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Computerized Dynamic Posturography Testing in Concussion: A Systematic Review

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Introduction

Computerized dynamic posturography (CDP) is frequently utilized in research and clinical practice for the assessment of sensory deficits following concussion in military and athletic populations. The Sensory Organization Test (SOT) assesses an individual's ability to integrate visual, proprioceptive, and vestibular inputs in order to maintain upright postural stability under six testing conditions. Each unique circumstance aims to determine how well a person is able to respond to conflicting sensory information or the removal of one or more sensory systems.¹ The system calculates a composite score along with visual, vestibular, and somatosensory ratios, which inform clinicians of the extent of the individual's balance impairment and assist with return to sport or return to duty decisions.² To our knowledge, there are no systematic reviews that synthesize the psychometric properties of CDP for individuals who have sustained a concussion.

Purpose

The purpose of this study was to conduct a systematic review of the psychometric properties of CDP for the assessment of individuals following concussion.

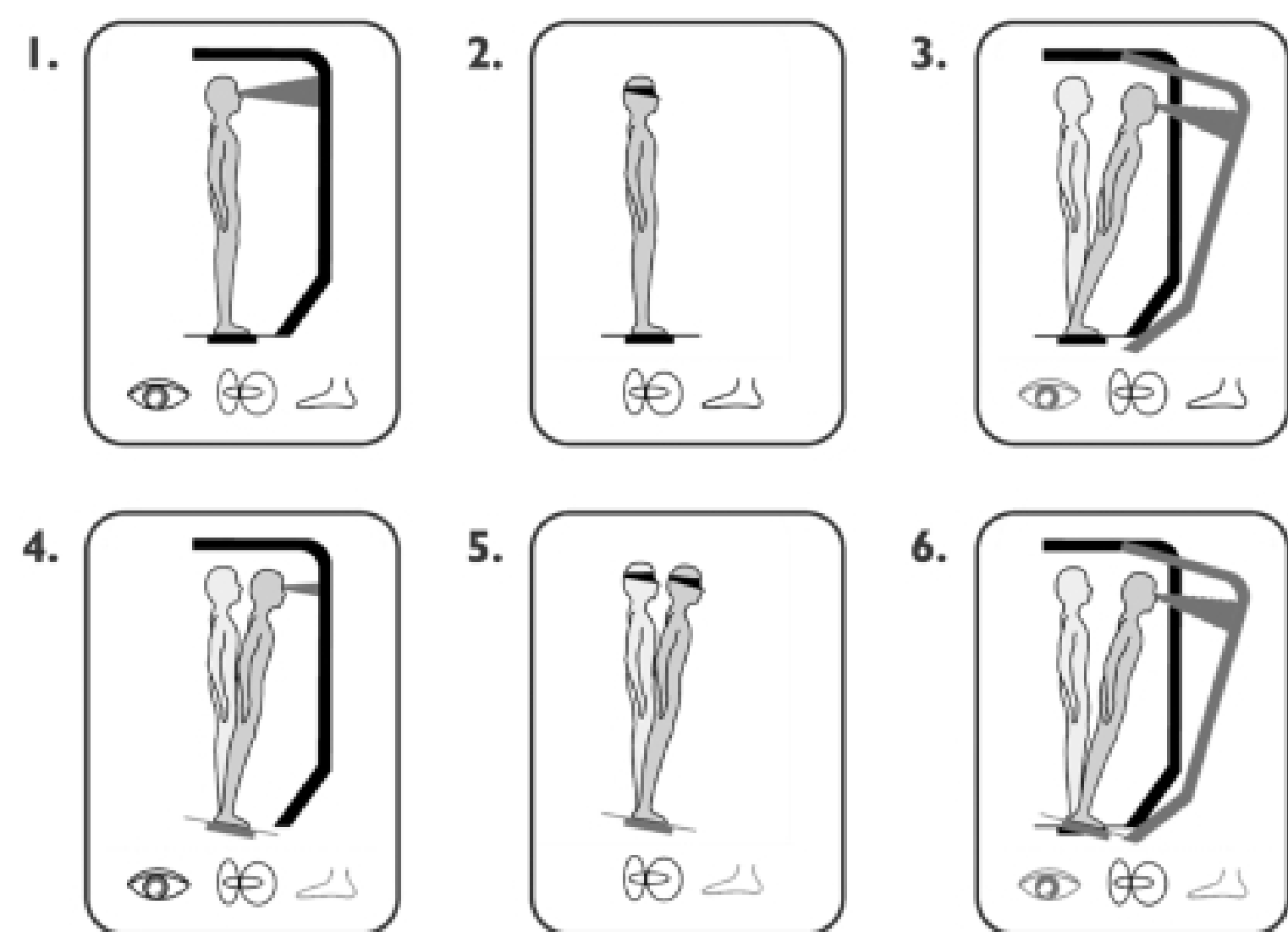


Figure 1. Sensory Organization Test Conditions
Condition 1: Normal vision, fixed support. Condition 2: Absent vision, fixed support. Condition 3: Sway-referenced vision, fixed support. Condition 4: Normal vision, sway-referenced support. Condition 5: Absent vision, sway-referenced support. Condition 6: sway-referenced vision, sway-referenced support. Image courtesy of Natus Medical Incorporated.

Methods

PubMed, EBSCOhost, ProQuest, SportDiscus, and CINAHL were searched for relevant peer-reviewed literature published between 1980 and September 2018 using the following terms: concussion, posturography, balance, stability, diagnosis, assessment, Sensory Organization Test, Head Shake Sensory Organization Test, motor control test, Biodex, and NeuroCom. Articles were included if they reported psychometric properties of CDP following concussion. Studies without full text available or not specifying severity of traumatic brain injury (TBI) were excluded. The titles and abstracts of all potentially relevant articles were screened, followed by full text examination by two researchers. In the event of a discrepancy, consensus was reached by tie breaker with a third researcher.

References

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Results

The initial search produced 2,295 results. Eight articles (765 participants) met the inclusion criteria. Five articles reported sensitivity of CDP in concussed populations and two articles reported specificity and likelihood ratios of CDP. Only one study reported the minimal detectable change (MDC) of CDP in concussed populations, and one study examined the practice effects of the measure. Two studies that included the SOT in a battery of tests concluded that CDP, as well as all concussion assessment tools tested, were more effective within a battery than as a standalone assessment. Psychometric properties and relevant key findings are shown in Tables 1 and 2.

Table 1. Psychometric Properties of CDP

Author, Year	Sensitivity	Specificity	Likelihood Ratios	Validity	Measures of Responsiveness (MDC, MCID, learning effect)
Resch et al., 2016 ³	SOT Composite: 0.725 Battery: 0.80	SOT Composite: 0.85 Battery: 0.975	SOT Composite: + LR: 4.83 - LR: 0.32 Battery: + LR: 0.86 - LR: 2.25	SOT composite score distinguished between concussed and healthy athletes within 24 hours of concussion diagnosis.	NT
Haran et al., 2016 ²	SOT Composite: 0.50-0.58	NT	NT	NT	NT
Register-Mihalik et al., 2013 ⁴	SOT Composite: 95% CI: 0.128 90% CI: 0.152 80% CI: 0.200 Total Battery: 95% CI: 0.280 90% CI: 0.349 80% CI: 0.500	SOT Composite: 95% CI: 0.949 90% CI: 0.949 80% CI: 0.923 Total Battery: 95% CI: 0.940 90% CI: 0.958 80% CI: 0.967	NT	NT	NT
Broglio et al., 2008 ¹	SOT Composite: 0.57	SOT Composite: 0.80	NT	NT	NT
Broglio et al., 2007 ⁵	61.9% sensitivity given an abnormality in any one of the four SOT measures. Composite: 36.5% Vestibular: 23.8% Somatosensory: 36.5% Visual: 31.7%	NT	NT	NT	MCID: 3.71 below baseline composite 2.35 below baseline somatosensory 3.47 below baseline visual 6.95 below baseline vestibular
Peterson et al., 2003 ⁶	NT	NT	NT	NT	Learning effect: less than 10% when conditions are randomized.
Kisilevski et al., 2001 ⁷	NT	NT	NT	Correlation between results of posturography and symptomology: 69% of participants who complained of vertigo demonstrated abnormal performance on CDP.	NT

NT = Not tested

Table 2. Article Characteristics

Author, Year	Study Design	Number of Participants	Study Population	Timeline
Resch et al., 2016 ³	Cross-Sectional	40 post-concussion (29 male, 11 female), 40 control (29 male, 11 female)	NCAA Division I Athletes	All participants with baseline CDP, patients sustaining concussion evaluated within 24 hours following injury
Haran et al., 2016 ²	Retrospective, Cross-Sectional	173 acute concussion, 30 subacute concussion	Service members suffering blast-related mTBI's while deployed	Acute group assessed within 7 days of injury, subacute group assessed within 89 days of injury
Register-Mihalik et al., 2013 ⁴	Retrospective Cohort	132 post-concussion (86 male, 46 female), 38 control (all male)	College-aged student-athletes	All participants with baseline CDP, participants sustaining concussion evaluated <5 days post-injury
Broglio et al., 2008 ¹	Retrospective Cohort	63 post-concussion (50 men, 13 women), 66 control (39 men, 27 women)	Athletes	All participants with baseline CDP, individuals sustaining concussion evaluated within 24 hours following injury
Broglio et al., 2007 ⁵	Cohort	63 participants	NCAA Division I Athletes	All participants evaluated at baseline, and within 24 hours of sustaining a concussion
Parsons et al., 2007 ⁸	Cohort	40 post-concussion (24 male, 16 females)	Division I collegiate athletes	All participants with baseline CDP, individuals sustaining concussion evaluated within 24 hours following injury
Peterson et al., 2003 ⁶	Prospective Cohort	24 post-concussion, 18 control	NCAA Division I Athletes	All participants with baseline CDP; patients sustaining concussion with day 1, day 2, day 3, and day 10 evaluations
Kisilevski et al., 2001 ⁷	Cohort	38 participants (26 male, 12 female)	Individuals hospitalized following head trauma	All participants completed examinations at 72 hours and 3 months following injury

Discussion

Validity

Results suggest a correlation between SOT performance and symptomology. In one study,⁷ 81% of the participants complained of vertigo, and 69% of these participants performed abnormally on CDP. The SOT was less sensitive than the ImPACT and HeadMinder concussion assessment tools. However, the ImPACT and HeadMinder both measure neurocognitive function, while the SOT quantitatively measures postural stability in stance.⁵

Sensitivity

The sensitivity of the SOT composite score for sports-related concussions ranged from 57% to 72.5% within 24 hours post-concussion.^{1,2,3,5} Register-Mihalik et al.⁴ reported a sensitivity of 20% up to five days after the initial injury. The sensitivity of the SOT for blast-related concussion was lower than sport-related concussion, which suggests that the effectiveness of the SOT as an assessment of postural stability following concussion may depend on the mechanism of injury.

Specificity

Specificity of the SOT ranged from 82% to 92.3%.^{1,3,4} Multiple articles included the SOT in an assessment battery with other tools including neuropsychological tests and self-reported symptoms. The sensitivity and specificity of the assessment battery as a whole was higher than those of the individual tests.^{2,4,5}

Although CDP may be useful for measuring sensory deficits following concussion, further research should examine the reliability, ceiling and floor effects, likelihood ratios, MCID, and MDC of CDP in concussed individuals.

Conclusion

TBI prevalence is as high as 20% among military personnel, with the majority being concussions.² Additionally, 5% of injuries in high school and collegiate athletes are concussions (1.6 to 3.8 million in the United States annually).⁵ There is no gold standard for concussion diagnosis, and return to sport/duty decisions are often difficult and subjective. This review synthesizes current evidence and identifies a need for further investigation to develop a more comprehensive understanding of the psychometric properties of CDP assessment following concussion.



Figure 2. CDP Testing Apparatus
Equipment utilized for the Sensory Organization Test.

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