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Influence of poor effort on self-reported symptoms and neurocognitive test performance following mild traumatic brain injury

Rael T. Lange,[1,2] Grant L. Iverson,[2,1] Brian L. Brooks,[3,4] and V. Lynn Ashton Rennison[5,6]

[1]British Columbia Mental Health & Addiction Services, Vancouver, British Columbia, Canada
[2]University of British Columbia, Vancouver, British Columbia, Canada
[3]Alberta Children's Hospital, Calgary, Alberta, Canada
[4]University of Calgary, Alberta, Canada
[5]Fraser Health Concussion Clinic, Coquitlam, British Columbia, Canada
[6]Royal Columbian Hospital, New Westminster, British Columbia, Canada

When considering a diagnosis of postconcussion syndrome, clinicians must systematically evaluate and eliminate the possible contribution of many differential diagnoses, comorbidities, and factors that may cause or maintain self-reported symptoms long after mild traumatic brain injury (MTBI). One potentially significant contributing factor is symptom exaggeration. The purpose of the study is to examine the influence of poor effort on self-reported symptoms (postconcussion symptoms and cognitive complaints) and neurocognitive test performance following MTBI. The MTBI sample consisted of 63 referrals to a concussion clinic, evaluated within 5 months post injury ($M = 2.0$, $SD = 1.0$, range = 0.6–4.6), who were receiving financial compensation from the Workers' Compensation Board. Participants completed the Post-Concussion Scale (PCS), British Columbia Cognitive Complaints Inventory (BC-CCI), selected tests from the Neuropsychological Assessment Battery Screening Module (S-NAB), and the Test of Memory Malingering (TOMM). Participants were divided into two groups based on TOMM performance (15 fail, 48 pass). There were significant main effects and large effect sizes for the PCS ($p = .002$, $d = 0.79$) and BC-CCI ($p = .011$, $d = 0.98$) total scores. Patients in the TOMM fail group scored higher than those in the TOMM pass group on both measures. Similarly, there were significant main effects and/or large effect sizes on the S-NAB. Patients in the TOMM fail group performed more poorly on the Attention ($p = .004$, $d = 1.26$), Memory ($p = .006$, $d = 1.16$), and Executive Functioning ($p > .05$, $d = 0.70$) indexes. These results highlight the importance of considering the influence of poor effort, in conjunction with a growing list of factors that can influence, maintain, and/or mimic the persistent postconcussion syndrome.

Keywords: Postconcussion symptoms; Response bias; Symptom validity testing; Test of Memory Malingering.

INTRODUCTION

When considering a diagnosis of postconcussion syndrome, clinicians must systematically evaluate and eliminate the possible contribution of many differential diagnoses, comorbidities, and factors that may *cause, mimic, or maintain* self-reported symptoms long after a mild traumatic brain injury (MTBI). Such factors include, but are not limited to: (a) the nonspecificity of postconcussion-like symptoms reported in healthy and non-TBI clinical groups (e.g., Dunn, Lees-Haley, Brown, Williams, & English, 1995; Iverson & Lange, 2003; Mickeviciene et al., 2004; Smith-Seemiller, Fow, Kant, & Franzen, 2003; Sullivan, Hall, Bartolacci, Sullivan, & Adams, 2002; Trahan, Ross, & Trahan, 2001); (b) premorbid personality characteristics (Garden, Sullivan, &

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Address correspondence to Rael T. Lange, British Columbia Mental Health and Addiction Services, PHSA Research and Networks, Suite 201, 601 West Broadway Street, Vancouver, British Columbia, V5Z 4C2, Canada (E-mail: rael.lange@gmail.com).

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Lange, 2010; Greiffenstein & Baker, 2001); (c) different methods used to elicit and document symptoms (Iverson, Brooks, Ashton, & Lange, 2009); (d) depression (Iverson, 2006; Suhr & Gunstad, 2002b); and (e) the role of various social–psychological factors (e.g., Ferguson, Mittenberg, Barone, & Schneider, 1999; Gunstad & Suhr, 2001; Hahn, 1997; Iverson, Lange, Brooks, & Ashton Rennison, 2010; Suhr & Gunstad, 2002a, 2005).

Without doubt, one potentially significant factor that clinicians must evaluate when considering a diagnosis of postconcussion syndrome is the influence of poor effort during cognitive testing and symptom exaggeration. Concerns regarding the role of financial compensation on symptom reporting have been expressed for many years (Binder & Rohling, 1996; Cook, 1972; Miller, 1961; Paniak et al., 2002; Reynolds, Paniak, Toller-Lobe, & Nagy, 2003). The majority of neuropsychologists routinely use measures of effort (Sharland & Gfeller, 2007), and position statements from leading neuropsychology organizations clearly state that measures of effort are an essential part of a neuropsychological evaluation (Bush et al., 2005; Heilbronner, Sweet, Morgan, Larrabee, & Millis, 2009). The position statement of the National Academy of Neuropsychology even goes as far as stating that "the clinician should be prepared to justify a decision *not* to assess symptom validity as part of a neuropsychological evaluation" (Bush et al., 2005, p. 421).

Typically, an evaluation of a patient with persisting problems following MTBI focuses on, but is certainly not limited to, the assessment of various self-reported symptoms (e.g., postconcussion symptoms and cognitive complaints), neurocognitive abilities (a brief or comprehensive evaluation), and effort (i.e., effort testing). The methods and procedures used might be selected based on the *DSM–IV* (*Diagnostic and Statistical Manual of Mental Disorders–Fourth Edition*) Category B and C research criteria for postconcussional disorder[1] that require the establishment of the presence of self-reported postconcussion symptoms and "evidence from neuropsychological testing or quantified cognitive assessment of difficulty in attention (concentrating, shifting focus of attention, performing simultaneous cognitive tasks) or memory (learning or recalling information)" (American Psychiatric Association, 2000, p. 761). There are a variety of ways in which a person might exaggerate symptoms (Nelson, Sweet, Berry, Bryant, & Granacher, 2007a). A person who chooses to appear more symptomatic or impaired than is actually the case is likely to (a) exaggerate cognitive deficits during neurocognitive testing, (b) exaggerate self-reported symptoms (i.e., cognitive complaints or postconcussion symptoms), or (c) both. Intuitively, it seems obvious that individuals who fail effort testing will score lower on neurocognitive testing in general (Backhaus, Fichtenberg, & Hanks, 2004; Constantinou, Bauer, Ashendorf, Fisher, & McCaffrey, 2005), and there is literature to support this (see Vickery, Berry, Inman, Harris, & Orey, 2001, for a meta-analytic review). However, it is not obvious whether poor effort will also be associated with exaggeration of self-reported symptoms (Green, 2007).

To date, there are only three studies that have specifically examined the influence of poor effort on self-reported postconcussion symptoms and cognitive complaints following MTBI. Iverson and colleagues (Iverson et al., 2010) examined the "good old days" bias in 90 patients receiving Workers' Compensation benefits following MTBI. In this study, postinjury symptom reporting and the "good old days" bias was associated with effort testing results. Patients who failed the Test of Memory Malingering (TOMM) not only reported more postinjury symptoms on the British Columbia Postconcussion Symptom Inventory (BC-PSI, Iverson, Zasler, & Lange, 2007b) than patients who passed the TOMM, but also retrospectively reported fewer symptoms prior to their injury. Tsanadis and colleagues (Tsanadis et al., 2008) compared self-reported symptoms on the Postconcussive Symptom Questionnaire (PSQ) in 158 patients evaluated in an outpatient Neuropsychology program following TBI (133 moderate-to-severe TBI, 25 mild TBI who failed effort tests). Patients with MTBIs who failed effort testing reported more symptoms post injury on the psychological, cognitive, and somatic indexes (but not the infrequency index) of the PSQ than did patients who sustained moderate-to-severe TBIs. In a follow-up study by these authors using the same sample, Tsanadis and colleagues (Tsanadis, Montoya, Millis, Hanks, & Fichtenberg, 2007) developed the Negative Impression Management (NIM) scale for the PSQ. Using the optimal cutoff score, the NIM had a sensitivity of .67 and specificity of .85 for detecting those patients with MTBIs who failed effort testing.

To our knowledge, no other studies have specifically examined the relationship between effort test failure and the reporting of postconcussion symptoms (or cognitive complaints) in a MTBI sample. However, other studies have examined the relationship between effort test performance and psychological test results, such as the Minnesota Multiphasic Personality Inventory–Second Edition (MMPI–2), in both TBI and non-TBI samples with mixed results. Some researchers have reported that failure on effort tests is associated with (a) exaggerated memory complaints in non-head-injury disability claimants (Gervais, Ben-Porath, Wygant, & Green, 2008); (b) MMPI–2 scale elevations (i.e., Hs1, D2, Hy3, Pt7, Sc8) in personal injury litigants (78% alleged MTBI; Larrabee, 2003b), MTBI personal injury litigants (Boone & Lu, 1999; Suhr, Tranel, Wefel, & Barrash, 1997), and personal injury litigants and disability claimants (Henry, Heilbronner, Mittenberg, Enders, & Domboski, 2009); (c) MMPI–2 scale elevations (i.e., RC1, RC8) in civil personal injury litigants (33% MTBI) and criminal

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[1] It is important to note that postconcussional disorder is not an official *DSM–IV* diagnostic category. *DSM–IV* presents only research criteria for postconcussional disorder in an effort to provide a common language for researchers and clinicians who are interested in studying this disorder. At the time of development of the *DSM–IV*, criteria for postconcussional disorder were proposed but were not included as an official category due to a lack of sufficient information (see American Psychiatric Association, 2000, p. 759, for more information).

defendants (Wygant et al., 2007); (d) exaggerated self-reported attention-deficit/hyperactivity disorder (ADHD) symptoms (Suhr, Hammers, Dobbins-Buckland, Zimak, & Hughes, 2008), and (e) exaggerated self-reported pain symptoms in personal injury litigants (86% alleged MTBI, Larrabee, 2003c, and non-head-injured disability claimants, Gervais, Rohling, Green, & Ford, 2004). In contrast, some researchers have failed to support a relation between effort tests and self-reported symptoms, with no association found between effort test performance and (a) Millon Clinical Multiaxial Inventory (MCMI–III) scale elevations in personal injury litigants (94% TBI; Ruocco et al., 2008); (b) self-reported symptoms of anxiety, posttraumatic stress disorder (PTSD), depression, nonsyndromal psychiatric complaints, or whiplash, in personal injury litigants (32% TBI; Stevens, Friedel, Mehren, & Merten, 2008); or (c) self-reported depression and anxiety in treatment-seeking patients following acquired brain injury (Locke, Smigielski, Powell, & Stevens, 2008). Despite the mixed findings, the majority of studies do support a relation between effort test failure and exaggerated self-reported symptoms on psychological tests.

The primary purpose of this study is to examine the influence of poor effort on self-reported symptoms (postconcussion and cognitive complaints) following MTBI. It is hypothesized that patients evaluated following a MTBI and who fail the TOMM will endorse a greater degree of self-reported symptoms (i.e., postconcussion symptoms and cognitive complaints) than do those patients evaluated following a MTBI and who passed the TOMM. A secondary purpose of this study is to examine the influence of poor effort on neurocognitive test performance as measured by the Screening Module of the Neuropsychological Assessment Battery (S-NAB; Stern & White, 2003). Although the relationship between poor effort and lower scores on a variety of neurocognitive tests is well established (Gervais et al., 2004; Green, 2007; Locke et al., 2008), to date, there are no independent studies that have evaluated the influence of cognitive effort test performance on the S-NAB (although some data from an analog malingering study are presented in the test manual; see White & Stern, 2003). It is hypothesized that patients evaluated following a MTBI and who failed the TOMM will perform worse on neurocognitive testing than do those patients who pass the TOMM.

METHOD

Participants

Participants were 63 patients (62.9% male) who were evaluated between September 2005 and March 2008 as part of a specialty clinic for people who are slow to recover from a mild traumatic brain injury. These patients were selected from a larger sample (*n* = 151) of consecutive referrals to this concussion clinic in Vancouver, British Columbia, Canada. The vast majority of cases were referred for intake assessments and/or cognitive screening evaluations (94%). A total of 4 additional patients, referred for full neuropsychological evaluations and who met the inclusion criteria below, were also included. Patients were included in the sample if (a) they had sustained an MTBI (*n* = 134, 88.7% of total sample), (b) English was their first language or they had sufficient English fluency to complete the interview, questionnaires, and neurocognitive testing (*n* = 131, 86.8% of total sample), (c) they had been administered the TOMM (*n* = 87, 57.6% of total sample), (d) they had completed the Post-Concussion Scale (PCS; *n* = 134, 88.7% of total sample) and British Columbia Cognitive Complaints Inventory (BC-CCI; *n* = 139, 92.1% of total sample), and (e) they had been tested within 6 months of injury (*n* = 140, 92.1% of total sample). A total of 63 patients met all five criteria.

All patients were receiving financial compensation through the provincial Workers' Compensation system at the time of evaluation. Patients were referred to the Concussion Clinic by their case manager if they were unable to return to work within 30 days following an injury. For the vast majority of patients, medical records were not available for review. For these patients, classification of MTBI was based on (a) self-reported loss of consciousness (LOC), posttraumatic amnesia (PTA), posttraumatic confusion (PTC), and (b) information regarding their injury as supplied by the case manager (e.g., witnessed LOC). We had a relatively low threshold for diagnosing the injury in that the person simply needed a plausible mechanism of injury combined with, at minimum, some degree of altered consciousness or confusion. As such, this sample includes a broad range of MTBI cases, from very mild injuries to injuries involving several hours of posttraumatic amnesia. Two previous studies involving patients from this cohort have been published (Iverson et al., 2009; Iverson et al., 2010).

The mean age and education of the sample was 42.8 years (*SD* = 12.3) and 12.5 years (*SD* = 2.0), respectively. Ethnicity of the sample was predominantly Caucasian (74.2%), with 9.7% East Indian, 4.8% Asian, 3.2% First Nations (i.e., aboriginal Canadians), and 8.1% of other ethnic origin. The majority of the sample reported English as their first language (69.4%), with 30.6% indicating that English was their second language. The breakdown regarding LOC, PTA, and PTC for the sample was as follows: LOC, 30.6% positive, 43.5% negative, 6.5% equivocal, and 19.4% missing information; PTA, 37.1% positive, 43.5% negative, 19.4% missing; PTC, 46.8% positive, 14.5% negative, 38.7% missing. Glasgow Coma Scale scores were not available in the vast majority of patients (83.9%) because (a) they were not transported to the hospital via ambulance, or (b) we did not have the ambulance crew report. Most of the patients did not undergo computed tomography (CT) scanning of their brain following their injury (69.4%). However, 30.6% underwent imaging, and 8.1% revealed evidence of a trauma-related abnormality (8.1% complicated mild TBI, 22.6% uncomplicated MTBI). All patients were evaluated within 4.6 months of sustaining their injury (mean = 2.0 months, *SD* = 1.0, range = 0.6 to 4.6 months). The breakdown of time post injury prior to evaluation was as follows: 0.6 to 1.9 months = 64.5%, 2 to 2.9 months = 17.7%, and 3 to 4.6 months = 17.7%.

Measures

Participants completed the Post-Concussion Scale (PCS; Lovell et al., 2006), the British Columbia Cognitive Complaints Inventory (BC-CCI; Iverson, 2003a, 2003b; Iverson & Remick, 2003), and the Test of Memory Malingering (TOMM, Tombaugh, 1996) as part of a larger test battery. A subgroup of the participants (*n* = 37) also completed selected tests from the screening battery of the Neuropsychological Assessment Battery (S-NAB; Stern & White, 2003).

The PCS is a 22-item measure designed to assess the presence and severity of postconcussion symptoms (e.g., headache, balance problems, nausea, fatigue, sensitivity to noise, irritability, sadness, nervousness, difficulty concentrating, difficulty remembering, visual problems). Each item is rated on a 7-point scale as follows: 0 = none, 1–2 = mild, 3–4 = moderate, and 5–6 = severe. A total score is obtained by summing the ratings for the 22 items. Total scores on the PCS range from 0 to 132.

The BC-CCI is a 6-item scale that measures perceived cognitive problems, including problems with concentration, memory, trouble expressing thoughts, word finding, slow thinking, and difficulty solving problems over the past 7 days. Each item is rated on a 4-point scale as follows: 0 = not at all, 1 = some, 2 = quite a bit, and 3 = very much. A total score is obtained by summing the ratings for the 6 items. Total scores on the BC-CCI range from 0 to 18.

The TOMM is a well-validated effort test that is commonly used by neuropsychologists (Sharland & Gfeller, 2007). The TOMM employs a forced-choice recognition paradigm using 50 black-and-white line drawings. During the study phase, the participant is shown each drawing for 3 seconds, with a 1-second interval. After the 50 items have been presented, each drawing is presented along with a distractor drawing. The participant is asked to choose the drawing that was shown during the study phase. The 50 line drawings are then shown a second time (i.e., “Trial 2”), followed by another test phase in which they are paired with 50 new distractor drawings. After approximately 15 minutes, an optional retention test may be given in which the original 50 items are paired with new distractors. Thus, the test is composed of three components: Trial 1, Trial 2, and retention. For these participants, all three trials were not routinely administered. In some cases, only Trial 1 was administered if the participant achieved a score of 50/50 (*n* = 3).

The Neuropsychological Assessment Battery (NAB, Stern & White, 2003) is a comprehensive modular battery of tests with demographically corrected norms for adults between the ages of 18 to 97 years. The entire test is composed of a screening battery (S-NAB) and five separate modules. The S-NAB is composed of five sections, which briefly assess attention, language, memory, spatial, and executive functions. The S-NAB consists of 12 individual tests across the five domains. From these 12 tests, a total of 16 *T* scores are derived, 14 of which contribute toward five separate Screening Index scores and one Total Screening Index score. In this sample, only seven tests (that derive 12 *T* scores[2]) were routinely administered, which contribute toward the Attention Index (Digit Span forward, Digit Span Backward. Numbers and Letters Part A and Part B), Memory Index (Shape Learning, Story Learning), and Executive Functioning Index (Mazes, Word Generation). *T* scores (*M* = 50, *SD* = 10), along with the Screening Index scores (*M* = 100, *SD* = 15), were examined in the present study. The *Screening Attention Index* is a composite score representing diverse neurocognitive abilities such as attention capacity, working memory, psychomotor speed, selective attention, divided attention, and sustained attention. The *Screening Memory Index* is a composite score based on both visual (i.e., shape learning) and verbal (i.e., story learning) learning and memory tests. The *Screening Executive Functions Index* is a composite score based on measures involving planning, judgment, conceptualization, verbal fluency, and generativity. For additional information regarding the tests and the domain scores, please refer to the test manuals (Stern & White, 2003; White & Stern, 2003).

Procedure

Participants were divided into two groups based on their performance on the TOMM: (a) TOMM fail, *n* = 15 and (b) TOMM pass, *n* = 48. For the subgroup of the participants who also completed the S-NAB (*n* = 37), 8 participants failed the TOMM, and 29 participants passed the TOMM. For the majority of patients who were classified as having failed the TOMM (*n* = 13/15), the criteria applied was based on cutoff scores recommended in the manual (Trial 2 < 45). However, an additional 2 patients were also included in this group whose TOMM performance was considered “suspicious.” For these two patients, scores on Trial 1 that were less than 36 were considered suspicious regardless of their scores obtained on Trial 2.[3] We decided to broaden our inclusion of suspected poor effort on Trial 1 for three reasons. First, researchers have expressed concern about the sensitivity of the TOMM to poor effort (Bauer, O’Bryant, Lynch, McCaffrey, & Fisher, 2007; DenBoer & Hall, 2007; Gervais et al., 2004; Tan, Slick, Strauss, & Hultsch, 2002; van Hout, Schmand, Wekking, Hageman, & Deelman, 2003). That is, the test is highly specific but relying on cutoff scores of 45 for Trial 2 or retention as the marker for poor effort might fail to detect some cases (i.e., false negatives). Second, scores in the mid 30s on Trial 1 of the TOMM are very uncommon and fall below two standard deviations from the mean, in healthy children, adults, and older adults (Iverson, LePage, Koehler, Shojania, & Badii, 2007a). Scores in this range are also more than 2

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[2] Several *T* scores are derived for the Numbers and Letters A test, including two separate scores for speed and errors. These two scores are combined into an efficiency score. The efficiency, but not speed and error, *T* score was included in the present analyses.

[3] The analyses in this study were also run without the inclusion of these 2 participants. There was not a difference on the outcome of the main findings.

standard deviations below the mean for children with psychiatric or neurological problems (Donders, 2005), adults with depression (Rees, Tombaugh, & Boulay, 2001), psychiatric inpatients (Gierok, Dickson, & Cole, 2005), adults with chronic pain and psychological distress (Iverson et al., 2007a), and older adults with mild symptoms of depression or anxiety (Ashendorf, Constantinou, & McCaffrey, 2004). Scores in the mid 30s are approximately two standard deviations below the mean for patients with aphasia (Tombaugh, 1997), temporal lobe epilepsy (Hill, Ryan, Kennedy, & Malamut, 2003), or traumatic brain injuries (Rees, Tombaugh, Gansler, & Moczynski, 1998; Tombaugh, 1997). Finally, researchers have laid the foundation for using Trial 1 as an indicator of possible poor effort (Bauer et al., 2007; Gavett, O'Bryant, Fisher, & McCaffrey, 2005; Horner, Bedwell, & Duong, 2006; O'Bryant, Engel, Kleiner, Vasterling, & Black, 2007; O'Bryant et al., 2008), which allowed us to include those MTBI patients who only received this first trial of the TOMM.

RESULTS

There were no significant differences between TOMM groups on age ($F = 0.017$, $p = .898$, $d = 0.05$), education ($F = 0.541$, $p = .467$, $d = 0.30$), days tested post injury ($F = 0.047$, $p = .830$, $d = 0.09$), gender (male: 75.0% fail, 65.5% pass, $\chi^2 = 0.257$, $p = .480$, Fisher's Exact Test), ethnicity (Caucasian: 50% fail, 86.2% pass, $\chi^2 = 6.817$, $p = .586$, Fisher's Exact Test), language (English as a foreign language, EFL: 50% fail, 82.8% pass, $\chi^2 = 3.655$, $p = .076$, Fisher's Exact Test), or brain injury severity (concussion/MTBI: 100% fail, 93.1% pass, $\chi^2 = 0.583$, $p = .610$, Fisher's Exact Test).

Descriptive statistics, Mann–Whitney *U* tests (due to non-normal distributions), and effect sizes (Cohen, 1988) for the PCS and BC-CCI by TOMM group are presented in Tables 1 and 2. The probability of Type 1 error increases when multiple statistical comparisons are made, and a more conservative *p* value of <.01 (or a Bonferroni correction) would be typically used here. However, the small sample size reduces statistical power, and the application of a *p* value of <.01 (or a Bonferroni correction) was considered too stringent. Thus, it was decided to apply a more liberal statistical approach by interpreting findings using $p < .05$.

There were significant main effects and large to very large effects sizes for the PCS ($p = .002$, $d = 0.79$) and BC-CCI ($p = .011$, $d = 0.98$) total scores. As expected, participants in the TOMM fail group scored higher than those in the TOMM pass group on both measures. For the PCS, significant main effects and medium–large to very large effects sizes were found on 12 of the 22 items. The largest effect sizes were found on symptoms of irritability, sadness, nervousness, and sleeping less than usual. Although not significant likely due to small sample size, medium effect sizes were also found on four additional

TABLE 1

Descriptive statistics and percentages of individual PCS symptoms endorsed at a moderate level or greater by group

	TOMM pass		*TOMM fail*						
	M	*SD*	*M*	*SD*	*p*	*d*	*TOMM pass (%)*	*TOMM fail (%)*	*p*
Headache	4.0	1.5	4.6	1.3	.133	0.45	63.8	73.3	.498
Nausea	1.9	1.9	2.7	1.9	.128	0.45	23.4	40.0	.177[a]
Vomiting	0.6	1.4	1.2	1.7	.123	0.39	8.5	20.0	.217[a]
Balance problems	2.7	1.5	3.4	1.5	.182	0.46	31.9	40.0	.565
Dizziness	3.0	1.5	3.4	1.8	.462	0.27	40.4	46.7	.670
Fatigue	3.7	1.7	4.8	1.0	.018	0.75	59.6	86.7	.050
Trouble falling asleep	3.1	2.0	4.6	1.6	.007	0.80	48.9	80.0	.035
Sleeping more than usual	2.6	2.3	1.8	1.9	.201	0.36	44.7	20.0	.088
Sleeping less than usual	1.9	2.3	4.3	1.8	.001	1.12	27.7	73.3	.002
Drowsiness	3.0	1.5	4.0	1.4	.021	0.67	34.0	73.3	.008
Sensitivity to light	2.5	1.8	2.8	2.0	.707	0.12	34.0	33.3	.960
Sensitivity to noise	2.7	1.7	2.5	2.2	.587	0.11	38.3	26.7	.412
Irritability	2.5	1.9	4.2	1.9	.005	0.90	34.0	66.7	.026
Sadness	2.3	1.9	4.1	1.8	.004	0.93	34.0	60.0	.074
Nervousness	2.0	1.7	3.9	1.7	.001	1.12	21.3	60.0	.007[a]
Feel more emotional	3.0	1.8	4.0	1.9	.049	0.56	40.4	66.7	.076
Numbness or tingling	1.6	1.7	3.0	2.3	.034	0.77	14.9	40.0	.048[a]
Feeling slowed down	3.6	1.5	4.4	1.5	.095	0.52	53.2	73.3	.169
Feeling mentally "foggy"	3.2	1.7	3.7	2.0	.275	0.28	42.6	60.0	.238
Difficulty concentrating	3.4	1.5	4.5	1.4	.029	0.70	46.8	73.3	.073
Difficulty remembering	3.0	1.7	4.3	1.7	.009	0.76	34.0	73.3	.008
Visual problems	1.6	1.7	2.8	2.1	.046	0.67	17.0	40.0	.071
Total	57.9	21.6	78.9	21.6	.002	0.98	—	—	—

Note. $N = 63$ (15 TOMM fail, 48 TOMM pass). TOMM = Test of Memory Malingering; PCS = Post-Concussion Scale.

[a] Fisher's Exact Test statistic interpreted due to the expected count in some cells less than 5.

TABLE 2

Descriptive statistics and percentages of individual BC-CCI symptoms endorsed at a moderate level or greater by group

	TOMM pass		*TOMM fail*						
BC-CCI symptoms	*M*	*SD*	*M*	*SD*	*p*	*d*	*TOMM pass (%)*	*TOMM fail (%)*	*p*
Forgetfulness/memory	1.8	0.8	2.5	0.7	.011	0.79	55.3	86.7	.029
Poor concentration	2.1	0.8	2.6	0.5	.030	0.68	78.7	100	.048[a]
Expressing thoughts	1.8	1.0	2.3	1.0	.120	0.44	57.4	80.0	.115
Word finding	1.9	0.9	2.5	0.6	.043	0.63	66.0	93.3	.034[a]
Slow thinking speed	2.0	0.9	2.3	0.6	.160	0.46	66.0	93.3	.034[a]
Problem solving	1.7	1.0	2.4	0.6	.010	0.81	53.2	93.3	.005
Total	11.4	4.3	14.5	3.4	.011	0.79	—	—	—

Note. N = 63 (15 TOMM fail, 48 TOMM pass). TOMM = Test of Memory Malingering; BC-CCI = British Columbia Cognitive Complaints Inventory.

[a] Fisher's Exact Test.

symptoms (headache, nausea, balance problems, feeling slowed down). For the BC-CCI, significant main effects, and medium–large to large effects sizes were found on four of the six items. The largest effect sizes were found on cognitive complaints of forgetfulness, poor concentration, and problem solving.

The percentage of participants endorsing the individual symptoms as moderate or greater on the PCS and BC-CCI is also presented in Tables 1 and 2. On the PCS, specific endorsement rates ranged from 20.0% to 86.7% in the TOMM fail group, with 13 symptoms endorsed by more than 60% of the group. In contrast, symptom endorsement rates in the TOMM pass group ranged from 8.5% to 63.8%, with only 1 symptom endorsed by more than 60% of the group. Using chi-square analyses, significantly higher rates of endorsed symptoms were found in the TOMM fail group on 8 of the 22 symptoms (all $p < .05$) and approached significance on an additional 4 symptoms (range: $p = .071$ to .076). Similarly, on the BC-CCI, specific endorsement rates ranged from 80% to 100% in the TOMM fail group, with all 6 symptoms endorsed by more than 80% of the group. In contrast, symptom endorsement rates in the TOMM pass group ranged from 53.2% to 78.7%, with no symptoms endorsed by more than 80% of the group. Significant differences in the percentages of endorsed symptoms were found on 5 of the 5 symptoms (all $p < .05$).

TABLE 3

Number of items on the PCS and BC-CCI endorsed at a moderate level or greater by TOMM group

	BC-CCI		*PCS*	
Number of symptoms	*TOMM fail*	*TOMM pass*	*TOMM fail*	*TOMM pass*
22[#]	—	—	0	0
21	—	—	0	0
20	—	—	0	0
19	—	—	13.3_{a}	0_{a}
18	—	—	26.7_{c}	2.1_{c}
17	—	—	26.7_{c}	4.3_{c}
16	—	—	26.7_{a}	6.4_{a}
15	—	—	40.0_{c}	10.9_{c}
14	—	—	53.3_{c}	14.9_{c}
13	—	—	53.3	27.7
12	—	—	66.7_{c}	27.7_{c}
11	—	—	66.7_{a}	38.3_{a}
10	—	—	66.7	42.6
9	—	—	73.3	48.9
8	—	—	73.3	48.9
7	—	—	80.0	55.3
6[#]	66.7_{c}	27.7_{c}	86.7	63.8
5	86.7_{c}	40.4_{c}	93.3_{a}	66.0_{a}
4	93.3_{b}	61.7_{b}	93.3	70.2
3	100_{a}	78.7_{a}	93.3	78.7
2	100	80.9	93.3	91.5
1	100	87.2	100	95.7
0	100	100	100	100

Note. N = 63 (15 TOMM fail, 48 TOMM pass). TOMM = Test of Memory Malingering; BC-CCI = British Columbia Cognitive Complaints Inventory; PCS = Post-Concussion Scale. Chi-square analyses—values with same subscript are significantly different at the following significance levels: $_{a}p < .05$, $_{b}p < .02$, $_{c}p < .01$, $_{d}p \le .001$.

[#] Maximum number of symptoms: PCS = 22, BC-CCI = 6.

Further comparisons of the prevalence of low scores on the PCS and BC-CCI between groups were undertaken by considering all symptoms simultaneously, on each measure separately. The cumulative percentages of the number of endorsed symptoms on the PCS and BC-CCI, by TOMM group, are presented in Table 3. For the PCS and BC-CCI, there were more symptoms endorsed at a moderate level or greater by the TOMM fail group than by the TOMM pass group for both measures. On the PCS, although there was only one significant difference when comparing the number of reported symptoms ranging from "1 or more" to "10 or more" symptoms (i.e., 5 or more, $p < .05$), there were significant differences on almost all comparisons when considering "11 or more" symptoms or greater. For example, 66.7% of the participants in the TOMM fail group reported the presence of 11 or more symptoms on the PCS, compared to 38.3% of participants in the TOMM pass group. On the BC-CCI, there were significant differences on all comparisons of "3 or more" symptoms. For example, 86.7% of the participants in the TOMM fail group

TABLE 4

Descriptive statistics and percentages of the individual S-NAB scores falling lower than the 16 percentile by group

	TOMM pass		*TOMM fail*						
	M	*SD*	*M*	*SD*	*p*	*Effect size*	*TOMM pass (%)*	*TOMM fail (%)*	*p*
Attention Index	92.2	14.6	72.1	21.1	.004	1.26	24.1	75.0	.013[a]
Digits Forward	41.3	10.3	34.4	10.1	.012	0.67	44.8	75.0	.133[a]
Digits Backwards	49.1	10.0	39.8	10.4	.026	0.93	17.2	37.5	.221[a]
N&L Part A Efficiency	48.0	9.3	32.5	12.7	<.001	1.54	13.8	50.0	.049[a]
N&L Part B Efficiency	47.7	11.4	38.0	16.4	.061	0.78	24.1	62.5	.055[a]
Memory Index	99.6	16.2	80.6	17.1	.006	1.16	20.7	50.0	.117[a]
Shape Learning Immediate	51.0	7.5	38.1	9.4	<.001	1.62	3.4	62.5	.001[a]
Shape Learning Delayed	50.9	7.6	49.1	11.7	.614	0.21	6.9	25.0	.198[a]
Story Learning Immediate	49.1	11.1	37.8	13.5	.019	0.98	10.3	50.0	.027[a]
Story Memory Delayed	48.6	12.2	38.5	12.4	.046	0.83	24.1	62.5	.055[a]
Executive Functions Index	99.4	19.2	86.5	15.0	.089	0.70	24.1	37.5	.367[a]
Mazes	51.1	13.7	46.0	11.2	.338	0.39	21.4	50.0	.128[a]
Word Generation	48.8	9.4	39.5	9.1	.019	0.99	17.9	37.5	.236[a]

Note. N = 37 (8 TOMM fail, 29 TOMM pass). TOMM = Test of Memory Malingering; S-NAB = Neuropsychological Assessment Battery Screening Module. N&L = Numbers and Letters. M = Mean. SD = Standard deviation. Effect sizes computed using Cohen's d.

[a] Fisher's Exact Test.

reported the presence of 5 or more symptoms on the BC-CCI, compared to 40.4% of participants in the TOMM pass group.

Descriptive statistics, analysis of variance (ANOVA) results, and effect sizes (Cohen, 1988) for the S-NAB subtests and index scores by TOMM group are presented in Table 4. There were significant main effects and very large effect sizes on the Attention Index (p = .004, d = 1.26) and the Memory Index (p = .006, d = 1.16). Patients in the TOMM fail group performed worse on the Attention Index and Memory Index than did the TOMM pass group. A large effect size was found on the Executive Functioning Index (d = 0.70), although not statistically significant likely due to small sample size (p > .05). Again, patients in the TOMM fail group performed worse on the Executive Functioning Index than did the TOMM pass group. Significant main effects were found on 7 of the 10 individual subtests of the S-NAB, with the TOMM fail group consistently performing lower on these measures than the TOMM pass group. Large to very large effect sizes were found on Digits Backwards, Numbers and Letters Part A Efficiency, Numbers and Letters Part B Efficiency, Shape Learning Immediate Recognition, Story Learning Immediate Recall, Story Memory Delayed Recall, and Word Generation.

The percentages of patients with low scores (i.e., <16th percentile or <1 standard deviation) on each of the S-NAB measures by group are also presented in Table 4.[4] Chi-square analyses were used to compare the proportion of low scores on each measure between groups. There was a significant difference in the proportion of low scores between groups on 4 of the 13 measures. However, the small sample size likely masked other differences between groups. For example, a difference of 30.2% was found on Digits Forward but was not statistically significant (p = .133). Overall, there were a greater number of low scores in the TOMM fail group than in the TOMM pass group. The prevalence of low scores on the three index scores in the TOMM fail group ranged from 37.5% to 75%. For the TOMM pass group, the prevalence of scores ranged from 20.7% to 24.1%. The prevalence of low scores on the 10 subtest scores in the TOMM fail group ranged from 25% to 75%, with 9 of the 10 measures having a prevalence rate greater than 25%. For the TOMM pass group, the prevalence of scores ranged from 3.4% to 44.8%, with only 1 of the 10 measures having a prevalence rate greater than 25%.

Further comparisons of the prevalence of low scores on the S-NAB between groups were undertaken by considering all measures simultaneously. For the purposes of these analyses, the three index scores were not included due to the measurement overlap with the individual subtest scores. A total of 10 S-NAB subtest scores were included (as mentioned in the Method, the individual T scores for Numbers and Letters A errors and speed were not included due to the overlap with Numbers and Letters A efficiency). The cumulative percentages of the number of low scores (< 16th percentile) by TOMM group are presented in Table 5.

For the S-NAB, there were significant differences in the number of low subtest scores between groups, with a higher percentage of patients from the TOMM fail group with multiple low scores than of patients from the TOMM pass group. For example, 75% of the patients in the TOMM fail group had four or more low scores, compared to 10.7% of patients in the TOMM pass group (p < .001).

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[4] A cutoff score of the 16th percentile was chosen for illustrative purposes only. Scores falling less than the 1st, 5th, and 10th percentiles were also calculated but were not included due to the low prevalence of scores in this range and due to page limitations. These data are available from the first author on request.

TABLE 5

Number of test scores on the S-NAB below the 16th percentile by TOMM group and the standardization sample

Number of low scores	*TOMM fail (cumulative %)*	*TOMM pass (cumulative %)*	*Standardization sample (cumulative %)*
10	12.5	—	—
9 or more	25.0_a	—$_a$	0.1
8 or more	25.0_a	—$_a$	0.3
7 or more	25.0_a	—$_a$	0.8
6 or more	25.0	3.6	2.3
5 or more	50.0_b	7.1_b	5.7
4 or more	75.0_d	10.7_d	12.2
3 or more	87.5_b	39.3_b	24.1
2 or more	87.5	53.6	43.3
1 or more	100	71.4	70.0
0	100	100	100

Note. $N = 37$ for S-NAB (8 TOMM fail, 29 TOMM pass). S-NAB = Neuropsychological Assessment Battery Screening Module; TOMM = Test of Memory Malingering; maximum number of scores is 10. Chi-square analyses—values with same subscript are significantly different at the following significance levels: $_{a}p < .05$, $_{b}p < .02$, $_{c}p < .01$, $_{d}p \leq .001$. Base rates of low S-NAB subtest scores were estimated using a Monte Carlo estimation program (Crawford et al., 2007) and subtest intercorrelations from Table C1 from the S-NAB technical manual (White & Stern, 2003).

The prevalence of low scores in the healthy S-NAB standardization sample, which can be readily calculated using a Monte Carlo estimation program (Crawford, Garthwaite, & Gault, 2007) and the S-NAB subtest intercorrelations found in Table C1 from technical manual (White & Stern, 2003), can also be used for comparison. For example, having four or more subtest scores <16th percentile is estimated to occur in 12.2% of the standardization sample, which is similar to the prevalence rate in the TOMM pass group (10.7%, $\chi^2 = 0.012$, $p > .05$) but significantly lower than the prevalence rate in the TOMM fail group (75%, $\chi^2 = 77.657$, $p < .001$).

DISCUSSION

The purpose of this study was to examine the influence of poor effort on self-reported symptoms (postconcussion and cognitive complaints) and neurocognitive test performance following MTBI. It was hypothesized that patients who failed the TOMM would endorse a greater degree of postconcussion symptoms and cognitive problems than would those patients who passed the TOMM. It was further hypothesized that patients who failed the TOMM would perform more poorly on tests of cognitive ability than would those patients who passed the TOMM. Overall, the results supported these hypotheses and are consistent with literature focusing on the association of poor effort and lower performance on objective neurocognitive tests following TBI (e.g., Gervais et al., 2004; Green, 2007; Locke et al., 2008), exaggerated self-reported postconcussion symptoms following MTBI (Iverson et al., 2010; Tsanadis et al., 2008), and exaggerated self-reported symptoms (not post-concussion-specific) in both non-TBI and TBI samples (Boone & Lu, 1999; Gervais et al., 2008; Gervais et al., 2004; Larrabee, 2003b, 2003c; Locke et al., 2008; Ruocco et al., 2008; Stevens et al., 2008; Suhr et al., 2008; Suhr et al., 1997; Wygant et al., 2007). In this study, compared to MTBI patients who passed the TOMM, MTBI patients who failed the TOMM (a) endorsed more postconcussion symptoms on the PCS, (b) endorsed more cognitive complaints on the BC-CCI, and (c) had lower scores on the Attention, Memory, and Executive Function indexes of the S-NAB. These findings are also consistent with a broader literature suggesting that individuals involved in litigation following MTBI tend to report more symptoms post injury, and perform worse on neurocognitive measures, than do nonlitigants (Carroll et al., 2004; Lees-Haley & Brown, 1993; Reynolds et al., 2003).

The results from this study are related to a much broader literature focusing on the relation between effort test performance and the validity scales on the Minnesota Multiphasic Personality Inventory–2 (MMPI–2, Butcher, Graham, Ben-Porath, Tellegen, & Kaemmer, 1989) and the Personality Assessment Inventory (PAI, Morey, 1991). Studies examining the PAI have found a moderate association between effort test failure and the Negative Impression Management (NIM) scale and to some degree the Infrequency scale (Haggerty, Frazier, Busch, & Naugle, 2007; Whiteside, Dunbar-Mayer, & Waters, 2009), but not all research has shown this relation (Sumanti, Boone, Savodnik, & Gorsuch, 2006). Studies examining the MMPI–2 have also found a modest association between effort test performance and some MMPI–2 validity scales (e.g., Fb, FBS: Larrabee, 2003a; Nelson, Sweet, & Heilbronner, 2007b), though other studies have found little to no association (Gervais, Wygant, & Ben-Porath, 2005; McCaffrey, O'Bryant, Ashendorf, & Fisher, 2003). This is perhaps not surprising because the standard MMPI–2/PAI validity scales are best suited for identifying blatant exaggeration of psychopathology (with the exception of FBS), not exaggerated postconcussion symptoms. Prompted by the modest association between effort test performance and the MMPI–2 validity scales, Gervais and colleagues (Gervais, Ben-Porath, Wygant, & Green, 2007) developed the MMPI–2 Response Bias Scale (RBS), designed specifically to predict effort test failure. To date, validation studies of the RBS have been promising, with researchers illustrating the clinical utility of the RBS to differentiate individuals who pass/fail effort testing (Gervais et al., 2008; Larrabee, 2008; Whitney, Davis, Shepard, & Herman, 2008) or those classified as having secondary/no secondary gain (Nelson et al., 2007b).

When we compare the methodology of the present study to the PAI/MMPI–2 literature above, there is only a marginal parallel between the self-reported symptoms used in this study (i.e., postconcussion symptoms/cognitive complaints) and the self-reported symptoms used to derive the traditional validity scales of the MMPI–2/PAI. However, a stronger parallel can be drawn between the self-reported symptoms in this study and the self-reported symptoms used to derive the RBS. Almost half of the items on the RBS relate to cognitive complaints and/or postconcussion-like symptoms (e.g., Items 31, 40, 97, 106, 147, 149, 165, 168, 229, 299, 309, 330). In addition, almost one third of the items of the RBS overlap with MMPI–2 scales associated with symptoms of depression (D) and somatic complaints (Hy) that are commonly reported following MTBI. With these similarities in mind, the results of this study are relatively consistent with much of the RBS literature that suggests an association between effort test failure and self-reported symptoms as measured by the RBS. Notably, however, Gervais and colleagues (Gervais et al., 2008) reported a weak relation between the RBS and performance on objective cognitive testing. Exploratory analyses of our own data suggest that the reverse is true in our sample of MTBI. Significant correlations were found between self-reported postconcussion symptoms (i.e., PCS total score) and the Attention ($r = -.40$, $p = .016$) and Memory Index ($r = -.40$, $p = .013$) of the S-NAB, but not the Executive Functioning Index ($r = -.06$, $p = .722$). However, there were no significant correlations found between self-reported cognitive complaints (i.e., BC-CCI total score) and the Attention ($r = -.18$, $p = .287$), Memory ($r = -.18$, $p = .277$), or Executive Functioning ($r = -.15$, $p = .378$) indexes.

As seen in Table 3, the neuropsychological test performance of patients who passed the TOMM was broadly normal, and for those who failed the TOMM it was impaired. This, obviously, is critical to appreciate. These workers were seen on average two months post injury. Had we not done effort testing, we would have assumed that a subset of them were frankly cognitively impaired. Instead, the performance of those who passed the TOMM was broadly normal and consistent with the literature on good neuropsychological outcome following MTBI (Belanger, Curtiss, Demery, Lebowitz, & Vanderploeg, 2005; Belanger & Vanderploeg, 2005; Carroll et al., 2004; Iverson, 2005; Ruff, 2005; Schretlen & Shapiro, 2003). To our knowledge, our study is the first study to evaluate the influence of cognitive effort test performance on the S-NAB in a clinical setting. The only other data currently available relate to data from an analog malingering study presented in the test manual (White & Stern, 2003) in which 50 healthy participants completed the S-NAB under instructions to feign cognitive impairment. When comparing the performance of the small number of patients with MTBI who failed effort testing in our study, there is remarkable similarity across two of the three indexes examined in this study. For the Attention and Memory indexes, on average, there were fewer than 3 index score points between the two groups (analog malingering study: Attention, $M = 68.5$, $SD = 17.9$; Memory, $M = 80.4$, $SD = 14.6$; current study: Attention, $M = 72.1$, $SD = 21.1$; memory, $M = 80.6$, $SD = 17.1$), and there was a similar number of participants in both groups with scores that fell less than the 16th percentile (analog malingering study: Attention = 78.5%; Memory = 64.7%; current study: Attention = 75.0%; Memory = 50.0%). For the Executive Functioning Index, the average performance of the analog malingering study participants was lower (analog malingering study: $M = 78.1$, $SD = 14.9$; current study: $M = 86.5$, $SD = 15.0$), and there was a greater proportion of participants with scores less than the 16th percentile (analog malingering study = 70.6%; current study = 37.5%). Nonetheless, the performance of the two groups is generally similar.

This study has several limitations. First, the patients were receiving financial compensation from the Workers' Compensation Board for their injury. As a result, the findings of this study are not necessarily generalizable to the broader adult civilian MTBI population. They might be more applicable to clinical samples that are receiving or seeking to receive financial compensation for their injury. Second, neuropsychological screening was not administered to all patients primarily due to a lack of time and resources allocated to the concussion clinic. The primary goal of the concussion clinic was to provide a brief intake evaluation for all patients. The focus of the intake evaluations was on the patients' psychological and neurobehavioral outcome. Although it is possible that this represented some form of systematic bias in our sample, we cannot think of how this might be the case—with the exception of people with English as a second language being less likely to undergo screening. Once initiated, the cognitive screening was always completed, so very slow performance and poor effort did not lead to discontinuation of the evaluation and exclusion from the analyses due to missing data. More cases underwent screening in the first 18 months, following which there was a gradual shift toward testing fewer cases. We do not believe this practice pattern created a systematic bias in the data, however. Third, only a single effort measure was used to assign participants to the TOMM fail group. One of the limitations of the TOMM is that some people who are giving poor or inadequate effort will not be identified on this test (DenBoer & Hall, 2007). As such, we may have failed to identify some people who were underperforming on testing. Although it is possible that some patients in our sample may have been misidentified, we do not feel that these factors would have changed the overall results of the study. Finally, the number of MTBI patients who failed the TOMM was much smaller than the group who passed the TOMM. Furthermore, only 8 patients who failed the TOMM were also administered the neurocognitive battery. Although the effect sizes were substantial, the small sample size makes it difficult to determine whether this was a representative sample of patients with MTBI, who were seeking financial compensation, and who failed effort testing.

The postconcussion syndrome is poorly understood and remains controversial. There are a myriad of factors, other than brain injury, that can influence, maintain, and/or mimic the persistent postconcussion syndrome (e.g., nonspecificity of symptoms, comorbidities, personality, interview method, depression, and social–psychological explanations). The results from this study highlight the influence of poor effort on both objective neurocognitive measures and self-report inventories. It is critical to consider issues of poor effort and possible symptom exaggeration when considering a diagnosis of postconcussion syndrome.

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