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Defining asymptomatic status following sports concussion: fact or fallacy?

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ABSTRACT

The current management of sports concussion involves a return to the baseline 'asymptomatic' status prior to returning to play and training. Unfortunately, although the term 'asymptomatic' is widely used it has not been operationally defined. This review identifies the need to formally define the term 'asymptomatic' as used in sports concussion, discusses some of the challenges associated with its definition and offers some possible solutions for further debate. The operational definition of the term 'asymptomatic' may provide the stimulus for further informed discussion at a future meeting of the international Concussion in Sport group, and by other peak sports medicine bodies involved in management guideline development.

Determining the safe return-to-play (RTP) of an athlete following a sports concussion is a challenge for the sports medicine practitioner. The self-reported symptoms (eg, headache, dizziness) together with impaired balance and cognitive function play an important role in making RTP decisions.[1] The summary and agreement,[2 3] position[4] and consensus statements[1 5] agree that the athlete should be 'asymptomatic' at rest and with exertion (physical and cognitive) in order to safely return to the game or practice.

Historically, the term 'asymptomatic' has been a key component of most RTP guidelines. Although the term was not specifically used, Hughenholtz and Richard in 1982 recommended that the 'training and competition should be avoided for at least several days, until all associated symptoms and any structural abnormalities have completely resolved' (page 829) before returning the athlete to activity following a concussion.[6] Nelson *et al*[7] were probably the first to use the actual term 'asymptomatic' in their management guidelines in 1984 for an athlete with mild head injury. The authors suggested that 'the athletes should not be permitted to return to activity until they are asymptomatic' (page 107). Cantu[8] in 1986, in his RTP guidelines, defined the term asymptomatic as 'no headache, dizziness or impaired orientation, concentration or memory during rest or exertion' (page 79). Subsequently, others such as American Academy of Neurology,[9] Colorado Medical Society[10] have incorporated this term into their RTP guidelines.

The current RTP rehabilitation protocol[1] recommended by the international Concussion in Sport (CIS) group has also incorporated the term asymptomatic in their protocol. This protocol specifies that the athlete with a concussion should 'rest until asymptomatic' and follow a graded, stepwise activity during which 'the athlete should continue to proceed to the next level if asymptomatic at the current level' (page i78). However, no guidance is given as to what is meant by the term 'asymptomatic', thus leaving the decision to the judgment of the individual doctor.

The Oxford online dictionary defines the term 'asymptomatic' as 'producing or showing no symptoms'.[11] However, the use of the term asymptomatic in sports concussion is confusing as clinicians and researchers have not operationally defined the meaning of the term 'asymptomatic' for an athlete with a concussion. Moreover, it appears that the term is synonymous for descriptors such as the 'symptom-free' status of an athlete, 'complete resolution' of symptoms, 'absence' of symptoms, return to the 'preseason baseline' of the symptoms, or 'scores equivalent to those reported by the specific control groups' used in the studies. The aim of this critical review is to identify the need to formally define the term 'asymptomatic' as used in sports concussion, discuss some of the challenges associated with its definition and offer some possible solutions for further debate.

POSTCONCUSSION SYMPTOMS AND THEIR MEASUREMENT

The assumption of asymptomatic status in the sports concussion field/literature is generally based on the self-reported symptoms of the athlete. The description of symptoms following a sport concussion has largely been influenced by the literature on the non-sporting head injury population.[12 13] Barth *et al*[14] were among the first to validate the acute symptoms associated with sports concussion in a large prospective study. Subsequent studies[15–22] have established a set of common symptoms sensitive to the effects of sports concussion with some grouping them under three symptom clusters (cognitive, somatic and affective)[23–26] However, this clustering of symptoms remains speculative and further research is needed to validate this categorisation.

The self-report symptoms are most often documented using a symptom scale/checklist.[20 27 28] A systematic review by Alla *et al*[29] identified six core symptom scales/checklists and some 14 variants, which differed in their naming, number of symptoms measured and terminology used to describe symptom items. The scales/checklists also varied in their approach to measurement with some recording symptoms on a 7-point Likert Scale (0=none, 6=severe), and some measuring dichotomously as 'Yes' or 'No'. In all cases, all the

symptoms included are equally weighted. At present, there is no scale/checklist that is considered as a 'gold standard' in the measurement of symptoms following a concussion, although the Postconcussion Symptom Scale (PCS) included in the Sport Concussion Assessment Tool 2 (SCAT2)[1] may attain this status in the future.

The three most common measurement variables derived from the Symptom Scores reported by an athlete are; the total number of symptoms (Symptom Score), Symptom Severity Score and symptom endorsements. The total number of symptoms is the sum of the number of symptom items that were reported as more than zero on a symptom scale/checklist regardless of their severity. For example, presence of the symptom 'headache' can be mild (score of 1), moderate (score of 2–4) or severe (score of 5 or 6). The Symptom Severity Score is the sum of the individual symptom items multiplied by their severity. The Symptom Severity Score consist of scores ranging from 0 to 6 for each of the individual symptom items. In this context, the higher the severity (0–6) of the individual symptom item, the greater would be the score. The maximum possible Symptom Severity Score is calculated as number of symptom items in a scale/checklist multiplied by six (for a 7-point Likert Scale). Symptom endorsement is the number (often expressed as percentage) of participants reporting an individual symptom item. The total number of symptoms is recommended as the primary method of symptom scoring in the SCAT2, with an additional option of deriving Symptom Severity Score for serial symptom measurements; a method of tracking recovery over time. In theory, for an athlete to be considered as asymptomatic, both the total number of symptoms and the Symptom Severity Score have to be zero, a situation deemed to be more or less impossible.

SYMPTOM REPORTING

Symptoms are state dependent[30] and have a tendency to vary with the time and day of measurement,[31] emotional status/anxiety, attitude, motivation, honesty and the willingness of the individual[32] who is reporting these symptoms. Moreover, symptom reporting is subject to a large number of psychological and perceptual biases[33] and is influenced by age, sex,[34] education, preinjury and injury characteristics such as general health status,[35] psychiatric distress, pain and medication.[36–39] Furthermore, it is evidenced that symptom reporting is influenced by factors such as premorbid personality characteristics,[40] day-to-day stress[41 42] attentiveness to the body and measures of competence or control.[33] Several models[43–45] have been proposed to explain the sociopsychological basis of symptom reporting and have been reviewed elsewhere.[46] In particular, the 'good old days' bias[43] argues that individuals underestimate preinjury symptoms and show a tendency to attribute postinjury symptoms to the injury whether they are directly related to injury or not. However, this is not applicable in the absence of baseline data. Another contentious area in relation to symptom reporting is that athletes may under-report or deny the presence of their symptoms[47] due to multiple factors.[48]

In addition, age, sex[34] and interindividual variability in symptom recovery[49] also can influence Symptom Scores, as the method of data collection.[50 51] In a recent study, Iverson *et al*[52] established that patients with mild traumatic brain injury (n=61) reported higher symptoms on a standardised questionnaire (mean Symptom Severity Score of 9.1±3.2) when compared with an open-ended interview method (mean Symptom Severity Score of 3.3±1.9).

POSTCONCUSSION-LIKE SYMPTOMS AT REST IN THE NON-CONCUSSED POPULATION

At any given point in time, non-concussed individuals report/demonstrate a range of symptoms similar to those associated with a concussion. Gouvier *et al*[53] were among the first to examine the presence of symptoms (eg, irritability, fatigue) similar to those reported following a concussion in non-concussed university students. Subsequent studies (Table 1) investigating the base rates of postconcussion-like symptoms have found a range of Symptom Severity Scores (0–78) in the non-concussed populations. These studies have utilised a variety of symptom scales/checklists with the number of symptom items ranging from 10 to 37. University students were the target population in most of these studies. The overall conclusion from these studies was that postconcussion-like symptoms are prevalent in the non-concussed population. Fatigue, irritability, headaches, nervousness, anxiety, poor concentration, depression and sleeping problems were the most commonly reported symptoms documented in most of these studies.

Table 1 summarises the symptom profiles (Symptom Scores, Symptom Severity Score and endorsement) reported at rest in the non-concussed population. The Symptom Severity Scores ranged from 3.5 to 10.1 (SD±3.3 to 12.4) in these studies. In addition, a preliminary examination of the Symptom Severity Scores of the 60 studies included in our previous systematic review[29] was conducted to verify the base rates of Symptom Severity Scores. The scores ranged from 1.0 to 9.0 (SD±1.0 to 12.5) for the control groups and from 2.0 to 14.0 (SD±4.0 to 12.5) for the preseason baseline scores of the athletes who were concussed during the season in those studies. Furthermore, symptoms are also observed in wider non-concussed populations. Symptoms such as irritability, anxiety and nervousness, insomnia, psychosomatic reactions and depression were reported to have occurred in individuals who are exposed to a variety of civilian and natural disasters,[54–56] and world wars[57 58] sometimes several months later.

POSTCONCUSSION-LIKE SYMPTOMS AT REST IN MEDICAL AND INJURED POPULATIONS

Postconcussion-like symptoms have been shown to be prevalent in various categories of medical patients. Fox *et al*[59] examined the base rates of postconcussion-like symptoms in non-concussed patients (n=1116) visiting departments of neurology, internal medicine and family practice. Headache (47%), fatigue (46%), irritability (42%), impatience (38%), concentration difficulties (32%), memory problems (27%), dizziness (27%), visual problems (24%), ear ringing (21%) and sensitivity to noise (15%) were frequently reported by the patients in their study. In other studies, medical patients with gastrointestinal disorders[60] or chronic fatigue syndrome[61] showed symptoms such as headache, fatigue, concentration difficulties, nervousness, sleep disturbances, nausea/vomiting and irritability.

Similarly, other studies have found a range of postconcussion-like symptoms in patients with psychiatric problems,[62 63] orthopaedic and general trauma patients,[64–67] individuals with post-traumatic stress and anxiety disorders,[68 69] depressed individuals,[36 70 71] personal injury litigants,[63 72] patients with whiplash injuries[73] and in patients with chronic pain.[74–76] These studies have utilised a variety of symptom scales/checklists with the included a number of items ranging from 13 to

Table 1 Symptom profile of non-concussed population at rest

					Symptom profile								
						Symptom Severity Scores							
							Mean (SD)			Range			
Study	Sample size (mean age)	Scale	Items	Rating	SS mean (SD)	Max score	Combined	Male	Female	Combined	Male	Female	Endorsements
Gouvier *et al*[53]	49 (19.4 Years)	PCL	37	Y/N	NR	NA	NR	NR	NR	NR	NR	NR	Often impatient – 2% Often looses temper – 37% Difficulty becoming interested – 36%
Gouvier *et al*[91]	50 (19.1 Years)	PCL	37	Y/N	7.7 (5.4)	NA	NR	NR	NR	NR	NR	NR	NR
		PCL PCS	17	Y/N	3.7 (3.0)	NA	NR	NR	NR	NR	NR	NR	NR
Wong *et al*[92]	88 (19 Years)	PCL	37	Y/N	14.0 (6.8)	NA	NR	NR	NR	NR	NR	NR	Ringing in the ears – 49% Trouble remembering things – 47% Often have headaches – 43%
		PCL PCS	17	Y/N	6.3 (3.3)	NA	NR	NR	NR	NR	NR	NR	NR
Machulda *et al*[93]	179 (20.7 Years)	SRS	37	5-PL	18.1 (6.2)	148	27.5 (14.0)	NR	NR	NR	NR	NR	Anxiety – 87% Fatigue – 83% Concentration difficulty – 80%
Chan[85]	85 (33.9 Years)	RPSC	16	5-PL	NR	64	9.4 (8.0)	NR	NR	0 - 31	NR	NR	Longer time to think – 66% Poor concentration – 59% Forgetfulness – 59%
Iverson and Lange[86]	104 (23.4 Years)	BC-PSI-Sf	13	6-PL	7.1 (3.5)	65	NR	NR	NR	NR	NR	NR	Fatigue – 76% Irritability – 72% Feeling sad – 61%
Covassin *et al*[34]	1209 (NR)	PCS (ImP)	22	7-PL	NR	132	NR	7.3 (11.5)	10.1 (12.4)	NR	NR	NR	Fatigue – 49%* Headache – 34%* Sleeping less than usual – 33%*
Lovell *et al*[83]	1746 (NR)	PCS (ImP)	22	7-PL	NR	132	NR	4.6 (7.7)	7.9 (11.5)	NR	0–56	0–78	NR
Wang *et al*[94]	124 (22.7 Years)	RPSC	16	5-PL	NR	64	9.3 (NR)	NR	NR	NR	NR	NR	Fatigue – 77% Longer time to think – 60% Poor concentration – 59%
Shehata *et al*[87]	260 (20.5 Years)	SCAT PCS	25	7-PL	NR	150	4.2 (NR)	3.5 (NR)	6.3 (NR)	NR	NR	NR	Fatigue – 37% Drowsiness – 23% Neck pain – 20%
Garden *et al*[37]	93 (NR)	BC-PSI-Sf	13	6-PL	NR	65	NR	NR	NR	NR	NR	NR	Headache – 83% Fatigue – 82% Irritability – 78%
Garden and Sullivan[36]	96 (NR)	BC-PSI-Sf	13	6-PL	NR	65	NR	NR	NR	NR	NR	NR	Headache – 81% Fatigue – 81% Irritability – 78%
Piland *et al*[95]	1065 (19.8 Years)	HIS	9	7-PL	NR	54	4.7 (6.0)	NR	NR	NR	NR	NR	Fatigue – 45% Drowsiness – 39% Headache – 38%

*Females.
BC-CRP PCS, British Columbia Concussion Rehabilitation Programme Postconcussion Scale; BC-PSI-Sf, British Columbia Postconcussion Symptom Inventory-Short From; Combined, males and females; HIS, Head Injury Scale; NR, not reported; PCL, Postconcussion Checklist; PCS, Postconcussion Symptom Scale; PCS (ImP), ImPACT Postconcussion Symptom Scale; PL, point Likert Scale; RPSC, Rivermead Postconcussion Symptoms Checklist; SCAT PCS, Sport Concussion Assessment Tool Postconcussion Symptom Scale; SRS, Symptom Rating Scale; SS, Symptom Score.

44. Fatigue and headache were reported as the most commonly endorsed symptoms in these studies. Thus, a range of studies on non-concussed, medical and injured populations indicate a non-specific constellation of postconcussion-like symptoms.

POSTCONCUSSION-LIKE SYMPTOMS PROVOKED WITH EXERCISE IN THE NON-CONCUSSED POPULATION

Exercise is an integral part of most RTP guidelines and is a component of the recommended sports concussion management.[1] The RTP rehabilitation protocol proposed by the consensus group[1] emphasises the need for an athlete to remain asymptomatic with exercise for their resumption of activities (game or practice). While the presence of postconcussion-like symptoms is established in the non-concussed and medical populations at rest, similar symptoms are also shown to occur with exercise in the non-concussed population. Recently, three studies[77–79] have been conducted to explore the symptoms provoked by exercise in the non-concussed population. The intensity of exercise and the symptom scale/checklist used to document symptoms varied between these studies. Table 2 summarises Symptom Severity Scores reported in these studies, which varied from 3.1 to 16.1 (SD±4.8 to 12.4).

Thus a wide range of literature is suggesting that symptoms similar to those associated with a concussion are present in the non-concussed population at rest and with exercise. These studies further indicate that it is highly unlikely that a player would be able to achieve a score of zero on a symptom scale/checklist following a concussion. Therefore, it is necessary that the asymptomatic status is defined, and an acceptable level of Symptom Scores (base rate or normative) established at rest and with exercise in order to assist RTP decisions following a sports concussion. Recent literature[80 81] discussing mild traumatic brain injury emphasised the importance of considering base rates in the accurate diagnosis of a condition and its and clinical formulation.

MOVING TOWARDS AN OPERATIONAL DEFINITION OF 'ASYMPTOMATIC' IN SPORTS CONCUSSION – AT REST

The literature reviewed here suggests the presence of a range of postconcussion-like symptoms in non-concussed population using a variety of data collection instruments and strategies. Furthermore, exercise in controlled settings has been demonstrated to elicit an increase in Symptom Scores on instruments commonly used to measure postconcussion symptoms. This creates a potential problem in making RTP decisions as the consensus statement recommends that the athlete should be symptom-free at rest and with graded activity before returning to practice or games. The clinician is thus left with a dilemma, whether the Symptom Scores they record are related to a concussion, other injuries (eg, whiplash or cervicogenic headache) or simply indicative of the individual's general health status at the time of

Table 2 Symptom profile in non-concussed population with exercise

Variable	Alla *et al*[77]		Covassin *et al*[89]	Gaetz and Iverson[79]
Sample size (age range)	60 (18–35 Years)	60 (18–35 Years)	54 (18–24 Years)	75 (18–24 Years)
Scale/checklist	SCAT PCS	SCAT PCS	PCS (ImP)	BC-CRP PCS
Items	18	18	22	16
Rating	7-PL	7-PL	7-PL	NR
Exercise intervention	Moderate intensity	High intensity	Maximal exercise test	Aerobic exercise protocol
Symptom profile				
SS*				
Combined				
Pre	1.0 (2.9)	1.0 (1.7)	NR	NR
Post	1.5 (3.1)	4.0 (3.4)	NR	NR
Male				
Pre	0.7 (1.7)	1.2 (2.0)	NR	NR
Post	1.2 (2.1)	4.9 (3.9)	NR	NR
Female				
Pre	1.4 (3.7)	0.8 (1.4)	NR	NR
Post	1.9 (3.9)	3.1 (2.6)	NR	NR
SSS				
Combined				
Pre	4.5 (9.6)	3.4 (4.7)	<1 (NR)†	
Post	6.6 (10.5)	13.8 (11.6)	4.0 (NR)†	
Male				
Pre	4.1 (8.6)*	3.7 (4.8)	NR	4.0 (4.9)
Post	3.1 (4.8)*	16.1 (12.4)	NR	4.3 (5.1)
Female				
Pre	4.9 (10.6)*	3.0 (4.4)	NR	6.8 (8.2)
Post	3.9 (8.7)*	11.4 (10.4)	NR	4.6 (5.2)
Endorsements	Fatigue/low energy – 62%	Fatigue/low energy – 73%	NR	NR
	Pressure in head – 40%	Balance problems/dizzy – 70%		
	Difficulty concentrating – 28%	Don't feel right – 58%		

*Scores re-worked from the original data.
†Scores represent that reported for the symptom 'fatigue' and are interpreted from the graph.
BC-CRP PCS, British Columbia Concussion Rehabilitation Programme Postconcussion Scale; NR, not reported; PCS (ImP), ImPACT Postconcussion Symptom Scale; Pre, prior to exercise; Post, immediately following exercise; SS, Symptom Scores; SSS, Symptom Severity Scores.

assessment – whether at rest or following a period of physical and/or cognitive activity. Players could be erroneously kept from participation if they were considered to be symptomatic for the wrong reason (eg, following exercise). Thus there is a need to consider population-based reference scores or the athlete's own baseline scores, obtained several times preseason, when making a decision as to what constitutes an asymptomatic status. While the RTP decision is not made on symptom profiles alone they do represent one aspect of the multidimensional decision, along with balance and cognitive testing. In many community settings where there is a lack of infrastructure or non-availability of well-informed medical professionals, symptom profiles may play the predominant role in decision making.

Recently, two studies have indirectly tackled the operational definition of the term 'asymptomatic', though the purpose of these studies was not to define the asymptomatic status itself. Lau *et al*[82] used a Symptom Severity Score of less than 7 on a 22-item computerised ImPACT PCS[83] as one of the criteria to clear acutely concussed athletes to RTP. In addition, they did not allow the players to RTP if they presented with a headache or other symptoms such as dizziness or balance problems, which were the primary symptoms associated with the initial diagnosis of the athlete's concussion. In order to address the pragmatic question of when it as appropriate to ask a recently concussed player to participate in an exercise provocation research protocol, Alla[84] chose an arbitrary Symptom Severity Score of 7 or less on the 25-item SCAT2 PCS to define the asymptomatic status at rest. This was largely based on the presence of Symptom Severity Scores reported in the non-concussed population.[77 85–87] The choice of this value recognised that, on any given day, an individual is likely to report a number of symptoms even when they have not been concussed. The value represented the lowest 5% of the 150-point maximum score for the scale. As the exercise provocation protocol permitted/encouraged the athlete to stop the protocol if they felt an increase in symptoms, it was considered a responsible decision.

A number of theoretical and pragmatic approaches can be considered in operationally defining the asymptomatic status of an athlete following a concussion. There is a need to consider a number of factors such as the state dependent nature of symptoms, number of previous concussions, the scale/checklist under consideration, the choice of measurement variable (Symptom Score or Symptom Severity Score) and whether any symptom or subset of symptoms should be considered differently in the decision. The approaches presented below need to take into account whether the player is being assessed immediately following a suspected concussion, at rest or as part of an exertion protocol incorporating physical activity.

Return of all symptoms to zero

The strict interpretation of RTP recommendation requires all symptoms to be asymptomatic, that is, zero. Thus, by default, all the symptoms must return to zero (Symptom Severity Score=0) before a player is permitted to return to practice or a game. While, in keeping with the recommended criteria and providing the utmost caution this approach may be impractical. Moreover, this is an expectation which does not recognise the fact that any individual, player or not, is likely to present with a number of postconcussion-like symptoms unrelated to a concussion both at rest and following a period of physical activity (Tables 1 and 2).

Return of acute postconcussion symptoms to zero

Each player with a sports concussion presents with an individualised profile of symptoms. In this approach, 'asymptomatic' is defined as the return to zero of acute symptoms that were associated with the suspected diagnosis of a concussion. Thus, only the acute symptoms reported at the time of the concussion are considered and monitored for a return to zero, thereby allowing for the presence of other symptoms on the checklist. However, this approach does not take into account the 'state' variability associated with every day symptom reporting and the possible late appearance of some symptoms. Thus, the decision making could be contaminated by the presence of naturally occurring (state) symptoms.

Return of all symptoms to preseason baseline values

This approach is aligned with that used in objective neuropsychological testing and assumes a return of neuropsychological/cognitive function to preseason baseline values, thus individualising the decision and taking into account interindividual variance. The 'state' dependent nature of symptoms and other factors (eg, honesty, general health status) influencing the symptom reporting by an athlete make it challenging to set an absolute baseline value for any athlete. Moreover, although recommended, baseline values are not always obtained in many situations, particularly at the community level where most concussions occur. Thus, the absence of baseline values will prohibit this approach to decision making.

Setting a decision score based on population variances

Where population variances for a specified scale/checklist are readily available, then a decision rule such as that based on±2 SD could be used, as is often the case in psychometric testing.[88] However, the SD of the Symptom Scores reported are generally quite large (Table 1) and may not be practically useful in determining the asymptomatic status. Furthermore, this approach may result in a high number of false decisions and may allow players to return to the game while still presenting with a spectrum of symptoms. Thus, this approach may not be pragmatic until such time that larger data sets with more robust SD for the various symptom scales/checklists are available.

Setting a criterion-referenced cut-off score

This approach posits the development of a specific criterion value that is operationally defined as representing the 'asymptomatic' state. This would serve as a cut-off value to assist in clinical decision making. Considering just the total number of symptoms (Symptom Score) as a cut-off score would be problematic in a definition of asymptomatic status, as the presence of a single symptom does not provide information about its severity (graded 0–6), although a Symptom Score of 'zero' would negate this situation. Therefore, it is necessary that the Symptom Severity Score, coupled with the severity of the individual symptom item (graded 0–6), is considered in defining asymptomatic status.

It is challenging to establish a specific cut-off score, whether mathematically or by expert opinion.[1] Nevertheless, an examination of Symptom Severity Scores reported in the literature (Table 1 and 2) indicate that it might be prudent to consider a Symptom Severity Score of say 5 or less for males and 6 or less for females. This value seems to be representative of values reported for the general population, notwithstanding the various scales used. Although, currently not supported by

international guidelines, athletes with a concussion exhibiting scores (5 or less for males and 6 or less for females) may still be considered as asymptomatic for their RTP. However, while choosing to adopt a cut-off value, it is important to ensure that the athlete's neurological examination is normal and, balance and cognitive functioning have returned to baseline values.[1]

Despite their individual strengths and weaknesses, it is necessary to move forward and begin investigating the use of one or more of these approaches. It is timely to take a pragmatic view that athletes are probably been returned to play while their Symptom Scores are close to but not zero. The choice of any given approach should recognise the following; (1) the multiplicity of symptom scales/checklists, (2) number of symptom measurement variables, (3) recognition of population values, (4) differences in symptom reporting between males and females and (5) that any recommended approach needs to be of universal application and not limited to a specific tool.

With this in mind, we argue that a criterion-referenced approach is worthy and demands further investigation as a possible solution. We have proposed a conservative criterion value for Symptom Severity Scores of 5 or less for males and 6 or less for females based on our interpretation of data in Table 1. The use of a Symptom Severity Score in this range is likely to return the same decisional outcome no matter on what scale (Table 1) it is recorded, as these scores are also in keeping with population-based values. The criterion-referenced cut-off scores presented here are not set in stone but proposed to generate further debate and investigation.

MOVING TOWARDS AN OPERATIONAL DEFINITION OF 'ASYMPTOMATIC' IN SPORTS CONCUSSION – WITH EXERTION

Current recommendation is that the athlete needs to be asymptomatic at rest and with exercise before proceeding through the stepwise rehabilitation protocol. It is further recommended that 'if any postconcussion symptoms occur while in the stepwise programme, the patient should drop back to the previous asymptomatic level'.[1] The above proposed symptom severity cut-off scores (5 or less for males and 6 or less for females) can be useful in determining the readiness of an athlete to participate in an exercise protocol and offers guidance for progression through each stage.

However, further caution is needed in determining the asymptomatic status following a period of exercise as Symptom Severity Scores are elevated immediately following exercise in non-concussed individuals (Table 2). It is challenging to set a cut-off score following a period of physical exertion, whether it is game related or part of an exercise provocation protocol, as Symptom Scores can be significantly influenced by the intensity and fatiguing effects of exercise.[77 89] This can be addressed by the development of a standardised exercise protocol which models the internationally recommended RTP protocol. This could serve as a reference for obtaining baseline Symptom Scores. A preliminary, progressive exercise protocol[84] is recently been trialled to document the symptom responses in both non-concussed and concussed participants. This research direction will assist in the development of a modified cut-off score to account for the effects of the exercise situation.

This review has raised issues concerning the definition of the asymptomatic status in sports concussion symptom reporting and provides some options for consideration. Underpinning this discussion is the concern for the health and safety of the athlete following a concussive injury. The ultimate RTP decision depends primarily on the experience and judgement of the sports medicine doctor who may be confronted with medicolegal issues including potential litigation, which may arise if widely accepted recommendations and standards of care are not followed.[90] Since the current recommendations state that the athlete must be 'asymptomatic' before returning to activity it is important that sports medicine doctors are given some guidance on the meaning of this term to reduce the potential liability associated with their decision making. While the spirit of providing safe advice (asymptomatic) is contained in the consensus statement there is a need for further examination and discussion of what specifically is meant by the term 'asymptomatic' to provide a more quantitative and evidenced based criteria to assist in the RTP decision making. The operational definition of the term 'asymptomatic' may provide the stimulus for further informed discussion at a future meeting of the international CIS group and by other peak sports medicine bodies.

What is already known on this topic

- An athlete needs to be asymptomatic at rest and with exertion prior to returning to play following a concussion.
- Postconcussion-like symptoms are prevalent in the non-concussed population at rest and with exercise.

What this study adds

- There is a need to operationally define the term asymptomatic as used in the RTP decision making following a sports concussion.
- A number of options are provided to stimulate further discussion of the term 'asymptomatic' as used in the sports concussion field.

CONCLUSION

The term 'asymptomatic' is widely being used in the sports concussion literature, however, it has not as yet been formally defined. The term is potentially confusing and misleading considering the fact that the postconcussion-like symptoms are present in the non-concussed population at rest and with exercise. The intent of this paper is not to offer solutions but rather to raise the issue for further consideration.

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REFERENCES

1. **McCrory P,** Meeuwisse W, Johnston K, *et al.* Consensus Statement on Concussion in Sport: the 3rd International Conference on Concussion in Sport held in Zurich, November 2008. *Br J Sports Med* 2009;**43**(Suppl 1):i76–90.
2. **Aubry M,** Cantu R, Dvorak J, *et al.* Summary and agreement statement of the First International Conference on Concussion in Sport, Vienna 2001. Recommendations for the improvement of safety and health of athletes who may suffer concussive injuries. *Br J Sports Med* 2002;**36**:6–10.
3. **McCrory P,** Johnston K, Meeuwisse W, *et al.* Summary and agreement statement of the 2nd International Conference on Concussion in Sport, Prague 2004. *Br J Sports Med* 2005;**39**:196–204.
4. **Guskiewicz KM,** Bruce SL, Cantu RC, *et al.* National Athletic Trainers' Association Position Statement: Management of Sport-Related Concussion. *J Athl Train* 2004;**39**:280–97.

5. **Herring SA,** Bergfeld JA, Boland A, *et al.* Concussion (mild traumatic brain injury) and the team physician: a consensus statement. *Med Sci Sports Exerc* 2006;**38**:395–9.
6. **Hugenholtz H,** Richard MT. Return to athletic competition following concussion. *Can Med Assoc J* 1982;**127**:827–9.
7. **Nelson WE,** Jane JA, Gieck JH. Minor head injury in sports: a new system of classification and management. *Phys Sportsmed* 1984;**12**:103–7.
8. **Cantu RC.** Guidelines for return to contact sports after a cerebral concussion. *Phys Sportsmed* 1986;**14**:755–83.
9. American Academy of Neurology. Practice parameter: the management of concussion in sports (summary statement). Report of the quality standards subcommittee. *Neurology* 1997;**48**:581–5.
10. **Kelly JP,** Nichols JS, Filley CM, *et al.* Concussion in sports. Guidelines for the prevention of catastrophic outcome. *JAMA* 1991;**266**:2867–9.
11. Oxford Dictionaries. *Asymptomatic*. *Oxford Dictionary Online*. Oxford: Oxford University Press, 2010.
12. **Denny-Brown D.** Disability arising from closed head injury. *JAMA* 1945;**127**:429–36.
13. **Meyer A.** The anatomical facts and clinical varieties of traumatic insanity. *Am J Insanity* 1904;**60**:373–441.
14. **Barth J,** Alves WM, Ryan TV, *et al. Mild head injury in sports: neuropsychological sequelae and recovery of function*. In: Levin HS, Eisenberg HM, Benton AL, eds. *Mild Head Injury*. Oxford: Oxford University Press, 1989:257–75.
15. **Maddocks D,** Saling M. Neuropsychological deficits following concussion. *Brain Inj* 1996;**10**:99–103.
16. **Collie A,** Makdissi M, Maruff P, *et al.* Cognition in the days following concussion: comparison of symptomatic versus asymptomatic athletes. *J Neurol Neurosurg Psychiatr* 2006;**77**:241–5.
17. **Collins MW,** Iverson GL, Lovell MR, *et al.* On-field predictors of neuropsychological and symptom deficit following sports-related concussion. *Clin J Sport Med* 2003;**13**:222–9.
18. **Erlanger D,** Kaushik T, Cantu R, *et al.* Symptom-based assessment of the severity of a concussion. *J Neurosurg* 2003;**98**:477–84.
19. **Iverson GL,** Brooks BL, Collins MW, *et al.* Tracking neuropsychological recovery following concussion in sport. *Brain Inj* 2006;**20**:245–52.
20. **Lovell MR,** Collins MW. Neuropsychological assessment of the college football player. *J Head Trauma Rehabil* 1998;**13**:9–26.
21. **McCrea M,** Guskiewicz KM, Marshall SW, *et al.* Acute effects and recovery time following concussion in collegiate football players: the NCAA Concussion Study. *JAMA* 2003;**290**:2556–63.
22. **McCrory PR,** Ariens T, Berkovic SF. The nature and duration of acute concussive symptoms in Australian football. *Clin J Sport Med* 2000;**10**:235–8.
23. **Alexander MP.** Mild traumatic brain injury: pathophysiology, natural history, and clinical management. *Neurology* 1995;**45**:1253–60.
24. **Kelly JP,** Rosenberg JH. Diagnosis and management of concussion in sports. *Neurology* 1997;**48**:575–80.
25. **Leclerc S,** Lassonde M, Delaney JS, *et al.* Recommendations for grading of concussion in athletes. *Sports Med* 2001;**31**:629–36.
26. **Piland SG,** Motl RW, Ferrara MS, *et al.* Evidence for the Factorial and Construct Validity of a Self-Report Concussion Symptoms Scale. *J Athl Train* 2003;**38**:104–12.
27. CogSport (Computer software) (program). Parkville, Victoria, Australia: CogState Ltd, 1999.
28. **Randolph C,** Millis S, Barr WB, *et al.* Concussion symptom inventory: an empirically derived scale for monitoring resolution of symptoms following sport-related concussion. *Arch Clin Neuropsychol* 2009;**24**:219–29.
29. **Alla S,** Sullivan SJ, Hale L, *et al.* Self-report scales/checklists for the measurement of concussion symptoms: a systematic review. *Br J Sports Med* 2009;**43**(Suppl 1):i3–12.
30. **Mathews G,** Deary IJ, Whiteman MC. *Stable Traits and Transient States*. Leiden: Cambridge University Press, 2009.
31. **Lewandowski L,** Rieger B, Smyth J, *et al.* Measuring post-concussion symptoms in adolescents: feasibility of ecological momentary assessment. *Arch Clin Neuropsychol* 2009;**24**:791–6.
32. **Bush SS,** Ruff RM, Tröster AI, *et al.* Symptom validity assessment: practice issues and medical necessity NAN policy & planning committee. *Arch Clin Neuropsychol* 2005;**20**:419–26.
33. **Pennebaker JW.** *The Psychology of Physical Symptoms*. New York: Springer-Verlag, 1982.
34. **Covassin T,** Swanik CB, Sachs M, *et al.* Sex differences in baseline neuropsychological function and concussion symptoms of collegiate athletes. *Br J Sports Med* 2006;**40**:923–7; discussion 927.
35. **McLean SA,** Kirsch NL, Tan-Schriner CU, *et al.* Health status, not head injury, predicts concussion symptoms after minor injury. *Am J Emerg Med* 2009;**27**:182–90.
36. **Garden N,** Sullivan KA. An examination of the base rates of post-concussion symptoms: the influence of demographics and depression. *Appl Neuropsychol* 2010;**17**:1–7.
37. **Garden N,** Sullivan KA, Lange RT. The relationship between personality characteristics and postconcussion symptoms in a nonclinical sample. *Neuropsychology* 2010;**24**:168–75.
38. **Carroll LJ,** Cassidy JD, Peloso PM, *et al.* Prognosis for mild traumatic brain injury: results of the WHO Collaborating Centre Task Force on Mild Traumatic Brain Injury. *J Rehabil Med* 2004;**36**:84–105.
39. **Bailey CM,** Samples HL, Broshek DK, *et al.* The relationship between psychological distress and baseline sports-related concussion testing. *Clin J Sport Med* 2010;**20**:272–7.
40. **Greiffenstein MF,** Baker WJ. Comparison of premorbid and postinjury MMPI-2 profiles in late postconcussion claimants. *Clin Neuropsychol* 2001;**15**:162–70.
41. **DeLongis A,** Folkman S, Lazarus RS. The impact of daily stress on health and mood: psychological and social resources as mediators. *J Pers Soc Psychol* 1988;**54**:486–95.
42. **Larsen RJ,** Kasimatis M. Day-to-day physical symptoms: individual differences in the occurrence, duration, and emotional concomitants of minor daily illnesses. *J Pers* 1991;**59**:387–423.
43. **Gunstad J,** Suhr JA. "Expectation as etiology" versus "the good old days": postconcussion syndrome symptom reporting in athletes, headache sufferers, and depressed individuals. *J Int Neuropsychol Soc* 2001;**7**:323–33.
44. **Hahn RA.** The nocebo phenomenon: concept, evidence, and implications for public health. *Prev Med* 1997;**26**:607–11.
45. **Suhr JA,** Gunstad J. "Diagnosis Threat": the effect of negative expectations on cognitive performance in head injury. *J Clin Exp Neuropsychol* 2002;**24**:448–57.
46. **Iverson GL,** Lange RT, Brooks BL, *et al.* "Good old days" bias following mild traumatic brain injury. *Clin Neuropsychol* 2010;**24**:17–37.
47. **Cima M,** Merckelbach H, Hollnack S, *et al.* The other side of malingering: supernormality. *Clin Neuropsychol* 2003;**17**:235–43.
48. **Delaney JS,** Lacroix VJ, Leclerc S, *et al.* Concussions among university football and soccer players. *Clin J Sport Med* 2002;**12**:331–8.
49. **Mooney G,** Speed J, Sheppard S. Factors related to recovery after mild traumatic brain injury. *Brain Inj* 2005;**19**:975–87.
50. **Quine S.** 'Does the mode matter?'A comparison of three modes of questionnaire completion. *Community Health Stud* 1985;**9**:151–6.
51. **Rhodes T,** Girman CJ, Jacobsen SJ, *et al.* Does the mode of questionnaire administration affect the reporting of urinary symptoms? *Urology* 1995;**46**:341–5.
52. **Iverson GL,** Brooks BL, Ashton VL, *et al.* Interview versus questionnaire symptom reporting in people with the postconcussion syndrome. *J Head Trauma Rehabil* 2010;**25**:23–30.
53. **Gouvier WD,** Uddo-Crane M, Brown LM. Base rates of post-concussional symptoms. *Arch Clin Neuropsychol* 1988;**3**:273–8.
54. **Adler A.** Neuropsychiatric complications in victims of Boston's Cocoanut Grove disaster. *JAMA* 1943;**123**:1098–101.
55. **Kinston W,** Rosser R. Disaster: effects on mental and physical state. *J Psychosom Res* 1974;**18**:437–56.
56. **McFarlane AC,** Papay P. Multiple diagnoses in posttraumatic stress disorder in the victims of a natural disaster. *J Nerv Ment Dis* 1992;**180**:498–504.
57. **Grinker RR,** Speigel JP. *Combat stress*. In: Sahakian W, ed. *Psychopathology Today*. Itasca, IL: Peacock FE, 1970:197–200.
58. **Russel CK.** War neurosis: some views on diagnosis and treatment. *Arch Neurol Psychiatry* 1919;**1**:25–38.
59. **Fox DD,** Less-haley PR, Earnest K, *et al.* Base rates of postconcussive symptoms in health maintenance organization patients and controls. *Neuropsychology* 1995;**9**:606–611.
60. **Hochstrasser B,** Angst J. The Zurich Study: XXII. Epidemiology of gastrointestinal complaints and comorbidity with anxiety and depression. *Eur Arch Psychiatry Clin Neurosci* 1996;**246**:261–72.
61. **Wearden AJ,** Appleby L. Research on cognitive complaints and cognitive functioning in patients with chronic fatigue syndrome (CFS): what conclusions can we draw? *J Psychosom Res* 1996;**41**:197–211.
62. **Fox DD,** Less-haley PR, Earnest K, *et al.* Post-concussive symptoms: base rates and etiology in psychiatric patients. *Clin Neuropsychol* 1995;**9**:89–92.
63. **Lees-Haley PR,** Brown RS. Neuropsychological complaint base rates of 170 personal injury claimants. *Arch Clin Neuropsychol* 1993;**8**:203–9.
64. **Mickeviciene D,** Schrader H, Obelieniene D, *et al.* A controlled prospective inception cohort study on the post-concussion syndrome outside the medicolegal context. *Eur J Neurol* 2004;**11**:411–9.
65. **Oddy M,** Humphrey M, Uttley D. Subjective impairment and social recovery after closed head injury. *J Neurol Neurosurg Psychiatr* 1978;**41**:611–6.
66. **McMillan TM,** Glucksman EE. The neuropsychology of moderate head injury. *J Neurol Neurosurg Psychiatr* 1987;**50**:393–7.
67. **Meares S,** Shores EA, Taylor AJ, *et al.* Mild traumatic brain injury does not predict acute postconcussion syndrome. *J Neurol Neurosurg Psychiatr* 2008;**79**:300–6.
68. **Lamprecht F,** Sack M. Posttraumatic stress disorder revisited. *Psychosom Med* 2002;**64**:222–37.

69. **Kennedy JE,** Jaffee MS, Leskin GA, *et al.* Posttraumatic stress disorder and posttraumatic stress disorder-like symptoms and mild traumatic brain injury. *J Rehabil Res Dev* 2007;**44**:895–920.
70. **Iverson GL.** Misdiagnosis of the persistent postconcussion syndrome in patients with depression. *Arch Clin Neuropsychol* 2006;**21**:303–10.
71. **Trahan DE,** Ross CE, Trahan SL. Relationships among postconcussional-type symptoms, depression, and anxiety in neurologically normal young adults and victims of mild brain injury. *Arch Clin Neuropsychol* 2001;**16**:435–45.
72. **Greiffenstein MF,** Baker WJ, Johnson-Greene D. Actual versus self-reported scholastic achievement of litigating postconcussion and severe closed head injury claimants. *Psychol Assess* 2002;**14**:202–8.
73. **Haldorsen T,** Waterloo K, Dahl A, *et al.* Symptoms and cognitive dysfunction in patients with the late whiplash syndrome. *Appl Neuropsychol* 2003;**10**:170–5.
74. **Gasquoine PG.** Postconcussional symptoms in chronic back pain. *Appl Neuropsychol* 2000;**7**:83–9.
75. **Smith-Seemiller L,** Fow NR, Kant R, *et al.* Presence of post-concussion syndrome symptoms in patients with chronic pain vs mild traumatic brain injury. *Brain Inj* 2003;**17**:199–206.
76. **Iverson GL,** McCracken LM. 'Postconcussive' symptoms in persons with chronic pain. *Brain Inj* 1997;**11**:783–90.
77. **Alla S,** Sullivan SJ, McCrory P, *et al.* Does exercise evoke neurological symptoms in healthy subjects? *J Sci Med Sport* 2010;**13**:24–6.
78. **Covassin T,** Schatz P, Swanik CB. Sex differences in neuropsychological function and post-concussion symptoms of concussed collegiate athletes. *Neurosurgery* 2007;**61**:345–50; discussion 350–1.
79. **Gaetz MB,** Iverson GL. Sex differences in self-reported symptoms after aerobic exercise in non-injured athletes: implications for concussion management programmes. *Br J Sports Med* 2009;**43**:508–13.
80. **McCaffrey RJ,** Bauer L, O'Bryant SE, *et al. Practitioner's Guide to Symptom Base Rates in the General Population*. New York: Springer Science and Bussiness Media, 2006.
81. **Powell GE.** Mild traumatic brain injury and postconcussion syndrome: the importance of base rates in diagnosis and clinical formulation. *J Neurol Neurosurg Psychiatr* 2008;**79**:237.
82. **Lau B,** Lovell MR, Collins MW, *et al.* Neurocognitive and symptom predictors of recovery in high school athletes. *Clin J Sport Med* 2009;**19**:216–21.
83. **Lovell MR,** Iverson GL, Collins MW, *et al.* Measurement of symptoms following sports-related concussion: reliability and normative data for the post-concussion scale. *Appl Neuropsychol* 2006;**13**:166–74.
84. **Alla S.** Development and validation of the Otago postconcussion return to play symptom based exercise assessment tool. PhD Unpublished. University of Otago, 2010.
85. **Chan RC.** Base rate of post-concussion symptoms among normal people and its neuropsychological correlates. *Clin Rehabil* 2001;**15**:266–73.
86. **Iverson GL,** Lange RT. Examination of "postconcussion-like" symptoms in a healthy sample. *Appl Neuropsychol* 2003;**10**:137–44.
87. **Shehata N,** Wiley JP, Richea S, *et al.* Sport concussion assessment tool: baseline values for varsity collision sport athletes. *Br J Sports Med* 2009;**43**:730–4.
88. **Cimino C.** *Principles of neuropsychological interpretation*. In: Vanderploeg RD, ed. *Clinician's Guide To Neuropsychological Assessment*. Second edition. New Jersey: Lawrence Erlbaum Associates, Inc, 2000:65–143.
89. **Covassin T,** Weiss L, Powell J, *et al.* Effects of a maximal exercise test on neurocognitive function. *Br J Sports Med* 2007;**41**:370–4; discussion 374.
90. **Sanders AK,** Boggess BR, Koenig SJ, *et al.* Medicolegal issues in sports medicine. *Clin Orthop Relat Res* 2005;**433**:38–49.
91. **Gouvier WD,** Cubic B, Jones G, *et al.* Postconcussion symptoms and daily stress in normal and head-injured college populations. *Arch Clin Neuropsychol* 1992;**7**:193–211.
92. **Wong JL,** Regennitter RP, Barrios F. Base rate and simulated symptoms of mild head injury among normals. *Arch Clin Neuropsychol* 1994;**9**:411–25.
93. **Machulda MM,** Bergquist TF, Ito V, *et al.* Relationship between stress, coping, and postconcussion symptoms in a healthy adult population. *Arch Clin Neuropsychol* 1998;**13**:415–24.
94. **Wang Y,** Chan RC, Deng Y. Examination of postconcussion-like symptoms in healthy university students: relationships to subjective and objective neuropsychological function performance. *Arch Clin Neuropsychol* 2006;**21**:339–47.
95. **Piland SG,** Ferrara MS, Macciocchi SN, *et al.* Investigation of baseline self-report concussion symptom scores. *J Athl Train* 2010;**45**:273–8.