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State anxiety and cortisol reactivity to skydiving in novice versus experienced skydivers

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Running head: Stress reactivity to skydiving

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Abstract

Previous studies have suggested that skydiving, a naturalistic stressor, is associated with increases in self-reported stress, anxiety and cortisol levels. However, it has not been established whether this stress reactivity is altered as a function of repeated exposure to skydiving. This is of interest due to previous observations that cortisol reactivity becomes habituated with repeated exposure to laboratory stressors, however, few studies have investigated such habituation to naturalistic stressors. State anxiety and cortisol reactivity to skydiving were measured in 11 first-time skydivers and 13 experienced skydivers (≥ 30 jumps, mean jumps = 397.6), who were to complete a solo skydive. The novice skydivers reported significantly greater levels of state anxiety prior to the jump; however, there were no differences in pre-jump levels of salivary cortisol. Both groups exhibited significantly elevated salivary cortisol levels immediately post-jump, relative to i) pre-jump and ii) recovery. However, the two groups were indistinguishable with regards to their cortisol reactivity to the skydive. These findings support previous research demonstrating that skydiving elicits acute cortisol activation. Further, they suggest that i) cortisol reactivity does not habituate in experienced jumpers, and ii) that there is lack of concordance between self-reported levels of anxiety and biological stress reactivity in experienced skydivers.

Keywords: Skydiving, stress reactivity, state anxiety, HPA axis, cortisol, habituation

1. Introduction

Skydiving is a reasonably popular extreme sport, with approximately 500,000 people partaking in their first skydive in the United States each year [1]. The British Parachute Association reported that a total of 243,220 parachute descents were made in 2011 [2], with the number of people taking part in the sport increasing by 27% since 1997. Given that skydiving is perceived as a high risk behaviour, attempts have been made to better understand the psychological profile of individuals who choose to partake in this activity. For example, it has recently been reported that skydivers report higher levels of sensation seeking than the normal population [3, 4, 5].

Skydiving has also previously been used as a naturalistic model of acute stress to assess the biological mechanisms involved in the stress response. In response to acute stress, two primary physiological stress systems are activated. The sympathetic-adrenal-medullary (SAM) axis, with the primary hormonal endpoints adrenaline (epinephrine) and noradrenaline (norepinephrine), activates the 'fight or flight' response, and is therefore associated with short-term physiological changes such as increased heart rate and blood pressure. The hypothalamic-pituitary-adrenal (HPA) axis, with the primary hormonal endpoint cortisol, is a slower acting mechanism which enables further mobilisation of physiological resources to enable the body to deal appropriately with the stressful stimulus. It is worthy of note that a meta-analysis of tasks which are designed to induce stress suggested that cortisol reactivity is most amenable to tasks with either i) high socio-evaluative threat, or ii) low perceived situational control [6]. Intuitively, skydiving comprises elements of both of these factors; thus, this activity is likely to elicit activation of the HPA axis.

A number of studies have now reported that skydiving is indeed associated with increased activation of these biological mechanisms. For example, skydiving leads to activation of both the SAM and HPA axis, as evidenced by post-jump increases in the SAM axis biomarker salivary α amylase and cortisol respectively in novice jumpers [7, 8]. Similarly, other factors which are associated with activation of the SAM axis, such as increased heart rate [9, 10] and symptoms of

hyperarousal, (e.g. heart racing, sweating, shaking/trembling and shortness of breath) [11], have been observed in individuals undertaking their first skydive.

These findings suggest that skydiving can modulate the activity of both the HPA and SAM axes; however, what remains unclear is whether this level of activity is modified with increased exposure, or habituation, to the stressor. Habituation is typically observed in laboratory situations where individuals demonstrate the greatest levels of HPA activation following the first stressor exposure and then diminished reactivity following subsequent exposure [12]. From this perspective, it would be expected that experienced skydivers, who have had greater exposure to skydiving and should therefore have greater levels of perceived control, would demonstrate reduced cortisol reactivity compared to novice or first time jumpers. Studies which have investigated this suggestion have typically focussed on reactivity of the SAM axis and observed post-jump increases in heart rate in both novice and experienced jumpers, but no differences between the groups [5, 13, 14]. Similarly, although experienced skydivers also demonstrate post-jump increases in cortisol [15], no studies to date have compared novice versus experienced skydivers in relation to reactivity of the HPA axis. Deinzer and colleagues [16] have reported that when novice skydivers undertake three skydives on the same day, cortisol reactivity to the third jump is significantly lower than the reactivity to the first two jumps, suggesting that cortisol responses to skydiving may habituate with experience. However, it is uncertain whether this decline in the cortisol response across the day could be accounted for by i) the naturally occurring diurnal cortisol decline, ii) repeated activation of the HPA axis and the release of adrenal hormones within a relatively short period, and/or iii) higher cortisol levels earlier in the day resulting from an elevated cortisol awakening response due to anticipatory stress (i.e. undertaking three skydives) [17]. A further study [18] considered the effects of repeated parachute jump training, over the course of 11 days, in Norwegian trainee soldiers, and reported a significant decrease in plasma cortisol levels following the training jumps with experience. However, the training jumps involved a jump from a 12 metre high tower down a zip-line; therefore, it is unlikely that such a training exercise would evoke a similar

psychobiological stress response as parachute jumping from an aeroplane, in which the potential risks to the participant are considerably greater. A comparison between novice and experienced skydivers would, therefore, provide a more effective paradigm in which to address the question of whether cortisol reactivity to skydiving habituates over time.

To the best of our knowledge, this is the first study to directly compare cortisol reactivity to and recovery from skydiving in first-time skydivers with that of substantially more experienced skydivers. It is of interest to investigate this question, in order to ascertain whether experience of a naturalistic stressor leads to physiological response habituation similar to that which has been observed from repeated exposure to laboratory stressors. The primary aim of the present study was to investigate whether there is any habituation to skydiving, in terms of a reduced cortisol response to this activity, in individuals with substantially greater skydiving experience. Secondly, behavioural comparisons between novice and experienced skydivers with regards to perceived anxiety were also made.

2. Method

2.1. Participants

A total of 24 healthy male participants were recruited from a parachute centre in the north of England, ranging in age from 18 to 50 years ($M_{\text{age}} = 28.04$, $SD_{\text{age}} = 11.10$). The sample comprised 11 novice skydivers carrying out their first solo skydive ($M_{\text{age}} = 21.8$, $SD_{\text{age}} = 5.3$), and 13 experienced skydivers, defined as people who had completed their Category A certificate solo skydiving qualification, and having completed at least 30 previous solo skydives ($M_{\text{descents}} = 397.6$, $SD_{\text{descents}} = 391.8$; $M_{\text{age}} = 33.8$, $SD_{\text{age}} = 12.2$). The novice group had not previously partaken in any form of skydiving activity, including solo and tandem formats. The two groups did not differ in terms of trait anxiety ($M_{\text{novice}} = 15.5$, $SD_{\text{novice}} = 10.8$; $M_{\text{experienced}} = 13.3$, $SD_{\text{experienced}} = 5.5$; $p = 0.54$).

2.2. Materials

2.2.1. Trait anxiety. The State-Trait Anxiety Inventory (STAI) [19] contains two parts: one which measures state anxiety, and one which measures trait anxiety. The trait anxiety subscale from the STAI comprises 20 items regarding the participant's general level of anxiety, which are measured on a 4 point Likert scale ('Almost never' – 'Almost always'). Participants are asked to report how they 'generally' feel. Sample items include 'I feel pleasant' and 'I feel nervous and restless', with positive items being reversed scored so that higher overall scores indicate greater trait anxiety. Possible scores range from 0 to 60. The coefficient alpha reliability reported by Spielberger et al. [19] was .86 for the trait anxiety subscale.

2.2.2. State anxiety. The state anxiety subscale of the STAI comprised 20 items, with responses being measured on a 4 point Likert scale ('Not at all' – 'Very much so'). The instrument asks participants to rate how they feel 'right now, that is, at this moment'. Sample items include 'I feel calm' and 'I feel nervous', with positive items being reverse scored so that higher overall

scores indicate greater state anxiety. Possible scores range from 20 to 80. Spielberger et al. [19] reported a coefficient alpha reliability of .54 for the state anxiety subscale.

2.2.3. Salivary cortisol. Saliva samples were collected using Salivette saliva collection tubes (Sarstedt, Nümbrecht, Germany). These tubes comprised a cotton roll within a plastic tube. In order to obtain the sample, participants were required to chew on this cotton swab for 3 minutes. Participants then placed the cotton roll back into the plastic tube. The Salivettes were returned to the researcher immediately after sample collection. Within 24 hours of collection, samples were frozen at -20 degrees Celcius until they were removed, defrosted and centrifuged at 3,000 rpm for 15 minutes to extract the saliva from the cotton swab. Salivary cortisol was then quantified for each sample by enzyme immunoassay (Salimetrics Europe, Newmarket, United Kingdom) conducted in accordance with the manufacturer's instructions. Intra-assay coefficients of variation were less than 10%.

2.3. Procedure

Ethical approval for the study protocol was obtained from the Ethics Committee of the School of Life Sciences at Northumbria University.

All testing took place between 1300 and 1700 when levels of cortisol are typically lower and more stable [20]. Participants provided informed consent upon arrival at the airfield. They were instructed not to consume any caffeine 2 hours prior to, and for the duration of the study in order to prevent any effects of caffeine on cortisol levels [21]. On completion of the consent forms, participants were instructed to complete the trait anxiety portion of the STAI. Saliva samples were collected in addition to the participants completing the state anxiety portion of the STAI at three time points: i) within 15 minutes prior to boarding the plane (with participants wearing their parachuting equipment), ii) immediately upon landing (and while still wearing parachuting equipment), and iii) one hour post-landing.

The novice group was taken up in the plane to an altitude of 3,500 ft for their descent (approximately 15 minutes flight time). On the instructor's command, the participants exited the plane and their parachute was automatically deployed for them by a static line as they fell away from the aircraft. It was then the student's responsibility to direct their canopy down to the ground, although they had a radio in their helmet through which the ground controller could direct them if necessary. The experienced jumpers were taken to an altitude of 13,000 ft (this aircraft had a faster climb rate, so also took approximately 15 minutes flight time to altitude). Unlike the novice group, the experienced jumpers were responsible for initiating their own parachute deployment after approximately 65 seconds of free-fall. Safety devices were in place for all participants from both groups: all participants' containers were fitted with two parachutes; a main canopy, and a reserve canopy.

2.4. Data Analysis

Data for state anxiety and cortisol were analysed separately using 2 (group: novice, experienced) \times 3 (time: pre-jump, immediately post-jump, 1 hour post-jump) mixed ANOVAs. Significant main effects were followed up using Bonferroni adjusted pairwise comparisons. Significant interaction effects were followed up using Bonferroni adjusted t-tests.

3. Results

3.1. State anxiety

A significant group \times time interaction was observed, $F(2, 20) = 20.32, p < 0.001$, with a large effect size (partial $\eta^2 = 0.67$).

A follow up independent-samples t-test run for each time point (Bonferroni adjusted $\alpha = 0.017$) showed that the difference between the conditions was significant for the 'pre-jump' time point $t(21) = -6.59, p < 0.001$, with state anxiety being higher for the novice condition. No significant between-group differences emerged for the 'immediately post-jump' time point $t(21) = -1.67, ns$, or the '1 hour post jump' time point $t(21) = -1.01, ns$ (see Figure 1).

INSERT FIGURE 1 ABOUT HERE

3.2. Cortisol

The group \times time interaction, $F(2, 21) = 1.60, ns$, partial $\eta^2 = 0.13$, and main effect of group, $F(1, 22) = 0.30, ns$, partial $\eta^2 = 0.01$ failed to reach significance. However, a significant main effect of time was observed, $F(2, 21) = 11.68, p < 0.001$, with a large effect size (partial $\eta^2 = 0.53$).

Post hoc Bonferroni pairwise comparisons on the main effect of time revealed that cortisol levels at the immediate post-jump time point were significantly higher than the pre-jump and 1 hour post-jump time point ($p = 0.001$ for both comparisons). This analysis also revealed that there was no significant difference between the pre-jump and 1 hour post jump time points (see Figure 2).

INSERT FIGURE 2 ABOUT HERE

4. Discussion

The primary aim of the present study was to investigate differences in cortisol reactivity to skydiving between novice and experienced jumpers. The novice group reported relatively higher subjective levels of anxiety immediately prior to boarding the plane than experienced jumpers. In addition, both groups exhibited increased salivary cortisol immediately following the jump, relative to before the jump and one hour post-jump. However, there were no differences between the novice group and the experienced group in terms of the cortisol reactivity profile. These findings support the view that skydiving is a naturalistic stressor which can evoke a physiological stress response. Further, our findings suggest that with regard to cortisol reactivity to skydiving, habituation does not occur with experience.

The observation that the novice skydivers had significantly elevated levels of anxiety immediately prior to the jump reflects the finding of Chatterton and colleagues [7]. However, it is of interest that state anxiety levels were not significantly elevated in experienced skydivers. The present study is among the first to compare novice to experienced skydivers directly; therefore, it is a noteworthy observation that subjective anxiety becomes habituated with skydiving experience. It would be of interest in future studies to systematically investigate the number of jumps that are typically required to induce this habituation effect with regard to pre-jump subjective anxiety.

Despite experienced skydivers reporting substantially lower levels of subjective anxiety prior to the jump than the novice skydivers, the cortisol reactivity profiles were similar for both groups. This finding suggests an apparent discordance between self-reported anxiety and physiological stress reactivity in the experienced skydivers, and mirrors a mismatch between self-reported stress and objectively measured cortisol which was reported in a previous study that investigated cortisol responses to skydiving in experienced skydivers [15]. Speculatively, this finding could reflect a reporting bias in the experienced group, or an actual dissociation between perceived anxiety and the HPA axis to an acute naturalistic stressor.

The cortisol profiles for both groups were characterised by significantly elevated levels of cortisol immediately following the skydive, relative to before, and one hour following the skydive. These findings align with previous observations that skydiving increases cortisol levels in both experienced [15], and novice [7, 8, 9] skydivers. However, our study is the first to directly compare cortisol reactivity to skydiving in novice versus experienced skydivers. Despite previous research supporting modulation of cortisol levels by skydiving in both of these groups, intuitively, we expected that there may have been some habituation of responding in the experienced group, leading to relatively higher cortisol levels in the novice group at the immediately post-jump time point. This hypothesis was also predicated by a previous finding by Deinzer et al. [16], which suggested that cortisol reactivity to skydiving decreases by the third jump in individuals who undertake three skydives on the same day. However, no significant differences in cortisol reactivity were observed between the novice and experienced groups in the present study. This finding is line with the work of Allison et al. [5], which observed an increase in SAM axis activity (heart rate) in both novice and experienced skydivers. Taken together, the current findings and those of Allison et al. [5], suggest that neither the SAM nor HPA axes are subject to habituation in response to multiple exposures to skydiving. On this basis, it can be inferred that physiological responses to naturalistic stressors are not subject to the same degree of habituation as laboratory stressors. This notion is supported by previous animal work [22], but previously remained relatively unexplored in human studies.

Leach and Griffith [14] also failed to observe a difference in sympathetic arousal (heart rate) in response to skydiving between novice and experienced skydivers. Interestingly, these authors noted a number of cases in which very experienced skydivers suffered fatal skydiving related accidents due to apparent cognitive failures associated with a lack of engagement with emergency recovery procedures. Further, in their study, Leach and Griffith [14] noted that the novice and experienced skydivers exhibited similar memory deficits (relative to a non-jump control condition) while in the plane, immediately prior to skydiving. Elevated cortisol has been associated previously

with memory deficits [23], suggesting that elevated levels of cortisol may be a mechanism underpinning memory deficits in both novice and experienced skydivers. This idea should be explored further in future studies.

The present study sheds light on the usefulness of skydiving as a stressor paradigm in future studies interested in investigating the role of HPA axis activation on various biological and psychological outcomes. As mentioned previously, habituation to laboratory stressors occurs over repeated exposure [12], meaning that many laboratory stressors are not appropriate for repeated measures designs in which evoked high levels of cortisol are required in multiple separate testing sessions. However, given that the cortisol response to skydiving appears not to habituate, skydiving could be a useful paradigm in which to evoke a cortisol response to a naturalistic stressor across multiple testing sessions. The relative lack of habituation to skydiving, compared to laboratory stressors may be due to the fact that this activity has potentially fatal consequences [24]. The risks associated with skydiving do not reduce with each jump undertaken, which could account for the lack of habituation of the cortisol response to skydiving observed in the present study. However, the lack of concordance between subjective state anxiety and cortisol reactivity to skydiving in the present study is a potential issue in terms of the usefulness of skydiving as a paradigm for evoking stress in situations where only subjective measurements of stress are available.

One limitation of the present study is that the type of skydive differed between the novice and experienced skydivers. The novice participants were taking part in their first solo skydive and therefore jumped without free-fall, from a height of 3,500 ft, with an automatically deploying parachute. This is a standard jump for a first-time solo skydiver. By contrast, the jumps undertaken by the experienced skydivers involved free-fall, were from a higher altitude, and required the participants to deploy their own parachute. Any observed differences could, therefore, be attributed to differences in jumping style; however, beyond number of jumps, it is important to consider that it is these very differences which contribute to the status of novice versus experienced skydivers and as such contribute to the stress experience. Furthermore, these are the conditions under which each

of these groups would jump under non-study related conditions, and it was important to maintain typical conditions to ensure the ecological validity of the study. Future research could potentially address whether there are inter-individual changes in cortisol reactivity to skydiving by measuring cortisol responses to each jump in a repeated measures fashion as skydivers progress from first-time jumpers through their training programme to the point of certification. It would also be beneficial in future studies to collect a greater number of saliva samples during the recovery period, during the time when cortisol levels would be at their post-stress peak. This would enable a greater understanding of cortisol recovery from a naturalistic stressor, and would enable adjustment for any inter-individual differences in the time at which the cortisol peak occurs.

4.1. Conclusion

In summary, the present study is the first to observe that skydiving induces an increase in cortisol levels in both novice and experienced skydivers, but that there are no differences in cortisol reactivity between these two groups. This is in context of relatively greater subjective anxiety in the novice group immediately prior to the jump. These findings suggest that physiological stress reactivity to skydiving does not habituate, and highlight the usefulness of skydiving as a naturalistic stressor in future research.

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Figure Captions

Figure 1. State anxiety levels for the experienced and novice group. Self-reports of state anxiety were obtained i) within 15 minutes prior to boarding the plane, ii) immediately upon landing, and iii) one hour post-landing. State anxiety was significantly higher in the novice group, relative to the experienced group, at the pre-jump time point.

Figure 2. Salivary cortisol levels for the novice and experienced groups. Saliva was sampled i) within 15 minutes prior to boarding the plane, ii) immediately upon landing, and iii) one hour post-landing. Salivary cortisol was significantly higher in both groups at the immediately post-landing time point, relative to the pre-jump and one-hour post jump timepoints. There were no significant between-group differences in salivary cortisol.

Figure1

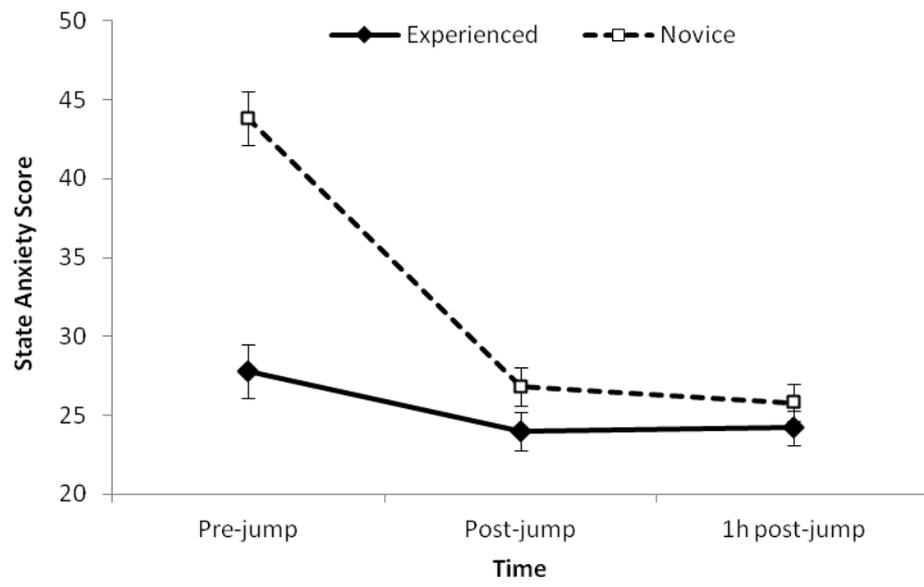


Figure2

