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The prognostic value of a screening tool for psychological risk factors after mild traumatic brain injury: prospective studies in Canada and New Zealand

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ABSTRACT

Objective To investigate the prognostic value of the Subgroups for Targeted Treatment (STarT) Screening Tool adapted for concussion (STarT-C) on persistent symptoms and disability at 6–9 months following mild traumatic brain injury (mTBI).

Design Secondary analysis of two prospective studies: an observational cohort study in New Zealand and usual care control arm of a clinical trial in Canada (ClinicalTrials.gov Registry (NCT04704037)).

Setting Participants in the New Zealand cohort were recruited from concussion clinics (five sites) and those in the Canadian cohort were recruited from emergency departments/urgent care centres (eight sites).

Participants New Zealand participants (n=93, median age 37 years, 60% women) were assessed at median=6 weeks post-injury (T1) and 6 months later (T2). Canadian participants (n=223, median age 38 years, 56% women) were assessed at median=2 weeks (T1) and 6 months later (T2).

Main outcome measures Symptoms at T2 were assessed using the validated Rivermead Postconcussion Symptoms Questionnaire (RPQ) and disability using the WHO Disability Assessment Schedule 2.0 12-item Interview.

Results In linear regression analyses, the STarT-C predicted symptom burden (R^2=18–36%) and disability (R^2=15–18%) at T2 in both cohorts. While the additional prognostic value over and above baseline variables was substantial (delta R^2 8–40%), the additional prognostic value over the RPQ at T1 was variable and generally lower (delta R^2=1–9%).

Conclusion The STarT-C—a brief screening tool—predicted persistent symptoms and disability in adults following mTBI. The incremental prognostic value of the STarT-C over the RPQ may be variable, but regardless, the tool may be useful for identifying those at risk of prolonged recovery who may benefit from early psychological intervention.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ We investigated the tool in two independent datasets that were prospectively collected in two different settings.
⇒ We assessed the incremental prognostic value over and above known predictors and reported the performance measures corrected for optimism.
⇒ The sample size of individual cohorts was relatively modest.
⇒ The effect of timing on the prognostic value of the tool cannot be disentangled from other factors.

INTRODUCTION

Each year, approximately 55 million people worldwide sustain a mild traumatic injury (mTBI).[1 2] A recent meta-analysis found that 18–31% of adults report persistent symptoms and 54% have functional limitations at 6 months post-injury.[3] Identifying who is at increased risk of poor outcomes is a top priority for researchers,[4] clinicians and people with lived experience of mTBI,[5] but to date, has been a major challenge.[4 6] Our inability to accurately predict outcomes after mTBI impedes clinical and resource management.

Although there is still no accepted risk stratification method to support clinical decision making in adults with mTBI, knowledge about prognostic factors has been rapidly accumulating.[4 7–10] Sociodemographic (eg, gender) and clinical (eg, psychiatric history) variables and, in particular, early symptoms have shown associations with persistent symptoms and disability at 6 months after mTBI.[7 8] However, a large percentage of variation in outcomes remains unexplained by these variables.[8 11] Apart from early symptoms, malleable psychological factors, including illness beliefs and coping, have emerged as strong predictors of mTBI outcome.[12–14] For instance, expecting a protracted recovery and avoiding usual activities due to fear of symptom exacerbation are linked to worse outcomes. Importantly, these factors are not only prominent predictors but also potential treatment targets.[15]

Psychological factors have not been routinely assessed as part of usual care after mTBI.[16 17] A major barrier to assessing psychological factors in clinical practice is that measuring relevant constructs requires a lengthy battery of questionnaires. A similar challenge in the assessment and prediction of disability was overcome in the management of low back pain by developing the Subgroups for Targeted Treatment (STarT) Back.[18] This brief screening tool (nine items) measures physical symptoms and psychological risk factors. It was designed to be readily deployable in primary care to improve risk stratification and guide stratified care. Generally, the STarT Back demonstrated a good ability to identify individuals who were at elevated risk for persistent disabling back pain[19–21] and who required early intervention,[21–24] and showed comparable performance to lengthier screening questionnaires.[22 25]

This study is the first to examine a new adaptation of the STarT Back tool for mTBI, also known as concussion (hereafter, referred to as the STarT-Concussion, or STarT-C). The STarT-C measures physical symptoms associated with concussion/mTBI and the same psychological risk factors as the original tool. It could be used alone or together with a recommended symptom inventory.[26 27] The STarT-C could inform early referral after mTBI to specialist care, or in the context of concussion clinic intake, streamline assessment to help identify which patients require deeper psychological characterisation. We studied the STarT-C in two prospective studies conducted in parallel in two geographical locations and clinical settings. We aimed to assess the prognostic value of the STarT-C for persistent symptoms and disability after mTBI, and its additional prognostic value over and above baseline predictors and a symptom inventory.

METHODS

Study population

This study involved a secondary analysis of two independent datasets: an observational cohort study in New Zealand ('New Zealand cohort') and the usual care control arm of a clinical trial[28] (ClinicalTrials.gov: NCT04704037) in British Columbia, Canada ('Canadian cohort'). Both studies have been approved by the local institutional review boards. The New Zealand cohort study examined psychological predictors of outcomes after mTBI. The Canadian trial examined the effectiveness of a practice guideline implementation tool for mental health screening in primary care.[28] The key methodological characteristics and differences between these datasets are summarised in table 1. In brief, the New Zealand study recruited adult patients presenting to concussion clinics within 90 days post mTBI.[29] The Canadian cohort study recruited adult participants who

Table 1 Characteristics of two studies: New Zealand cohort and Canadian cohort

Study location	New Zealand	Greater Vancouver, British Columbia, Canada
Study design	Observational cohort; participants randomised (5:1) to standard group (two study visits and monthly phone follow-ups) or control group (one study visit).	Clinical trial; participants randomised (1:1) to usual care control group or an experimental intervention.
Recruitment location	Concussion clinics (five sites)	Emergency departments and urgent care centres (eight sites)
Data collection time	February 2019 to October 2021	February 2021 to May 2023
Inclusion criteria	Mild TBI (WHO Neurotrauma Task Force definition); >16 years; <90 days since injury	Mild TBI (WHO Neurotrauma Task Force definition); 18–69 years; presentation within 72 hours of injury
Exclusion criteria	Non-mTBI-related injuries requiring hospital admission or a severe unstable medical condition not related to the mTBI (eg, cancer)	Prior mTBI within 6 months preceding the index injury, a pre-existing severe and unstable medical (eg, cancer) or psychiatric condition (eg, psychotic disorder requiring hospital admission in the previous year)
Total N recruited	145, n=110 randomised to standard group	537, n=254 randomised to control group
Time 1 (T1) assessment	<90 days post-injury (median 6 weeks)	2 weeks post-injury (median 15 days)
Time 2 (T2) assessment	6 months after T1 (median 31 weeks post-injury)	6 months post-injury
Sample for the primary analysis of this study	Participants randomised to standard group with T1 and T2 assessments; n=93	Participants randomised to control group with T1 and T2 assessments; n=223

mTBI, mild traumatic brain injury; TBI, traumatic brain injury.

Table 2 Distribution of the STarT-C items and the total score at T1 (New Zealand cohort: median 6 weeks post-injury/ Canadian cohort: 2 weeks post-injury)

	New Zealand cohort	Canadian cohort
n	93	223
STarT-C total score (median (IQR))[1]	6 (4, 7)	5 (4, 7)
STarT-C psychological subscore (median (IQR))	2 (1, 3)	2 (1, 3)
STarT-C risk categories (%)		
Low risk	18 (19.4)	47 (21.1)
Medium risk	56 (60.2)	125 (56.1)
High risk	19 (20.4)	51 (22.9)
Items		
Overall, how bothersome have your concussion symptoms been in the last 2 weeks?		
Not at all	0 (0)	8 (3.6)
Slightly	11 (11.8)	40 (17.9)
Moderately	25 (26.9)	75 (33.6)
Very much	43 (46.2)	72 (32.3)
Extremely	14 (15.1)	28 (12.6)
Bothersomeness=very much/extremely (%)*	57 (61.3)	100 (44.9)
I have had headaches at some time in the last 2 weeks=agree (%)	87 (93.5)	204 (91.5)
I have had neck pain at some time in the last 2 weeks=agree (%)	76 (81.7)	177 (79.4)
It is not really safe for a person with a condition like mine to be physically active=agree (%)*	32 (34.4)	118 (52.9)
I have felt too tired to do work or daily activities in the last 2 weeks=agree (%)	72 (77.4)	165 (74.0)
Turning my head quickly makes me feel dizzy or unsteady=agree (%)	61 (65.6)	138 (61.9)
Worrying thoughts have been going through my mind a lot of the time in the last 2 weeks=agree (%)*	51 (54.8)	132 (58.9)
I feel that my concussion symptoms are terrible and are never going to get any better=agree (%)*	10 (10.8)	22 (9.9)
In general, in the last 2 weeks, I have not enjoyed all the things I used to enjoy=agree (%)*	58 (62.4)	1 (57.4)

[1]New Zealand cohort: 3 participants did not respond to one (n=2) or all (n=1) items; Canadian cohort: 10 participants did not respond to one (n=8), two (n=1) or three (n=1) items.
*Items used for psychological subscore.
STarT-C, Subgroups for Targeted Treatment Screening Tool adapted for concussion; T1, time 1.

presented to an emergency department (ED) or urgent care centre within 72 hours of mTBI.[29]

Measures

Predictor variables

Baseline sociodemographic and injury variables were self-reported and/or derived from clinical records. We selected the most prominent baseline predictors of outcome from previous prognostic modelling studies[7 8] that were available in both datasets: age, gender, education, race/ethnicity, pre-injury depression or anxiety, and previous TBI. We assessed non-linear effects for age.

Questionnaires at T1

Questionnaires were first administered at the median of 6 weeks post-injury (Q1–Q3: 5–8) in the New Zealand cohort and at the median of 15 days (Q1–Q3: 12–18) in the Canadian cohort.

The STarT-C (table 2; Online supplemental Appendix 1) consists of nine items, including eight binary (agree/disagree) items assessing symptoms and psychological risk factors and one item that queries bothersomeness of symptoms from 0 (not at all) to 4 (extremely). Compared with the original STarT Back tool, the items identifying symptoms characteristic to back pain (pain spreading down leg(s), shoulder or neck pain, walking only short distance, dressing more slowly) were modified to identify symptoms characteristic to mTBI/concussion (headache, neck pain, fatigue, dizziness with head movement). The total score, ranging from 0 to 9, was calculated as the sum of all items, with item 'bothersomeness' dichotomised, as with the STarT Back (online supplemental Appendix 1).[18] The total score was not calculated for participants with missing responses to one or more STarT-C items, and they were excluded from the analyses. Using the STarT

Back tool algorithm (online supplemental Appendix 1),[18] we derived the psychological subscore and risk categories: low risk (psychological support likely not needed), medium risk (monitor the need for psychology referral) and high risk (refer to psychology).

The Rivermead Postconcussion Symptoms Questionnaire (RPQ) measured the severity of 16 symptoms that commonly occur following mTBI, on a scale from 0 ('never experienced') to 4 ('severe problem'). The total RPQ score was calculated as the sum of all RPQ items, with responses 1 ('same as before the injury') counted as 0. A higher score indicates a higher severity of symptoms. When <15% of responses (≤2 items) were missing, they were replaced using a prorating method (see table 3).[30]

Outcomes at T2

Outcomes were assessed at 6 months following T1. The RPQ was used to assess the severity of persistent symptoms. Missing items were handled as described for T1 (see table 3).

The WHO Disability Assessment Schedule 2.0 12-item Interview version was used to assess overall disability. It includes 12 items measuring cognition, mobility, self-care, interpersonal functioning, life activities and community participation on a scale of 0–4 for each item. We used Rasch transformation of the total score from ordinal to interval scale with a maximum score of 48, where higher scores indicate greater disability.[31] When <15% responses (one item) were missing, they were replaced by mean responses to other items (see table 3).[32]

Statistical analyses

We described participant characteristics, baseline predictors and responses to questionnaires in terms of median (with IQR) and frequencies. We reported the frequency of responses to each STarT-C item. To examine the prognostic value of the STarT-C total score and risk stratification, we performed ordinary least squares regression analyses. We reported the proportion of explained variance (R^2).

To examine the overall additional prognostic value of the STarT-C, we compared models with (a) baseline predictors, (b) the RPQ at T1 and (c) baseline predictors and the RPQ at T1 with models (a)–(c) plus the STarT-C total score/psychological subscore using the likelihood ratio (LR) test. We quantified the difference between models in terms of the increase in R^2 (ie, delta R^2). We visualised the differences using histograms of the predicted values for a reference model and a new model: if the additional predictor is useful, a second histogram is expected to be widened, with increased variance. We reported delta R^2 after correcting for optimism (delta R^2 without this correction is reported in Appendix 2online supplemental Appendix 2). The optimism and CIs were derived using a bootstrapping procedure with n=500 random samples.

To examine the prognostic value of the individual STarT-C items and their additional prognostic value over the RPQ total score, we analysed the associations between the items at T1 and outcomes at T2 using univariable and multivariable ordinary least squares regression analyses. We quantified the associations by regression coefficients and 95% CIs. The analyses were performed in R Studio V.4.2.1, using rms[33] and forestplot[34] packages.

Patient and public involvement

Patients or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this secondary analysis.

RESULTS

Study population

We analysed n=93 participants in the New Zealand cohort and n=223 in the Canadian cohort who completed T1 and T2 assessments (flow chart in online supplemental Appendix 3). In both datasets, the majority of participants were aged 30–50 years, identified as women and as being white, and had a postsecondary degree (table 3). A notable percentage of participants reported a history of anxiety or depression (New Zealand: 60%; Canada: 40%).

Distribution of STarT-C scores and items

The STarT-C total scores were approximately normally distributed in both datasets, slightly skewed towards higher values, which indicate higher risk (online supplemental Appendix 4). Using the risk classification algorithm, about 20% of participants in both cohorts were categorised as low or high risk, and the remainder as medium risk (table 2). The response frequencies for individual items were similar in both datasets (table 2). The most skewed responses were obtained for the following items: "I have had headaches at some time in the last two weeks" (>90% of participants agreed), and "I feel that my concussion symptoms are terrible and are never going to get any better" (~10% agreed).

The prognostic performance of the STarT-C

The StarT-C risk stratification was prognostic of outcomes at T2 (figure 1): the level of symptoms and disability aligned with the risk category (with less distinction in disability between the medium-risk and high-risk groups in the New Zealand cohort). Accordingly, the STarT-C total score predicted persistent symptoms and explained 36% (95% CI 25 to 47%) of variation in persistent symptoms in the New Zealand and 18% (95% CI 9 to 26%) in the Canadian cohort. Furthermore, the STarT-C total score predicted disability and explained 18% (95% CI 7 to 32%) of variation in disability in the New Zealand cohort and 15% (6 to 24%) in the Canadian cohort.

The additional prognostic value of the STarT-C for the prediction of outcomes after mTBI

Persistent symptoms

The baseline model in the New Zealand cohort did not explain variation in persistent symptoms (table 4), and the addition of the STarT-C markedly increased the R^2

Table 3 Baseline characteristics: participants included in the analyses

New Zealand cohort		Canadian cohort	
n	93	n	223
Age (median (IQR))	37.02 (28.41, 52.62)	Age (median (IQR))	38.00 (28.00, 51.25)
Gender=men (%)	37 (39.8)	Gender=men (%)	94 (42.2)
		Other (%)*	3 (1.3)
Ethnicity		Ethnicity	
New Zealand European	69 (74.2)	White	143 (64.7)
New Zealand Māori (indigenous)	6 (6.5)	East/SE Asian	44 (19.9)
Asian	4 (4.3)	South Asian	13 (5.9)
		Indigenous	5 (2.3)
		Latinx	3 (1.4)
		Middle Eastern	3 (1.4)
Other†	14 (15.1)	Other Prefer not to say/missing	4 (1.8) 7 (2.7)
Education		Education	
Less than high school‡	9 (9.7)	Less than high school‡	2 (0.09)
High school quals	26 (28.0)	High school	39 (17.5)
Post high-school training	26 (28.0)	Post high school training	55 (24.7)
Tertiary	32 (34.4)	Tertiary	127 (57.0)
Preinjury depression/anxiety	55 (59.8)	Previous depression/anxiety	90 (40.4)
Previous TBI	46 (49.5)	Previous TBI	84 (37.7)
Cause of injury		Cause of injury	
Fall/head to object	30 (34.1)	Fall/head to object/(other)	114 (51.1)
MVA/road (bicycle)	28 (31.8)	MVA/road (bicycle)	49 (22.0)
Assault	7 (8.0)	Assault	13 (5.8)
Other	23 (26.1)	Sport	47 (21.6)
LOC		LOC	
Yes	44 (47.3)	Yes	54 (24.2)
No	42 (45.2)	No	117 (52.0)
Unknown	7 (7.5)	Unknown	53 (23.8)
Time to T1, weeks (median (IQR))	6 (5, 8)	Time to T1, days (median (IQR))	15 (12, 18)
RPQ T1 total score§ (median (IQR))	32 (25, 38)	RPQ T1 total score¶ (median (IQR))	21 (11, 33)
Outcomes at T2			
RPQ total score** (median (IQR))	11 (6, 20)	RPQ total score†† (median (IQR))	10 (2, 29)
WHODAS Rasch total score‡‡ (median (IQR))	18.9 (17.41, 21.65)	WHODAS Rasch total score§§ (median (IQR))	11.23 (4.09, 16.88)

*For analyses combined with 'Women' due to small frequency.
†n=1 Latino, N=1 South African, n=12 European.
‡For analyses combined with 'high school' due to small frequency.
§Prorating scores for n=2 participants missing 1 item and n=1 missing 2 items.
¶Prorating scores for n=15 participants missing 1 item and n=1 missing 2 items.
**Prorating scores for n=5 participants missing 1 item.
††Prorating scores for n=10 participants missing 1 item.
‡‡Prorating scores for n=4 participants missing 1 item.
§§Prorating scores for n=1 participant missing 1 item.
LOC, Loss of consciousness; MVA, Motor vehicle accident; RPQ, Rivermead Postconcussion Symptoms Questionnaire; T1, Time 1; T2, Time 2; TBI, traumatic brain injury; WHODAS, WHO Disability Assessment Schedule 2.0.

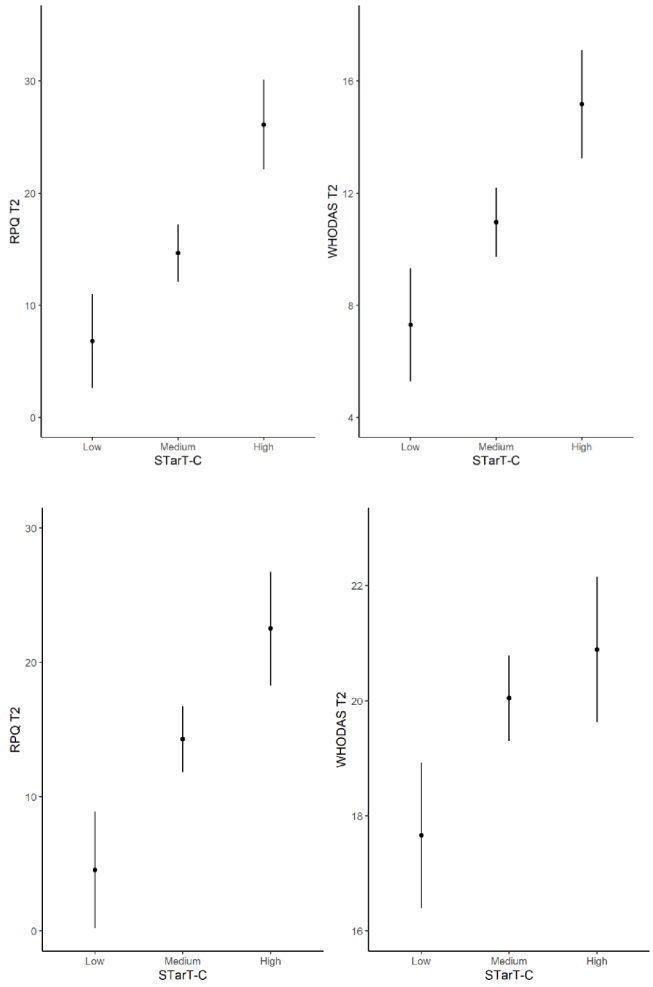

Figure 1 Prediction of persistent symptoms (RPQ) and disability (WHODAS) at T2 by the STarT-C risk stratification (estimates with 95% CIs) (*upper: New Zealand cohort, under: Canadian cohort*). RPQ, Rivermead Postconcussion Symptoms Questionnaire; STarT-C, Subgroups for Targeted Treatment Screening Tool adapted for concussion; T2, time 2; WHODAS, WHO Disability Assessment Schedule.

(table 4; online supplemental Appendix 5). The addition of the STarT-C to the RPQ improved the model fit and notably increased the R^2 (table 4). The psychological subscore also showed additional prognostic value over the RPQ with slightly smaller increase in the R^2 compared with the total score (table 4).

When added to the baseline model in the Canadian cohort, the STarT-C substantially improved the prognostic performance (table 4; online supplemental Appendix 6). However, adding the STarT-C to the models with the RPQ only or the baseline model plus the RPQ did not significantly improve the model fit (table 4). These patterns were also obtained for the additional prognostic value of the psychological subscore (table 4).

Disability

In the New Zealand cohort, the baseline model for the prediction of disability had a poor model fit, and the addition of the STarT-C increased the R^2 (table 4; online supplemental Appendix 7). The addition of the STarT-C total score, or the psychological subscore, did not improve the model with the RPQ only (table 4). The results were consistent for the baseline+RPQ model (table 4).

In the Canadian cohort, adding the STarT-C to the baseline model led to better model performance (table 4, online supplemental Appendix 8). The STarT-C showed a small additional prognostic value for disability compared with the RPQ model and to the baseline model plus the RPQ (table 4). Similarly, the psychological subscore improved the baseline model (table 4), but the added value to the RPQ and to the baseline model plus the RPQ was negligible (table 4).

The associations between the STarT-C items and outcomes at T2

The individual items of the STarT-C were associated with persistent symptoms at T2 in both cohorts (online supplemental Appendix 9). In both datasets, items assessing anxiety, bothersomeness of symptoms, fatigue and dizziness were significantly associated with disability (online supplemental appendix 10). After adjusting for the RPQ at T1, the associations were weaker for all items. Items measuring neck pain in the Canadian cohort and anxiety in the New Zealand cohort were significantly associated with persistent symptoms when adjusted for the RPQ at T1. The item measuring anxiety remained significantly associated with disability after the adjustment (online supplemental appendix 10).

DISCUSSION

We adapted a brief questionnaire for assessing the risk of poor outcome and the need for psychological intervention from the low back pain field (STarT Back tool), and examined its prognostic value in two mTBI cohorts. In both cohorts, the STarT-C was prognostic of persistent postconcussion symptoms and disability assessed 6 months later and consistently showed additional prognostic value over and above baseline variables. The additional prognostic value over a commonly used and recommended[27] measure of postconcussion symptoms, the RPQ, was variable and generally modest, and the strongest for predicting persistent symptoms in adults presenting to concussion clinics.

The prognostic performance of the STarT-C aligns with validation studies of the original STarT Back tool[18 21 23 35] with overall moderate performance for the prediction of disability associated with low back pain.[25] Additionally, we considered it important to examine its incremental prognostic value above and beyond readily available sociodemographic and clinical variables, and a measure of postconcussion symptoms. Symptom inventories such as the RPQ are strongly recommended for assessment after mTBI in primary care, specialist and research settings[26 27 36] and have established prognostic utility.[7 8 37] The additional prognostic value of the STarT-C over the RPQ for persistent symptoms was strongest in adults who

Table 4 The additional prognostic value of the STarT-C total and psychological subscore for the prediction of mTBI outcomes at 6–9 months post-injury in the New Zealand (n=93‡) and Canadian (n=223) cohort: change (delta) in optimism-corrected proportion of explained variance (R^2) and comparison of goodness-of-fit (LR χ^2)

Outcome	Persistent symptoms (RPQ)		Disability (WHODAS)	
	New Zealand	Canada	New Zealand	Canada
Reference	**Baseline* model**		**Baseline* model**	
R^2 % (95% CI)	−13 (−20 to −3)	10 (2 to 19)	6 (−6 to 16)	14 (6 to 23)
	Δ R^2 % (95% CI)		**Δ R^2 % (95% CI)**	
+ STarT-C	40 (26 to 54)	11 (5 to 19)	17 (6 to 33)	8 (3 to 16)
+ STarT-C subscore	31 (18 to 45)	8 (3 to 16)	10 (1 to 23)	6 (2 to 13)
	LR χ^2, p value		**LR χ^2, p value**	
+ STarT-C	4.20, p<0.001	3.16, p<0.001	1.91, p<0.001	2.56, p<0.001
+ STarT-C subscore	3.14, p<0.001	2.43, p<0.001	1.21, p<0.001	2.12, p<0.001
Reference	**RPQ model**		**RPQ model**	
R^2 % (95% CI)	28 (16 to 40)	27 (18 to 39)	17 (4 to 32)	17 (9 to 27)
	Δ R^2 % (95% CI)		**Δ R^2 % (95% CI)**	
+ STarT-C	9 (2 to 18)	1 (−1 to 4)	1 (−2 to 7)	1 (−1 to 5)
+ STarT-C subscore	7 (1 to 15)	0 (−1 to 2)	−1† (−3 to 3)	0 (−1 to 3)
		LR χ^2, p value	**LR χ^2, p value**	
+ STarT-C	1.44, p<0.001	3.43, p=0.06	2.73, p=0.10	5.60, p=0.02
+ STarT-C subscore	1.10, p<0.001	0.72, p=0.39	0.78, p=0.38	2.34, p=0.13
Reference	**Baseline*+RPQ model**		**Baseline*+RPQ model**	
R^2 % (95% CI)	17 (4 to 29)	28 (18 to 38)	10 (−3 to 25)	23 (14 to 32)
	Δ R^2 % (95% CI)		**Δ R^2 % (95% CI)**	
+ STarT-C	12 (4 to 22)	1 (−1 to 3)	2 (−2 to 10)	1 (−1 to 5)
+ STarT-C subscore	8 (2 to 17)	0 (0 to 2)	−1 (−3 to 6)	0 (−1 to 3)
	LR χ^2, p value		**LR χ^2, p value**	
+ STarT-C	1.58, p<0.001	3.43, p=0.06	4.73, p=0.03	6.21, p=0.01
+ STarT-C subscore	1.15, p<0.001	1.24, p=0.27	2.07, p=0.15	4.04, p=0.04

*Age, gender, education, ethnicity, previous mental health disorder, previous TBI.
†When optimism-corrected, it is possible that a more complex model has a lower R^2 than a less complex model.
‡n=92 in baseline models.
LR χ^2, likelihood ratio χ^2 test; RPQ, Postconcussion Symptoms Questionnaire; STarT-C, Subgroups for Targeted Treatment Screening Tool adapted for concussion; WHODAS, WHO Disability Assessment Schedule 2.0; Δ, delta.

presented to concussion clinics at a median of 6 weeks post-injury (New Zealand cohort). It was small to negligible in adults who were recruited from EDs/urgent care and assessed at 2 weeks post-injury (Canadian cohort), and was smaller for the outcome disability. The contribution of psychological factors typically increases over the weeks following mTBI.[38] Similarly, the performance of the STarT Back tool was shown to depend on the setting,[25 39] outcome[25] and timing,[40] and was found to be worse in the acute phase (<2 weeks).[41]

The STarT-C may have demonstrated incremental prognostic value over the RPQ in the New Zealand cohort because most New Zealand participants were highly symptomatic and there was less variability in T1- RPQ scores. We suggest that the STarT-C (total score or the psychological subscore only) has greater potential to refine prognosis and inform triaging in this setting, supplementing a symptom inventory such as the RPQ. In unselected (more heterogeneous) patients identified at EDs/urgent centres, a symptom inventory alongside other clinical indicators of prolonged recovery, for example, history of migraine may be sufficient.

One of the reasons for the limited additional prognostic value of the STart-C over the RPQ is a partial overlap between the symptoms assessed. For example, both query fatigue (albeit with differently worded items). However, some STarT-C items remained prognostic even after the adjustment for the RPQ, which suggests that they have unique prognostic value. In particular, 'worrying thoughts' showed unique associations with the outcomes, which is not surprising considering that anxiety is not assessed by the RPQ and has been shown to predict mTBI outcome.[42 43] Similarly, 'neck pain' predicts outcomes after mTBI,[9 44] but it is not included in the RPQ.

The STarT Back tool has been successfully implemented in primary care as a standalone tool to identify the risk of persistent disabling symptoms and target interventions according to risk.[45 46] TBIs classified as 'mild' are in several ways similar to low back pain: both conditions have a high prevalence, are associated with non-specific symptoms and are perpetuated at least in part by psychological factors. As a brief tool that measures both symptoms and psychological factors prognostic of outcome after mTBI, the STarT-C could be a useful screening tool in primary care settings, in which it is necessary to make rapid referral decisions. As in the field of back pain, adults at low risk could be offered a brief educational intervention, adults at medium risk could be referred to a treatment focused on the management of physical symptoms (eg, headache management, vestibular therapy and physiotherapy) and adults at high risk could be referred to a higher level of care that includes psychological therapy. Based on systematic reviews, no treatments for symptoms after mTBI are clearly effective for all symptomatic individuals,[47] and interventions tailored to risk profiles may lead to better recovery.

If used together, symptom inventories can provide more detailed insight into the type and severity of symptoms, whereas the STarT-C may inform on co-occurring psychological mechanisms requiring attention, such as maladaptive coping.[13 48–51] To optimise their use, the STarT-C items that measure physical symptoms (ie, overlap with the RPQ) could be replaced with items assessing other psychological constructs that appear important for mTBI recovery. The STarT-C does not cover psychological flexibility,[52 53] anxiety sensitivity,[54 55] somatic hypervigilance[56 57] and perceived injustice,[58 59] which may also contribute to mTBI outcomes. In a specialist context, the responses on the STarT-C individual items may inform assessment (ie, which lengthier instruments should be used) before targeted treatment.[15]

This study has some limitations. The two cohorts differed in multiple ways (geographical location, setting, time of assessment), such that we cannot isolate the individual effect of these factors on the prognostic performance of the STarT-C. Despite the differences between the cohorts, the patterns of responses to the STarT-C and the associations between the STarT-C and outcomes were similar in both cohorts. Another limitation was the relatively small sample size (n=93) in the New Zealand cohort; however, we prespecified analysed variables and reported model performance indices corrected for overfitting. Furthermore, the Canadian cohort does not include adults 70 years or older and people who experienced mTBI but only sought care from the general practicioners or other community providers, reducing generalisability. Enrolled participants had a relatively high rate of self-reported preinjury mental health disorders, potentially due to self-selection bias for a study targeting mental health following mTBI. The New Zealand sample included only treatment-seeking adults, which explains a relatively high rate of preinjury mental health disorders and pre-existing TBI. Preinjury depression/anxiety and previous TBI were self-reported and not extracted from medical records or assessed by validated instruments; therefore, it is possible that the rates were overestimated or underestimated.

In conclusion, the STarT-C was prognostic of persistent symptoms and disability in adults with a recent mTBI (Canadian cohort) and those seeking outpatient specialty care for persistent symptoms (New Zealand cohort). The incremental prognostic value of the STarT-C over the RPQ may be variable, but regardless, the tool may be useful for identifying those at risk of prolonged recovery who may benefit from early psychological intervention. This brief screening tool may be especially useful in time-limited clinical settings, where using more comprehensive measures of symptoms and psychological factors after mTBI is infeasible. Larger cohort studies should validate our results and determine the optimal timing for using the STarT-C. Particularly, additional research is needed to validate the prognostic performance of the STarT-C risk subgroups and investigate whether using the STarT-C to triage patients to targeted treatment improves mTBI outcomes.

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Ethics approval This study involves human participants. Approval for the New Zealand study was received from New Zealand's National Health and Disability Ethics Committee (ref 18/CEN/79). For Canadian study, all study procedures were approved by the University of British Columbia's Office of Research Ethics (H20-00562), Vancouver Coastal Health Research Institute and Provincial Health Services Authority. Participants gave informed consent to participate in the study before taking part.

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