Stress-Induced Cortisol, Mood, and Fat Distribution in Men

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Abstract

Objective: A previous study in our laboratory (Moyer et al., Obes Res. 1994;2:255-62) found that, in response to uncontrollable laboratory stress, women with a high waist-to-hip ratio (WHR) had higher cortisol reactivity, poorer coping skills, and lower anger responses than women with low WHR. We aimed to compare high WHR men's stress responses to these women.

Research Methods and Procedures: The current study examined cortisol reactivity and psychological data of 27 healthy high WHR men exposed to the same laboratory challenges as the women from our previous study. Men's data are discussed in relation to that of the high and low WHR women.

Results: Men responded to the stress with increases in both cortisol and blood pressure. In comparison with the high and low WHR women, men had significantly higher total cortisol on the stress day. However, when comparing a subsample of men and women matched in WHR's, differences in cortisol secretion were greatly diminished and no longer significant. In addition, men had higher desire for control than both high and low WHR women, and lower mood reactivity than low WHR women. Despite the lower mood reactivity of high WHR groups, the high mood reactors among the high WHR women, and to a lesser extent, men, tended to have higher cortisol reactivity.

Discussion: These results suggest that the psychological differences and greater exposure to cortisol observed among the high WHR men and women may have played a role in contributing to their greater abdominal fat depots.

Key words: stress, cortisol, waist-to-hip ratio, mood, gender

Introduction
Abdominal fat distribution, as opposed to gluteofemoral fat distribution, is a large risk factor for many conditions such as hypertension, high serum lipids, coronary heart disease, diabetes mellitus, stroke, and endometrial carcinoma independently from overall obesity (as measured by body mass index (BMI)) (1). Waist-to-hip ratio (WHR), a rough index of visceral fat depots, is a stronger predictor of certain health outcomes, such as stroke, than is BMI (2-4). Given the strong association between high WHR and poor health, an important goal is to identify factors that lead to accumulation of abdominal fat. Although there are many well-established causes for abdominal obesity, such as genetic, endocrine, and behavioral factors (physical activity, diet, weight cycling, alcohol, and cigarette smoking) (5-7), the potentially important role of stress has been understudied.

Prospective studies have demonstrated that chronic stress and cortisol reactivity lead to preferential deposition of abdominal fat, in rats, and in primates (8,9). Cortisol is present in the presence of insulin increases lipoprotein lipase, a fat accumulating enzyme. These effects on lipoprotein lipase are much greater at the abdominal region, because abdominal fat tissue has a higher density of glucocorticoid receptors and greater blood flow, compared with gluteofemoral tissue (10).

In humans, cross-sectional studies have found high cortisol excretion in response to stress among women with greater abdominal fat, compared with controls (11,12). Moyer and colleagues (12) found that high WHR women also had poor coping skills and lower anger than low WHR women. High cortisol and low anger can be considered a defeated response to stress (13) and may contribute to abdominal fat depots. Men tend to have greater abdomin...
fat than do women, and although sex hormones may be partly responsible for this difference, high cortisol reactivity may also play a role.

Therefore, the purpose of this study was to examine cortisol reactivity and psychological responses to stress in men with central fat distribution. Because high WHR women have the male pattern of fat distribution and tend to have higher androgenicity (1), we predicted that high WHR men would respond to stress physiologically (higher cortisol) and psychologically (lower anger, worse coping skills) similar to the high WHR women. Men's data are discussed in relation to our earlier data on high and low WHR women (12).

Research Methods and Procedures

Participants

Participants were 27 healthy men, aged 18 years to 42 years old, with a BMI between 25 and 40, and a WHR of >0.80. Recruitment procedure and laboratory protocol were identical to that used in the Moyer et al. (12) study. Participants were recruited through newspaper advertisements and flyers. Exclusion criteria were history of smoking, regular consumption of alcohol, and other factors that may influence fat distribution.

Procedure

Participants completed an initial eligibility visit, when their anthropomorphic measurements were assessed, and they were given the psychological trait questionnaires to fill out at home. Two laboratory sessions were scheduled at the exact same time on two consecutive days to control for the timing of the diurnal rhythm of cortisol. The sessions were scheduled between 10:00 AM and 2:00 PM, and each individual was tested separately. The stressful tasks were spatial, mathematical, and verbal tasks. Participants were given unrealistic time constraints and bogus negative feedback to induce feelings of uncontrollability and helplessness. To obtain resting levels of cortisol, participants first rested for 30 minutes, a typical baseline period in studies of cortisol reactivity. Saliva samples were collected at baseline, and after 15 minutes, 30 minutes, and 60 minutes of stress, and 30 minutes after the end of the stress period. The protocol and nature of the stressors are fully described in Moyer et al. (12). A manipulation check confirmed that the stress day was experienced as more stressful than the following control day, similar to the earlier study (12).

Anthropomorphic Measures

Anthropomorphic measures were taken by a trained nurse. Body circumferences were measured with a fiberglass tape measure to the nearest 1 mm, according to the method of Calloway et al. (14). Waist circumference was taken at the midpoint between the lower rib margin and iliac crest. Hip circumference was taken at the widest buttock circumference. Percent fat was measured using skinfold thicknesses while standing. Lange standard calipers were used on the triceps, biceps, subcapsular, and suprailiac regions.

Biological Measures

Saliva samples were collected into small cups, transferred to vials, and immediately stored at -70°C. Salivary cortisol was assayed using radioimmunoassay (Hazelton Laboratories, Rockville, MD). The assay sensitivity was 5 ug/dl. to 10 ug/dl. and interassay coefficients of variation were 11.9% for low pool and 10.4% for high pool cortisol. Salivary cortisol was examined as area under the response curve (AUC), to get a summative measure of total cortisol secreted over the session. This was calculated by taking the sum of each two consecutive cortisol samples, multiplied by the amount of time between the samples, and adding these [i.e., ((cort1+cort2)·15 minutes)+((cort2+cort3)·15 minutes)+((cort3+cort4)·30 minutes)+((cort4+cort5)·30 minutes)].

Blood pressure and heart rate were measured with an electronic monitor immediately before and after the stressors on the stress day, and the rest on the control day.

Psychological Measures

To assess both trait and state psychological variables that may affect cortisol reactivity, we administered the Daily Stress Inventory (15), Attributional Style Questionnaire (16), Desirability of Control (17), and Self-Control Scale (SCS) (18), as well as two measures assessing current mood before and after the challenges: the Profile of Mood States (POMS) (19), and a Visual Analog Scale of mood adjectives. The validity and reliability of these scales are well demonstrated, as detailed in Moyer et al. (12). To assess mood reactivity to the stressor, the difference between prestressor and poststressor mood from the POMS subscales were calculated. To create a composite of negative mood reactivity, the average of this change score was calculated for negative emotions of depression, anger, and anxiety.

Statistical Analyses

Paired Student's t-tests were used to compare stress and rest cortisol of the men. An analysis of variance (ANOVA) compared total cortisol of the men with women from the previous study to examine if men were higher in stress day cortisol than the women. Paired t-tests were used to test for changes in mood from baseline to poststress, and mood changes between groups were used to compare ANOVA. In addition, we used ANOVA to examine whether mood interacted with WHR in explaining cortisol secretion. All p values are two-tailed.

Results

Descriptive and Psychological Data

Men were an average age of 28±1.3 years (range from 20 to 40). They had a mean BMI of 29.3±0.5, percent body
fat of 26.5%±0.7, and WHR of 0.92±0.10. Their average scores on psychological traits were as follows: Attributional Style Questionnaire = 11.7±0.7, Desirability of Control = 111.9±1.8, and SCS = 34.6±0.4.

**Cardiovascular Measures**

Changes in cardiovascular measures from prestress to poststress showed significant increases in both diastolic and systolic blood pressure, and a decrease in heart rate, confirming the stressful nature of the tasks (see Table 1). On the control day, there were no significant changes in blood pressure, but again a decrease in heart rate (not shown).

**Cortisol**

Men secreted significantly more cortisol on the stress day (AUC = 128.1 μg/dL/60 minutes±8.1) than the control day (AUC = 102.0 μg/dL/60 minutes±7.9; t = 2.9, p<0.01). To compare men to women, an ANOVA of total cortisol secreted (AUC) on stress and control days was performed. On the stress day, the ANOVA was significant [F(2,64) = 10.05, p<0.005]. Planned comparisons showed that men were higher than both groups of women (and, as reported in Moyer et al., the high WHR women secreted more cortisol than the low WHR women) (see Figure 1). On the control day, however, the ANOVA was not significant [F(2,64) = 2.26, p = 0.11].

It is important to examine whether the observed higher cortisol reactivity of men was due to the association between cortisol reactivity and high WHR, or to other unspecified gender-related differences. If there was no independent association between cortisol and gender, but only between cortisol and WHR, we would expect gender differences to disappear after controlling for WHR. Therefore, WHR was statistically controlled, using analyses of covariance, whereas cortisol was examined between all three groups. Although the difference in total cortisol on stress day between the three groups was still significant, the effect size was reduced by almost half after controlling for WHR [decreasing from a large (f=0.62) to a medium (f=0.33)-sized effect]. The men were still significantly higher than both groups of women. However, the high WHR women were now similar in cortisol to the low WHR women.

In another post hoc attempt to compare men and women's cortisol reactivity while controlling for WHR, men (n = 5) and high WHR women (n = 14) were selected to be matched on WHR (average WHR for both groups = 0.83). There were no significant differences in any measures of cortisol, including their average change in cortisol (men's mean = -0.14±0.12, women's mean = -0.08±0.06, p = 0.66), total cortisol (men's AUC = 109.7±12.9, women's AUC = 95.8±11.9, p = 0.45), and cortisol at any single time-point.

**Mood Reactivity**

Mood was responsive to both stress and control sessions. During stress, men increased significantly in 3 of 7 negative emotions or states, including defeat, anxiety, and confusion (as shown by paired t-tests, p's<0.05). In contrast, on the control day, they significantly decreased in five negative emotions or states, including stress, depression, anxiety, anger, vigor, and confusion. When compared with the women, men were similar in mood reactivity to the high WHR women. On the stress day, the high WHR women significantly increased in only two emotions (defeat and anxiety), whereas the low WHR women significantly increased in all seven emotions measured (data not shown). ANOVA tested directly for significant differences in mood changes between groups. Men were significantly lower in anger reactivity than low WHR women [F(2,64) = 6.86, p<0.005]. They were similar to high WHR

**Table 1. Blood pressure and heart rate changes on stress day**

<table>
<thead>
<tr>
<th>Measure</th>
<th>Prestressor</th>
<th>Poststressor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart rate (bpm)</td>
<td>64.3±2.0</td>
<td>61.0±2.1*</td>
</tr>
<tr>
<td>Diastolic blood pressure (mmHg)</td>
<td>75.0±3.7</td>
<td>78.4±2.5*</td>
</tr>
<tr>
<td>Systolic blood pressure (mmHg)</td>
<td>118.0±2.7</td>
<td>127.0±2.8*</td>
</tr>
</tbody>
</table>

Values are means±standard error of the mean.

*p<0.05, comparison between prestressor and poststressor values.

![Figure 1: Total cortisol (cortisol AUC units are μg/60 minutes/dL) during stress by the WHR group. Differences between each group are significant: (men>high WHR women>low WHR women; p's<0.05). Error bars represent the standard error of the means.](image-url)
women, who were also lower in anger than low WHR women, as reported by Moyer et al. (12).

To assess whether average mood reactivity (from the POMS composite) was related to WHR across all groups, a correlation between average mood reactivity, and WHR was calculated. The correlation was negative ($r = -0.25$, $p<0.05$), suggesting that higher WHR is indeed related to lower mood reactivity.

**Cortisol, Mood, and WHR**

We also wanted to assess whether mood reactivity was related to cortisol reactivity, and whether this relationship between mood and cortisol may differ between the three WHR groups. We performed a 3x2 ANOVA using WHR group (15), average mood reactivity (20; high or low, based on a median split), and their interaction, to predict cortisol output on the stress day, as well as cortisol output on the control day. On the stress day, there was the main effect for WHR group, as described herein and in Figure 1, and an interaction between WHR group with mood reactivity [$F(2,69) = 6.4$, $p<0.005$]. Planned multiple comparisons were performed, using Fisher’s least-squares difference tests, to see how groups differed. As shown in Figure 2, for high WHR men and women only, mood reactivity was related to higher cortisol. This difference in cortisol between high and low mood reactors was significant for high WHR women. For low WHR women, however, mood reactivity was related to significantly lower cortisol. In fact, the low WHR women with high mood reactivity secreted significantly less cortisol than all other groups ($p$'s<0.05).

In the ANOVA assessing how mood and WHR group related to cortisol on the control day, there was an interaction between stress day’s mood reactivity and WHR group on next day’s cortisol [$F(2,69) = 5.0$, $p<0.01$]. Examination of the means and planned multiple comparisons showed that men had similar control day cortisol (AUC) in both high and low mood reactive groups (low mood reactors: 100.3 µg/dL/60 minutes, standard error (SE) = 36.8 vs. high mood reactors: 104.4 µg/dL/60 minutes, SE = 31.4). For high WHR women, those who were mood reactive had significantly greater cortisol than all other groups the following day (low mood: 86.6 µg/dL/60 minutes, SE = 40.5 vs. high mood: 151.1 µg/dL/60 minutes, SE = 93.9). Lastly, low WHR women who were mood reactive to the stressors tended to have lower cortisol the following day (85.8 µg/dL/60 minutes, SE = 26.3 vs. high mood: 66.7 µg/dL/60 minutes, SE = 22.0). To summarize, the interaction between WHR, mood, and cortisol on the control day was largely driven by the high WHR women who were highly mood reactive during stress; these women secreted the most cortisol the following day.

**Discussion**

Men with high WHR responded to stress with increases in both cortisol and blood pressure. In comparison with the data presented earlier in women (12), men were similar to the female samples in age and BMI, but had significantly higher WHRs. In terms of cortisol, men were similar to women on the control day, but secreted significantly more total cortisol on the stress day.

In addition to having higher cortisol, men were also different in psychological factors—desire for control, coping skills, and mood reactivity. Men were significantly higher than all women in desire for control ($p<0.05$), a gender difference also found in Burger and Cooper (17). A strong drive to control events in one’s life may predict greater helplessness and depression in response to uncontrollable stress (17), and thus greater cortisol reactivity. In general, men tend to respond physiologically with greater magnitude (in cortisol and other indices of arousal) across different episodes of achievement stress, whereas women are more selective and moderate in their cortisol responses (21,22). One study found that men responded with higher cortisol to a psychological stressor, but not to an exercise or CRF challenge (23). Together, these studies suggest that gender differences in appraisal and coping with stress, such as a strong drive to control events, may mediate the higher cortisol reactivity of men.

Men also scored significantly higher on a measure of cognitive and behavioral self-control strategies (SCS) than the high WHR women. This is in contrast with other studies that have found men to score lower on these coping skills (24). Thus, the high WHR women had uncharacteristically poor coping skills for women, being lower than both the low WHR women and men.

In addition, when comparing change in mood between groups, both men and high WHR women had less mood reactivity in general, especially in feelings of anger. We also

![Figure 2: Total cortisol during stress by WHR and mood reactivity groups.](image-url)
found that, despite their lower overall emotional reactivity as a group, those who did report increases in negative mood were more likely to have higher cortisol, significantly so for the high WHR women. Conversely, negative mood reactivity was related to lower cortisol for low WHR women, and thus high mood reactivity appears benign or even protective among low WHR women.

It is difficult to resolve the findings that, whereas the high WHR groups had lower mood reactivity and higher cortisol overall, those with high mood reactivity tended to have the highest cortisol reactivity. Many animal studies have demonstrated that cortisol specifically reflects feelings of distress with little control—an analog to learned helplessness (25–27). Those with the greatest mood and cortisol reactivity may have been experiencing a defeated or helpless response to stress. We must also note that low mood reactivity—mainly lack of anger accompanied by high cortisol—has also been interpreted as a submissive or defeated response to stress (12,13).

In summary, high WHR men and women secreted more cortisol, especially those who became most distressed during the stressors. We have thus extended past results demonstrating the relationship between stress-induced cortisol and WHR to a sample of men, and found that they had a defeated response to stress like the high WHR women. We found more physiological (high cortisol reactivity) and psychological (i.e., low mood reactivity on average) similarities between men and high WHR women, than between high and low WHR women, suggesting that psychophysiological response to stress may be more related to WHR than to gender. In fact, when we control for WHR, either statistically or by matching subsamples on WHR, we find little or no differences in cortisol between high WHR men and high WHR women.

Parallels may be drawn between our high and low WHR groups and Frankenhaeuser et al.’s (22) men and women, in terms of the levels of emotional vs. physiological reactivity. In response to examination stress, Frankenhaeuser et al. found that women had much more economical physiological responses than men. Women were significantly lower in catecholamines and cortisol, but paid a much higher psychological cost—they reported more intense negative feelings. Similarly, the low WHR women in the present study reported more intense anger, and had significant increases in all negative emotions, accompanied by lower or no cortisol reactivity. In contrast, the high WHR women and men responded more like Frankenhaeuser’s men, reporting less overall negative affect, while being higher in cortisol reactivity that day. Thus, high WHR women may respond to stress more like men.

Given android-shaped women’s hormonal milieu of higher androgenicity, and their similarities to men in their increased risk of cardiovascular disease and diabetes (28), it is not surprising that our android-shaped women responded similar to the men. This is consistent with other laboratory stress studies that have found that women with high androgenicity (who tend to have greater central fat) respond to stress with cortisol levels similar to men (29,30).

We can speculate as to how sex hormones may influence behavioral and adrenocortical responses to stress. Oxytocin secretion during stress tends to reduce stress reactivity, including decreasing anxiety and cortisol levels (31,32). Females tend to secrete more oxytocin during stress than males (31,33). Relatedly, androgens suppress oxytocin, whereas estrogens enhance it (33,34). Furthermore, oral contraceptive users tend to have attenuated cortisol reactivity to stress (35). Women with abdominal obesity tend to have lower female sex hormones and higher androgens (28,36), and thus likely have higher testosterone reactivity to stress (typically found in males), which itself is related to greater hostility (37). Our women with abdominal obesity may have greater testosterone and lower levels of estrogen and oxytocin (which can buffer adrenocortical reactivity) than the low WHR women. The sum of these hormonal effects may have influenced the android women to respond to stress similarly to the men—with higher cortisol.

We now address the unexpected finding of relations between mood reactivity and cortisol 24 hours later. For high WHR women, those with greater mood reactivity (who became depressed, anxious, and angry/hostile) had significantly higher total cortisol the next day than those who did not increase in these emotions. These findings of higher next-day cortisol could be interpreted in many ways. One possibility is that high WHR women who became distressed during the stressors had much poorer cortisol recovery, showing elevations up to 24 hours later, whereas those less mood reactive recovered more quickly. Thus, the high mood reactors may have hypersecreted cortisol over the entire 24 hours between testing sessions. In fact, the high mood reactors were already higher in cortisol by the first resting measure of “basal” cortisol, suggesting that the hypersecretion may have started before or upon re-entering the laboratory.

Another possibility is that re-entering the laboratory triggered their higher cortisol secretion, either through a conditioned physical response or more likely due to psychological distress or negative expectations of the second (control) session. Their increase in hostility (which was related to high next day cortisol) may also reflect distrust and suspicion about the “supposed” rest session, and possibly expectations of additional stressors, despite the debriefing information that the control session would be benign.

These findings on mood reactivity suggest it may play a mediating role in cortisol reactivity and recovery for high WHR women. However, our findings that mood reactivity was related to next day cortisol were unexpected, and thus demand further replication before any conclusions can be drawn. Recently, Perna and McDowell (38) found that ex-
exercise-induced elevations in cortisol were prolonged for up to 20 hours later in a high stress group, compared with a low stress group. Cortisol recovery may be a more valid measure of chronic stress and disease vulnerability than cortisol reactivity during stress, because chronic stress exposure can damage the hypothalamo-pituitary-adrenocortical axis feedback loop (39,40). Such damage could lead to prolonged exposure to cortisol after stress, greater overall cumulative exposure over time, and thus to greater central fat accumulation and risk for other stress-induced pathology.

We cannot determine the causality of the relationships between hormonal responding to stress and abdominal fat from this limited cross-sectional study. However, given intra-abdominal fat’s extreme sensitivity to cortisol, and animal studies showing stress leads to abdominal fat (8,9), it is likely that increased cortisol led to increased fat depots, rather than the reverse. Our results on mood reactivity relating to higher cortisol reactivity, significantly among women and with a similar trend among the men, lend indirect support to the causal sequence of emotional stress triggering hypersecretion of cortisol, which in turn may increase abdominal fat accumulation.

In addition, genetics affect both fat distribution and cortisol (20,41). Genetics may play a role in the relationship between excessive cortisol exposure and abdominal fat by influencing cortisol reactivity (or possibly affecting mood, which could influence cortisol exposure). In support of this, Bouchard (20) recently found a genetic variation in the glucocorticoid receptor among lean people with visceral fat.

The main limitation to the current data is that it does not fully permit us to confirm these interactions between cortisol reactivity, mood, gender, and WHR. The men had even higher cortisol reactivity than high WHR women, but also had significantly higher average WHR than high WHR women, which is due to an inherent gender difference. Population means of high WHR for men are significantly higher than means of high WHR for women, which makes matching on WHR for a true gender comparison extremely difficult. Men with a low WHR will usually have a lower BMI, and comparing an obese (high WHR) to an average weight group of men (lower WHR) would also not disen-tangle the effects of gender from WHR, because obesity may influence both physiological and psychological variables. Future studies that use more accurate assessment of intra-abdominal fat (e.g., magnetic resonance imaging, ultrasound, or CT scan rather than WHR) may lead to a better matching of the body composition of men and women, allowing for more accurate gender comparisons to be made.

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References