

# Neuropsychological Performance Associated with Multiple Concussions in a Primarily Pediatric Sample

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## INTRODUCTION

- There continues to be debate regarding degree of neuropsychological impairment following multiple concussions with individual studies and meta-analyses reporting mixed findings.
- Some suggest mild cumulative neuropsychological impairment with increased concussions, but most published studies have not shown this.
- Few prior studies have reported accounting for confounding medical comorbidities, neurodevelopmental and psychiatric comorbidities, and/or performance validity testing (PVT) when attributing impairment to multiple concussions.
- The purpose of the present study was to compare neuropsychological scores from a brief multi-domain evaluation between individuals who sustained one or more concussions after accounting for confounding medical comorbidities and effort.
- Based on previous findings, we hypothesized there would be no significant differences in neuropsychological performance among concussion groups.

## PARTICIPANTS & METHODS

### Participants:

- Patients ages 8-21 years old (n = 404) were referred for outpatient neuropsychological assessment due to the cognitive impact of one or more concussions (i.e., mild uncomplicated traumatic brain injury) in a pediatric hospital setting from 2012-2018.
- Most patients were experiencing prolonged recovery (i.e., > 3 months).
- Exclusion criteria:
  - Confounding medical comorbidity (n = 24; e.g., epilepsy, extremely low birthweight)
  - Verbal IQ < 70 (n = 14)
  - Failure of two PVTs (n = 13)
  - Outliers (i.e., extreme duration since injury; n = 2)
- 351 patients remained and were grouped by 1 (n = 175), 2 (n = 90), or 3+ (n = 86) concussions.
  - Those in the 3+ concussion group had the following concussion frequencies: 3, n = 46; 4, n = 24; 5, n = 6; 6, n = 4; 7, n = 3; and 8, n = 3
- Patients with specific neurodevelopmental or psychiatric comorbidities were included due to high prevalence in this sample and base rates in the general population:
  - ADHD and learning disability (LD) were pre-injury diagnoses
  - Mood/anxiety or adjustment disorder diagnoses were a combination of pre- and post-injury diagnoses
  - 228 patients had no comorbidity, 123 had at least one comorbidity
- All patients passed a PVT (i.e., Medical Symptom Validity Test [MSVT] or Test of Memory Malingering [TOMM]):
  - Most patients passed the initial PVT (i.e., MSVT; n = 310)
  - Some initially failed the MSVT and then passed the TOMM (n = 41)

### Measures:

- 17 neuropsychological test scores across 7 cognitive domains were examined. See Table 1.

Table 1. Scores included in analyses.

Domain	Measures/Scores	Reference Name	
Verbal IQ	Wechsler Intelligence Scale for Children-4th edition (WISC-IV) Verbal Comprehension Index (VCI)	VIQ*	
	Wechsler Intelligence Scale for Children-5th edition (WISC-V) VCI, Wechsler Adult Intelligence Scale-3rd edition (WAIS-III) VCI, Wechsler Adult Intelligence Scale-4th edition (WAIS-IV) VCI, or Shipley-2 Verbal IQ (VIQ)		
	Delis- Kaplan Executive Function System (D-KEFS) Trail Making Test (TMT) Motor Speed (MS)		D-KEFS TMT MS
	Symbol Search (WISC-V/WISC-IV/WAIS-IV/WAIS-III) Digit Symbol Coding (WISC-V/WISC-IV/WAIS-IV/WAIS-III)		Symbol Search** Coding**
Processing Speed	Digit Span (WISC-V/WISC-IV/WAIS-IV/WAIS-III)	Digit Span**	
	D-KEFS Verbal Fluency (VF) Category Switching Accuracy (CSA)	D-KEFS VF CSA	
	D-KEFS TMT Letter-Number Switching (LNS)	D-KEFS TMT LNS	
	D-KEFS Color Word Interference Inhibition (CWI)	D-KEFS CWI	
Learning	Rey Auditory Verbal Learning Test (RAVLT) Total Learning (TL)	RAVLT TL	
	Brief Visuomotor Memory Test-Revised (BVMTR) TL	BVMTR-TL	
Memory	RAVLT Delayed Recall (DR)	RAVLT DR	
	Brief Visuomotor Memory Test-Revised (BVMTR) DR	BVMTR-DR	
Visuospatial	Visual Motor Integration Test-6th edition Visual Perception	VMI-VP	
Motor	Grooved Pegboard (GP) Dominant Hand (DH) & Non-Dominant Hand (NDH)	GP DH & GP NDH	
	Dynamometer DH & NDH	Grip DH & Grip NDH	

\* Only one of five VIQ scores was used per patient

\*\* Only one of four scores from Wechsler scales was used per patient

### Statistics:

- All standardized test scores were converted to z-scores.
- Multiple Analyses of Variance (MANOVAs) were used to compare neuropsychological performances:
  - between the three concussion groups
  - between those who had a comorbidity (i.e., ADHD, LD, adjustment, and mood/anxiety) and those without a comorbidity, regardless of number of concussions
  - between those who passed the MSVT and those who failed the MSVT but passed the TOMM, regardless of number of concussions
- Distributions of all variables were examined, and nonparametric tests were used accordingly. Descriptive data are presented as means and standard deviations for simplicity.

## RESULTS

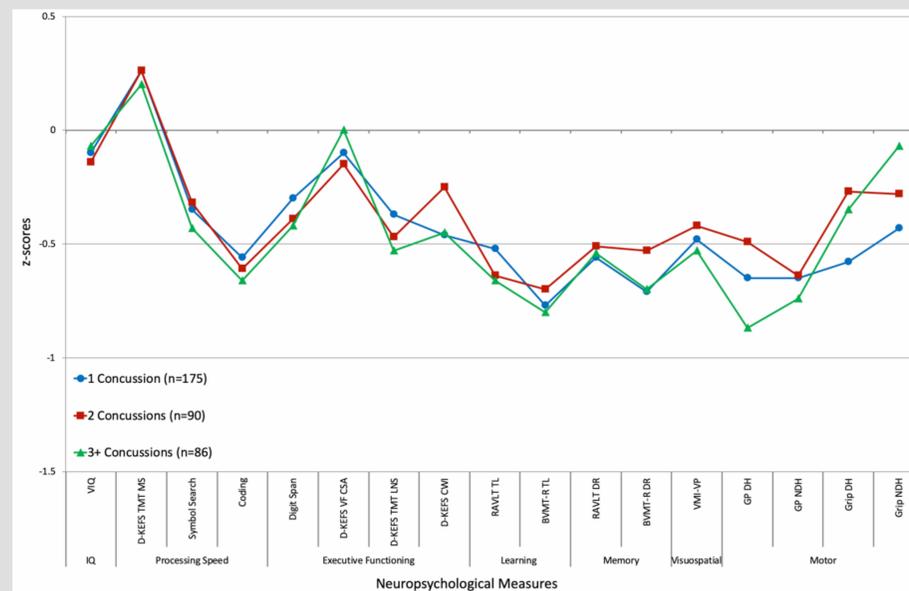
- The three concussion groups did not significantly differ with regard to race, duration of time since injury, number of patients with a comorbidity, or number of patients who failed the MSVT ( $p > 0.05$ ).
- The 3+ concussion group was significantly older (Cohen's  $d = 0.38$ ) and had fewer females (Cramer's  $V = 0.16$ ) than those in the 1 concussion group. See Table 2.

Table 2. Concussion groups' sociodemographics.

	Whole Sample (n=351)	1 Concussion (n=175)	2 Concussions (n = 90)	3+ Concussions (n=86)
Age (years)	15 ± 2.41	14.63 ± 2.55	15.15 ± 2.55	15.50 ± 2.00
Gender (% males)	59.80	52.57	63.33	70.93
Race (% Caucasian)	86.3	84.57	83.33	93.02
Duration Since Injury (Months)	5.84 ± 6.49	5.72 ± 6.10	6.27 ± 7.68	5.62 ± 5.94

- The three concussion groups did not significantly differ on any of the 17 neuropsychological scores ( $F(34, 560) = 0.77, p = 0.82; Wilks' \lambda = 0.91$ ). See Figure 1.

Figure 1. Neuropsychological performances in those with 1, 2, and 3+ concussions.



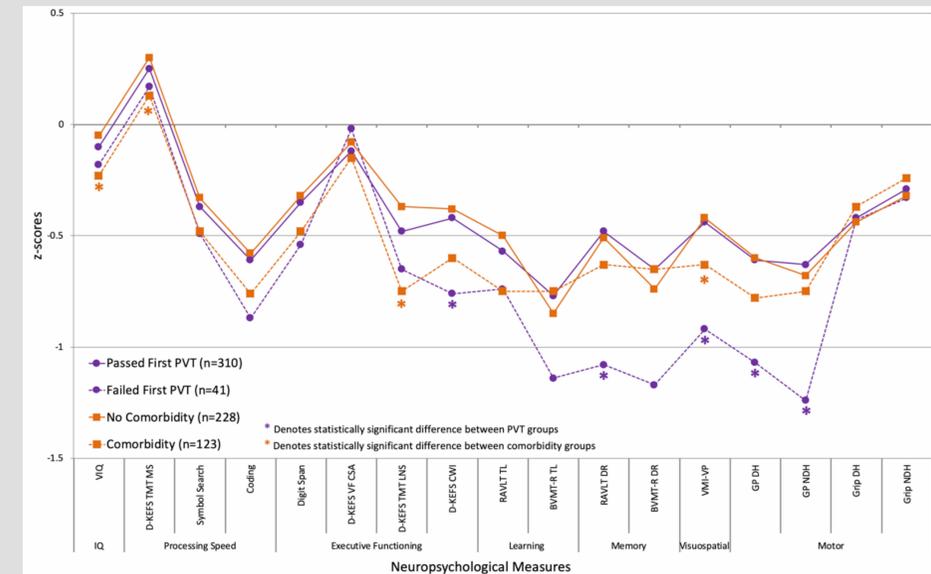
- Regardless of number of concussions:
  - The two PVT groups did not significantly differ with regard to age, sex, race, duration since injury, rate of comorbidities, or number of concussions ( $p > 0.05$ ).
  - The two comorbidity groups, likewise, did not significantly differ on the aforementioned variables or rate of PVT failure ( $p > 0.05$ ). See Table 3.

Table 3. PVT and comorbidity groups' sociodemographics.

	Passed PVT (n=310)	Failed PVT (n=41)	No Comorbidity (n = 228)	Comorbidity (n=123)
Age (years)	14.95 ± 2.44	15.38 ± 2.25	15.09 ± 2.42	14.84 ± 2.42
Gender (% males)	60.97	51.22	60.09	59.34
Race (% Caucasian)	86.77	82.92	85.96	93.02
Duration Since Injury (Months)	5.83 ± 6.53	5.92 ± 6.29	6.01 ± 7.22	5.52 ± 4.83

- Those who initially failed the MSVT performed significantly worse than those who passed the MSVT on measures of inhibition, verbal memory, visual perception, and bilateral fine motor coordination.
- Those with a comorbidity performed significantly worse than those without a comorbidity on measures of verbal IQ, motor speed, cognitive flexibility, and visual perception. See Figure 2.

Figure 2. Neuropsychological performances by the presence/absence of a comorbidity and passage/failure of the MSVT.



## CONCLUSIONS & IMPLICATIONS

- As hypothesized and consistent with many prior findings, results demonstrate no significant differences in neuropsychological performance among adolescents and young adults with 1-3+ concussions after accounting for comorbidities and effort.
- Lack of meaningful differences among concussion groups could indicate:
  - No cumulative cognitive effect of multiple concussions
  - No apparent cumulative cognitive effect of multiple concussions within several months of the most recent concussion
  - Lack of sensitivity of neuropsychological measures in identifying cognitive effects among those with multiple concussions
- Current results suggest that low scores on neuropsychological tests in adolescents and young adults are associated with the presence of certain comorbidities and/or effort rather than lifetime number of concussions.
- Findings do not rule out the possibility of cognitive impairment associated with multiple concussions emerging at a later point in time.
- Providers assessing post-concussion cognitive functioning should assess for effort and comorbidities and subsequently incorporate this knowledge into their interpretation of results.

## LIMITATIONS & FUTURE DIRECTIONS

- Different Wechsler scales were used to determine verbal IQ, processing speed, and digit span, which may have impacted findings.
- Due to sample size, combining those with three or more concussions into a single group may have obscured potential differences in those with the most concussions.
- Despite the large sample size, examining PVTs and comorbidities by number of concussions was not feasible.
- Most patients in this study reported prolonged recovery. Despite the lack of group differences in duration since most recent concussion, the timing at which neuropsychological assessment occurs after injury may contribute to varied findings in the literature.



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