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The effects of a heat acclimation protocol in persons with spinal cord injury

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ABSTRACT

Persons without spinal cord injury (SCI) physiologically acclimate between seven to fourteen consecutive days of exercise in the heat. Decreased resting and exercise core temperature, decreased heart rate, increased plasma volume and increased thermal comfort during exercise are changes consistent with heat acclimation. Autonomic dysfunction after SCI impairs heat dissipation through sweating and vasodilation. The purpose of this study is to determine if seven consecutive days of exercise in the heat would result in physiologic changes consistent with heat acclimation in persons with SCI. Ten persons with SCI divided into two groups: tetraplegia (n=5) and paraplegia (n=5) exercised in 35 °C using an arm ergometer at 50% W_{peak} for 30 min followed by 15 min rest. This protocol was repeated over seven consecutive days. Heart rate (HR), skin temperature, aural temperature (T_{aur}), rate of perceived exertion (RPE), rate of perceived thermal strain (RPTS), and plasma volume (PV) were measured throughout the protocol. There were no significant differences in resting T_{aur} exercise T_{aur}, mean skin temperature, HR, PV, RPE or RPTS over the 7 days for either the tetraplegic or paraplegic group. Participants with SCI did not demonstrate the ability to dissipate heat more efficiently over 7 days of exercise at 35 °C. The lack of heat acclimation seen in persons with SCI has implications for the athlete and non-athlete alike. For the SCI athlete, inability to acclimate will impair performance and endurance especially in warm environments, compared to the person without SCI. For the SCI non-athlete, there is a greater risk of heat-related illness in warm environments that can negatively affect participation in outdoor activities and thus quality of life.

1. Introduction

Heat acclimation in able-bodied persons results in improved sweating and cutaneous blood flow at a given core temperature to improve heat dissipation (Lorenzo and Minson, 2010). Heat acclimation therefore results in reduced physiological strain as evidenced by lowered resting core and both reduced core temperature and heart rate (HR) during exercise (Kampmann et al., 2008; Garrett et al., 2009). Furthermore, fluid losses from sweating lead to increased fluid regulatory hormones that raises plasma volume by 25% from minutes to hours after exercise in the heat.[2] These physiologic responses improve thermal comfort, endurance and performance in the heat (Sunderland et al., 2008; Lorenzo et al., 2010).

Although heat acclimation occurs in able-bodied individuals, spinal cord injury (SCI) results in reduced sweat rates and/or impaired cutaneous vasodilation below the lesion, which may prevent effective heat acclimation (Huckaba et al., 1976; Totel et al., 1971). Studies in SCI show that both at rest and during exercise, the effectiveness of thermoregulation varies according to residual sympathetic function and the extent to which thermoregulatory reflexes are compromised (Popa et al., 2010; Price, 2006; Pritchett et al., 2010). Due to compromised vasomotor and sudomotor activity below the level of injury, such persons have impaired ability to regulate core temperature during heat exposure (Price, 2006; Price and Campbell, 2003). Specifically, tetraplegics demonstrate a complete absence of, or significant reduction in, sweating (depending on the completeness of injury) whereas those with paraplegia demonstrate a sweating response that is proportional to the lesion level (Hopman et al., 1993; Price and Campbell, 2003; Huckaba et al., 1976). During prolonged exercise in cool conditions (25 °C), paraplegic athletes demonstrate whole body sweat losses similar to those for matched able-bodied athletes (Price and Campbell, 1997, 1999b; Dawson et al., 1994). This suggests that

Abbreviations: AIS, American Spinal Injury Association Impairment Scale; PP, paraplegia; SCI, spinal cord injury; T_{aur}, aural temperature; T_{skin}, skin temperature; TP, tetraplegia; W_{peak}, peak power output

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sweating is increased within the smaller sensate surface area so that paraplegic athletes can maintain thermal balance in cool conditions (Price, 2006). In contrast, during exercise in cool conditions (25 °C), tetraplegic athletes demonstrate greater and continual increases in core temperature when compared to paraplegic athletes, a response accentuated during exercise in hot conditions (Price and Campbell, 2003, 1997, 1999b; Trbovich et al., 2014). Few studies have examined thermoregulatory responses to exercise in hot conditions of SCI persons. In preparation for the upcoming Paralympics in Brazil, a recent review article stated that the lack of knowledge of heat acclimation in SCI athletes makes competition/training recommendations for this population difficult (Price, 2015). Furthermore, non-athletic SCI persons often limit or avoid activities involving heat exposure to prevent overheating and the associated discomfort. Effective heat acclimation could not only improve performance in SCI athletes but may also improve the ability of non-athletic SCI persons to undertake activities in the heat and thus improve their quality of life. The aim of this study was to examine thermoregulatory responses of SCI persons during heat acclimation. We hypothesized that persons with tetraplegia would not demonstrate heat acclimation whereas those with paraplegia would demonstrate some degree of heat acclimation responses proportional to their level of injury and sweating capacity.

2. Material and methods

2.1. Setting

Data collection occurred in an exercise lab and an environmental controlled chamber. All study procedures were approved by the local institutional review board.

2.2. Participants

Participants were recruited from a Veterans Affairs clinic and were included if they utilized a manual wheelchair, could propel an upper extremity ergometer, and carried a diagnosis of chronic (> 1 year) SCI. Participants were excluded by a history of heat-related illness, cardiovascular disease, were pregnant (self-report) or had an acute illness. Ten persons volunteered and were divided into two groups: tetraplegia (TP) (n=5) and paraplegia (PP) (n=5). Body mass index (BMI) was measured for each participant. SCI classification and neurological exam from the International Standards for Neurological Classification of Spinal Cord Injury (ISNCSCI) exam was obtained from the medical record. The significant differences between groups were time since injury, which would not likely have any effect on thermoregulatory function; and peak power output that is expected to be less in the TP group given the neurologically impaired arm muscles in this group (Table 1). All medications of participants are recorded in Table 2. Participants were recreationally active but not highly trained. None had undertaken prior heat acclimation training. All refrained from caffeine and alcohol in the 24 h prior to visits and fasted for two hours prior to each visit.

Table 2
Medications of participants.

Participant	Anticholinergics	Other
TP1	n/a	synthroid oxycodone
TP2	oxybutynin	baclofen
TP3	oxybutynin	tizanadine diazepam
TP4	n/a	n/a
TP5	n/a	n/a
PP1	oxybutynin nortriptylene	baclofen omeprazole
PP2	n/a	dantrolene
PP3	n/a	cyclobenzaprine fexofenadine synthroid wellbutrin
PP4	n/a	n/a
PP5	oxybutynin	docusate sennosides gabapentin

Abbreviations: PP: Paraplegia, TP: Tetraplegia.

2.3. Preliminary tests

An exercise test was conducted to establish individual baseline values for peak power output (W_{peak}). The protocol began with exercise on an arm crank ergometer All tests were undertaken on a specific arm crank ergometer (Ergoline, Ergoselect 400) at 5 W for 2 min (min) with increases of 5 W every 2 min at a cadence of 60 revolutions per min until volitional exhaustion. W_{peak} of all participants are reported in Table 1.

2.4. Heat acclimation protocol

2–3 days after preliminary testing, participants began the seven consecutive day heat acclimation protocol. Each day, participants arrived at the laboratory having followed the same pre-exercise conditions noted earlier. In addition, participants were asked to arrive euhydrated. Although hydration was not specifically measured participants were provided with fluids following every exercise sessions and were advised to continue drinking throughout the remainder of the day, prior to their next visit. Participants exercised continuously at 50% W_{peak} for 30 min (see Table 1 for HA exercise work rates of each participant) followed by 30 min of passive recovery. Each exercise session was scheduled at the same time of day (± 1 h) to avoid circadian variations (Winget et al., 1985). On arrival at the laboratory participants rested for 15 min in an air-conditioned environment (22.4

Table 1
Demographics and peak power outputs of participants.

Participant	Sex	Age	ISNCSCI classification	Etiology of SCI	Years since injury	BMI	Peak power (Watts)
TP1	M	57	C6 AIS B	MVA	34	20.3	45 W
TP2	F	37	C7 AIS D	MVA	16	17.1	30 W
TP3	M	46	C7 AIS B	MVA	16	25.1	40 W
TP4	M	47	C5 AIS A	MVA	10	25.8	50 W
TP5	M	41	C7 AIS A	spina bifida	34	34.9	40 W
Mean (SD)		45.6 (7.5)			22.0 (11.2)	24.6 (6.8)	40 (9.4)
PP1	M	41	T7 AIS A	transverse myelitis	6	26.7	110 W
PP2	M	50	T11 AIS C	bicycle accident	1.5	26	120 W
PP3	M	60	L3 AIS D	MVA	12	27.7	100 W
PP4	M	55	L1 AIS A	fall	17	22.2	130 W
PP5	M	19	T12 AIS A	MVA	2	24.9	50 W
Mean (SD)		45.0 (16.1)			7.7 (6.7)	25.5 (2.1)	98 (39.6)
Between group P value		P=0.94			P=0.04	P=0.80	P=0.03

Abbreviations: AIS: ASIA Impairment Scale, BMI: Body Mass Index, ISNCSCI: International Standards for Neurological Classification of Spinal Cord Injury, MVA: Motor Vehicle Accident, PP: Paraplegia, SCI: Spinal Cord Injury, TP: Tetraplegia.