The Effects of Cortisol on Memory Recall

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Abstract

The overall objective of this study was to test the effects of cortisol on memory recall in females in the same menstrual phase (follicular). Baseline cortisol levels were taken of ten female subjects. A 30 word list of negative and neutral words was administered. Twenty-four hours later subjects recalled the words given and cortisol samples were obtained. Thirty days later, the subjects’ cortisol levels were taken prior to being naturally stressed, by way of exercise at 60% heart rate max., to increase cortisol levels. Saliva assays were taken prior to memorizing a thirty word list again. Twenty-four hours later subjects were asked to recall and provide a final saliva assay. Saliva samples were analyzed for changes in cortisol levels. There were significant (p< 0.05) differences in word recall between negative and neutral words both before exercising and after exercising. The mean cortisol concentration taken prior to exercising was 0.99 µg/dl. Levels taken immediately after exercising had mean concentration of 0.96 µg/dl. Results from paired repeated measure showed no statistical difference between cortisol levels prior to and after exercising.

Introduction

Many physiological disturbances in the body evoke a stress response that serves to restore homeostasis and assist in physiological adaptation. Glucocorticoids (GCs), produced by the stress-responsive hypothalamic-pituitary-adrenal axis, help regulate this response (Newcomer et al. 1999, Roozendaal 2002). Cortisol, a glucocorticoid, controls the response to stress by promoting gluconeogenesis and reducing the inflammatory response (Ronald et al. 1998).

Studies investigating the effects of acute GC treatments on memory have reported conflicting results. Glucocorticoids are known to modulate memory functions with elevated cortisol levels being associated with impaired declarative memory (Elzinga et al. 2005). Kuhlmann and Wolf (2006) provided cortisol or a placebo to study participants prior to showing them emotionally provoking or neutral pictures. Cortisol had no effect on immediate recall but led to an increased recall of the emotionally provoking pictures 24 hours later. They concluded that cortisol enhanced recall of emotional material.
Rimmele et al. (2003) administered cortisol or placebo to subjects who were then presented with either a neutral or an emotionally-moving story. Memory was tested one week later. They found that the recall was enhanced for the neutral story with cortisol administration but memory was impaired for the emotional story.

While most researchers have focused on memory retrieval of pictures and stories, some studies have tested the effects of cortisol on word retrieval. Kuhlmann et al. (2005a) demonstrated that glucocorticoids enhanced memory consolidation but impaired delayed memory retrieval of emotional words. Participants in the study were given cortisol prior to testing. When a delayed recall test was administered five hours later, they concluded cortisol significantly impaired retrieval of negative words. These findings suggest emotional material is sensitive to the memory modulating effects of stress hormones. Kuhlmann et al. (2005b) conducted the same experiment as described above changing one variable, performing the experiment in a more relaxed test setting. They concluded cortisol had no effect on memory retrieval of either emotional or neutral words suggesting that the experimental setting can influence the effects of cortisol on memory.

A review of 16 studies determined that the timing of the GC administration was a major determinant of the effects of cortisol on human memory (Het et al. 2005, Maheu et al. 2005). The studies that administered cortisol prior to retrieval reported a significant decrease in memory performance. Studies that administered cortisol before learning found on average no effect. Further analysis on these experiments indicated that studies which administered cortisol in the morning found significant memory impairment, while studies conducted in the afternoon observed a small but significant memory enhancement (Het et al. 2005). Stressing participants in the morning, at the time of high circulating
levels of corticosteroids, saturated the corticosteroid receptors in the brain, thus impairing declarative memory for emotionally arousing material unrelated to the stressor (Maheu et al. 2005). Thus supporting the idea that the timing of GC administration is a major determinant of the effects of GC’s on human memory.

Endogenous or exogenous gonadal sterols may also influence the effects of cortisol on memory. Kuhlmann and Wolf (2005) tested the effects of cortisol on recall of women taking oral contraceptives verse those who were not on oral contraception. There were significant differences between the two groups, they concluded that the differences were due to levels of gonadotropins. The purpose of this study was to test the effects of cortisol on memory recall in females in the same menstrual phase (follicular).

Methods

Ten females were selected for the study. The test protocol was approved by the Brigham Young University-Hawaii Institutional Review Board. All subjects were questioned about their menstrual status; only those in the follicular phase were tested. Baseline cortisol concentrations were measured by immunoassay of saliva samples. Salimetrics oral swabs (SOS) were used to take saliva samples; the swab was removed from the plastic insert inside the centrifuge tube and placed into the mouth. The swab was placed under the tongue for 1-2 minutes, thus fully saturating the swab with approximately one milliliter or more of saliva. The swab was returned to the plastic insert and the cap was snapped shut. Each participant was then presented with a list of 15 negative words and 15 words with a neutral connotation. (See appendix 1.) Each subject was allowed to study the list for 15 minutes. Twenty-four hours later the subjects were
asked to recall as many words as possible. A follow-up saliva sample was then taken. The subjects were tested one month later using the same list of negative and neutral words but in a different order, after being exercised on a treadmill at 60% of their heart rate maximum for 15 minutes, to raise cortisol levels. A third saliva sample was assayed for cortisol concentrations before exercise and a fourth sample was assayed after exercise. Twenty-four hours later subjects were asked to recall as many words as possible, followed by the fifth and final saliva assay. All saliva assays were stored at -20°F until sent to Salimetrics Inc. for analysis. Differences in cortisol concentration and recall were analyzed by paired repeated measures ANOVA with a post-hoc test.

Results

The mean number of negative recalled words prior to stressing was 10.8 (± 3.05 SD) (Figure 1). The mean number of neutral words prior to stressing the subjects was 12.1 (± 2.88 SD) (Figure 1). After stressing the subjects, the mean number of negative words was 12.1 (± 3.7 SD) and the mean number of neutral words was 13.7 (± 1.83 SD) (Figure 2).
Figure 1. The mean (± SD) number of words recalled from a list of 30 words, 24 hours after introduction to the list of words.

Figure 2. The mean (± SD) number of words recalled from a list of 30 words, 24 hours after introduction to the list of words.
There were significant (p< 0.05) differences in word recall between negative and neutral words both before exercising and after exercising (Table 1). There was no statistical difference in total word recall for either test given (Table 1).

Table 1. The comparison of p-values between Day 1 Negative vs. Neutral word recall, Day 31 Negative vs. Neutral word recall and Total word recall of Day 1 vs. Day 31.

<table>
<thead>
<tr>
<th></th>
<th>Day 1 Negative vs. Neutral Word Recall</th>
<th>Day 31 Negative vs. Neutral Word Recall</th>
<th>Total Word Recall, Day 1 vs. Day 31</th>
</tr>
</thead>
<tbody>
<tr>
<td>P-Value</td>
<td>p = 0.0176</td>
<td>p = 0.033</td>
<td>p = 0.122</td>
</tr>
</tbody>
</table>

On day 30, cortisol levels were taken prior to and following exercise to determine if cortisol levels were elevated. The mean cortisol concentration taken prior to exercising was 0.99 µg/dl. Levels taken immediately after exercising had mean concentration of 0.96 µg/dl; there was no statistical difference between levels prior to and after exercising (Figure 3).
Discussion

Kuhlman et al. (2005a) study, participants were administered cortisol and five hours after were tested with word recall; cortisol was found to impair retrieval of negative words. Experimental setting may have been an influence, thus Kuhlmann et al. (2005b) performed the experiment again, but changed the test setting, to a more relaxed atmosphere. These researchers concluded that cortisol had no effect on memory retrieval of negative or neutral words. This study also used recall as a way to detect the effects of cortisol on memory recall, however, cortisol was not administered. These previously
mentioned studies suggested that cortisol played a role in memory retrieval, this study found differences in retrieval without changing cortisol levels.

Timing of cortisol administration has been previously demonstrated to affect memory. Natural GC levels are high in the mornings. Stressing subjects in the morning may have over stimulated the receptors and therefore caused impairative memory for emotional arousing material unrelated to the stressor (Maheu et al. 2005). In this present study, subjects were naturally stressed by the way of exercise. Subjects exercised for 15 minutes at 60% heart rate max intensities was not high enough to change cortisol levels. Studies have shown that exercising at 70% heart rate max is effective to increase cortisol levels (Grace 2000). This study showed there were memory differences without an increase in endogenous or exogenous cortisol.

In previous studies there were differences between women who were taking contraceptives compared to women who were not as different levels of gonadotropins are released (Kuhlmann and Wolf 2005). To eliminate this variable, all participants in this study were not on oral contraceptives. The differences in this study were not due to hormonal changes.

There were significant differences in word recall but they were not due to cortisol or gonadotrophins. In retrospect, the fact that cortisol was not increased allowed differences to be seen without cortisol. Future research on the nature of recall of negative words might use other variables besides cortisol.
References


Appendix 1

Negative Words
-cancer
-abuse
-divorce
-exam
-pain
-blood
-shame
-knife
-rape
-failure
-death
-fight
-coma
-terrorist
-assault

Neutral Words
-aquarium
-field
-vase
-computer
-range
-desk
-astronomy
-carrot
-rain
-tree
-apple
-light
-tarmac
-car
-museum