

# Procedural Shortcomings With Near Point of Convergence Assessment May Lead to Inappropriate Prognosis of Concussion Injury in Athletes: Letter to the Editor

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## Dear Editor:

We read with great interest the recent article published in *AJSM* by Duprey et al titled “Convergence Insufficiency Identifies Athletes at Risk of Prolonged Recovery From Sport-Related Concussion.”<sup>6</sup> We commend the authors for contributing such a large retrospective review to the enlightening body of knowledge concerning the efficacy of convergence insufficiency as a clinical prognostic tool. However, there are certain ineludible shortcomings within the current study’s methodology and criteria that we believe could greatly misguide the scientific community. The concerns of note include (1) convergence insufficiency measurement procedures that are inconsistent with the literature, (2) incomplete criteria determining “full recovery,” and (3) inability to acknowledge and account for key confounding variables that affect recovery prognosis.

The current study encompassed 270 athletes (147 male, 123 female; mean age, 14.7 years [range, 10-21 years]), who were diagnosed with a sport-related concussion by 1 of 2 sports medicine-trained physicians working in the same clinic. The definition of concussion was standardized for diagnosis by utilizing the consensus statement produced by the Fourth International Conference on Concussion in Sport.<sup>16</sup> The authors defined convergence insufficiency as a near point of convergence (NPC) score >6 cm, as measured by the physician moving one’s finger toward the patient’s nose at a rate of 3 to 5 cm/s. Measurement was taken from the bridge of the patient’s nose to the tip of the physician’s finger when the patient announced diplopia or blurred vision. Following the initial diagnosis, the subject’s recovery time was then tracked, and full recovery was reported once the subject was symptom free (according to SCAT3 symptom checklist), exhibited normal physical examination results, was completing full school days, and had a return of baseline neurocognitive test scores. The statistically significant results ( $P < .001$ ) of the current study shaped the authors’ conclusion that athletes who experience convergence insufficiency immediately after injury are at increased risk of prolonged recovery after sport-related concussion.<sup>6</sup>

The authors note that they remained consistent with previous literature in their classification of convergence insufficiency, yet they elected to record the NPC measurement using a method that is grossly inconsistent with the literature.<sup>10,12,13,19,20,23</sup> For example, the researchers chose to move the convergence target at a rate of 3 to 5 cm/s toward the patient’s nose; however, multiple studies uniformly selected a rate of 1 to 2 cm/s,<sup>1,12,13,22</sup> including the study to which the authors claimed to have remained consistent.<sup>8</sup> This attenuated speed was shown to possess a higher efficacy in detecting receded NPC values among subjects of varying ages (6-30 years,  $P < .001$ ),<sup>1</sup> which ultimately assists in clinical diagnoses as fewer false negatives will occur. Furthermore, statistical analysis of the interrater reliability of NPC measurements between physicians produced a kappa statistic of .32 ( $P < .001$ ), showing fair agreement. This meager kappa value could directly be a result of tester error when a standard accommodative ruler is not utilized. The authors defend their decision to use a fingertip as the convergence insufficiency target by stating that the literature has not shown one target type to be more effective than another. This is incorrect, as the use of an accommodative ruler was shown to be more effective at detecting receded NPC values than other methods, such as a pencil or fingertip ( $P < .001$ ).<sup>1</sup> Finally, the authors inadvertently acknowledge this demerit when they state that the current study provides a cost-effective method for assessing recovery time, while they failed to implement such cost-effective tools themselves.

The reviewed study included the authors’ decision to employ a plethora of preexisting conditions as exclusion criteria yet not consider other significant confounding variables, such as physical activity and daily cognitive load, as prime limitations to the study. The neurometabolic cascade that accompanies mild traumatic brain injury has been well studied and delineates not only ischemic and hypoglycemic conditions but also a deformation in axonal cytoskeletal components, such as microtubules. These sequelae are chief mechanisms afflicting the insulted neuro-ophthalmologic circuitry and are the avenues by which premature physical activity and cognitive strain delay the authors’ primary outcome measure: recovery time. For example, premature physical activity immediately following mild traumatic brain injury results in a sharp increase in glycolytic demand of working tissues (eg, cortical, muscular). This, coupled with cerebral hypoperfusion, further taxes the dearth of cortical glycose, ultimately leading to neuronal apoptosis if unchecked. Furthermore, symptomology such as blurred vision and dizziness derive from the axon’s inability to effectively conduct and propagate action potentials. These outcomes are the result of subaxolemmal and axonal cytoskeletal deformation via proteolysis and mechanoperforation. Ultimately, the dysfunction of the involved  $\text{Na}^{2+}$ ,  $\text{Ca}^{++}$ , and  $\text{Na}^{2+}/\text{Ca}^{++}$  exchanger channels, with microtubule deformation, cause pathologically high membrane voltage values as well as neuronal spheroids that significantly impede the propagated message and can result in prolonged clinical signs and symptoms if antagonized prematurely. These physiologies have been acknowledged, and robust recommendations of acute rest (24-48

TABLE 1  
Previous Reports on the Utility of Near Point of Convergence on Mild Traumatic Brain Injury<sup>a</sup>

Author	Subjects <sup>b</sup>	Study Design	Key Finding
Mucha et al (2014) <sup>18</sup>	64 athletes; 13.9 ± 2.5 y	Cross-sectional	NPC distance was significantly greater in the concussed group vs the control group ( $P < .001$ ). Mean difference between groups was 4.0 cm (95% CI, 1.9-6.1 cm)
Anzalone et al (2017) <sup>2</sup>	167 subjects; 11-19 y	Retrospective chart review	Convergence insufficiency failed to predict delayed recovery (univariate hazard ratio, 95% CI, $P = .107$ )
Capó-Aponte et al (2017) <sup>3</sup>	500 US military personnel	Retrospective chart review	NPC was receded among patients with mTBI (8.35 cm) relative to normative values ( $P = .302$ )
Capó-Aponte et al (2012) <sup>4</sup>	40 US military personnel (20 with mTBI)	Cross-sectional	Mean NPC oculomotor function was significantly different between mTBI group and controls ( $P = .0003$ )
Cheever et al (2018) <sup>5</sup>	89 athletes (31 with mTBI); 17.8-25.2 y	Prospective repeated measures	NPC was significantly receded among athletes during initial visit for acute (DOI ≤10 d prior) and postacute (DOI ≥16 d prior) mTBI ( $P < .05$ ) and remained receded in the postacute group during a 2-wk follow-up ( $P < .05$ )
Ellis et al (2017) <sup>8</sup>	399 athletes; 13.9 y (males), 15.4 y (females)	Retrospective review	Vestibulo-ocular dysfunction (including NPC) was significantly related to development of postconcussion syndrome ( $P < .0001$ )
Ellis et al (2015) <sup>7</sup>	101 athletes; 14.2 ± 2.3 y	Retrospective review	Vestibulo-ocular dysfunction was prevalent among 28.6% and 62.5% of adolescents following sport-related concussion and postconcussion syndrome, respectively
Gallaway et al (2017) <sup>9</sup>	218 patients with mTBI; 6-72 y	Retrospective chart review	Convergence insufficiency was the most prevalent (47%) oculomotor deficit
Howell et al (2018) <sup>11</sup>	64 adolescent athletes (33 with mTBI)	Cross-sectional	Patients with receded NPC (55%) had significantly slower gait speed and shorter stride length
Master et al (2018) <sup>15</sup>	432 patients with mTBI; 5-18 y	Retrospective cohort	NPC was receded among 35% of patients
Pearce et al (2015) <sup>19</sup>	78 athletes; 14.31 ± 2.77 y	Cross-sectional	Patients with receded NPC (42%) exhibited significantly worse neurocognitive impairment and reported higher symptom scores versus those with normal NPC
Storey et al (2017) <sup>23</sup>	275 patients; 5-18 y	Retrospective cohort	Abnormal NPC at initial visit was not correlated to the duration ( $P = .69$ , Spearman rho) or use of intervention ( $P \geq .999$ , Wilcoxon rank sum) leading to recovery
Yorke et al (2017) <sup>24</sup>	105 adolescents; 15.4 y	Cross-sectional descriptive	NPC demonstrated an intraclass correlation of .95 (95% CI, 0.89-0.98; $P < .001$ )
Kawata et al (2016) <sup>12</sup>	29 NCAA Division I healthy football athletes	Prospective observational	Subconcussive head impacts resulted in a significant difference in NPC values between high- vs low-impact players across multiple time points (range, $P < .01$ to $P < .001$ )
Kawata et al (2016) <sup>13</sup>	20 healthy young adults; 18.9 y (controls), 20.7 y (heading)	Repeated measures	Ten consecutive soccer headings significantly receded NPC values from baseline ( $P < .01$ ) and were significantly different from kicking/control subjects (range, $P < .01$ to $P < .001$ ) at both time points postintervention
McDevitt et al (2016) <sup>17</sup>	72 active college student athletes (12 with mTBI); 21.5 ± 3.4 y	Cross-sectional	NPC values were significantly correlated to participant health status (concussed vs nonconcussed) ( $r = 0.337$ , $P = .004$ )
Adler et al (2007) <sup>1</sup>	51 healthy patients; 6-30 y	Cross-sectional	Use of an accommodative ruler was more effective at detecting receded NPC values versus other methods (eg, pencil tip, fingertip) ( $P < .001$ )

<sup>a</sup>CISS, convergence insufficiency symptom survey; DOI, date of injury; mTBI, mild traumatic brain injury; NCAA, National Collegiate Athletic Association; NPC, near point of convergence.

<sup>b</sup>Age presented as mean ± SD or range.

hours) have been cited.<sup>14,16,21</sup> Given this, there is burgeoning evidence suggesting that physical and cognitive load can affect recovery time, potentially in a deleterious manner if conducted too soon, and therefore undermines the robust qualities of the study's findings. Last, the authors' definition of recovery is one that excludes completion of a return to play (RTP) protocol, which all athletes must complete before achieving full recovery status. This RTP protocol is a stepwise increase in physical load and is designed to verify that autonomic and physiologic responses to exercise have been reestablished without symptom provocation. The RTP protocol is an integral part of safely and confidently establishing full recovery of

athletes and has therefore become legislation throughout the United States. These facts then beg the question why the authors did not include such a protocol in their criteria of recovery. Failing to establish a thorough recovery status should be regarded as another chief mitigation in the study's data and, subsequently, their findings.

We congratulate the authors again for contributing such a large study that praises the use of NPC and convergence insufficiency as a quantitative tool to help elucidate the effects of neurotrauma, as this corroborates the findings of several other studies (Table 1). However, as the need grows for quantitative methods to accurately assess concussion, we believe that the aforementioned clarifications should

be considered to limit misguided trust of the present findings and the efficacy of such methods.

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## Procedural Shortcomings With Near Point of Convergence Assessment May Lead to Inappropriate Prognosis of Concussion Injury in Athletes: Response

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### Authors' Response:

We thank the authors of the recent letter to the editor for taking the time to analyze and provide feedback for our article "Convergence Insufficiency Identifies Athletes at Risk of Prolonged Recovery From Sport-Related Concussion." We strongly disagree with their opinion that the study's methodology and criteria could greatly misguide the scientific community. We believe that their concerns are based on an idiosyncratic perspective in a field where variability exists.

The authors of the letter to the editor describe our methods for measuring near point of convergence (NPC) as "inconsistent with the literature"; however, it is indisputable that there is no consistent method in the literature for measuring NPC. Cooper and Jamal<sup>3</sup> confirmed this in "Convergence Insufficiency—A Major Review," in which the authors clearly state,

Although NPC is an easy clinical test to administer, there has not been consensus on how the test should be performed, with methodology varying from study to study. Variables include the type (eg, penlight, ruler, accommodative target) and size of the fixation target, the point from which the NPC is measured (eg, spectacle plane, bridge of nose, corneal plane,

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