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# Effects of abdominal binding on field-based exercise responses in Paralympic athletes with cervical spinal cord injury

Christopher R. West[a], Ian G. Campbell[a], Victoria L. Goosey-Tolfrey[b], Barry S. Mason[b], Lee M. Romer[a,*]

[a] Centre for Sports Medicine and Human Performance, Brunel University, UK
[b] School of Sport, Exercise & Health Sciences, The Peter Harrison Centre for Disability Sport, Loughborough University, UK

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ABSTRACT

Abdominal binding has been shown to improve resting cardiorespiratory function in individuals with cervical SCI, but it is not yet clear whether this approach improves the exercise response.

*Objectives:* To determine the effects of abdominal binding on parameters relating to wheelchair sports performance in highly-trained athletes with cervical SCI.

*Design:* Repeated-measures field-based study.

*Methods:* Ten Paralympic wheelchair rugby players with motor-complete SCI (C5–C7) completed a series of exercise tests in two conditions (bound and unbound). The following parameters were assessed: agility and acceleration/deceleration performance; cardiorespiratory function and gross efficiency during submaximal wheelchair propulsion; anaerobic performance and propulsion kinematics during a 30 s Wingate test; repeated sprint performance during a 10 × 20 m test; and aerobic performance during a repeated 4 min push test.

*Results:* Compared to unbound, 6 of 17 field-based performance measures changed significantly with binding. Time to complete the acceleration/deceleration test decreased ($p = 0.005$), whereas distances covered during the repeated 4 min push test increased ($p < 0.043$). Binding elicited significant reductions in minute ventilation during submaximal wheelchair propulsion ($p = 0.040$) as well as blood lactate accumulation and limb discomfort during the second set of the repeated 4 min push test ($p = 0.012$ and 0.022). There were no statistically significant effects of binding on any other variable.

*Conclusions:* Abdominal binding improves some important measures of field-based performance in highly-trained athletes with cervical SCI. The changes may be attributable, at least in part, to improvements in trunk stability, ventilatory efficiency and/or haemodynamics.



## 1. Introduction

Physical capacity in individuals with cervical spinal cord injury (SCI) is compromised due to loss of functional muscle mass and descending sympathetic control.[1] Sublesional paralysis results in less active muscle mass during arm exercise compared to non-disabled individuals. Redistribution of blood flow during arm exercise is impaired due to a lack of sympathetic vasoconstriction below the lesion and a decreased effectiveness of the venous muscle pump resulting from the paralysis of leg muscles. In addition, abdominal compliance is increased secondary to expiratory muscle paralysis.[2] The subsequent reduction in abdomino-thoracic pressure gradient further compromises ventricular filling pressure and stroke volume.[3]

Electrical stimulation of lower limb muscles and lower-body positive pressure (antigravity suit) have been shown to increase cardiac output and oxygen uptake during maximal exercise in individuals with cervical SCI.[4,5] Neither intervention is feasible for use during competitive sport. An alternative method for improving cardiorespiratory function during exercise is to apply external abdominal compression using an elastic binder. Abdominal binding increases intra-abdominal pressure and provides a fulcrum for the diaphragm to contract against. The subsequent enhancement of diaphragmatic function reactivates the pump action of the diaphragm and increases the abdomino-thoracic pressure gradient, thereby enhancing venous return and consequently improving ventricular filling pressure, stroke volume and systolic cardiac performance.[6] Numerous studies have reported positive cardiorespiratory benefits of abdominal binding at rest in individuals with SCI.[7] In the only study to investigate the effects of binding on the physiological responses to exercise in athletes with SCI, Kerk et al.[8] found no effect of binding on oxygen uptake during submaximal or

* Corresponding author.
*E-mail address:* lee.romer@brunel.ac.uk (L.M. Romer).

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maximal exercise. That study, however, was delimited to individuals with thoracic SCI, who, due to greater preservation of muscle mass and partial or full sympathetic control of the myocardium and upper-body vasculature, would be expected to benefit less than individuals with cervical lesions.

Wheelchair rugby is a Paralympic sport for athletes with loss of function in both the upper and lower limbs. The majority of wheelchair rugby players have cervical SCI. The sport is dominated by frequent, intermittent, short-term power demands superimposed on a background of aerobic activity.[9,10] The ability to apply force to the hand-rim and to change direction quickly are likely prerequisites for successful performance. While trunk orientation is an important determinant of hand-rim force,[11] impairment of trunk function consequent to abdominal muscle paralysis may result in sub-optimal positioning for force application. We reasoned that, in addition to potential cardiorespiratory benefits, abdominal binding might improve trunk range of motion thereby enabling greater force to be applied to the hand-rim and subsequent enhancement of wheelchair propulsion.

The aim of the study was to determine the effects of abdominal binding on performance-related parameters in elite wheelchair rugby players with cervical SCI. We hypothesised that abdominal binding would improve performance in tests that are reliant upon cardiorespiratory function and/or trunk stability.

## 2. Methods

After ethics committee approval and written informed consent, ten wheelchair rugby players volunteered to participate in the study (Table 1). The participants were members of the Great Britain Wheelchair Rugby squad preparing for the London 2012 Paralympic Games. Participants were free from acute and chronic cardiorespiratory disorders and were undertaking ≥15 h/week of endurance, strength, and sport-specific training. Participants were classified for neurologic level and completeness of injury[12] and for sporting classification.[13] The research adhered to the tenets of the Declaration of Helsinki.

Procedures were performed during two field-based testing sessions separated by ≥48 h but ≤1 week. During the first session, participants completed three testing stations in two conditions (unbound and bound). At station 1, participants were assessed for agility and acceleration/deceleration performance. At station 2, participants were assessed for cardiorespiratory function and gross efficiency during submaximal wheelchair propulsion as well as for anaerobic performance and propulsion kinematics during a 30 s Wingate test. At station 3, participants were assessed for repeated sprint performance using a 10 × 20 m test. During the second session, participants were assessed in both conditions for aerobic performance using a repeated 4 min push test (station 4). The order of stations and conditions was randomised and counterbalanced. Stations 1–3 were separated by 30 min of rest in order to minimise carryover effects. Likewise, each condition was separated by a rest period of 10 min (station 1) or 30 min (stations 2–4). Stations 1–3 were performed on the wooden sprung floor of a sports hall. Station 4 was performed on the 140 m straight of an indoor athletics track. At the start of each testing session, participants emptied their bladder to minimise the possibility of autonomic dysreflexia[14] and performed a 15 min standardised warm-up. Participants wore gloves for all of the tests and used their own rugby chair with rear-wheel tire pressure standardised to 7.6 bar. To enable inferences regarding the practical significance of findings, within-day reliability coefficients for the field-based measures of agility, acceleration/deceleration, and aerobic performance were assessed on a separate occasion in a subgroup of participants ($n = 6$).

*Agility test*: Four cones were used to demark a 5 m square area. Three further cones were placed equidistant along the centre line and participants completed a figure-of-eight around these cones. Infrared timing gates (Brower TC, Draper, UT, USA) were placed either side of the middle cone so that the time to complete left and right turns could be separated from the total time. The timing gates were set to the lowest height possible so that they were started and stopped when the front castors of the wheelchair passed through. Participants completed the test 3 times with 60 s rest between each trial, and the fastest time was recorded.

*Acceleration/deceleration test*: The test consisted of a 5 m forward push, a 2.5 m backward push, and a 12.5 m forward push. Participants started with their front castors 30 cm behind the start line and completed the test 3 times with 60 s rest between each trial. The fastest time was recorded.

*Submaximal propulsion test*: Participants performed 5 min of wheelchair propulsion at 1.4 m s$^{-1}$ on an ergometer (Bromakin, Loughborough, UK). Pilot data showed that all participants could maintain this exercise intensity with a respiratory exchange ratio (RER) <1. Oxygen uptake ($\dot{V}_{O_2}$) and carbon dioxide output ($\dot{V}_{CO_2}$) for the final 2 min of exercise were assessed using the Douglas bag technique.[15] Energy expenditure was calculated from $\dot{V}_{O_2}$ and $\dot{V}_{CO_2}$.[16] Power output was determined using previously described methods.[17] Gross efficiency was calculated as the ratio of power output to total energy expended.[18] Heart rate for the final 2 min of exercise was assessed using telemetry (Polar Vantage NV, Polar Electro Oy, Kempele, Finland).

*30 s Wingate test*: The Wingate test was preceded by 5 min of submaximal pushing (see Submaximal propulsion test) followed by two all-out 3 s sprints. The actual test commenced from a rolling start (1 m s$^{-1}$) to help overcome the initial inertia of the ergometer. Participants were assessed for peak and mean power, time to peak power, and fatigue index ([peak power – minimum power]/peak power).

**Table 1**
Descriptive characteristics.

| Participant | Sex | Lesion level | AIS class | IWRF class | Age (year) | Stature (m) | Mass (kg) | Time post injury (year) |
|---|---|---|---|---|---|---|---|---|
| 1 | M | $C_{6-7}$ | A | 2.5 | 37.1 | 1.80 | 71.7 | 17 |
| 2 | M | $C_{6-7}$ | A | 2.0 | 30.5 | 1.75 | 62.5 | 10 |
| 3 | M | $C_{5-6}$ | A | 2.5 | 30.7 | 1.95 | 103.1 | 12 |
| 4 | M | $C_{5-6}$ | A | 0.5 | 26.8 | 1.65 | 54.0 | 8 |
| 5 | F | $C_{6-7}$ | A | 1.5 | 24.1 | 1.61 | 52.8 | 5 |
| 6 | M | $C_7$ | B | 2.5 | 29.2 | 1.93 | 68.0 | 9 |
| 7 | F | $C_{6-7}$ | A | 1.0 | 27.0 | 1.66 | 46.7 | 10 |
| 8 | M | $C_{6-7}$ | A | 2.5 | 29.9 | 1.73 | 61.0 | 9 |
| 9 | M | $C_{6-7}$ | B | 2.5 | 28.7 | 1.84 | 68.5 | 3 |
| 10 | M | $C_6$ | A | 1.5 | 36.8 | 1.85 | 70.9 | 12 |
| | | | | | 30.1 ± 4.1 | 1.77 ± 0.11 | 65.9 ± 15.5 | 10 ± 4 |

*Abbreviations*: AIS, American Spinal Injury Association Impairment Scale (A = complete lesion to E = normal function); IWRF, International Wheelchair Rugby Federation classification (0.5 = least function to 3.5 = most function).