1,295 university students). In addition, a sample of 115 high school and university athletes in the acute recovery period from concussion were examined (i.e., within 3 days).

Preliminary analyses showed that women tend to report more symptoms than men. Moreover, young people with a self-reported history of learning or speech problems, or special education placement, reported more symptoms than those without this history.

Therefore, normative and psychometric analyses were stratified by level (high school / university), gender, and learning / special education status.

The "regular education" samples were comprised of 588 high school boys, 119 high school girls, 803 university men, and 236 university women. The special education samples were comprised of 156 high school boys, 31 high school girls, 196 university men, and 60 university women.

It is important to note that inclusion in the so-called "special education" groups does not mean that the person (a) had a formally diagnosed learning disability, or (b) attended special education classes or programs. All subjects who self-reported any past speech therapy, learning problems (e.g., reading or math), ADHD, or special education placement were included in these groups.

The concussed athletes were all evaluated within 3 days injury. The sample was comprised of 83 young men and 32 young women.

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Original Postconcussion Scale

Directions: After reading each symptom, please circle the number that best describes the way you have been feeling **today**. A rating of **0** means you have **not** experienced this symptom today. A rating of **6** means you have experienced **severe** problems with this symptom today.

Symptom	None	Mild		Moderate		Severe	
Headache	0	1	2	3	4	5	6
Confusion/Disorientation	0	1	2	3	4	5	6
Difficulty Remembering Incident	0	1	2	3	4	5	6
Nausea	0	1	2	3	4	5	6
Vomiting	0	1	2	3	4	5	6
Dizziness	0	1	2	3	4	5	6
Balance Problems	0	1	2	3	4	5	6
Fatigue	0	1	2	3	4	5	6
Trouble Falling Asleep	0	1	2	3	4	5	6
Sleeping More Than Usual	0	1	2	3	4	5	6
Drowsiness	0	1	2	3	4	5	6
Sensitivity to Light/Noise	0	1	2	3	4	5	6
Irritability	0	1	2	3	4	5	6
Sadness	0	1	2	3	4	5	6
Nervousness	0	1	2	3	4	5	6
Numbness or Tingling	0	1	2	3	4	5	6
Feeling Slowed Down	0	1	2	3	4	5	6
Feeling Like "In a Fog"	0	1	2	3	4	5	6
Difficulty Concentrating	0	1	2	3	4	5	6
Difficulty with Memory	0	1	2	3	4	5	6

Current Version of the Scale – Used for this Project

Symptom	Minor		Moderate		Severe	
Headache	1	2	3	4	5	6
Nausea	1	2	3	4	5	6
Vomiting	1	2	3	4	5	6
Balance Problems	1	2	3	4	5	6
Dizziness	1	2	3	4	5	6
Fatigue	1	2	3	4	5	6
Trouble Falling Asleep	1	2	3	4	5	6
Sleeping More Than Usual	1	2	3	4	5	6
Sleeping Less Than Usual	1	2	3	4	5	6
Drowsiness	1	2	3	4	5	6
Sensitivity to Light	1	2	3	4	5	6
Sensitivity to Noise	1	2	3	4	5	6
Irritability	1	2	3	4	5	6
Sadness	1	2	3	4	5	6
Nervousness	1	2	3	4	5	6
Feeling More Emotional	1	2	3	4	5	6
Numbness or Tingling	1	2	3	4	5	6
Feeling Slowed Down	1	2	3	4	5	6
Feeling Mentally “Foggy”	1	2	3	4	5	6
Difficulty Concentrating	1	2	3	4	5	6
Difficulty Remembering	1	2	3	4	5	6
Visual Problems	1	2	3	4	5	6

Instead of zero, subjects checked a box if they were “not experiencing the symptom.”

Descriptive Statistics & Psychometric Analyses

Descriptive statistics and psychometric analyses are provided in Table 18. The mean, median, standard deviation, interquartile range, and range of total scores, for each group, are presented. As seen from the measures of central tendency (mean and median) and the ranges, the distributions of total symptom scores are clearly skewed. This is illustrated graphically, for two samples, in Figures 1 and 2. The distribution of scores for the clinical sample is not severely skewed (Figure 3).

Table 18. Descriptive and psychometric analyses.

									Confidence Interval	
Group	**N**	**Mean**	**Median**	**SD**	**IQR**	**Range**	**Alpha**	**SEM**	**.80**	**.90**
High School – Regular Education										
Boys	588	4.8	2	7.9	0-6	0-54	.89	2.62	3.35	4.30
Girls	119	7.7	3	13.7	0-9	0-78	.94	3.36	4.30	5.50
High School – Special Education										
Boys	156	8.8	3	13.0	0-11	0-64	.92	3.68	4.71	6.03
Girls	31	5.3	3	6.3	1-8	0-26	.75	3.15	4.03	5.17
College – Regular Education										
Young Men	803	4.5	2	7.5	0-6	0-56	.88	2.60	3.33	4.26
Young Women	236	8.0	5	10.3	0-10	0-55	.88	3.57	4.57	5.85
College – Special Education										
Young Men	196	9.9	5	13.5	0-13	0-63	.91	4.05	5.18	6.64
Young Women	60	9.8	7	11.4	2-14	0-55	.91	3.42	4.38	5.61
Athletes with Concussions										
Young Men	83	26.8	22	20.2	10-39	0-81	.92	5.71	7.31	9.37
Young Women	32	35.8	29.5	25.2	18-57	2-95	.94	6.17	7.90	10.12
Total Sample	115	29.3	25	22.0	11-43	0-95	.93	5.82	7.45	9.55

Preliminary analyses suggest that women report more symptoms than men, and those with a history of special education or learning problems report more symptoms than those without this history. The statistics presented in this table are stratified by level, gender, and special education status. Descriptive statistics: Sample size, Mean, Median, Standard Deviation, Interquartile Range, Range. Reliability: Cronbach's Unstandardized Alpha (this represents the lower bound of reliability), Standard Error of Measurement, .80 and .90 Confidence Intervals.

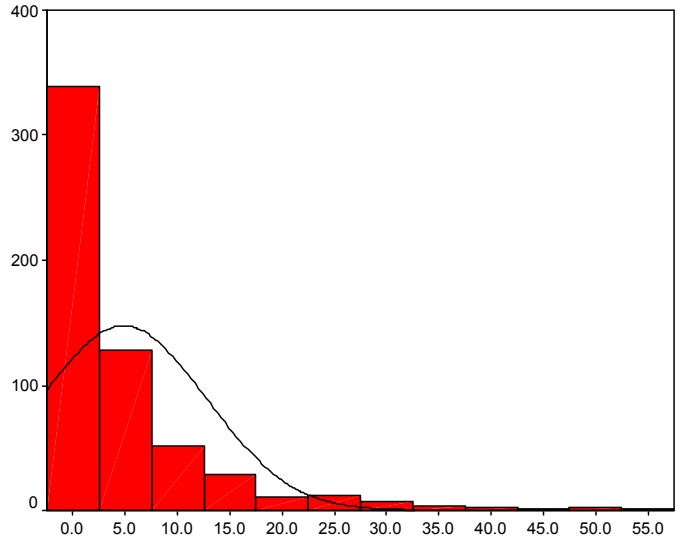
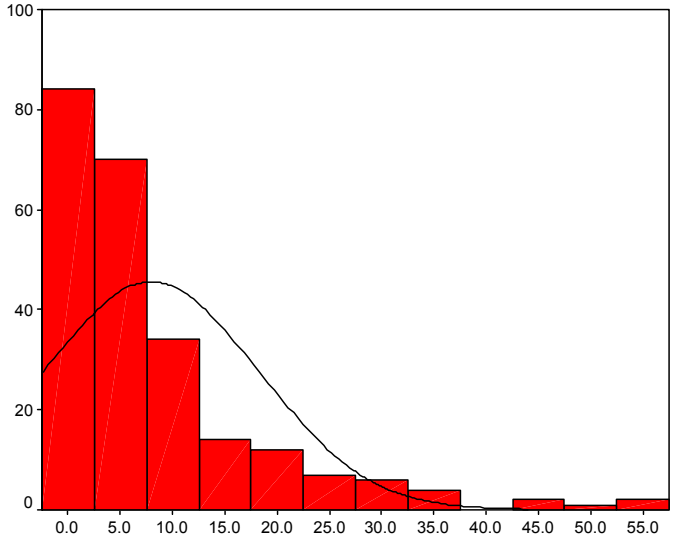


Figure 1. High School Boys – Regular Education

Figure 2. University Women – Regular Education



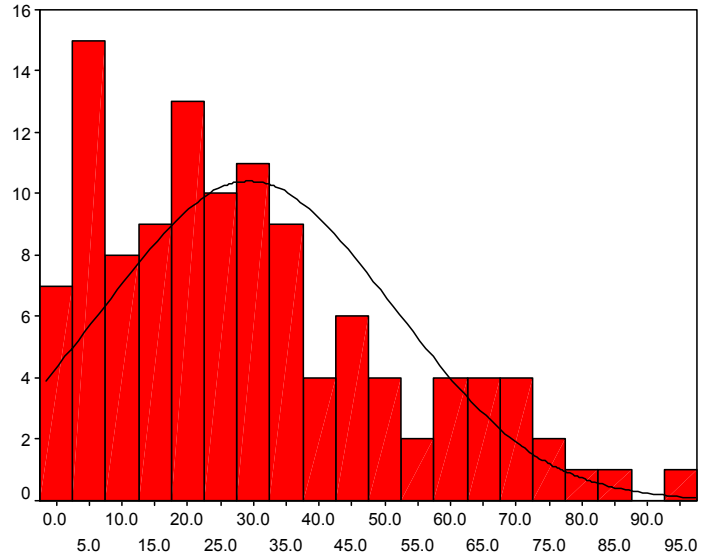


Figure 3. Distribution of scores in concussed athletes.

Scale Reliability

According to classical test theory, obtained scores (or measures) are only estimates of "true" scores because they contain measurement error. Measurement error is closely related to test reliability. Reliability refers to the consistency or stability of test scores. Reliability can be viewed as the ability of an instrument to reflect an individual score that is minimally influenced by error. Reliability should not be considered a dichotomous concept; rather it falls on a continuum. One cannot say an instrument is reliable or unreliable, but more accurately should say it possesses a high or low degree of reliability for a specific purpose, with a specific population (Franzen, 1989, 2000)[2].

The internal consistency reliability of the scale was estimated using Cronbach's alpha (Cronbach, 1951). Alpha is believed to represent the lower bound for the true reliability of the scale (SPSS 9.0 Base Manual, p. 362). Alpha is influenced by the number of items on the scale, the average inter-item covariance, and the average item variance.

As seen in Table 18, internal consistency reliability ranged from .88 - .94 in the large samples of high school and college regular education students. The small sample of high school girls in special education (n = 31) had a lower reliability estimate ($\alpha = 0.75$), but the other three larger samples of special education students had high reliability estimates (.91 - .92). The internal consistency reliability for the clinical sample of 115 concussed athletes also was high ($\alpha = 0.93$).

The standard error of measurement (SEM) is considered an estimate of measurement error in a person's observed test score. Typically, SEMs are calculated in standard deviation units using the formula below. SEMs are calculated in three steps. First, the reliability coefficient is subtracted from one. Second, the square root of this value is obtained. Third, this square root is multiplied by the sample standard deviation.

SEMs for the different groups also are presented in Table 18. These SEMs were used to create confidence intervals. A confidence interval represents a range or band of scores, surrounding an observed score, in which the individual's "true" score is believed to fall. The 80% (.80) confidence interval is obtained by multiplying the SEM by a z-score of 1.28 and the 90% (.90) confidence interval is obtained by multiplying the SEM by a z-score of 1.64.

For college men, the 80% confidence interval for the total score is approximately +/- 4 points (i.e., 3.3) and the 90% confidence interval is approximately +/- 5 points (i.e., 4.26).

Test-retest reliability was examined in 82 concussed high school and college athletes. They completed the scale within 2 days of their concussion and again within 4 days. The test-retest reliability in this sample was .80. Notably, their mean score at time 1 was 24.6 and their mean score at time 2 was 12.0.

[2] Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. Psychometrika, 16:3, 297-234.
Franzen, M.D. (1989). Reliability and validity in neuropsychological assessment. New York: Plenum Press.
Franzen, M.D. (2000). Reliability and validity in neuropsychological assessment. (2nd Edition) New York: Kluwer Academic/Plenum Press.

Normative Scores & Classification Ranges

As seen in Figures 1 – 3, the distributions of total scores are skewed. With this degree of skew, forced-normalization of the distributions will (a) distort the true nature of the construct being measured; that is, healthy young people's total symptoms are not normally distributed in the population, and (b) result in increased interpretation error.

Therefore, the natural distribution of scores was examined and classification ranges were created that reflect proportions of normative subjects. Classification descriptors were created that reflect raw score ranges and percentile rank ranges in the natural distribution of scores. For example, in Table 19, 40.5% of high school boys obtained a total score of zero on the scale. Thus, a score of zero would be considered "Low – Normal". In contrast, only 10% scored 14 or higher, so scores between 14 and 21 are considered "High" and scores of 22 or greater are considered "Very High."

The classification ranges for high school and university students in regular education are presented in Tables 19 – 22. The ranges for those with a history of special education are presented in Tables 23 – 26. The sample of high school girls with a history of special education is very small; this table is provided for general information (Table 24). We recommend using Table 3 for all high school girls.

Table 19. Classifications, raw scores, and percentile ranks based on a sample of **588 regular education high school boys**.

Classification	Raw Scores	Percentile Ranks for Players
Low – Normal	0	40.5
Normal	1 – 6	49 – 76
Unusual	7 – 13	79 – 90
High	14 – 21	91 – 95
Very High	22+	> 95

Table 20. Classifications, raw scores, and percentile ranks based on a sample of **119 regular education high school girls**.

Classification	Raw Scores	Percentile Ranks for Players
Low – Normal	0	29.4
Normal	1 – 8	40 – 75
Unusual	9 – 17	76 – 90
High	18 – 39	91 – 95
Very High	40+	> 95

Table 21. Classifications, raw scores, and percentile ranks based on a sample of **803 regular education university men.**

Classification	Raw Scores	Percentile Ranks for Players
Low – Normal	0	43.3
Normal	1 – 5	50 – 75
Unusual	6 – 12	78 – 90
High	13 – 20	91 – 95
Very High	21+	> 95

Table 22. Classifications, raw scores, and percentile ranks based on a sample of **236 regular education university women**.

Classification	Raw Scores	Percentile Ranks for Players
Low – Normal	0	26.7
Normal	1 – 10	32 – 75
Unusual	11 – 21	79 – 90
High	22 – 31	91 – 95
Very High	32+	> 95

Table 23. Classifications, raw scores, and percentile ranks based on a sample of **156 high school boys with a history of "special education[3]"**.

Classification	Raw Scores	Percentile Ranks for Players
Low – Normal	0	31
Normal	1 – 10	39 – 74
Unusual	11 – 26	76 – 90
High	27 – 38	92 – 95
Very High	239+	> 95

Table 24. Classifications, raw scores, and percentile ranks based on a sample of **31 high school girls with a history of "special education"**.

Classification	Raw Scores	Percentile Ranks for Players
Low – Normal	0	19
Normal	1 – 6	32 – 74
Unusual	8 – 14	81 – 90
High	15 – 19	93 – 97

[3] It is important to note that inclusion in the so-called "special education" groups does not mean that the person (a) had a formally diagnosed learning disability, or (b) attended special education classes or programs. All subjects who self-reported any past speech therapy, learning problems (e.g., reading or math), ADHD, or special education placement were included in these groups.

Table 25. Classifications, raw scores, and percentile ranks based on a sample of **196 university men with a history of "special education"**.

Classification	Raw Scores	Percentile Ranks for Players
Low – Normal	0	28
Normal	1 – 12	34 – 74
Unusual	13 – 28	77 – 90
High	29 – 41	91 – 95
Very High	42+	> 95

Table 26. Classifications, raw scores, and percentile ranks based on a sample of **60 university women with a history of "special education"**.

Classification	Raw Scores	Percentile Ranks for Players
Low – Normal	0	17
Normal	1 – 13	22 – 73
Unusual	14 – 21	78 – 90
High	22 – 31	91 – 95
Very High	32+	> 95

Interpreting Change on the Postconcussion Scale

A common method for interpreting change on a self-report inventory is to apply the reliable change methodology. This method relies heavily on the standard error of the difference score. The standard error of the difference (S_{diff}) can be used to create a confidence interval (i.e., a prediction interval in the statistical literature) for test-retest difference score. Essentially, this confidence interval represents the probable range of measurement error for the distribution of difference scores. The formula for calculating the S_{diff} is printed below.

$SEM_1 = SD\sqrt{1-r_{12}}$ Standard deviation from time 1 multiplied by the square root of 1 minus the test-retest coefficient.

$SEM_2 = SD\sqrt{1-r_{12}}$ Standard deviation from time 2 multiplied by the square root of 1 minus the test-retest coefficient.

$S_{diff} = \sqrt{SEM_1^2 + SEM_2^2}$) Square root of the sum of the squared SEMs for each testing occasion.

The reliable change methodology allows the clinician to reduce the adverse impact of measurement error on test interpretation. To represent clinically significant improvement, the change score must be statistically reliable. However, the converse is not true; a statistically reliable change does not necessarily guarantee a clinically meaningful change. For example, if an athlete demonstrated a major increase in symptoms measured 24 hours post injury, and then obtained a score that showed statistically reliable improvement a few days later, yet the symptom endorsement was still extremely high, this change might not be interpreted as clinically meaningful improvement. In other words, there was real change for the better, but the athlete was still far from recovered.

Using the earlier example of the concussed athletes, the test retest reliability was .80. The standard deviation for time 1 was 24.6 and the standard deviation for time 2 was 12.0. The SEM for time 1 was 11.0 and for time 2 is 5.4. Thus, the S_{diff} = 12.2, and the .80 confidence interval = 15.7.

The problem with applying the reliable change methodology to concussed athletes is that their experience of postconcussion symptoms is rapidly changing over a short time period. Thus, the phenomenon under study is not reasonably stable. In the example of the 82 concussed athletes, only 2.4% got worse over time by 10 or more points, whereas 45% got better by 10 or more points. Ten points represents the 90% confidence interval surrounding the time 1 test score in concussed athletes (see Table 18, last column).

Thus, because concussions typically result in a radical change in symptom reporting from baseline, followed by rapid improvement, the reliable change methodology has serious limitations in its practical application.

Clinical Interpretation of the Postconcussion Scale

Baseline Testing: If baseline testing is conducted, and an athlete endorses a high number of symptoms, he or she should be canvassed to identify factors relating to this symptom reporting. For example, an athlete might report a large number of symptoms due to depression or situational life stress. Retesting will likely be necessary following resolution of these factors, if transient, to get a better estimate of baseline functioning.

Postconcussion Testing: Immediately following concussion, athletes often report a large number of symptoms on a postconcussion inventory. There typically is rapid resolution of these symptoms over the next several days, and sometimes weeks. Knowing normal and abnormal symptom score ranges for athletes is helpful for interpreting the clinical significance of the symptom reporting patterns, irrespective of the reliability of the measures.

Step 1: Look up the classification range in Tables 19 – 26.

Step 2: Consider that the athlete's "true score" falls in the range of +/- 8 points surrounding the obtained score (last row of Table 18).

Step 3: Retest the athlete in a few days. If his/her score drops by 10 or more points, this is probably real improvement. If his/her score gets worse by 2 or more points, this should be taken seriously because athletes rarely get worse over time. In fact, of the 82 players tested twice, only 5% got worse by 5 or more points over the retest interval.

Step 4: Keep in mind that improvement doesn't mean recovery. Tables 19 – 26 can be used to determine when an athlete's score falls in the broadly normal range. In our view, athletes who continue to report symptoms outside the broadly normal range, under most circumstances, should continue to rest.

Appendix A.
Normative Tables
Quick Reference

Table A.1. Approximate Classification Ranges for Index Scores: Boys Ages 13 – 15 (N = 183)

	Verbal Memory	Visual Memory	Processing Speed	Reaction Time
Impaired	≤ 63	≤ 49	≤ 16.2	≥ .76
Borderline	64 – 73	50 – 60	16.3 – 24.2	.75 - .67
Low Average	74 – 79	61 – 68	24.3 – 30.1	.66 - .61
Average	80 – 92	69 – 86	30.2 – 37.8	.60 - .53
High Average	93 – 96	87 – 93	37.9 – 44.2	.52 - .49
Superior	97 – 99	94 – 97	44.3 – 50.2	.48 - .45
Very Superior	100	98 – 100	≥ 50.3	≤ .44

Table A.2. Approximate Classification Ranges for Index Scores: Boys Ages 16 – 18 (N = 158)

	Verbal Memory	Visual Memory	Processing Speed	Reaction Time
Impaired	≤ 68	≤ 51	≤ 26.4	≥ .74
Borderline	69 – 74	52 – 59	26.5 – 29.6	.73 - .64
Low Average	75 – 79	60 – 70	29.7 – 33.6	.63 - .59
Average	80 – 92	71 – 88	33.7 – 42.5	.58 - .50
High Average	93 – 98	89 – 93	42.6 – 47.7	.49 - .47
Superior	99	94 – 96	47.8 – 51.1	.46 - .43
Very Superior	100	97 – 100	≥ 51.2	≤ .42

Table A.3. Approximate Classification Ranges for Index Scores: Girls Ages 13 – 18 (N = 83)

	Verbal Memory	Visual Memory	Processing Speed	Reaction Time
Impaired	≤ 68	≤ 49	≤ 18.9	≥ .75
Borderline	69 – 77	50 – 59	19.0 – 28.9	.74 - .67
Low Average	78 – 83	60 – 69	29.0 – 32.7	.66 - .61
Average	84 – 93	70 – 88	32.8 – 42.3	.60 - .51
High Average	94 – 98	89 – 92	42.4 – 47.0	.50 - .49
Superior	99 – 100	93 – 98	47.1 – 51.1	.48 - .45
Very Superior	--	99 – 100	≥ 51.2	≤ .44

Table A.4. Approximate Classification Ranges for Index Scores – University Men (N = 410)

	Verbal Memory	Visual Memory	Processing Speed	Reaction Time
Impaired	≤ 71	≤ 51	≤ 23.8	≥ .75
Borderline	72 – 77	52 – 60	23.9 – 28.3	.74 - .67
Low Average	78 – 82	61 – 68	28.4 – 32.4	.66 - .61
Average	83 – 94	69 – 94	32.5 – 42.0	.60 - .52
High Average	95 – 97	95 – 97	42.1 – 46.0	.51 - .48
Superior	98 – 99	98 – 99	46.1 – 50.0	.47 - .45
Very Superior	100	100	≥ 50.1	≤ .44

Table A.5. Approximate Classification Ranges for Index Scores – University Women (N=97)

	Verbal Memory	Visual Memory	Processing Speed	Reaction Time
Impaired	≤ 70	≤ 48	≤ 23.3	≥ .70
Borderline	71 – 82	49 – 59	23.4 – 29.7	.69 - .64
Low Average	83 – 86	60 – 69	29.8 – 34.3	.63 - .60
Average	87 – 97	70 – 88	34.4 – 42.1	.59 - .52
High Average	98 – 100	89 – 93	42.2 – 46.3	.51 - .50
Superior	---	94 – 96	46.4 – 49.2	.49 - .48
Very Superior	---	97 – 100	≥ 49.3	≤ .47

Appendix B. Postconcussion Scale
Quick Reference Tables

Step 1: Look up the classification range.

Step 2: Consider that the athlete's "true score" falls in the range of +/- 8 points surrounding the obtained score (last row of Table 18).

Step 3: Retest the athlete in a few days. If his/her score drops by 10 or more points, this is probably real improvement. If his/her score gets worse by 2 or more points, this should be taken seriously because athletes rarely get worse over time. In fact, of the 82 players tested twice, only 5% got worse by 5 or more points over the retest interval.

Step 4: Keep in mind that improvement doesn't mean recovery. The tables can be used to determine when an athlete's score falls in the broadly normal range. In our view, athletes who continue to report symptoms outside the broadly normal range, under most circumstances, should continue to rest.

Table B.1. 588 regular education high school boys.

Classification	Raw Scores	Percentile Ranks for Players
Low – Normal	0	40.5
Normal	1 – 6	49 – 76
Unusual	7 – 13	79 – 90
High	14 – 21	91 – 95
Very High	22+	> 95

Table B.2. 119 regular education high school girls

Classification	Raw Scores	Percentile Ranks for Players
Low – Normal	0	29.4
Normal	1 – 8	40 – 75
Unusual	9 – 17	76 – 90
High	18 – 39	91 – 95
Very High	40+	> 95

Table B.3. 803 regular education university men

Classification	Raw Scores	Percentile Ranks for Players
Low – Normal	0	43.3
Normal	1 – 5	50 – 75
Unusual	6 – 12	78 – 90
High	13 – 20	91 – 95
Very High	21+	> 95

Table B.4. 236 regular education university women

Classification	Raw Scores	Percentile Ranks for Players
Low – Normal	0	26.7
Normal	1 – 10	32 – 75
Unusual	11 – 21	79 – 90
High	22 – 31	91 – 95
Very High	32+	> 95

Table B.5. 156 high school boys with a history of "special education[4]"

Classification	Raw Scores	Percentile Ranks for Players
Low – Normal	0	31
Normal	1 – 10	39 – 74
Unusual	11 – 26	76 – 90
High	27 – 38	92 – 95
Very High	239+	> 95

Table B.6. 31 high school girls with a history of "special education"

Classification	Raw Scores	Percentile Ranks for Players
Low – Normal	0	19
Normal	1 – 6	32 – 74
Unusual	8 – 14	81 – 90
High	15 – 19	93 – 97

Table B.7. 196 university men with a history of "special education"

Classification	Raw Scores	Percentile Ranks for Players
Low – Normal	0	28
Normal	1 – 12	34 – 74
Unusual	13 – 28	77 – 90
High	29 – 41	91 – 95
Very High	42+	> 95

Table B.8. 60 university women with a history of "special education"

Classification	Raw Scores	Percentile Ranks for Players
Low – Normal	0	17
Normal	1 – 13	22 – 73
Unusual	14 – 21	78 – 90
High	22 – 31	91 – 95
Very High	32+	> 95

[4] It is important to note that inclusion in the so-called "special education" groups does not mean that the person (a) had a formally diagnosed learning disability, or (b) attended special education classes or programs. All subjects who self-reported any past speech therapy, learning problems (e.g., reading or math), ADHD, or special education placement were included in these groups