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# Does a standardised exercise protocol incorporating a cognitive task provoke postconcussion-like symptoms in healthy individuals?

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ABSTRACT

*Objectives:* To explore whether an exercise protocol, alone and in combination with two selected cognitive tasks related to working memory, provokes postconcussion-like symptoms in healthy individuals.
*Design:* Prospective single cohort semi-randomised crossover repeated measures (time × condition) design.
*Methods:* 36 healthy individuals completed three submaximal exercise protocol conditions, namely: exercise alone, exercise with the paced auditory serial addition task, and exercise with Tetris. Self-reported symptoms were measured before exercise and 1-min and 15-min after the cessation of each exercise protocol using the Sports Concussion Assessment Tool 2-Postconcussion symptoms scale.
*Results:* Analysis of variance indicated a significant increase in symptom scores over time ($p < 0.001$), but no effect between conditions ($p = 0.371$) or a significant time × condition interaction ($p = 0.444$).
*Conclusions:* The combination of working memory tasks and a symptom provoking submaximal exercise protocol did not have an additional effect on the provocation of self-reported symptoms in healthy individuals. Furthermore, the two distinct methods of cognitive load delivery, controlled (paced auditory serial addition task) and pragmatic (Tetris), did not lead to a differential symptom response. These findings provide an initial insight into the scientific foundations for the symptom provocation model that is integral to the currently accepted clinical postconcussion return-to-play protocol.


## 1. Introduction

A safe return to play (RTP) following a sports related concussion is one of the most difficult tasks faced by the sports medicine professional.[1,2] Making safe RTP decisions for an athlete who has a concussion is a key responsibility of the clinician to ensure that an athlete is not returned to sport whilst still recovering from a concussion.[1] Premature RTP may place the athlete at potential risk for severe short-[3,4] and long-term[5,6] consequences; thus, safe RTP strategies are considered to be a critical aspect for the overall management of the athlete with a concussion.

The 'graduated RTP protocol' originally proposed by the Concussion in Sport Group[7] and included in subsequent consensus statements and related assessment tools[1,8] is an international best practice protocol which has become widely cited[9] and disseminated in clinical practice. This protocol outlines six progressive stages of incremental tasks related to sport performance with tasks ranging from light aerobic exercise to sport specific activities. Safe progression through the six stages eventually leads to the full RTP of the athlete upon medical clearance. Each progression within the graduated RTP protocol hinges on the athlete being 'asymptomatic' at rest, and also after the physical and cognitive exertion associated with each level.[1] This principle of relying on postconcussive symptoms for RTP decision making is similar to the practice of identifying an athlete with a potential concussion by measuring their symptoms following the concussive incident. The current RTP protocol is fundamentally based on the notion that if any postconcussive symptoms are detected, the athlete's nervous system is still yet to fully recover, and the athlete is not ready to return to full sporting activities. However, despite the common use of the term 'asymptomatic', Alla and colleagues have questioned the exact meaning of this term within the contexts of RTP protocols, noting that there is no operational definition of the term 'asymptomatic'[10] and it is well known that similar (concussion-like) symptoms are evident

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across the general population.[11,12] While there are a number of scales and checklists available[13] the postconcussion symptom scale (PCS) included in the Sport Concussion Assessment Tool 2 (SCAT2)[1] has gradually become the reference standard as is reflected by its growing uptake in recent studies.[11]

The SCAT2 RTP protocol is pragmatic and clinically practical; however, it has not been subjected to scientific scrutiny and thus, there is a need for the operationalisation and standardisation of key exercise and cognitive parameters imbedded in the RTP protocol. Although researchers have attempted to standardise selected elements of the RTP protocol,[14,15] the investigation into its fundamental constructs of symptom provocation is still exploratory. While respecting the conceptual underpinnings of the SCAT2 RTP protocol, Alla[16] used elements of the dual-task paradigm[17] to explore key exercise parameters of the protocol with added cognitive tasks. While the incorporation of a reaction time task does provide a generalised measure of central nervous system function, it is sporadic in nature and may not challenge the nervous system in the same way as a more concentrated mental activity involving executive functions. Working memory, a sub-component of executive functions, is a common requirement in most sports. Cognitive tasks such as attention control and decision making processes that are common in sporting scenarios are heavily reliant on the function of working memory.[18] Furthermore, working memory related to visual processing and spatial awareness are also crucial elements to successful sport performance.[19]

The primary purpose of this study was to investigate if the addition of a cognitive task to a submaximal exercise protocol would provoke a greater number, or severity, of self-reported symptoms in healthy individuals than that generated by exercise alone. It is hypothesised that the addition of a cognitive load to the graded submaximal exercise protocol will provoke a greater symptom response in comparison to the exercise protocol alone. The secondary purpose was to explore whether there were differences in the symptom responses to a submaximal exercise protocol coupled with a controlled laboratory based cognitive task (paced auditory serial addition task (PASAT)), compared with a submaximal exercise protocol coupled with a more pragmatic cognitive task (Tetris).

## 2. Methods

A total of 36 participants (18 males and 18 females) aged between 18 and 30 years, who participated in regular physical activity (e.g. 2–3 times per week) were recruited. Of the 36 participants, 35 participants had not sustained a concussion within the last 12 months prior to testing. One male participant had a history of a concussion 5 months prior to testing where his symptoms lasted for 1 day, and was not experiencing any post-concussive symptoms at the time of testing. Individuals who were considered to be at risk for exercise participation, as indicated by answering 'yes' to any of the questions from the Physical Activity Readiness Questionnaire,[20] and those with self-reported musculoskeletal injuries and/or neurological conditions which might be a contraindication for participation in physical activities or influence the responses to symptom reporting, were excluded. Eligible participants gave written informed consent prior to beginning the protocol. The study was approved by the University of Otago Human Ethics Committee.

This study employed a prospective single cohort semi-randomised crossover repeated measures experimental design. Three independent exercise conditions were ordered into six balanced permutations and an equal number of males and females were randomly stratified into each permutation. The order for the administration of the three distinct exercise protocols were counter-balanced to minimise any potential order effect, and a 48-h washout interval was scheduled between each session to allow for the dissipation of any exercise associated effects.

Three different exercise protocols (conditions) were employed: (1) submaximal exercise protocol (SMEP) alone; (2) submaximal exercise protocol combined with the PASAT (SMEP + P); and (3) submaximal exercise protocol combined with Tetris (SMEP + T). For SMEP + P and SMEP + T conditions, the cognitive tasks were administered at baseline and during each target heart rate (THR) zone (THR zones 1, 2, and 3).

The SMEP employed in this study is an adaptation of the physical work capacity – 170 protocol[21] modified by Alla.[16] The SMEP required the participants to cycle on a cycle ergometer (Monark 818e – Stockholm, Sweden) at submaximal level. A 2-min warm-up was followed by three 5-min incremental stages at pre-defined THR zones of 115–130, 131–145 and 146–165 beats per minute (bpm), and concluded with a 2-min cool-down.

Two distinct forms of a cognitive loading task were used to determine the differences in the provocation of self-reported symptoms between a laboratory based cognitive task (PASAT) and a pragmatic cognitive task (Tetris) when coupled with a physical load. The PASAT[22] is a standardised neuropsychological test designed to assess working memory.[23] Although the PASAT is more commonly used as an assessment tool, it is an ideal instrument to be used as a stressor of the nervous system. The PASAT was administered by providing a series of auditory stimuli in the form of single numerical digits, and the participants were instructed to successfully sum the two most recent digits. A 2.0-s inter-stimulus interval (ISI) was selected to provide sufficient challenge whilst avoiding ceiling effects.[23] The PASAT responses were recorded through an iPad voice recording application – QuickVoice® Recorder (nFinity Inc.) Version 2.5.5. Tetris is a ubiquitous game which requires various cognitive processes including working memory.[24] Tetris is played by rotating the orientation and position of seven differently configured blocks that descend from the top of a 10 by 20 matrix. The objective of the game is to construct complete horizontal rows. If a row is complete, that particular row is cleared from the screen. The participants were instructed to 'clear as many lines as possible' during each 2-min period. A licenced Apple iPad version of the game – Tetris® (Electronic Arts Inc.) – Version 1.5.55 was used.

The Sports Concussion Assessment Tool 2-Postconcussion symptoms (SCAT2-PCS) scale[1] was the primary outcome measure. Although an updated version (SCAT3)[8] of the SCAT2 was recently published, the SCAT2 was the most recent and widely used at the time this study was conducted. The SCAT2-PCS scale consists of 22-symptom items, and the severity of each symptom is measured on a 7-point Likert scale ranging from 0 (none) to 6 (severe). For each symptom, the participants are instructed to circle the number which best represents how they feel at the time of testing. These variables were measured before exercise (PRE), 1-min (POST-1) and 15-min (POST-2) after the cessation of each exercise protocol. Two frequently reported measures were taken from the SCAT2-PCS scale. The total number of symptoms (TNS) is the total count of symptoms reported by the participant (regardless of their severity), and ranges between 0 (no symptoms reported) and 22 (maximum possible number of symptoms). A higher score represents a greater endorsement of symptoms. The symptom severity score (SSS) is the sum of the symptom severity for each individual symptom, and ranges between 0 (no symptoms reported) and 132 (maximum score). A higher score represents a greater severity in the symptoms that are reported.

The following variables were recorded for the purpose of monitoring the participants' adherence to the protocol. Heart rate (HR) was recorded in 'bpm' during the last 5 min of the initial preparatory phase (PRE) and at every 30-s interval throughout the entire protocol. The participant's rating of perceived exertion (RPE) was recorded using a 15-point (6–20) Borg scale.[25] The 15-points of