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Effect of chronic exposure to height on the psychophysiological responses to a climbing task

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ABSTRACT

Rock climbing offers a potential therapeutic intervention for trainee firefighters, construction workers or for those with acrophobia. To examine the therapeutic potential of climbing we examined the extent of differences in psychophysiological responses between climbers and non-climbers. Responses of 15 climbers and 14 non-climbing matched controls to a 20-metre ladder climb were assessed. Climbers ascended the ladder more quickly ($p < 0.0005$; $d = 1.15$) than non-climbers without significant differences in peak heart rate ($p = 0.906$; $d = 0.05$) or peak oxygen uptake ($p = 0.136$; $d = 0.83$). The climbers demonstrated a blunted psychophysiological response, reporting lower levels of cognitive anxiety ($p = 0.036$; $d = 0.84$), lower peak cortisol concentrations ($p = 0.010$; $d = 1.04$), a decreased relative anticipatory heart rate rise ($p = 0.008$; $d = 1.06$) as well as reporting a higher mean level of self-confidence ($p = 0.007$; $d = 1.10$). Physiological and psychological responses were lower for climbers when compared with non-climbers. Consequently, the climbers in this study appeared to demonstrate a degree of habituation to working at height, most likely due to chronic exposure. In a climbing context coaches should consider the potential effects of elevated anxiety for beginner climbers and its impact on their learning. Climbing appears to represent a potential therapeutic intervention for those with height-induced elevations in anxiety.

1. Introduction

For those beginning a career in the construction industry or as a fire-fighter, any anxiety associated with working at height can be debilitating such that it interferes with on the job training (Ting, Palminteri, Lebreton, & Engelmann, 2020). To date, research focused on the demands of fire-fighting has tended to concentrate on the environmental demands of the profession, and consequently there appear to be gaps in the literature in regard to fear of height in fire-fighting trainees (Horn, Stewart, Kesler, DeBlois, Kerber, Fent et al., 2019). In recent years for those with acrophobia there has been a growing interest in the use of virtual reality to form part of therapeutic interventions for patients (Diemer, Lohkamp, Mühlberger, & Zwanzger, 2015). There has been a lesser focus on the potential of climbing in the real-world as a therapeutic intervention for people with acrophobia.

In a climbing context, performance is underpinned by a significant psychophysiological component (Draper, Dickson, Fryer, & Blackwell, 2011; Draper, Jones, Fryer, Hodgson, & Blackwell, 2008; Draper, Jones, Fryer, Hodgson, & Blackwell, 2010; Giles et al., 2014). A growing number of studies have assessed the psychological and physiological responses of elite and advanced level rock climbers to a variety of factors, including but not limited to: route knowledge (Draper et al., 2008), potential fall distance (Baláš et al., 2017) and, climber protection (Dickson, Fryer, Blackwell, Draper, & Stoner, 2012; Fryer, Dickson, Draper, Blackwell, & Hillier, 2013). These studies found that higher stress trials negatively affect performance: resulting in slower climbing time, greater cognitive anxiety, and lower self-confidence (Dickson et al., 2012; Fryer et al., 2013), increased catecholamine concentrations (Baláš et al., 2017), and an elevated cortisol response (Draper et al., 2008).

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As for fire-fighters and construction workers who work at height regularly and for those with acrophobia, research with those new to climbing or for non-climbers is limited. To date, only the work of Pijpers and colleagues provides findings for novices (e.g., Pijpers, Oudejans, Holsheimer, & Bakker, 2003). In this research, Pijpers et al. (2003) found that novices demonstrated significant elevations in anxiety and heart rate (HR), when compared with climbers. However, Pijpers and colleagues work was conducted using low level traverses (moving sideways along a wall) rather than ascending to height which is the more common style in rock climbing (Pijpers et al., 2003). Currently there is no known research investigating the psychophysiological responses to climbing to height for novice or non-climbers. Such work would be of relevance not only in a climbing context, but also for those who have to work at height in their work or for those suffering with acrophobia, where climbing might represent a therapeutic intervention.

It is most likely that psychophysiological responses of non-climbers have not been reported due to the technical and safety concerns associated with the sport. Free-hanging wire ladder climbs are often used as a training tool for climbers, but also offer a non-sport-specific task that could enable non-climbers to easily ascend to height. The purpose of this study was to examine psychophysiological responses of climbers and non-climbers to a 20-meter wire ladder climbing task. Given the possible effects of habituation for climbers, our expectation was that, in comparison to the non-climbers, the climbers would (i) ascend the ladder more quickly; (ii) be less cognitively and somatically anxious; (iii) have greater self-confidence; (iv) while showing a lower anticipatory rise in HR and (v) lower cortisol concentrations.

2. Methods

2.1. Study Design

This cross-sectional study was designed following the STROBE guidelines for cross-sectional observational studies and were followed for the reporting of the results (Poorolajal, Cheraghi, Irani, & Rezaeian, 2011; Vandenbroucke, von Elm, Altman, Gøtzsche, Mulrow, Pocock, et al., 2007).

2.2. Participants

Fifteen experienced climbers (herein referred to as ‘climbers’), who were all regularly exposed to ascending at height, and 14 non-climbing matched controls who were unaccustomed to rock climbing or height exposure, participated in the current study (described in Table 1). Climbers were recruited from local climbing walls on the basis that they took part in sport climbing, and regularly ascended walls 15 – 20 meters in height at least twice a week (self-reported 6 month redpoint grade of 15.2 ± 2.9: Draper et al., 2016). Non-climbers had no prior experience of rock climbing and did not participate in any other activities or work that required them to ascend to height. Groups were matched for height, mass, and physical activity status. Exclusion criteria included current or recent smoker, a diagnosis of, or receiving medications for, cardiac or cardiovascular disease, anxiety, depression or acrophobia. Written informed consent was obtained and medical health questionnaires (PAR-Q and novel study form) were completed prior to participation. Institutional ethical approval, which conformed to the principles of the Declaration of Helsinki, was granted prior to data collection.

Table 1: Participants anthropometric and physiological data (mean ± SD)

	NON-CLIMBERS		**EXPERIENCED CLIMBERS**	
	Female (n= 4)	Male (n = 10)	Female (n = 3)	Male (n = 12)
Age (y)	38.7 ± 12.6	32.9 ± 9.8	37.9 ± 2.0	26.7 ± 8.7
Height (m)	1.63 ± 0.03	1.76 ± 0.07	1.67 ± 0.06	1.77 ± 0.07
Mass (Kg)	59.3 ± 9.0	71.4 ± 10.8	61.8 ± 2.4	73.1 ± 9.5

Note: y, years; m, meters; Kg, kilograms

2.3. Procedure

Participants attended a single session in order to complete an ascent of a 20-meter high indoor wire ladder (Figure 1). To reduce the impact of circadian rhythm, particularly on salivary cortisol concentrations, sessions were completed between the hours of 3 and 8 PM. Participants were asked not to alter their training regime in the run-up to the study, and to choose a session that allowed for adequate rest, avoiding strenuous exercise for 24 hours prior. Finally, to avoid sample contamination and ergogenic effects, participants were asked to refrain from consuming food and any caffeinated beverages within two hours of the visit.

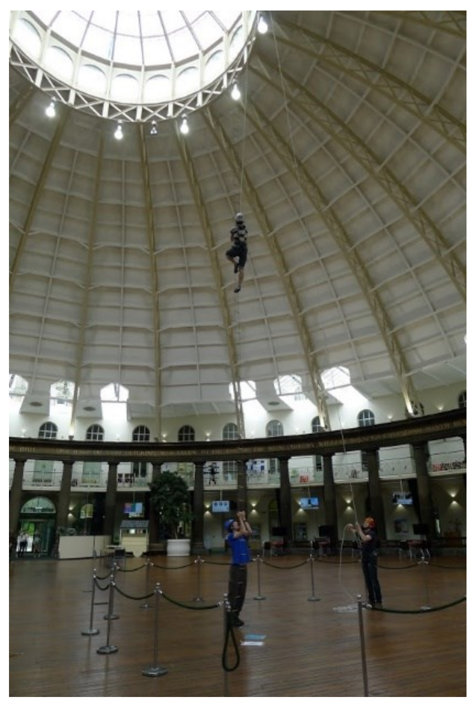

Figure 1: Illustration of the ladder, belay and climbing set-up for the 20m wire ladder climb

As shown in Figure 1, the ladder climbing session took place in a large indoor space, allowing for a moveable, flexible, 20-meter high free-hanging wire ladder (150 mm rung width, 4 rungs per meter: Lyon Equipment, France) to be suspended from the ceiling, along with a semi-static safety rope. Safety gear included helmet, harness and a top rope used with belayer. Participants were instructed to wear comfortable trainers and loose fitting clothing. The flexible wire ladder climbing task was chosen as it was unfamiliar to all participants. In keeping with previous rock climbing studies, the participants completed a standardised warm-up consisting of 5-minutes light jogging (free running) at 60% of maximal HR (HR_{MAX}), and 5-minutes of stretching and mobilising (Dickson et al., 2012; Draper et al., 2011). Following the warm-up, all participants were given instruction on how to climb the wire ladder (taking one rung at a time and climbing at a comfortable self-paced speed). The $K4b^2$ was air, gas, turbine, and delay calibrated between participants. Finally, the pre-climb salivary samples were collected. Oxygen uptake and HR were measured for the duration of the test using a portable metalizer ($K4b^2$, Cosmed, Rome, Italy), and $\dot{V}O_2$ data were averaged at 15-second intervals. Participants began climbing in their own time. Heart rate and $\dot{V}O_2$ were measured continuously using the Polar V800 and $K4b^2$, respectively. Salivary cortisol was sampled as soon as the participant returned to the ground. A 20-minute passive recovery period then commenced, with salivary cortisol collected at 5-minute intervals.

2.4. Measures

2.4.1. State Anxiety

The revised competitive state anxiety inventory (CSAI-2R) was used to measure state anxiety (Cox, Martens, & Russell, 2003). The CSAI-2R is a 17-item inventory, with each item scored on a Likert scale ranging from 1 ("not at all") to 4 ("very much so"). The scores for each participant were combined to create a score on each of the three subscales: (1) somatic anxiety (e.g., my heart is racing), (2) cognitive anxiety (e.g., I am concerned about performing poorly), and (3) self-confidence (e.g., I am confident because I can mentally picture myself reaching my goal). Cronbach's alpha was calculated for the CSAI-2R sub-scales and all appeared to have good internal consistency: somatic ($\alpha = 0.91$), cognitive ($\alpha = 0.88$), and self-confidence ($\alpha = 0.88$). State anxiety was assessed using the CSAI-2R inventory between the warm-up and starting the climb.

2.4.2. Heart Rate

Heart rate was recorded using a Polar H7 chest strap and V800 HR monitor (HRM; Polar, Finland). Anticipatory HR response was calculated as the percentage change from seated rest (for 5 min) to one minute prior to climbing. Peak HR (HR_{PEAK}) was taken as the highest HR observed during the ascent. Pulmonary gas exchange was measured using on-line breath by breath (b^2) analysis throughout each test using the $K4b^2$. Data were smoothed (5 breath moving average), and $\dot{V}O_{2PEAK}$ was determined as the highest 15-second average.

2.4.3. Salivary Cortisol

All saliva samples were collected using salivettes (Sarstedt AG & Co, Germany). In accordance with previous research (Gonzalez, Del Mar Bibiloni, Pons, Llompart, & Tur, 2012), participants were instructed not to brush their teeth 30-minutes before attendance, not to consume water 5-minutes before any sample, and not to consume food 2-hours before arrival. Following the method set out by Westermann, Demir, and Herbst (2004), saliva samples were analysed for cortisol concentration using an enzyme-linked immunosorbent assay (ELISA) Kit (Saliva RE52611, IBL International, Germany). Intra-assay coefficients of variation were 3.95% and 4.68% for the low and high saliva controls, respectively. Salivary cortisol response was calculated as the percentage change from pre-climb cortisol concentration. Cortisol concentrations were expressed as nmol/L or percentage.

2.5. Statistical Analyses

Normal distributions were ascertained, and homogeneity of variance was confirmed after visual assessment of the frequency histogram and a Shapiro–Wilk's test, respectively. All descriptives are reported as mean ± SD. For meaningfulness, mean differences (MD) and 95% confidence intervals ($CI_{95\%}$) were used. Gender differences in all variables were considered using a series of independent samples t-tests – no significant differences were apparent in any variables other than height and body-mass; consequently, male and female data were considered together. The magnitude of the group difference was calculated by independent samples *t*-tests. A two-way ANOVA (group*sampling time) was used to investigate change from pre-climb in saliva cortisol concentrations between groups. Pairwise differences were examined using paired and independent samples *t*-test. Corrections for multiple comparisons were made using the Benjamini and Hochberg (1995) false-discovery rate (FDR) method (Glickman, Rao, & Schultz, 2014). The magnitude of the difference was determined using η_p^2 for multiple comparisons and Cohen's *d* for comparisons between two groups. All data were analysed using SPSS (Version 25).

3. Results

Mean (±SD) ascent time, $\dot{V}O_2$, HR and CSAI-2R for the non-climbers and climbers during the ladder ascent are shown in Table 2. Independent samples *t*-test demonstrated that the non-climber group climbed significantly slower than the climbers ($t_{(27)} = 3.08$ $p < 0.0005$; MD = 60.25 sec, $CI_{95\%}$ 19.92, 100.58; $d = 1.15$). There was no statistical difference in HR_{PEAK} ($t_{(27)} = 0.12$, $p = 0.906$; MD = 0.66 $b \cdot min^{-1}$, $CI_{95\%}$ -10.75, 12.07; $d = 0.05$) or $\dot{V}O_{2PEAK}$ ($t_{(26)} = 1.58$, $p = 0.136$; MD = 4.15 $mL \cdot kg^{-1} \cdot min^{-1}$, $CI_{95\%}$ -1.47, 9.78; $d = 0.83$).

As shown in Table 2, the non-climbers reported significantly greater cognitive anxiety ($t_{(27)} = 2.21$, $p = 0.036$; MD = 3.05, $CI_{95\%}$ 0.22, 5.88; $d = 0.84$), and lower self-confidence ($t_{(27)} = 2.94$, $p = 0.007$; MD = -4.95, $CI_{95\%}$ -1.49, -8.41; $d = 1.10$), when compared to the climbers (Table 2). There was no significant difference in somatic anxiety ($t_{(27)} = 1.74$, $p = 0.093$; MD = 1.96, $CI_{95\%}$ -0.35, 4.29; $d = 0.66$). The non-climbers had a significantly greater percentage rise in anticipatory HR response ($t_{(27)} = 2.85$, $p = 0.008$; MD = 14%, $CI_{95\%}$ 4, 24; $d = 1.06$).

Table 2: Climb time, $\dot{V}O_2$ and HR, state anxiety, self-confidence and anticipatory heart responses (mean ± SD)

	NON-CLIMBERS	EXPERIENCED CLIMBERS	*ES (d)*	*Significance*
CLIMB TIME *(seconds)*	172.9 ± 71.6	112.7 ± 23.2	1.15	$p < 0.0005$*
HR ($b \cdot min^{-1}$) peak	162.1 ± 10.9	162.8 ± 15.2	0.05	$p = 0.906$
$\dot{V}O_2$ ($mL \cdot kg^{-1} \cdot min^{-1}$) peak	32.3 ± 4.6	36.5 ± 5.5	0.83	$p = 0.136$
CSAI-2R				
Somatic anxiety	14.3 ± 3.8	12.3 ± 2.1	0.66	$p = 0.093$
Cognitive anxiety	15.9 ± 4.8	12.8 ± 2.2	0.84	$p = 0.036$*
Self-confidence	27.7 ± 5.1	32.7 ± 4.0	1.10	$p = 0.007$*
Anticipatory rise in HR (%) *(Percentage difference from rest to 1 minute pre-climb)*	33 ± 14	19 ± 13	1.06	$p = 0.008$*

*Notes: HR heart rate; b.min⁻¹ beats per minute; $\dot{V}O_2$ volume of oxygen; $mL \cdot kg^{-1} \cdot min^{-1}$ millilitres per minute per kilogram; CSAI-2R competitive state anxiety inventory; * significant following FDR correction.*

A mixed model ANOVA (group*sampling time) revealed a significant interaction for salivary cortisol ($F_{(5,135)} = 4.29$, $p = 0.001$; $\eta_p^2 = 0.137$). Post-hoc FDR corrected paired samples *t*-tests demonstrated a statistically significant increase from pre-climb salivary cortisol only for the non-climbers 15-minutes after the climb ($t_{(13)} = 5.57$, $p < 0.0005$; MD = 2.49 nmol/L, $CI_{95\%}$ 1.53, 3.47; $d = 0.84$). As shown in Figure 2, a post-hoc FDR corrected independent samples *t*-tests demonstrated statistically greater salivary cortisol concentrations for the non-climbers than the climbers at 0, 5, 10, 15 and 20 minutes post climb, but not pre-climb, with the greatest difference observed 15-minutes' after the climb ($t_{(27)} = 2.78$, $p = 0.010$; MD = 3.50 nmol/L, $CI_{95\%}$ 0.92, 6.07; $d = 1.04$).

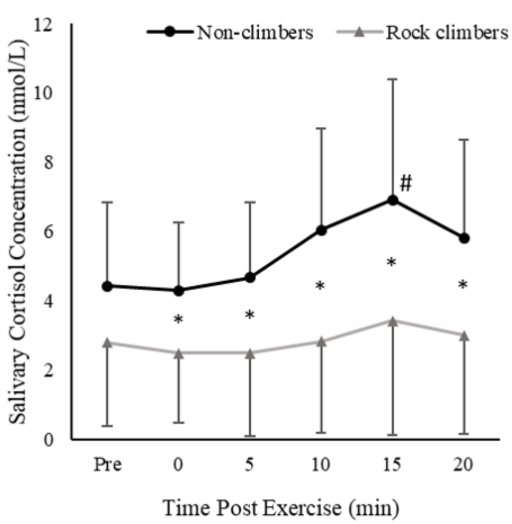

Figure 2: Salivary cortisol pre- and post-exercise (nmol/L). *statistical difference between groups, # statistical difference from pre-climb values.

4. Discussion

As a risk management sport which involves participants ascending to heights where potential harm is significant, rock climbing could offer a therapeutic intervention for trainee firefighters, construction workers or for those with acrophobia. As an initial investigation in this area, our aim was to examine psychophysiological responses of climbers and non-climbers to a 20-meter wire ladder climbing task. The main findings of the study were that: (a) non-climbers ascended at a significantly slower rate without any significant differences in HR_{PEAK} or $\dot{V}O_{2PEAK}$; (b) the non-climbers reported significantly greater cognitive anxiety and lower self-confidence, and (c) anticipatory HR rise and peak saliva cortisol concentrations were significantly higher than those sampled at baseline only for the non-climbers.

The free-hanging ladder climbing task was novel to all participants, non-climbers and climbers alike. Despite the climber's ability there were no significant differences in average or peak HR or $\dot{V}O_2$ between groups (Table 2). The lack of difference in cardiovascular measures between groups is unsurprising as many studies have also found no difference between ability groups of experienced climbers (Bertuzzi, Franchini, Kokubun, & Kiss, 2007; Draper et al., 2010; España-Romero et al., 2009); furthermore, it's known that it is not the systemic cardiovascular measures that separate climbing ability groups but the smaller changes inside small muscle groups, like the forearms, that are more important in determining performance (Fryer, Giles, Palomino, de la O Puerta, & España-Romero, 2018). However, despite this there were significant differences in the rate of ascent, with non-climbers taking ~ 60 seconds longer to ascend the ladder. It is conceivable that differences in pace of locomotion resulted because of climbing experience and/or elevated anxiety resulting in the conscious control and slowing of movements (Nieuwenhuys & Oudejans, 2012). The latter explanation is more likely, as differences in climbing pace between groups were also accompanied by a significantly greater psychophysiological response (Table 2 & Figure 2) in the non-climbers, due to anxiety in response to the ladder climbing task. Furthermore, while it is impossible to eliminate the former, its contribution is likely to be less significant as the task was novel to all, and all were instructed to ascend in the same way with a supinated grip (atypical for climbers). In support of the anxious disruption of movement, differences in climbing pace with anxiety have also been demonstrated in a climbing task by Pijpers et al. (2003), who reported significant alterations in movement behaviour when anxious novice climbers traversed a route at height, leading to slower and less fluent movement. Similarly, in a more typical climbing context, Draper et al. (2011) found unsuccessful intermediate climbers ascended a route significantly slower than successful climbers. Therefore, the slowing of the pace of ascent likely represents the anxious disruption of the non-climbers' movements, although further research would be necessary to confirm this (Nieuwenhuys & Oudejans, 2012).

The non-climbers displayed a significantly greater cortisol response (Figure 2), anticipatory rise in pre-climb HR, cognitive anxiety and lower self-confidence (Table 2) in comparison to the climbers, suggesting an increased nervous response to the ladder climbing task. More specifically, it is conceivable that the non-climbers elevated cortisol response occurred due to elevated hypothalamic-pituitary-adrenal axis activation, stimulated by increased anxiety due to the ladder task or even anticipation of the task (Kirschbaum & Hellhammer, 2000). This proposal is further supported by the non-climbers' greater self-reported cognitive anxiety and pre-climb anticipatory rise in HR from rest (Tables 2 and 3). Conversely, despite the novelty of the ladder climbing task, the blunting of the climbers' cortisol response may have resulted from familiarity with ascending to height or through self-selection into the sport as a result of predisposition for working at height (Kirschbaum et al., 1995), the most likely explanation is one of habituation. Pre-climb heart rate and self-reported state anxiety would appear to provide a means of tracking stress response over time, although further research will be necessary to establish if this is the case; possibly through assessing the responses of novice climber to repeated ladder ascents.

The results of previous climbing psychophysiology research are discordant having failed to identify significant differences in either cortisol or anticipatory HR between abilities groups or in response to different tasks (Dickson et al., 2012; Fryer et al., 2013), for a review of this research see Giles et al. (2014). In contrast, the findings of the current study lend support for climbers having a sport specific blunted psychophysiological response. Whilst it could be speculated that some of the increased peak cortisol response in non-climbers might have been due to the greater exercise duration (Hill et al., 2008) and greater anaerobic energy system contribution (Bertuzzi et al., 2007). However, it is unlikely that exercise intensity solely affected peak cortisol response, as (a) HR and $\dot{V}O_2$ were similar between the groups; (b) there was no relationship between climb time and cortisol (p = 0.179; r = -0.266); and (c) excess post-exercise oxygen consumption was similar between groups ($p < 0.0005$).

Given the non-climbers' increased level of anxiety in response to the task, coaches and instructors should be aware of the implications arising because of the need to ascend to height when working with novices or when training people to work at height, particularly considering anxieties implications for performance and learning, most likely associated with brain-stem activation as a part of the flight or fight response. While anxiety is known to have implications for climbing performance (Pijpers et al., 2003), it is also associated with interference in learning and discontinuation of sport participation and less pleasure while participating (Crane & Temple, 2015). Future research should consider the implications of anxiety when ascending to height for the learning of technical movement skills in climbers; research should also consider the role of anxiety towards ascending to height for sport progression and enjoyment. Finally, the potential for health-based studies where climbing could be used to modify or help with anxiety disorders should be explored.

5. Conclusion

In order to explore the psychophysiological responses to ascending to height for climbers and non-climbers a low skill ladder climbing task was selected for our study. Consequently, this study appears to be the first to compare psychophysiological responses of non-climbers and climbers, providing insight into habituation, and consequential blunting of psychophysiological responses through involvement in rock climbing. Our data suggest that climbers display an attenuated psychophysiological response to ascending to height when compared with non-climbers. Based on the results of the present study, if not due to self-selection to the sport, it is possible that climbers are habituated to ascending to height. We would speculate, given our findings, that the most likely explanation is one of habituation. Given these findings, rock climbing may offer a distracting therapeutic intervention for trainee firefighters, construction workers or for those with acrophobia which affords a blunting of the fear of height response.

Conflict of Interest

No potential conflict of interest was reported by the authors

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