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# Self-esteem levels and cardiovascular and inflammatory responses to acute stress

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ABSTRACT

Acute mental stress tests have helped to clarify the pathways through which psychosocial factors are linked to disease risk. This methodology is now being used to investigate potentially protective psychosocial factors. We investigated whether global self-esteem might buffer cardiovascular and inflammatory responses to acute stress. One hundred and one students completed the Rosenberg Self-Esteem Scale. Heart rate and heart rate variability (HRV) were recorded for 5 min periods at baseline, during two mental stress tasks, (a speech and a color-word task) and 10, 25 and 40 min into a recovery period. Plasma levels of tumor-necrosis factor-α (TNF-α), interleukin-6 (IL-6) and interleukin-1 receptor antagonist (IL-1Ra) were assessed at baseline, immediately post-stress and after 45 min recovery. Repeated measures analysis of variance demonstrated that heart rate levels were lower across all time points in those with high self-esteem, although heart rate reactivity to stress was not related to self-esteem. There were no differences in baseline HRV, TNF-α, IL-6 or IL-1Ra. Multiple linear regressions revealed that greater self-esteem was associated with a smaller reduction in heart rate variability during the speech task, but not the color-word task. Greater self-esteem was associated with smaller TNF-α and IL-1Ra responses immediately following acute stress and smaller IL-1Ra responses at 45 min post-stress. In conclusion, global self-esteem is associated with lower heart rate and attenuated HRV and inflammatory responses to acute stress. These responses could be processes through which self-esteem protects against the development of disease.



## 1. Introduction

Psychosocial factors are known to influence physical health. Studies of reactivity to and recovery from acute mental stress have been used to elucidate possible pathways through which psychosocial factors contribute to disease risk. The influence of psychosocial risk factors on autonomic, neuroendocrine and immune reactions to acute stress has been established (Brotman et al., 2007; McEwen, 2007). In recent years, attempts have also been made to identify psychosocial factors which could help to protect against the risk of disease. Positive psychosocial factors such as optimism, positive emotions and social support have been associated with improved health outcomes and reduced biological stress reactivity (Pressman and Cohen, 2005; Rozanski and Kubzansky, 2005). Another potentially important protective factor is self-esteem.

Self-esteem refers to subjective judgements of personal worth or adequacy and self-acceptance. Self-esteem is partly heritable, but is also dependent on childhood and early life approval and self-belief generated through interaction with family, peers and others (Baumeister et al., 2003; Raevuori et al., 2007). Those with high self-esteem tend to posses clearer self-concepts, are less vulnerable to depression and anxiety, and are more likely to value positive affect and persist in the face of failure (Lyubomirsky et al., 2006). The relationship between self-esteem and depression is well established. A classic series of papers by Brown et al. (1990a,b,c,d) documented the role of self-esteem not only in predicting the onset of clinical depression, but its relationship with other risk factors and influence on the course of recovery. Findings regarding self-esteem and physical health have been less consistent. Baumeister et al. (2003) reviewed the literature on health behavior, and concluded that self-esteem had a variable association with smoking, alcohol abuse, drug use and sexual behavior. One prospective observational epidemiological study found a twofold increased risk for all cause mortality over a period of 10–15 years in those with low self-esteem, with the relationship appearing to be largely mediated by hopelessness (Stamatakis et al., 2004). Relationships between self-esteem and biological measures have also been studied. Pruessner et al. (2005) found that self-esteem levels were related to hippocampal volume, as assessed using structural magnetic resonance imaging in both young and old adults. The presence of the association across a wide age spectrum could mean that hippocampal volume changes precede self-esteem differences rather than the reverse, so the causal direction is uncertain. However, Reitzes and Mutran (2006) found that self-esteem predicted

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changes in functional health over two years in a sample of 737 older adults, while an analysis of the Dunedin Health and Development Study showed that low self-esteem levels in adolescents predicted poorer physical health at age 26 (Trzesniewki et al., 2006). Therefore, there is preliminary evidence that self-esteem levels are relevant to physical health.

There may also be direct psychobiological links between self-esteem and health related processes. Studies have focussed mainly on cardiovascular and neuroendocrine responses to stress. Seeman et al. (1995) showed in the MacArthur studies of successful aging that self-esteem in a small sample of 70 years old was inversely associated with cortisol responses to a driving simulation task, while differences in cortisol response were only related to self-esteem in a study of younger adults when perceptions of failure were induced with negative feedback (Pruessner et al., 1999). A similar pattern has been observed in relation to cardiovascular reactivity (Hughes, 2007; Rector and Roger, 1997). For example, Hughes (2007) measured self-esteem levels prior to participants performing a picture-matching task. They were then given feedback comparing their performance to average scores. The feedback was randomised to be positive, negative or neutral. Negative feedback provoked an adverse response with a larger cardiovascular reaction in those with low self-esteem. By contrast, in a series of studies concerned primarily with self affirmation, Taylor and colleagues did not find that a positive psychological responses construct loading heavily on self-esteem was associated with cardiovascular or neuroendocrine stress reactivity (Creswell et al., 2005; Taylor et al., 2003).

No studies to date have investigated the relationship between self-esteem and autonomic cardiac control or inflammatory responses to acute stress. We measured both heart rate and heart rate variability in this study. Increased heart rate is related to the progression of coronary atherosclerosis and cardiovascular mortality (Fox et al., 2007) and as such is an important element of cardiovascular disease risk. Short-term heart rate variability is determined by cardiac autonomic balance, and impaired heart rate variability predicts cardiovascular disease risk and prognosis (Stein and Kleiger, 1999; Task Force, 1996). Heart rate variability is reduced during acute and chronic stress (Chandola et al., 2008; Hemingway et al., 2001; Lucini et al., 2005), and has been associated with depression, obesity and hypertension (Masi et al., 2007; Rottenberg, 2007). The relation between self-esteem and heart rate variability is not yet defined.

We also assessed the relation between self-esteem and interleukin-6 (IL-6), tumor-necrosis factor-alpha (TNF-$\alpha$) and interleukin-1 receptor antagonist (IL-1Ra) responses to mental stress. All three cytokines are implicated in pathogenesis and coronary heart disease etiology (Steptoe and Brydon, 2008). These cytokines are sensitive to acute stress tasks in humans (Steptoe et al., 2007) and individual differences in responsivity predict cardiovascular risk progression (Brydon and Steptoe, 2005). One study of middle-aged women demonstrated a negative correlation between plasma IL-6 and self-esteem levels (Sjögren et al., 2006), but did not measure IL-6 responses to stress. To our knowledge no studies to date have investigated the relation between IL-1Ra, TNF-$\alpha$ and self-esteem, either under resting conditions or following acute mental stress.

Previous research has shown that acute stress can cause contractions in plasma volume, since elevated blood pressure increases hydrostatic pressure, moving plasma from capillaries to interstitial spaces (Pattersson et al., 1995). This could result in a corresponding change in cytokine concentration, even if the absolute levels in the circulation remained the same (Mischler et al., 2005). Changes in plasma volume are typically assessed through measurements of hematocrit and hemoglobin (Dill and Costill, 1974), but in this study we used hematocrit to control for the extent to which changes in hemoconcentration accounted for stress-induced cytokine responses.

The aim of this study was to examine the relationships between global self-esteem levels and hemodynamic, autonomic and inflammatory responses to stress. It was hypothesized that higher levels of self-esteem would be associated with attenuated reactivity to and quicker recovery from acute stress.

## 2. Methods

### 2.1. Participants

One hundred and three participants were recruited from University College London. Participants were mainly students and consisted of 34 (33%) males and 69 (77%) females. They were recruited as part of a broader study that examined stress responsivity and family history of cardiovascular disease risk. Results from this study have previously demonstrated heightened cardiovascular responsivity in individuals with a family history of cardiovascular disease risk, while cytokine responses were associated with adiposity (Brydon et al., 2008; Wright et al., 2007). Participants were screened for illnesses including cold and flu symptoms, and medication including antidepressants and antibiotics. In addition, participants were required to refrain from taking ibuprofen or aspirin for 10 days before testing and not to consume caffeine or alcohol for 12 h before testing. Two participants who had extreme body mass index (BMI) values (43.4 and 15.6) were excluded from the analyses. Written informed consent was obtained and ethical approval was granted by the University College Hospital Medical Research Ethics Committee.

### 2.2. Mental stress tasks

Two 5 min mental stress tasks were administered that have previously been used in cardiovascular research (Ketterer et al., 2000; Light et al., 1993; Muldoon et al, 1992). The first task was a computerised color-word interference task. This entails the presentation of the name of a color at the top of the screen (green, red, blue or yellow) which is printed in an incongruent color. Presented simultaneously at the bottom of the screen are the four possible names of the colors, again printed in an incongruent color. The participant has to select the word at the bottom of the screen which names the color that the word at the top of the screen is printed in and press the corresponding computer key. Presentation speed is programmed to vary in response to performance accuracy in order to maintain pressure. Participants were informed that their performance would be recorded and were allowed a 30 s practice before the task began. The second task was a public-speaking task where participants are presented with a potentially stressful real-life situation and given 2 min to prepare a 3 min speech in response which they were informed was video-recorded and rated for performance.

### 2.3. Psychosocial and adiposity measures

Self-esteem levels were assessed with Rosenberg's (1965) Self-Esteem Scale. This is perhaps the most commonly used Self-Esteem Scale (Blascovich and Tomaka, 1991) and consists of ten items such as "On the whole, I am satisfied with myself" and "All in all, I am inclined to feel I am a failure". Participants rated their agreement with on a four point Likert scale (strongly agree, agree, disagree and strongly disagree) and scores could range from 0 to 30 with higher scores indicating higher levels of self-esteem. The Cronbach's $\alpha$ in this sample was .88. The scale has been validated in a number of languages and used in a variety of populations and cultures (Pullmann and Allik, 1998; Schmitt and Allik, 2005). It has previously been related to various psychosocial factors including neuroticism, depression and social support (Judge et al., 2002; Schmitz et al., 2003). Subjective stress was measured at six time points throughout the session on a 7 point Likert scale (from 0 *not at all* to 7 *very*). In addition each task was rated for perceived levels of difficulty, involvement with the task, perceived performance and controllability on the same Likert scale. Body weight was measured with participants in underwear to the nearest 0.1 kg and height was measured to the nearest 0.5 cm. Weight in kilograms divided by height in metres squared was calculated to give body mass index. Participants were asked to report how many times in the previous 28 days they had engaged in vigorous physical activity for 20 min and the average number of active hours per week was calculated. .

### 2.4. Cardiovascular measures

Heart rate and heart rate variability (HRV) were monitored with an impedance cardiogram (VU-AMD, Amsterdam, Holland). Continuous measurements over 5 min were recorded and the mean taken to provide an average heart rate value (Willemsen et al., 1996). HRV was assessed using the root-mean-square successive difference (rMSSD) time domain index (Task force, 1996). For each 5 min recording, the difference between each inter-beat interval was squared, the mean taken and the square root of the mean calculated to produce the rMSSD value.

### 2.5. Cytokine assays and hematocrit measures

Whole blood was drawn using a 21-gauge butterfly needle into Vacutainers containing EDTA as an anticoagulant. Samples were immediately centrifuged at 1250*g* for 10 min at room temperature, and plasma was removed, aliquoted into 0.5 ml portions and snap frozen at −80 °C. IL-1Ra concentrations were determined using a commercial high-sensitivity ELISA (R&D Systems, Oxford, UK). The IL-1Ra assay had a limit of detection of 15 pg/ml and inter- and intra-assay CVs of <10%. TNF-α and IL-6 concentrations were determined with high-sensitivity two-site ELISAs (R&D Systems, Oxford, UK). The limit of detection for TNF-α was 0.10 pg/ml with inter- and intra-assay CVs of <10%. The limit of detection for IL-6 was 0.09 pg/ml with inter- and intra-assay CVs of 9.2% and 5.3%, respectively. Hematocrit was assessed for each blood sample with a micro-hematocrit centrifuge and reader (Hawksley Gelman, Lancing, Sussex, UK).

### 2.6. Procedure

Sessions began at 12:30 and participants underwent a structured interview assessing their current health, age and smoking status. Height and weight were measured and the AMD monitoring system was fitted. A venous cannulla was then inserted into the non-dominant forearm and participants were left to rest for 30 min. Baseline heart rate and heart rate variability were recorded for the last 5 min of this period. Baseline stress ratings were taken, after which the first blood sample was drawn. The two mental stress tasks were then administered in fixed order, beginning with the color-word task. Heart rate and heart rate variability were monitored throughout. After each task participants completed task appraisal questionnaires, and a second blood sample was drawn at the end of the speech task. Participants then rested for 45 min, during which the self-esteem questionnaire was completed. Heart rate and HRV were recorded for three 5 min periods after 10, 25 and 40 min. Additional subjective stress ratings were taken at the end of each of these periods, and a third blood sample was drawn after 45 min.

### 2.7. Statistical analyses

Self-esteem scores were split into tertiles to allow for repeated measures analyses. Analysis of variance and $\chi^2$ were used to perform group comparisons of demographic characteristics, baseline subjective stress, heart rate, heart rate variability, IL-6, TNF-α and IL-1Ra.

Multi-level modelling or latent growth analysis could be used to analyse these data, but we chose to apply repeated measures analysis of variance to examine the effects of mental stress on physiological and subjective responses, with Greenhouse Geisser adjustments where required. Self-esteem group was the between-subject factor and time the within-subject factor. Stress reactivity and recovery effects were calculated by subtracting the baseline from subsequent values, and were analysed using multiple linear regressions. The independent variables in these analyses were self-esteem, baseline values of the measure in question, age, gender, BMI and smoking status. Additional analyses included subjective stress and perceived performance ratings in the regression models, to test whether any differences in physiological response were secondary to subjective experiences. In the analysis of cytokine stress reactions, the change in hematocrit was included as an additional covariate. Analyses were carried out using SPSS v 13.0 and results are presented as means ± standard deviation.

Complete data were available for age, gender, smoking status, BMI and subjective stress ratings ($n = 101$). Complete heart rate data were available for 98 participants, heart rate variability data for 95 participants, TNF-α levels for 88, IL-6 levels for 91 and 84 participants had IL-1Ra data. One participant was removed from the HRV analysis and four from the IL-1Ra analysis due to values being outwith acceptable ranges. The remainder of the missing data were due to problems with blood sampling, assays or equipment failures.

## 3. Results

### 3.1. Participants' characteristics

Mean self-esteem scores were 24.9 ± 2.53, 30.3 ± 1.03 and 36.1 ± 2.48 for the low, medium and high tertiles, respectively. Table 1 presents the descriptive characteristics and baseline measures of the participants in relation to self-esteem level. There were no differences between the three self-esteem groups in age, gender

**Table 1**
Descriptive characteristics of participants in relation to self-esteem level

| Variable | Self-esteem Level | | | |
|---|---|---|---|---|
| | Low | Medium | High | *p*-Value |
| *Gender* | | | | |
| Male | 9 (29%) | 13 (33.32%) | 12 (38.7%) | .721 |
| Female | 22 (71%) | 26 (66.7%) | 19 (61.3%) | |
| Age (years) | 20.81 ± 2.07 | 21.67 ± 2.09 | 21.68 ± 20.7 | .162 |
| Current smoker | 7 (22.6%) | 4 (10.3%) | 5 (16.1%) | .372 |
| BMI (kg/m$^2$) | 22.81 ± 2.84 | 23.59 ± 3.11 | 23.22 ± 2.55 | .528 |
| *Physical activity* | | | | |
| Active hours per week | 1.76 ± 1.86 | 2.15 ± 1.83 | 2.77 ± 1.95 | .108 |
| *Baseline* | | | | |
| Stress level (0–7) | 2.52 ± 1.41 | 1.87 ± .86 | 1.84 ± 1.00 | **.024** |
| Heart rate | 72.7 ± 10.5 | 73.2 ± 8.1 | 67.2 ± 9.2 | **.017** |
| Heart rate variability | 59.7 ± 39.1 | 47.6 ± 22.6 | 64.4 ± 27.4 | .059 |
| TNF-α (pg/ml) | 1.1 ± .32 | 1.09 ± .19 | 1.2 ± .20 | .228 |
| IL-6 (pg/ml) | 0.7 ± .06 | 0.7 ± .06 | 0.8 ± .11 | .427 |
| IL-1Ra (pg/ml) | 191.7 ± 83.3 | 173.7 ± 70.2 | 192.1 ± 99.6 | .698 |

p-Values for regressions with no covariates, unadjusted means displayed.

distribution, smoking status, BMI, habitual physical activity level or baseline HRV, TNF-α, IL-6 or IL-1Ra. There were, however, differences in subjective stress ratings and heart rate, higher self-esteem being associated with lower baseline heart rate and subjective stress. Physical activity levels were relatively high in this study sample compared with UK norms, probably because of recruitment from an active student population.

### *3.2. Subjective stress responses*

Fig. 1 shows the pattern of subjective stress response in the three self-esteem groups. The main effects of time ($F$ $(5{,}490) = 229.5$, $p < .001$) and self-esteem group ($F$ $(2{,}98) = 3.3$, $p < .05$) were significant. Participants with lower self-esteem had higher levels of subjective stress during the session. Subjective stress ratings increased during the tasks and returned to baseline levels at the first recovery point. Interestingly, participants in the three self-esteem groups rated the tasks as equally difficult (4.75 ± 1.1), involving (5.0 ± 0.9) and controllable (3.5 ± 0.9). There were, however, differences in the rating of performance for the speech task ($p < .01$), with those with higher self-esteem rating their performance higher.

### *3.3. Cardiovascular measures*

Heart rate increased during the tasks and returned to baseline level by the first recovery measure ($F$ $(2.24{,}216.96) = 1165.0$; $p < .001$). A repeated measures analysis with age, gender, BMI and smoking status as covariates demonstrated a main effect for self-esteem group ($F\,(2{,}91) = 4.78$; $p = .011$) with no interaction between time and self-esteem ($F$ $(10{,}475) = 1.06$; $p > .1$). As can be seen in the lower panel of Fig. 1, participants with higher self-esteem had lower heart rate throughout the session, with no difference in reactivity or recovery. Since regular physical activity is associated with lower heart rate, and there was a trend for participants with greater self-esteem to be more physically active, we tested whether the relationship between heart rate and self-esteem was due to physical activity differences. However, when physical activity was included as a covariate in the repeated measures analysis of heart rate, it did not alter the relationship between self-esteem and heart rate ($F\,(2{,}89) = 3.87$; $p = .024$).

There was no difference in baseline HRV between the three self-esteem groups ($p = .524$). The mental stress tasks had a significant effect on HRV ($F\,(5{,}470) = 53.50$; $p < .001$), with a reduction in HRV of 15.1 ms for the color-word task and 19.7 ms for the speech task. Linear regressions with age, gender, baseline HRV, BMI and smoking status as covariates demonstrated that self-esteem was a significant predictor of HRV reactivity to the speech task ($\beta = -.12$; $p = .040$). As shown in Fig. 2, participants with greater self-esteem had a smaller HRV reduction during the speech task. Self-esteem was not a significant predictor of response to the color-word task and did not predict HRV during the recovery phase. The results of these analyses were not altered either by the inclusion of physical activity or perceived performance, as additional covariates. Inclusion of speech task stress ratings somewhat reduced the predictive value of self-esteem ($\beta = -.11$; $p = .069$), even though stress ratings were not significant predictors in themselves ($\beta = .074$; $p = .24$).

### *3.4. Cytokine measures*

There was no difference in plasma IL-6, TNF-α or IL-1Ra at baseline between the self-esteem groups. There was a significant effect of time for TNF-α ($F$ $(2{,}174) = 3.49$; $p = .033$) and for IL-6 ($F$ $(2{,}180) = 17.26$; $p < .001$). There was no significant effect of time for IL-1Ra concentrations ($F$ $(1.85{,}153.82) = .644$; $p > .05$). There were, however, wide individual differences in stress responses in all three cytokines: changes in TNF-α ranged from −0.27 to +0.35 pg/ml, IL-6 from −1.07 to +3.0 pg/ml and IL-1Ra from −296.6 to +303.5 pg/ml. Self-esteem was inversely associated with stress-induced changes in TNF-α post-task ($\beta = -.219$ $p = .036$) after adjustment for baseline TNF-α concentration, age, gender, BMI, smoking status and hematocrit. Additionally, self-esteem predicted IL-1Ra stress responses immediately after tasks ($\beta = -.219$;

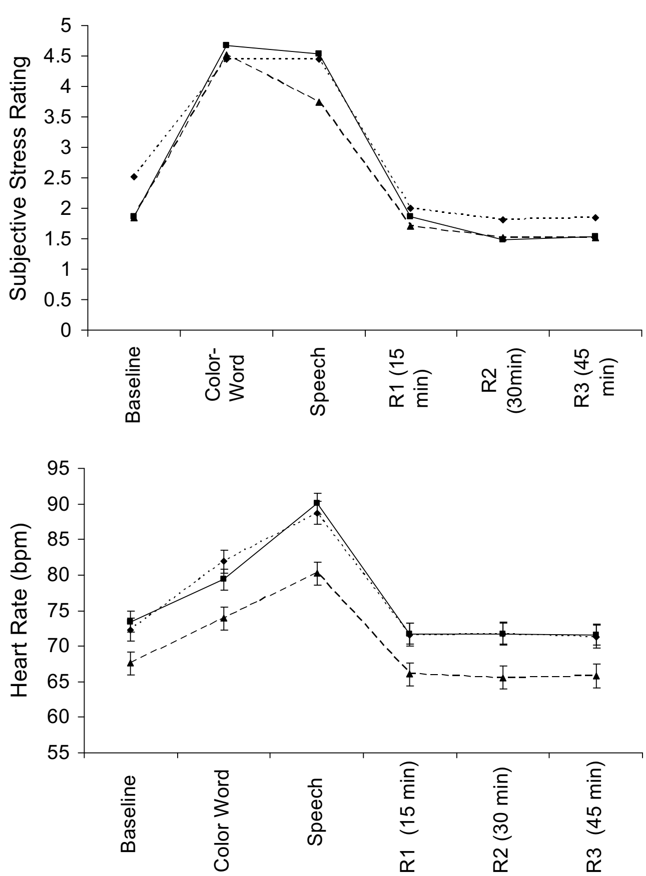


**Fig. 1.** Mean subjective stress ratings (upper panel) and heart rate (lower panel) before (baseline), during (color-word and speech) and at 15 (R1), 30 (R2) and 45 (R3) min after two acute stress. Heart rate values are adjusted for gender, BMI, age and smoking status and bars are standard error of the mean. Comparison of higher (—▲—), medium (—■—) and low (--♦--) self-esteem groups.

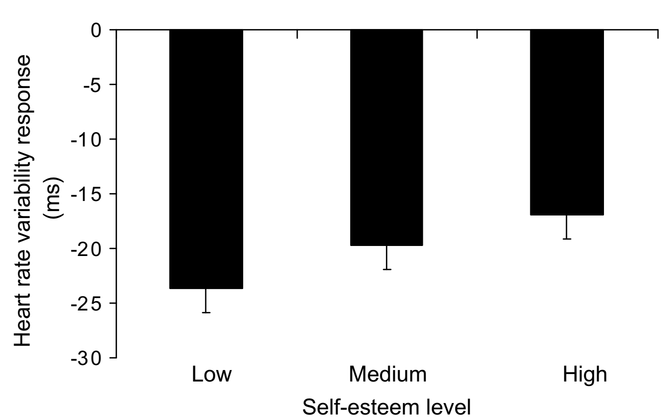


**Fig. 2.** Association between self-esteem and HRV responses to the speech task. Data are presented as means ± standard error of the mean, adjusted for gender, BMI, age smoking status and baseline HRV.

$p = .036$) and 45 min later ($\beta = -.261$; $p = .014$), independently of covariates. The relationships between self-esteem and cytokine responses are illustrated in Figs. 3 and 4. Participants in the low self-esteem group showed the largest increases in cytokines, while those in the high self-esteem group responded with a small reduction in cytokine level. The effects were also independent of subjective stress level during and after the tasks and subjective performance during the tasks. Cytokine stress responses were also associated with self-esteem when it was modeled as a continuous variable. Neither IL-6 responses immediately after the tasks nor 45 min later were associated with self-esteem.

## 4. Discussion

The present study was designed to assess autonomic, hemodynamic and inflammatory responses to acute stress in relation to self-esteem. Individuals who had higher self-esteem had lower subjective stress levels and heart rates throughout the session. In addition, higher levels of self-esteem were related to smaller reductions in heart rate variability in response to tasks, and smaller stress-induced increases in TNF-α and IL-1Ra concentration. These findings were independent of the effects of age, gender, BMI, baseline subjective stress and smoking status. The fact that inflammatory responses were associated with self-esteem independently of hematocrit suggests that changes in cytokine concentration are not due solely to increases in hemoconcentration.

The finding that subjective stress was negatively related to self-esteem throughout the session concurs with other research which has found lower stress ratings both before and after mental stress tasks for individuals with high levels of self-resources including self-esteem (Creswell et al., 2005). Our prediction that people with high self-esteem would be less responsive to acute stress was not confirmed in the case of heart rate. Instead, heart rate levels were lower throughout the session in those with high self-esteem, but reactivity levels did not differ. Currently, there is no documented optimal heart rate, but cardiovascular risk appears to increase progressively with increments of 5 beats per minute for resting heart rates over 60 beats per minute (Fox et al., 2007). The difference between the low self-esteem and the high self-esteem group in this study was just over 5 beats per minute, with those high in self-esteem having a mean resting heart rate of 67.2 beats per minute. It cannot be concluded from this cross-sectional study that low self-esteem contributed to differences in heart rate, but it may be a factor that should be considered within the psychosocial risk profile.

This difference in heart rate at every timepoint differs slightly from previous research (Hughes, 2003, 2007). Both studies used

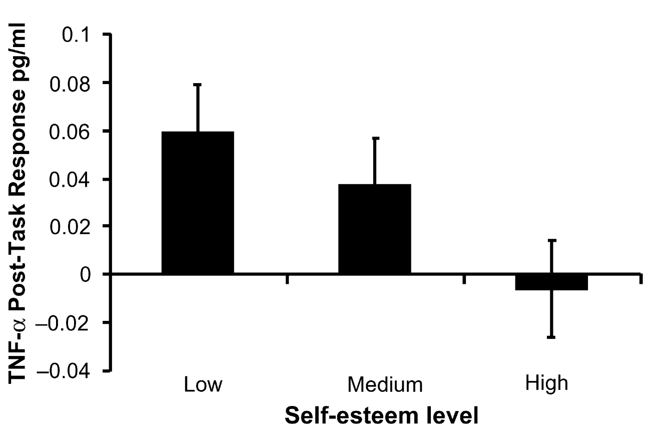


**Fig. 3.** Association between self-esteem and TNF-α post-task response. Data are presented as means ± standard error of the mean, adjusted for gender, BMI, age smoking status and baseline TNF-α.

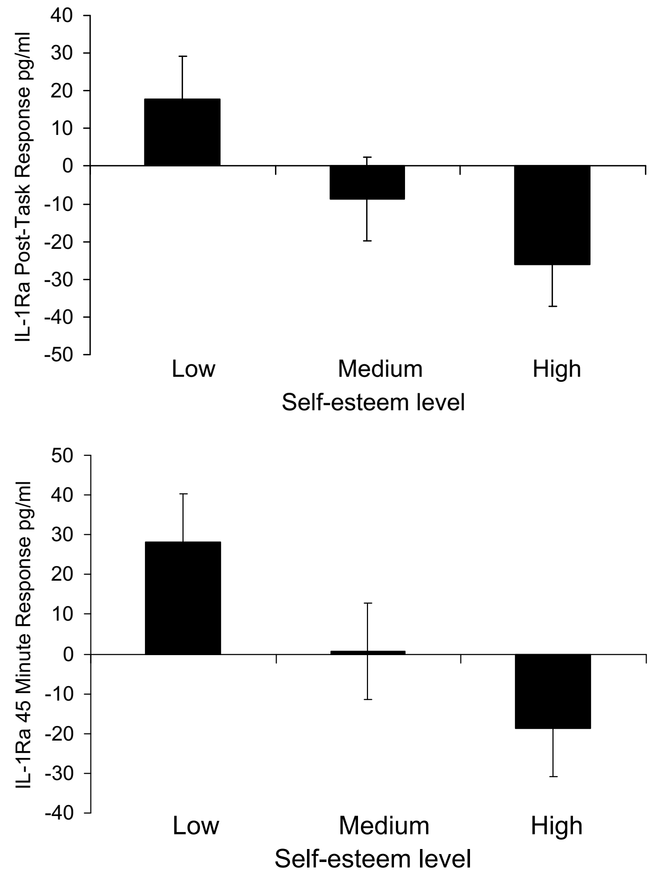


**Fig. 4.** Association between self-esteem and IL-1Ra responses post-task (upper panel) and IL-1Ra responses 45 min post-task (lower panel). Data are presented as means ± standard error of the mean, adjusted for gender, BMI, age, smoking status and baseline IL-1Ra .

Rosenberg's Self-Esteem Scale and performed a median split to separate student participants into high and low self-esteem groups. In Hughes's first study, there was no difference between the two groups for baseline heart rate and there was no main effect for self-esteem on heart rate during the testing session. Baseline values were not reported for the second study, but again there was no main effect for self-esteem on heart rate, as measured at various times during mental stress testing. In an attempt to explain the difference in baseline heart rate with respect to self-esteem between this research and our own, we examined levels of physical activity. Although there was a trend for a positive correlation between self-reported physical activity level and self-esteem, inclusion of activity level in the model did not alter the significance of the relationship between self-esteem and heart rate. The effect was also significant after smoking, gender, age and BMI were taken into account statistically.

Heart rate variability is influenced both by sympathetic and parasympathetic innervation, so is susceptible to the effects of mental stress. HRV also has prognostic power for future health and lower HRV has been linked to future cardiovascular disease risk (Stein and Kleiger, 1999), risk of sudden cardiac death in a range of clinical populations from multiple sclerosis to diabetes mellitus (Ranpuria et al., 2008), all-cause mortality in women with coronary heart disease (Janszky et al., 2004), and depression (Rottenberg, 2007; van der Kooy et al., 2006). Heart rate variability is reduced during acute stress and smaller decreases indicate better maintenance of vagal tone. To date, no studies have assessed the relation between HRV stress responses and self-esteem. We have demonstrated that high levels of self-esteem were associated with a smaller reduction in HRV, with the link potentially being explained by rating of subjective stress. The results indicate a potentially protective link between self-esteem and mental and physical health.

The only previous study that has assessed self-esteem levels and inflammatory markers found a correlation between self-esteem and plasma IL-6 (Sjögren et al., 2006). IL-6 secretion is stimulated by both TNF-α and IL-1 (Papanicolaou et al., 1998; Yudkin et al., 2000). IL-6 production in response to acute stress has previously been shown to differentiate between high and low socioeconomic status groups, but only 2 h after acute stress testing; IL-6 responses did not differentiate between socioeconomic status groups up to 75 min following testing (Brydon et al., 2004). It is possible that the null results for IL-6 in our study were due to insufficient recovery time following the stress tasks. This study, however, provided evidence of high self-esteem levels being associated with lower reactivity in TNF-α and IL-1Ra levels. Self-esteem was inversely associated with increases in TNF-α immediately post-stress, and inversely associated with IL-1Ra responses immediately post-stress and at 45 min. The timing concurs with previous research from our laboratory where both TNF-α and IL-1Ra responded immediately to acute stress, and IL-1Ra had a continued response (Hamer and Steptoe, 2007; Steptoe et al., 2001). The relationship between self-esteem and cytokine responsivity was not explained by ratings of subjective stress or task performance.

Elevated circulating levels of TNF-α and IL-1Ra have been reported in a number of chronic inflammatory conditions (Bradley, 2008; Dinarello, 1996). IL-1Ra is synthesised following production of interleukin-1β (IL-1β), and since IL-1β levels are difficult to detect in circulating blood, is often used as an index of IL-1β (Dinarello, 1996; Pereira et al., 1994). IL-1β and TNF-α play a central role in both the initiation and development of atherosclerotic lesions (Dinarello, 1996; Hoge and Amer, 2006; Popa et al., 2007). Both of these cytokines are also implicated in the pathogenesis of various forms of leukaemia and rheumatoid arthritis (Choy and Panayi, 2001; Hoge and Amer, 2006). In addition, elevated plasma levels of TNF-α and IL-1Ra have been reported in patients with clinical depression (Maes et al., 1997; Tuglu et al., 2003) and low self-esteem is a significant predictor of the onset of depression (Brown et al., 1990a,b,c,d).

This study has several limitations. The data are cross-sectional and it is possible that self-esteem is affected by responses to stress which occur in daily life. In addition, this study involved a large majority of women. Although men tend to have higher self-esteem than women, the size of the difference is very small (Kling et al., 1999), but the mechanisms which link self-esteem and health could still differ by gender. The participants were all young adults with relatively high levels of self-esteem. Extension of this research is necessary to clarify whether relationships hold for different age groups or for those with lower levels of self-esteem. As Reitzes and Mutran (2006) point out, self-esteem levels during adolescence are related to economic prospects including leaving school early and graduating college, so those with low self-esteem are less likely to participate in a study involving university students. Additionally, the design of the study does raise an alternative explanation of the data: self-esteem was assessed during the post-stress recovery period, so it is possible that levels were influenced by the experience of the two stress tasks. The Rosenberg Self-Esteem Scale was used as a trait measure but small fluctuations in self-esteem level have been recorded, both over short periods of time, and in response to manipulations such as failure induction (Gruenewald et al., 2004; Leary et al, 1998; Rasmussen et al., 1996). We did not carry out a manipulation of success, but acknowledge that completion of the tasks could still have an effect on self-esteem level. Stress appraisal and performance could also potentially affect both self-esteem level and reactivity. However, the primary associations between physiological responses and self-esteem described in the results remained strong after controlling for both subjective stress ratings and performance ratings. This indicates that self-esteem was linked to inflammatory responses independently of cognitive and emotional appraisals. Additionally, we examined global self-esteem and its relationship to responses to specific tasks. Stronger relationships may have been demonstrated if specific self-esteem domains relevant to these tasks were investigated. Future research could also benefit from examining global self-esteem levels in more naturalistic settings, for example, measuring the relationship between self-esteem and cortisol levels over the course of the day.

In conclusion, this study has demonstrated that self-esteem levels are related to baseline heart rate and autonomic and inflammatory stress responses. These measures have prognostic power for future cardiovascular disease and, although the differences produced here were small, if repeated frequently over a period of years this pattern of response could have implications for future health status. Extending this research to examine different age groups and performing longitudinal research would further clarify the relation between self-esteem and adverse reactions to acute stress.

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