



# Acute Sleep Changes Following Sport-related Concussion are Associated with Increased Intra-individual Variability on the ImPACT



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## Purpose

The purpose of this study was to examine how sport-related concussion (SRC) in college athletes contributes to increased cognitive performance variability (a marker of CNS functioning and efficiency) on the ImPACT, and whether changes in sleep influenced this variability. Specifically, this investigation aimed to determine:

- 1) Whether SRC contributes to increased (a) within-domain (WD) cognitive performance variability (a.k.a., inconsistency) and (b) across-domain (AD) performance variability (a.k.a., dispersion) relative to baseline.
- 2) Whether athletes who report sleep changes experience greater increases in WD and AD variability following SRC than athletes with no sleep changes post-concussion.

## Methods & Design

30 University of Florida football players from the UF Concussion Databank who sustained a concussion from 2008 to 2014 were analyzed. The retrospective analysis consisted of multiple steps:

- 1) Standard scores (SSs) were computed for the five ImPACT composite domains (Verbal Memory, Visual Memory, Visual Motor Speed, Reaction Time, Impulse Control) and for each of the six ImPACT subtests.
- 2) Athletes' indices of baseline/post-concussion variability (individual std. deviations) were derived
  - a) Within-domain (WD): Average SS deviation between subtest scores *within* each cognitive domain.
  - b) Across-domain (AD): Average SS deviation between composite scores *across* all domains
- 3) Using the Post-Concussion Scale (PCS), athletes were grouped based on presence (n = 16) or absence (n = 14) of reported changes in sleep (trouble sleeping, sleep more/less than usual) post-concussion.

## Analyses

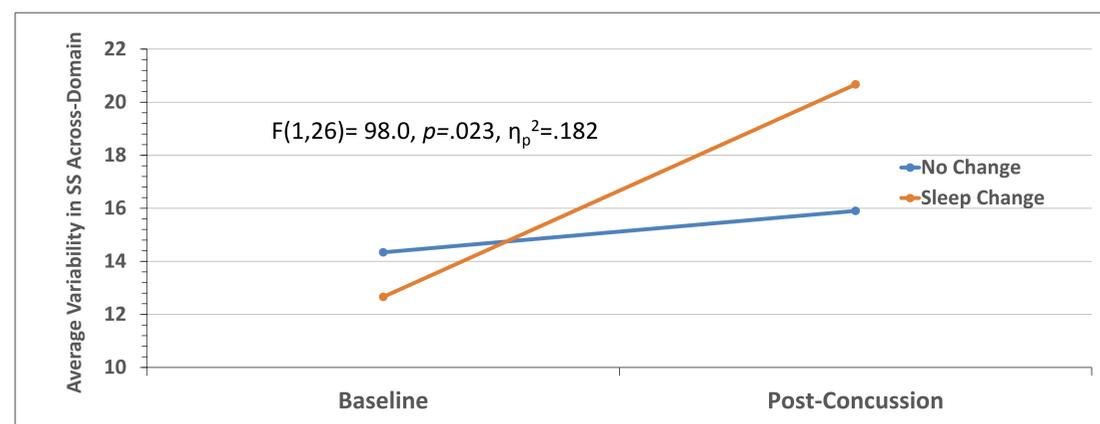
1. Using paired-samples *t*-tests, does WD and AD variability increase after SRC?
  - How many athletes experienced relative increases in variability after SRC?

**Table 1:** Results of paired-samples *t*-tests comparing differences in across-domain (AD) and within-domain (WD) variability in cognitive performance at baseline and post-concussion

Index/Measure	Baseline M (SD) <sup>a</sup>	Post-Concussion M (SD) <sup>a</sup>	N (%) Increase <sup>b</sup>	<i>t</i> <sup>c</sup>	<i>p</i>
<b>Within-Domain Variability</b>	--	--	--	--	--
Verbal Memory	10.5 (5.7)	17.3 (8.0)	19 (64%)	-3.39	<b>.002</b>
Visual Memory	10.9 (8.3)	10.7 (6.5)	18 (60%)	0.13	.898
Visual Motor Speed	9.3 (6.3)	19.3 (13.0)	21 (70%)	-3.61	<b>.001</b>
Reaction Time	10.6 (6.5)	14.1 (8.6)	17 (57%)	-1.84	.076
Impulse Control	9.6 (10.7)	8.6 (8.9)	15 (50%)	0.47	.642
<b>Across-Domain Variability</b>	13.4 (3.6)	18.5 (6.0)	22 (73%)	-4.43	<b>&lt;.001</b>

<sup>a</sup> M/SD scores represent values derived from athletes' average SS std. deviation across or within domains; <sup>b</sup> Number and percent of athletes who experienced increased variability post-concussion; <sup>c</sup> *df* = 29

2. Using repeated measures ANCOVAs, do post-concussive changes in WD or AD variability differ between athletes who report sleep changes after SRC and those that do not?
  - *Model covariates:* Days since injury (Range: 1-2), Reported magnitude of PCS changes in sleep (Range: 1-11)



**Figure 1:** Line graph depicting covariate-adjusted means for across-domain (AD) cognitive performance variability at baseline and post-concussion for athletes who reported changes in sleep following concussion (Sleep Change) and those reporting no changes (No Change)

## Results

- 1) SRC and changes in WD and AD variability:
  - a) Compared to performance at baseline, WD variability **increased significantly** post-concussion *only in the domains of Verbal Memory and Visual Motor Speed*
  - b) Following concussion, AD variability **increased significantly**.
    - Most athletes experienced increased variability post-SRC
- 2) Differences in post-concussive changes in WD and AD variability between sleep groups:
  - a) Following concussion, WD variability *did not differ* between athletes with/without reported changes in sleep
  - b) AD variability **was significantly greater** for athletes who experienced changes in sleep compared to those who did not.

## Conclusions

Indices of intra-individual cognitive performance variability may provide unique and clinically-meaningful information about acute changes that occur following sport-related concussion (SRC). We found evidence that across-domain variability in cognitive performance *increased* following SRC, while variability within-domains increased only for verbal memory and visual motor speed. Athletes who reported changes in sleep after concussion demonstrated greater across-domain variability than those whose sleep patterns remained stable. This suggests that performance instability (potentially suggestive of impaired CNS functioning) across domains measured by the ImPACT is influenced by factors attributable to abnormal sleep patterns after concussion. Further inquiry into the mechanisms behind this observation and how post-injury sleep influences neurocognitive recovery appears warranted.

## Limitations

This study was retrospective and limited by a small, homogenous sample of college football players with valid baseline assessments who completed post-concussion assessments within 2 days of injury (more athletes have been assessed but have data that do not fit these criteria). Sleep changes were operationalized based on participants' subjective report and not based on widely-used, standardized measures to quantify sleep.



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