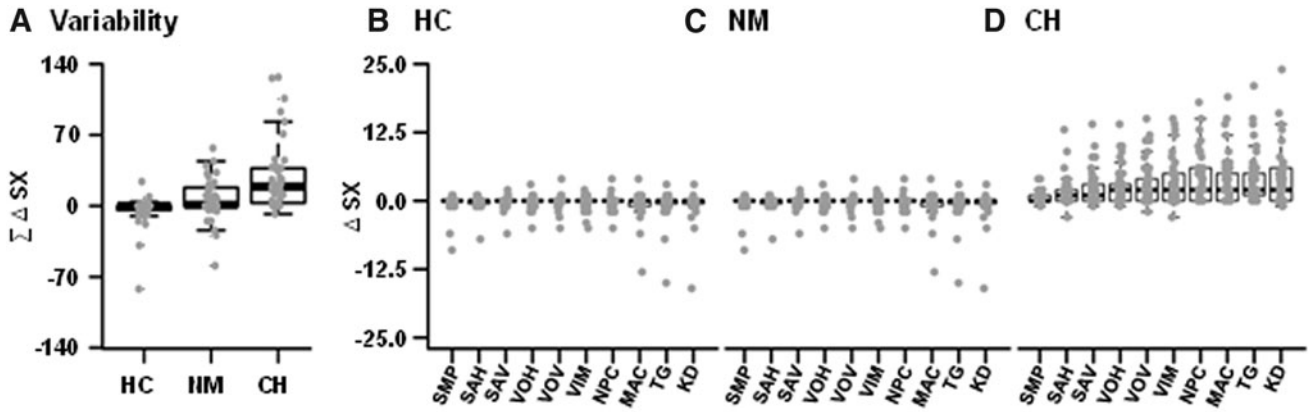
Supplementary Text

Methods

Selected tests were derived from a number of different sources or newly devised as part of the examination. All participants were required to rate the degree to which they experienced four symptoms (headache, dizziness, nausea, and fogginess)[1] on an 11 point Likert scale prior to the start of the neurosensory examination and immediately following each task listed subsequently, unless otherwise specified. An 11 point Likert scale was used for symptom ratings and included two visual anchors, with 0 corresponding to ''no symptoms at all'' and 10 corresponding to ''worst imaginable symptoms.''

1. A measure of symptom validity is highly recommended in the pediatric mild traumatic brain injury (pmTBI) literature,[2] but does not exist for any current standardized neurosensory tests. We therefore developed a test that was nonspecific to the vestibulo-ocular, ocular motor, or vestibulospinal system, and was not expected to result in symptom provocation. Specifically, the task required the vigorous dorsiflexion of both feet for ~20 sec (referred to as the double dorsiflexion foot stretch [DDFS]). To avoid any bias, the DDFS was always administered first, prior to any other neurosensory examination.
2. The Vestibular/Ocular Motor Screening (VOMS) represents the most well-developed, standardized screening tool for vestibulo-ocular and ocular motor functioning following concussion.[1] As a result, several measures (i.e., smooth pursuits, horizontal and vertical saccades, horizontal and vertical vestibulo-ocular reflex, visual motion sensitivity) were directly derived from this instrument. Per recommendations,[1] a metronome was used to guide the tempo of movements for selected tests. The following sections briefly document the key parameters utilized for each of the individual tests and were derived directly from the VOMS manual.
   a. Smooth pursuit: Examiner holds up index finger ~3 feet from participant's nose (midline) 1.5 feet off to examiner's left. Examiner's finger moves at a 2 sec interval to 1.5 feet off to the examiner's right, and back to 1.5 feet to the examiner's left. Two horizontal repetitions are completed. A similar procedure is then repeated along a vertical line, with the examiner's finger starting 1.5 feet above midline to 1.5 feet below midline at a 2 sec interval for two repetitions.
   b. Horizontal saccades: 10 quick repetitions at a self-paced frequency. Examiner holds two index fingers ~3 feet from the participant's nose (midline) and 1.5 feet to the examiner's right and left. One repetition = eyes returning to starting point.
   c. Vertical saccades: 10 quick repetitions at a self-paced frequency. Examiner holds two index fingers ~3 feet from the participant's nose and 1.5 feet above and below midline. One repetition = eyes returning to starting point.
   d. Horizontal vestibular-ocular reflex: 10 repetitions with ~20 degrees of deflection. Right to left midline excursion (shaking head ''no'') paced by a 5 Hz pure tone with a specified timing of 180 beats per min. Symptom report taken 10 sec after the test is complete.
   e. Vertical vestibular-ocular reflex: 10 repetitions with ~20 degrees of deflection. Up to down midline excursion (nodding ''yes'') paced by a 5 Hz pure tone with specified timing of 180 beats per min. Symptom report taken 10 sec after the test is complete.
   f. Visual motion sensitivity test: five repetitions with ~80 degrees of deflection. Right to left midline excursion paced by a 5 Hz pure tone with specified timing of 50 beats per min. Symptom report taken 10 sec after the test is complete.
3. The VOMS measurement of near point of convergence was replaced with a standardized procedure that uses the Astron accommodative rule (Gulden Ophthalmics, Elkins Park, PA) with a standard single 20/30 card as the visual target[3,4] placed against the participant's glabella. Distance to convergence (measured to the nearest half cm and averaged across three trials) was recorded when either the participant reported image doubling on the 20/30 card or when the clinician noticed binocular loss of convergence. If no break was observed or reported, the participant was assigned a value of 2.0 cm. The slide rule was started at 20 cm and was moved from there toward the participant at a speed of 1–2 cm per sec. If the participant could not see the letters as a single target on the slider rule card at 20 cm, the examiner started the card at 30 cm instead. Symptom report was taken immediately after the third trial.
4. Monocular accommodation was also measured to the nearest half cm using the same rule and standard card as near-point convergence placed above the participant's brow centered along the pupil, and was acquired over a single trial for each eye. Participants were instructed to hold an occluder over the eye not being measured. If the participant could not see the letters on the slider rule card at 20 cm, the examiner moved the card back to 30 cm. Accommodation testing was discontinued when the participant reported blurring of the image. The slide rule was moved at a distance of 1–2 cm per sec. Symptom report was taken after completion of testing of the second eye.
5. A tandem gait test was utilized to measure balance, with participants taking 10 paces (steps) forwards and backwards with their eyes open or closed (5 steps each) on a 15 foot taped line. An error was categorized by any loss of balance that resulted in a side step off the tape, and error scores were recorded for each of the four portions of the examination and summed to create a total error measure.
6. The King–Devick test quantifies saccadic eye movements using rapid number naming of a fixed target.[5,6] The test was collected using electronic data capture (Apple iPad2 with iOS 5) placed on its stand ~16 inches from participants at the University of New Mexico Hospital Emergency Department (UNMH) and collected with paper and pencil at the The Children's Hospital of Philadelphia Minds Matter Concussion



SUPPLEMENTARY FIG. S1. Scatter box depicting symptom variability across all tests (sum of the change in symptoms across all tests = $\sum \Delta$ SX; **A**) and following each of the individual tests (change in symptoms following each of individual test = Δ SX; **B–D**) for each group (HC, healthy control; NM, University of New Mexico Hospital Emergency Department patients; CH, The Children's Hospital of Philadelphia Minds Matter Concussion Program patients). Labels for individual tests include: SMP, smooth pursuits; SAH, horizontal saccades; SAV, vertical saccades; VOH, horizontal vestibular-ocular reflex; VOV, vertical vestibular-ocular reflex; VIM, visual motion sensitivity; NPC, near point of convergence; MAC, monocular accommodative amplitude; TG, tandem gait; KD, King–Devick test.

Program (CHOP) site. Performance-based metrics from the King–Devick test included total number of errors and total time to complete the test.

Secondary analyses

Results from secondary analysis examining total post-concussion syndrome (PCS) symptom variation were similar to principal analyses focused on symptom provocation. Specifically, there was a main effect of group ($F_{2,118} = 27.64$, $p < 0.001$; (Fig. S1A). Simple effects tests indicated that the CHOP pmTBI group demonstrated the largest symptom variation relative to both the UNMH pmTBI ($t_{75} = 3.73$, $p < 0.001$) and healthy control (HC) groups ($t_{73.6} = 8.54$, $p < 0.001$), with UNMH patients also exhibiting significantly greater symptom variation than HC ($t_{63.8} = 3.24$, $p = 0.002$). The degree of total PCS symptom variation on each individual test across the three groups is provided in Figure S1.

Principal analyses were repeated examining the effects of point of care on pre-examination symptomatology and total symptom provocation while excluding pmTBI patients with any comorbidities (i.e., attention-deficit/hyperactivity disorder [ADHD] or learning disorder) from both samples. Results from the reduced sample that excluded patients with comorbid disorders from both points of care were statistically similar to principal analyses, suggesting that the presence of comorbid disorders did not explain point of care differences observed in the principal analyses. In addition, excluding patients with comorbidities did make classification in the binary logistic regressions more sensitive with the addition of symptom provocation to the model for patients in both cohorts.

Finally, we investigated whether symptom provocation would classify patients across both sites who were recovered or not at the time of their examination, using the normative cutoff derived from HC (five symptoms or fewer). Using this pre-examination symptom cutoff, 40.0% of UNMH patients and 43.9% of CHOP patients were classified as symptomatic at the time of their visit. Results from a binary logistical regression indicated that symptom provocation significantly (Wald = 15.34; $p < 0.0001$) classified recovered (89.4%) from non-recovered (64.7%) patients with a moderate degree of overall accuracy (79.0%).

References

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