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The effects of walking posture on affective and physiological states during stress

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ABSTRACT

Background and objectives: Embodiment theory proposes that motor processes are associated with emotions and cognitions. Previous research has shown that walking posture can influence affective memory bias. This study further investigated this theory by looking at the effects of an upright versus slumped walking posture on psychological and physiological states when faced with a psychological stressor.

Methods: Seventy-three healthy adults completed baseline self-report measures of affect, power, and sleepiness, and physiological measures of blood pressure, galvanic skin response, and skin temperature. After walking in their usual posture, the same self-report and physiological measures were obtained. Participants were then randomly allocated into one of two groups where they were asked to walk in either an upright posture or a slumped posture. While walking, participants underwent a psychological stressor. After experimental walking, the same self-report and physiological measures were obtained.

Results: The upright walking posture group showed significantly improved psychological states including less low arousal negative affect, less sleepiness, less pain and marginally greater feelings of power than the slumped walking posture group. Physiologically, the upright walking posture group showed significantly lower systolic blood pressure, galvanic skin response, and marginally lower skin temperature than the slumped walking posture group.

Limitations: This was a short-term laboratory-based experiment and results may not generalise to other situations.

Conclusions: Walking posture can affect both psychological and physiological states. Applications of these findings may have implications for improving mental and physiological health.

1. Introduction

Embodiment theory suggests that experiences of emotions and cognitions are associated with muscular states, including facial expressions, body postures, and movements (Winkielman et al., 2015). Research supporting this theory has shown that manipulating body posture can affect psychological responses. For example, an upright posture while seated has been linked with improvements in affective states, feelings of power, and sleepiness compared to slumped posture (Hao, Yuan, Hu, & Grabner, 2014; Nair, Sagar, Sollers, Consedine, & Broadbent, 2015; Ranehill et al., 2015; Riskind & Gotay, 1982).

Facial expressions and body postures have been shown to influence physiological and psychological responses to acute psychological stressors. Participants experimentally manipulated to have smiling facial expressions during a stressor reported less reduction in positive affect and had slower heart rates during recovery than participants with neutral expressions (Kraft & Pressman, 2012). Furthermore, participants experimentally manipulated to have an upright posture during a stressor had higher pulse pressure, reported better mood and higher arousal, and used fewer negative emotion words than those manipulated to have slumped posture (Nair et al., 2015). Other research has shown that participants in a supine posture (lying down) reported lower anticipatory anxiety prior to a stressor than those standing, which may involve a difference in baroreceptor load (Lipnicki & Byrne, 2008).

Research has now begun to examine the effects of posture during walking on psychological responses, showing effects on affective memory bias and alertness. People manipulated to walk with a 'happy' style recalled more positive words than negative words, than people

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manipulated to walk with a 'depressed' style (Michalak, Rohde, & Troje, 2015). Furthermore, after engaging in a slumped posture during walking, healthy people experienced decreased alertness compared to people adopting a skipping gait pattern (Peper & Lin, 2012). However, there has been little research investigating the effects of posture while walking on affective states especially during stress. If different styles of walking alter physiological and psychological responses to stress, then this could both support embodiment theory and have implications for stress management interventions.

There is some evidence that manipulating body posture can influence physiology, although effects are complex. A more upright posture tends to be associated with lower blood pressure and lower arm temperature, although there are inconsistent results for effects on galvanic skin response (Gellman et al., 1990; Sun et al., 2012; Tikuisis & Ducharme, 1996; Tulen, Boomsma, & Man in 't Veld, 1999; Wenger & Irwin, 1936). Walking short distances increases galvanic skin response, but there is limited research into the acute effects of walking on blood pressure, and there are inconsistent results regarding skin temperature (Boettger et al., 2010; Rowell, Murray, Brengelmann, & Kraning, 1969; Shimizu, Kosaka, & Fujishima, 1998; Whitley & Schoene, 1987).

This research aimed to investigate whether an upright walking posture could produce immediate short-term improvements to psychological states (affective states, feelings of power, sleepiness, and perceived pain) and physiological states (blood pressure, galvanic skin response, and skin temperature) compared to a slumped walking posture during a psychological stressor. In other words, whether upright walking posture may act as a buffer against stress compared to a slumped walking posture. An experiment was employed in which participants were randomly allocated into either the upright walking posture group or the slumped walking posture group. Similar to prior studies (Nair et al., 2015; Wilkes, Kydd, Sagar, & Broadbent, 2017), a stress task was used (the Trier Social Stress Test) to elicit affective responses. Laboratory induction of stress via this test has been shown to increase cortisol, galvanic skin response, blood pressure, heart rate, reported stress, anxiety, as well as worsen negative mood and reduce sleepiness (Allen, Kennedy, Cryan, Dinan, & Clarke, 2014).

It was hypothesised that participants in the upright walking posture would report less negative affective states, greater feelings of power, and less sleepiness after the psychological stressor compared to participants in the slumped walking posture. It was also hypothesised that participants in the upright walking posture would have lower blood pressure, lower galvanic skin response, and lower skin temperature compared to participants in the slumped walking posture, suggestive of a lower stress response.

2. Material and methods

2.1. Participants

The sample size was determined before recruitment commenced using the power analysis programme G*Power 3 (Faul, Erdfelder, Lang, & Buchner, 2007). The expected effect size was based on Michalak et al. (2015) who reported a medium to large effect size (d = 0.77). A sample size of 66 (n = 33 per group) was required to detect an effect size d = 0.77, at 80% power, and at a significance level of 0.05. To account for potential missing data, the sample size target was set to N = 73 (+10%).

A total of 118 people expressed interest in the study and were assessed for eligibility (Fig. 1). The inclusion criteria were those who were: (1) able to read, write, and speak proficiently in English; (2) able to walk unaided at three kilometres per hour for 19 min; and (3) over the age of 18 years. The exclusion criterion was those who were not able to adopt the assigned posture. Of these people, one person did not meet the inclusion criteria, one was excluded because they were not able to adopt a slumped posture, two declined to participate, and 41 did not participate due to other reasons. A total of 73 out of 114 eligible people agreed to participate and gave written informed consent. Ethics approval for this study was obtained on 07/05/2015 from the University of Auckland Human Participants Ethics Committee.

2.2. Apparatus

Participants walked on a SciFit AC7000 treadmill which allowed control over the level of physical activity and environmental factors. All participants were initially asked to walk on the treadmill in their usual natural walking style and were not directed on posture or arm swing to obtain usual walking posture measurements. Pointers made from red duct tape were positioned on either the wall in front of the treadmill at eye level or on the treadmill's stationary plastic area that meets the top of walking belt below eye level, and were used to direct participants' head angle and eye gaze depending on which experimental group they were in (the upright posture group were told to look at the pointer on the wall, and the slumped posture group were told to look at the pointer on the treadmill). A Panasonic HC-V160 video camera mounted on top of a tripod was used to record each participant's usual walking and experimental walking, and was placed one metre away on the right side of participants to obtain side-on postural angles of the head, trunk, and arms.

2.3. Instruments

An altered version of the actual affect component of the *Affect Valuation Index* (AVI; Tsai, Knutson, & Fung, 2006) was administered before usual walking, after usual walking, and after experimental walking to assess affective state. There were five response options from 1 (*very slightly or not at all*) to 5 (*extremely*), for items composing eight subscales, each assessing a different arousal state dimension of affect: high arousal positive (enthusiastic, excited, strong); positive (content, happy, satisfied); low arousal positive (rested, calm, peaceful, relaxed); low arousal (quiet, still, passive); low arousal negative (dull, sleepy, sluggish); negative (lonely, sad, unhappy); high arousal negative (fearful, hostile, nervous); and high arousal (aroused, astonished, surprised) affective states.

A *Feelings of Power Scale* was administered to all participants before usual walking, after usual walking, and after experimental walking to assess state feelings of power. Participants rated how *dominant, in control, powerful,* and *confident* they felt from 1 (*not at all*) to 5 (*extremely*), modified from Cuddy, Wilmuth, and Carney (2012).

The *Stanford Sleepiness Scale* (SSS; Hoddes, Zarcone, Smythe, Phillips, & Dement, 1973) was administered to all participants before usual walking, after usual walking, and after experimental walking to assess levels of sleepiness. The SSS consisted of one item and required respondents to select one of seven statements best representing their level of perceived sleepiness, from 1 (*feeling active, vital, alert, or wide awake*) to 7 (*no longer fighting sleep, sleep onset soon; having dream-like thoughts*).

A *Visual Analogue Scale* (VAS) was administered to all participants once after experimental walking to assess whether posture during walking influenced participants' current pain. The scale consisted of a horizontal line in which participants were instructed to rate their current level of pain on a VAS ranging from 0 (*no pain*) to 10 (*worst possible pain*). The scale was added halfway through the study after some participants complained of experiencing pain.

Galvanic skin response (perspiration) and skin temperature measurements were obtained from the Basis Peak wrist-worn fitness tracker at five timepoints: five minutes before usual walking, during usual walking, during experimental walking, during speech task, and five minutes after experimental walking and stress task (recovery). The Basis Peak, manufactured by Basis Science Inc. and Intel Cooperation, has a galvanic skin response sensor and a skin temperature sensor on the underside for continuous measurements of galvanic skin response and skin temperature. To obtain good measurements, the Basis Peak

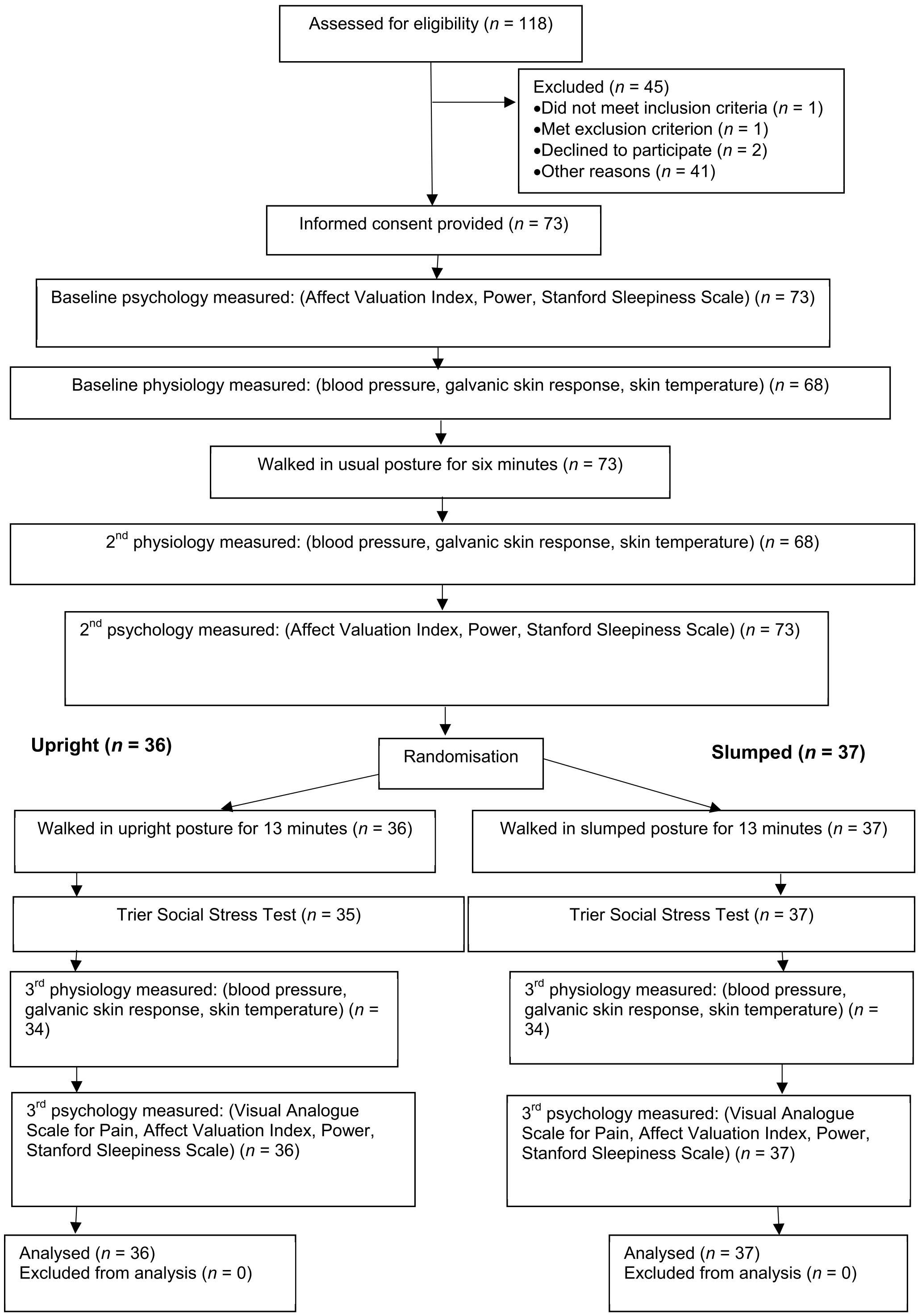

Fig. 1. Flow chart showing participant recruitment and experimental procedures.

was worn securely and slightly above the wrist.

An automatic blood pressure monitor with intellisense (Omron model: IA2 HEM-7011-CAU) measured all participants' blood pressure before usual walking, after usual walking, and after experimental walking. To ensure a reliable reading, any clothing was removed from participants' upper arm, participants sat on a chair with their feet flat on the floor and an arm placed on a table so that the arm cuff was the same level as their heart, and the arm cuff was applied to their upper right arm.

2.4. Procedure

Eligible people who expressed interest were sent a Participant Information Sheet and booked into a laboratory session at the Body Composition Laboratory in Auckland Hospital. Before participants came to the laboratory, they were asked to wear either spandex or tight-fitting clothing to ensure that gait marker placement was a reliable and accurate reflection of anatomical landmark location, as well as to wear comfortable shoes to walk in. Participants' core metrics were entered into the Basis Peak activity tracker: participant number, gender, date of

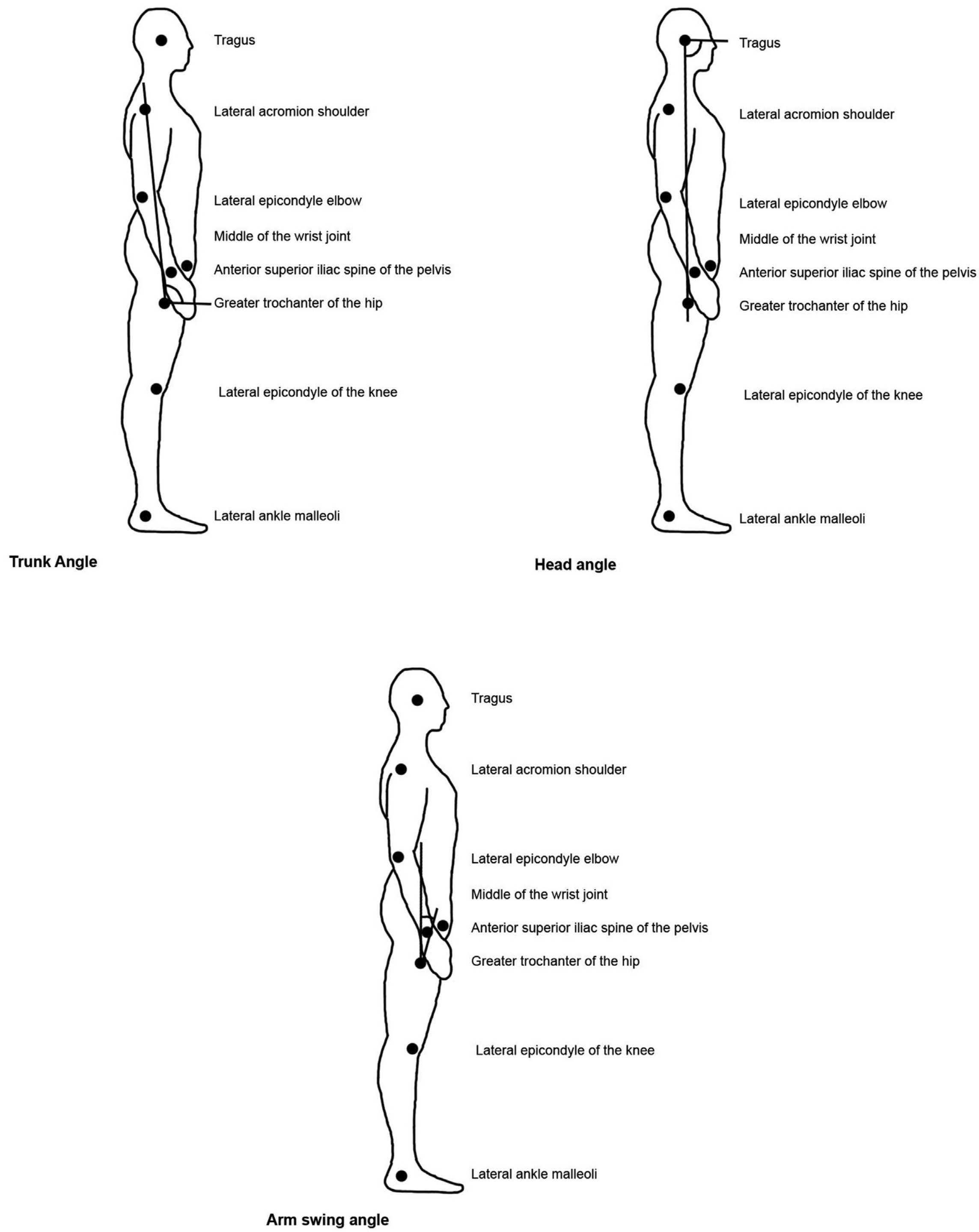

Fig. 2. Assessment of trunk angle, head angle, and arm swing angle.

birth, height (centimetres), and weight (kilograms). Upon arrival at the laboratory, participants were told a cover story that this study was investigating the effects of walking on cognitive processing. They were not told that there were two groups and were unaware of hypotheses. Participants read and signed the written consent form to participate in this study.

The experiment began with the researcher securely fitting the Basis Peak monitor slightly above the participants' left wrist to obtain continuous measurements of galvanic skin response and skin temperature. For assessment of sagittal plane posture during gait, reflective markers were placed on bony anatomical landmarks for ease of reproducibility between participants. A modified form of the Helen Hayes marker set was used to allow for measurement of trunk, head, and arm swing angles from video analysis (marker placement: tragus, lateral ankle malleoli, lateral epicondyle of the knee, greater trochanter of the hip, anterior superior iliac spine of the pelvis, middle of the wrist joint, lateral epicondyle elbow, and lateral acromion shoulder). To uphold the cover story, participants were told that gait markers were used to allow clearer visibility of their walking on the video recording, which concealed the true purpose of allowing postural measurements during walking using the video recording.

Baseline measurements including self-report questionnaires and blood pressure readings were obtained five minutes after the participant sat down. During usual (baseline) walking participants were asked to walk on the treadmill in their usual walking style at three kilometres per hour for six minutes to obtain usual walking posture measurements. After baseline walking, participants sat down again and completed the second set of measurements including self-report measures and blood pressure measures.

Next, participants were randomised to either the upright walking posture or the slumped walking posture group. All participants walked on the treadmill at three kilometres per hour for 13 min, but instructions differed depending on group allocation. Participants in the upright group were asked to walk holding an upright posture stretching their spine, keeping their shoulders back, keeping their head level, looking ahead, and swinging their arms during walking. Participants in the slumped group were asked to walk holding a hunched over posture bending their spine, slumping their shoulders forward, keeping their head down, looking downwards at the pointer on the treadmill, and holding their arms still during walking. At the third minute of the experimental walking, all participants began a 10-min stress task involving a modified version of the Trier Social Stress Test. In the first five minutes of the test, participants were told to prepare a speech to a panel of judges explaining why they would be a good candidate for their dream job, and that they were competing for one of two $150 Westfield vouchers. In the last five minutes, participants were required to speak continuously and were prompted to keep speaking if they stopped. At the 13th minute, participants stopped walking on the treadmill and sat down in the chair. Then, participants completed the last set of measurements including the self-report and blood pressure measures. The Basis Peak activity tracker and the gait markers were removed after five minutes resting. When all participants had completed the study and data had been analysed, a debrief letter was emailed that described the cover story used.

2.5. Analysis

Independent t-tests were conducted at baseline to check for differences between groups. A manipulation check was conducted to ensure participants from both groups had similar postures during usual walking and different postures during experimental walking (either upright or slumped). Participants' postures were assessed at midway points during usual walking and during experimental walking. To assess postural angles, still images from the video recordings were selected and measured using Kinovea, a software tool for the analysis, measurement, comparison, and motion observation of videos ("Kinovea," n.d.). Participants' trunk angle was measured using an acute angle with the vertex at the marker on the greater trochanter of the hip, one side of the angle at the marker on the lateral acromion shoulder, and the other side of the angle parallel to the horizontal plane (Fig. 2). Head angle was measured using an acute angle with the vertex at the marker on the tragus, one side of the angle at the marker on the greater trochanter of the hip, and the other side of the angle parallel to the horizontal plane (Fig. 2). Arm swing angle was measured using an acute angle with the vertex at the marker on the greater trochanter of the hip, one side of the angle at the marker on the middle of the wrist joint, and the other side of the angle parallel to the vertical plane (Fig. 2).

Change scores for affect variables, feelings of power, sleepiness, systolic blood pressure and diastolic blood pressure, were calculated by subtracting scores after experimental walking from scores after usual walking. Analyses of covariance (ANCOVAs) were conducted to investigate whether the two postural groups differed on these change scores after controlling for scores after usual walking for all of these variables (Vickers & Altman, 2001). For galvanic skin response and skin temperature, change scores were calculated between during usual walking and each of the subsequent time points (during experimental walking, during speech task, and recovery), and ANCOVA conducted controlling for scores during usual walking. An independent *t*-test was conducted to compare the upright and slumped groups on levels of perceived pain at the end of the experiment. Missing data for some questions meant that analyses were conducted with slightly fewer participants, on a case by case basis, as indicated by slight differences in the degrees of freedom. As per the recommendations of Perneger (1998) and Armstrong (2014), no adjustments were made to the level of statistical significance for the number of tests.

3. Results

There were no significant differences between groups at baseline for any variables.

3.1. Manipulation checks of head angle, trunk angle, and arm swing angle

There were no significant differences between groups in head, trunk, and arm swing angles during usual walking (all p greater than .30). During experimental walking, people in the upright group displayed a more upright head angle ($M = 96.15$, $SD = 6.75$) than people in the slumped group ($M = 55.70$, $SD = 11.65$); $t(1, 51) = 17.32$, $p < .001$; Cohen's $d = 4.25$, degrees of freedom adjusted for unequal variance). In addition, people in the upright group displayed a more upright trunk angle ($M = 92.74$, $SD = 4.75$) than the slumped group ($M = 76.15$, $SD = 10.72$) during experimental walking ($t(1, 44) = 8.14$, $p < .001$); Cohen's $d = 3.17$, degrees of freedom adjusted for unequal variance). People in the upright group also exhibited a larger arm swing angle ($M = 58.47$, $SD = 14.52$) than the slumped group ($M = 26.67$, $SD = 11.16$) during experimental walking ($t(1, 65) = 10.03$. $p < .001$), Cohen's $d = 2.46$. This showed the manipulation was successful.

3.2. Affect

ANCOVA showed a significant difference between groups on changes to low arousal negative affect (dull, sleepy, sluggish) when controlling for affect after usual walking ($F(1, 70) = 4.20$, $p = .044$, $\eta_p^2 = 0.06$). The estimated marginal mean change in the upright group was −0.30, 95% CI [-0.75, 0.15], whereas the estimated marginal mean change in the slumped group was 0.36, 95% CI [-0.09, 0.79].

There was also a significant effect of experimental walking style on changes to high arousal affect (aroused, astonished, surprised) when controlling for high arousal affect after usual walking ($F(1, 70) = 4.36$, $p = .040$, $\eta_p^2 = 0.06$). The estimated marginal mean change in the upright group was 1.00, 95% CI [0.41, 1.59]; estimated marginal mean change in the slumped group was 1.87, 95% CI [1.23, 2.45]. There were no other significant group differences in any other affect subscale after walking in the experimental posture. Overall, the upright group felt less low arousal negative affect and less high arousal than the slumped group after experimental walking.

3.3. Feelings of power

ANCOVA showed a marginally significant effect of experimental group on change in feelings of power, controlling for feelings of power after usual walking, $F(1,70) = 3.77$, $p = .056$, $\eta_p^2 = 0.05$. The estimated marginal mean change in the slumped group was −1.20, 95% CI [−2.142, −0.26], and the estimated marginal mean change in the upright group was 0.12, 95%CI [-0.83, 1.08]. The upright group felt more powerful than the slumped group after experimental walking.

3.4. Sleepiness

ANCOVA analysis showed that there was a significant difference in change in sleepiness between groups, when controlling for sleepiness after usual walking, $F(1,70) = 4.47$, $p = .038$, $\eta_p^2 = 0.06$. The estimated marginal mean change for the upright group was −0.44, 95% CI

[−0.79, −0.09]; estimated marginal mean change in the slumped group was 0.08, 95% CI [−0.26, 0.42]. The upright group felt less sleepy than the slumped group.

3.5. Pain

On average, participants in the slumped group reported higher levels of pain ($M = 28.47$, $SD = 25.04$) than participants in the upright group ($M = 7.93$, $SD = 11.27$). This difference (−20.54, 95% CI [−34.47, −6.60]) was significant ($t(23) = -3.0528.27$, $p = .006$, $d = 1.06$; degrees of freedom adjusted for unequal variance).

3.6. Blood pressure

ANCOVA showed a significant difference between groups in changes to systolic blood pressure (SBP) after experimental walking, controlling for values after usual walking, F(1,70) = 5.96, p = .017, $\eta_p^2 = 0.08$. Estimated marginal mean change to SBP in the upright group was 4.83 mmHg, 95% CI [1.02, 8.65]; estimated marginal mean change to SBP in the slumped group was 11.40 mmHg, 95% CI [7.64, 15.17]. SBP increased more in the slumped group than in the upright group after experimental walking.

There was no significant difference between groups in changes to diastolic blood pressure (DBP) after experimental walking when controlling for DBP after usual walking, $F(1,70) = 0.49$, $p = .485$, $\eta_p^2 = 0.01$.

3.7. Galvanic skin response

ANCOVA showed no significant difference between groups in changes to galvanic skin response (GSR) during experimental walking compared to during usual walking, when controlling for GSR during usual walking, $F(1, 65) = 0.27$, $p = .603$.

There was a significant difference between groups in changes to GSR during the speech task compared to during usual walking, when controlling for GSR during usual walking, $F(1, 65) = 5.24$, $p = .025$, $\eta_p^2 = 0.07$. Estimated marginal mean increase in GSR in the upright group was 0.86, 95%CI [−0.59, 0.76]; estimated marginal mean increase in GSR in the slumped group was 1.19, 95% CI [0.51, 1.86].

There was also a significant difference between groups in changes to GSR during recovery compared to during usual walking, when controlling for GSR during usual walking, $F(1, 65) = 7.66$, $p = .007$, $\eta_p^2 = 0.10$. Estimated marginal mean increase in GSR in the upright group was 0.174, 95%CI [−0.77, 1.12]; estimated marginal mean increase in GSR in the slumped group was 2.04, 95%CI [1.09, 2.99]. This shows that GSR was higher in the slumped group than the upright group during and after the speech task.

3.8. Skin temperature

ANCOVA showed no significant difference between groups in changes to skin temperature during experimental walking compared to during usual walking, after controlling for temperature during usual walking, $F(1, 65) = 0.16$, $p = .900$.

There was a marginally significant difference between groups in changes to skin temperature during the speech task compared to during usual walking, controlling for temperature during usual walking, $F(1, 65) = 3.96$, $p = .051$, $\eta_p^2 = 0.06$. Estimated marginal mean change in temperature in the upright group was −0.01 °C, 95% CI [−0.30, 0.29]; estimated marginal mean increase in temperature in the slumped group was 0.41 °C, 95% CI [0.12, 0.71].

There was no significant difference between groups in changes to temperature during recovery compared to during usual walking, when controlling for temperature during usual walking, $F(1, 65) = 2.39$, $p = .13$, $\eta_p^2 = 0.04$.

4. Discussion

This study shows that a person's walking posture during a stressor can have significant effects on both psychological and physiological responses. As hypothesised, adopting an upright walking posture significantly improved dull, sleepy, and sluggish feelings (low arousal negative affect), decreased sleepiness, and marginally increased feelings of power, compared to walking with a slumped posture. Physiologically, adopting an upright walking posture was associated with a significantly lower galvanic skin response, lower systolic blood pressure response, and marginally lower skin temperature compared to people who adopted a slumped walking posture. An upright walking posture therefore appears to make people more resilient to stress compared to a slumped walking posture, in support of previous research on the beneficial effects of smiling and upright seated postures (Kraft & Pressman, 2012; Nair et al., 2015).

The upright walking posture was also associated with lower reported pain. Differences in pain between the groups may have been partly responsible for differences between groups in reported outcomes. To rule out this explanation, further research is needed in which pain levels are equivalent between groups. Contrary to expectations, high arousal affect (aroused, astonished, surprised) increased more in the slumped group during the stressor than in the upright group. This could be because the participants were surprised that they were asked to walk in a slumped posture on the treadmill, as some participants made this comment after the experiment.

Participants in the upright walking group reported marginally greater feelings of power than the slumped walking group. This finding contributes to the ongoing debate about the robustness of the effects of power posing, a research paradigm in which people hold expanded postures for 2 min compared to people who hold contracted postures (Cesario, Jonas, & Carney, 2017). Despite many studies failing to replicate the hormonal findings of an initial study (Carney, Cuddy, & Yap, 2010; Ranehill et al., 2015), a meta-analysis by Gronau et al. (2017) showed a reliable effect of power posing on feelings of power. Along similar lines, this study suggests that changing an individual's walking style to reflect a more upright walking posture can improve feelings of power compared to a slumped walking posture when under stress, although the effects were only marginally significant.

The physiological responses need to be interpreted keeping in mind both the effects of the stressor and of the posture itself. Blood pressure has been shown to increase in response to the Trier Social Stress Test (Allen et al., 2014). Upright standing posture has been associated with lower systolic blood pressure compared to slumped standing posture (Jorde & Williams, 1986), since a slumped standing posture can cause muscle tension that can result in blood pressure increases (Freyschuss, 1970). Therefore the observed effects may be due to a reduced stress response in the upright posture, direct effects of upright posture, or a combination of both. More research is needed to tease these effects apart.

The galvanic stress response increased markedly during the speech task and during recovery in the slumped walking posture group only. Previous work has shown that galvanic skin response increases after performing stressful psychological tasks (Allen et al., 2014; Cohen, Swanson, Naliboff, Schandler, & McArthur, 1986; Sun et al., 2012). Since there was no increase in galvanic skin response in the upright walking group, this suggests that the upright posture was helping to reduce stress levels. These effects are unlikely to be due to postural effects alone, since there are mixed findings for whether posture can increase galvanic skin response or not (Cohen et al., 1986; Wenger & Irwin, 1936).

Participants in the upright walking posture had marginally lower skin temperature compared to participants in the slumped walking posture during the stress task. The effect of psychological stress on skin temperature varies as to whether skin temperature is measured peripherally or centrally; one study suggests that although finger temperature reduces, wrist temperature is not affected by stress (Vinkers et al., 2013). Likewise, the association between posture and skin temperature depends on the location of the body. Arm temperature tends to decrease as a function of a more upright posture (Tikuisis & Ducharme, 1996). To our knowledge, this is the first study investigating the effects of an upright versus slumped walking posture on wrist temperature. Therefore, the cause of this effect is unclear, and reduced wrist temperature may be predominantly due to posture rather than stress.

The theory of embodiment may provide the best explanation for the observed effects. This theory proposes that body, affect, and cognitive states are not separate components of subjective experiences, but rather they are understood as relational integrated factors of one coherent state of embodiment (Gallagher & Bower, 2014). Therefore, changes to any of the bodily, affective, cognitive, environmental, or intersubjective states elicit responses from the person as a whole. Therefore, this theory suggests that bodily states such as walking posture can elicit associated emotions and cognitions.

While preliminary, these results have potential practical implications. Michalak et al. (2009) showed that there are similarities between gait patterns of some clinically depressed people and gait patterns of healthy people expressing sadness, particularly a slumped posture, reduced walking speed, reduced arm swing, reduced up-and-down movements of the head, and stronger lateral body sway. It is possible that adopting a more upright walking posture with a forward eye gaze direction and large arm swing may improve depressive symptomology. However, the therapeutic effects of manipulating walking style in clinically depressed populations have yet to be investigated and this is a potential direction for future research.

There are some limitations of the study. First, the study was conducted in a laboratory on a treadmill so these findings cannot necessarily be generalized to real-world settings. Future research could investigate whether these findings have real-world applications by assessing replicability using a longitudinal design and involving ecological momentary assessment methods. Second, it is difficult to tease apart the effects of the postural manipulation from the stress task on some of the outcome variables. It is not known whether the postural manipulation by itself would have similar effects on physiological and psychological states if there was no stress task performed. To investigate the separate effects of the postural manipulation and the stress task during experimental walking, future research could use a 2 by 2 design in which both posture and stress are manipulated. Third, even though the study tried to reduce expectancy effects by upholding a cover story that the study was investigating "the effects of walking on cognitive processing", instructions to participants in the slumped group to hold a "downward" posture may have led to an association with a "downward" effect on their mental states.

5. Conclusions

In summary, this study found that walking with an upright posture during a stressful task resulted in feeling less sleepy, less surprised, and more powerful than walking in a slumped posture. It also resulted in lower galvanic skin response, lower skin temperature, and lower systolic blood pressure. Overall, these results provide preliminary support for the hypothesis that changing an individual's gait patterns can alter their psychological and physiological states during a stressful task. This is the first study to provide insight into the effects of changing an individual's walking posture and style on psychological and physiological health outcomes during a stressor, and more research is needed to tease apart the mechanisms and generalisability of these effects.

Declaration of interests

None.

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Conflicts of interest

None.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jbtep.2018.09.004.

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