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Psychological hardiness predicts neuroimmunological responses to stress

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Psychological hardiness characterizes people who remain healthy under psychosocial stress. The present exploratory study investigates possible links between hardiness and several immune and neuroendocrine markers: IL-6, IL-12, IL-4, IL-10, & neuropeptide-Y. A total of 21 Norwegian navy cadets were studied in the context of a highly stressful military field exercise. Blood samples were collected midway, and again late in the exercise when stress levels were highest. Psychological hardiness (including commitment, control, and challenge) was measured two days before the exercise. While all subjects scored high in hardiness, some were high only in commitment and control, but relatively low in challenge. These "unbalanced" hardiness subjects were also more stress reactive, showing suppressed proinflammatory cytokines (IL-12), increased anti-inflammatory cytokines (IL-4, IL-10), and lower neuropeptide-Y levels as compared to the hardiness-balanced group. This study thus shows that being high in hardiness with a balanced profile is linked to more moderate and healthy immune and neuroendocrine responses to stress.

Keywords: hardiness; stress; immune system; neuropeptide-Y

Psychological hardiness refers to the three interrelated personality characteristics known as commitment, control and challenge, which together appear to protect individuals from the negative health effects of stress (Kobasa, 1979; Maddi, 2002). Links between hardiness and healthy stress coping have been well documented (Britt, Adler, & Bartone, 2001; Maddi, 2002), but the biological mechanisms that mediate these effects are still not well understood. Dolbier et al. (2001) found more robust immune system responses (mean lymphocyte proliferation) in high-hardiness subjects. Also, Zorrilla, Derubeis, and Redei (1995) reported that hardiness was associated with higher basal levels of adrenal-pituitary hormones.

A newer study identified a subgroup of hardiness subjects (Bartone, Valdes, Spinosa, & Robb, 2011) that showed an unbalanced hardiness profile in which challenge scores were substantially lower than control and commitment scores. This may indicate a lack of flexibility which could make them more vulnerable to stress associated with ambiguous or uncertain conditions. In our exploratory study, we...
investigated the relationship between a balanced vs. unbalanced hardiness profile and several bio-markers related to stress responses in military personnel participating in a highly stressful exercise.

Studies have shown that heightened levels of stress hormones like glucocorticoids and catecholamines suppress the production of pro-inflammatory cytokines, and stimulate the production of anti-inflammatory cytokines (Elenkov & Chrousos, 2002; Padgett & Glaser, 2003; Padgett, Marucha, & Sheridan, 1998). Studies have also linked effective stress responses to higher levels of neuropeptide-Y (Morgan et al., 2002; Yehuda, Brand, & Yang, 2006). On this basis we hypothesized that individuals in the balanced hardiness group, due to a lower stress response, would show higher response levels of IL-6, IL-12, neuropeptide-Y, and lower response levels of IL-4 and IL-10, as compared to individuals with an unbalanced hardiness profile.

**Method**

**Participants**

The participants in the study were recruited from the Royal Norwegian Naval Academy where all cadets are highly pre-selected to be able to handle stressful situations. Of the 40 officer cadets ready to participate in a winter exercise, 31 initially agreed to participate in the study. Due to difficulty locating all the participants in the field, we were only able to collect blood samples from 22 of the initial 31 participants (N=22).

**Measures and biomarkers**

**Hardiness**

Hardiness was assessed with the Norwegian adaptation of the Dispositional Resilience Scale (DRS-15-R; Hystad, Eid, Johnsen, Laberg, & Bartone, 2010). The Cronbach’s alphas in the present sample were .79 for the total score, and .61, .71 and .71, respectively, for the dimensions Commitment, Control and Challenge.

**Biomarkers**

Dried blood spots were analyzed at the Ultramicro Analytical Immunochemistry Laboratory, National Institutes of Health, Bethesda, Maryland (USA) using recycling immunoaffinity chromatography (Phillips, 2001). Through analyses of peripheral blood samples, we obtained measures of IL-6, IL-12, IL-4, IL-10, and neuropeptide-Y1.

**Situation and procedures**

The objective for the weeklong exercise was training for international operations. By design, stressful conditions increased dramatically after day five of the exercise. Blood samples were collected at day five (Time 1/Low Intensity) and at day seven (Time 2/High Intensity) of the exercise. With the use of a sharp lancet, a drop of blood was drawn from the participants’ index finger and transferred to a filter-paper strip.

The study was approved by the Norwegian Regional Ethics Committee for Medical Research. Two days prior to the exercise, the 31 initial participants signed the consent form and completed the DRS-15-R.
Data analyses

All but one subject scored above published means in total hardiness (Bartone, Eid, Johnson, Laberg, & Snook, 2009; Hystad et al., 2010), making this a high-hardiness group overall. Examination of item level responses suggested this subject likely did not understand the instructions and was therefore excluded from further analysis. For the remaining subjects, those with consistent hardiness facet scores were classified as “hardiness balanced”. Here, the difference between any two facet scores was no greater than four. A “hardiness unbalanced” group was next defined as subjects who showed a difference of five or more points between any two facet scores. Cases meeting this condition showed the greatest discrepancies between control and challenge, with challenge always being lower than control. These cut-points were based on a recent cluster analysis of a larger data set (N = 430; Bartone, 1998).

Analyses of variance (ANOVA) for repeated measures were used to assess the effects of time and the dimensions of hardiness on the biomarkers.

Missing data (.3% of DRS-15-R data) were handled through the use of multiple imputations with pooled data (Graham, 2009).

Results

Descriptive statistics for DRS-15-R and the biomarkers are presented in Table 1.

Group differences

For IL-6 levels, we found a significant main effect ($F(1,19) = 31.76, p < .001, \eta^2_p = .626$) for time, where IL-6 levels increased overall from day five to day seven. No significant interaction effect was found, and the between-subject effect was also not significant.

Results for IL-12 showed a significant main effect for time ($F(1,19) = 10.9, p = .004, \eta^2_p = .365$) with levels decreasing from day five to day seven. Further, a significant interaction effect was observed between hardiness balanced vs. unbalanced and time, with the unbalanced group showing a decline in IL-12 levels from day five to day seven.

Table 1. Standard deviations, means, maximum and minimum scores for DRS-15-R (hardiness) and the biomarkers.

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Min</th>
<th>Max</th>
<th>Mean</th>
<th>SD</th>
<th>Normal range</th>
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<tbody>
<tr>
<td>DRS-15-R</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Balanced</td>
<td>14</td>
<td>32</td>
<td>42</td>
<td>38.07</td>
<td>3.06</td>
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<tr>
<td>Unbalanced</td>
<td>7</td>
<td>32</td>
<td>40</td>
<td>36.14</td>
<td>2.55</td>
<td></td>
</tr>
<tr>
<td>Day 5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IL-6</td>
<td>21</td>
<td>6.3</td>
<td>18.3</td>
<td>12.01</td>
<td>3.05</td>
<td>6.0 ± 7.6(a)</td>
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<tr>
<td>IL-12</td>
<td>21</td>
<td>8.1</td>
<td>25.5</td>
<td>12.28</td>
<td>4.22</td>
<td>7.5 ± 2.4(a)</td>
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<tr>
<td>IL-4</td>
<td>21</td>
<td>6.9</td>
<td>12.1</td>
<td>9.72</td>
<td>1.31</td>
<td>0.00(a)</td>
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<tr>
<td>IL-10</td>
<td>21</td>
<td>2.7</td>
<td>22.3</td>
<td>10.08</td>
<td>5.59</td>
<td>0.3 ± 0.3(a)</td>
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<tr>
<td>Neuropeptide-Y</td>
<td>21</td>
<td>0.7</td>
<td>7.7</td>
<td>3.48</td>
<td>2.36</td>
<td>5.9 ± 2.2(b)</td>
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<tr>
<td>Day 7</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IL-6</td>
<td>21</td>
<td>43.3</td>
<td>320.8</td>
<td>111.18</td>
<td>87.51</td>
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<tr>
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<td>6.6</td>
<td>14.7</td>
<td>10.14</td>
<td>2.58</td>
<td></td>
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<tr>
<td>IL-4</td>
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<td>8.65</td>
<td>1.85</td>
<td></td>
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<td>33.82</td>
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<tr>
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<td>35.1</td>
<td>16.65</td>
<td>7.68</td>
<td></td>
</tr>
</tbody>
</table>

All biomarkers values expressed in picogram/milliliter.

\(a\) de Jager et al., 2007, \(b\) Lettgen, Wagner, Hanze, Lang, & Rascher, 1994)
seven, while the hardiness balanced group remained fairly stable ($F(1,19)=11.3$, $p=.003$, $\eta_p^2=.374$) (Figure 1). Overall between-subject effects were not significant.

For IL-4 results showed no significant main effect for time, but a significant interaction effect between time and hardiness balance ($F(1,19)=6.79$, $p=.017$, $\eta_p^2=.263$; Figure 2). As can be seen, the balanced hardiness group declines in IL-4 over time, while the unbalanced group increases. The between-group factor was not significant.

Results for IL-10 showed a main effect for time ($F(1,19)=75.15$, $p<.001$, $\eta_p^2=.798$), with all subjects increasing over time (Figure 3). The interaction between time and hardiness balance was not significant, although hardiness unbalanced subjects showing a greater increase in IL-10 under higher stress conditions ($p<.12$). The between-group effect was, however, significant ($F(1,19)=4.87$, $p=.040$, $\eta_p^2=.204$), with the unbalanced group showing somewhat higher levels of IL-10.

For neuropeptide-Y, a significant main effect for time was observed, with levels increasing overall from day five to day seven ($F(1,19)=37.73$, $p<.001$, $\eta_p^2=.665$). Furthermore, a significant interaction effect was seen, with the hardiness balanced group increasing over time, while the unbalanced group remains stable.

![Figure 1](image-url). Means and standard errors of IL-12 levels measured early (time 1) and late (time 2) in the exercise. The means are separated for balanced and unbalanced hardiness.
increasing in Neuropeptide Y (NY) as stress levels increased in the exercise ($F(1,19)=6.14$, $p=.023$, $\eta^2_p = .244$) (Figure 4). The between-group contrast was also significant, with hardiness-balanced group higher in NY ($F(1,19) = 4.55$, $p = .046$, $\eta^2_p = .193$).

**Discussion**

Our study demonstrated an association between the personality trait hardiness and several immune response markers for healthy young officer cadets exposed to a stressful military exercise.

**Pro- and anti-inflammatory responses**

No significant effects for IL-6 were found between the balanced and unbalanced hardiness groups, but there was a significant interaction with time. The increase in IL-6 levels with increased stress was contrary to our prediction that this pro-inflammatory cytokine would be suppressed with stress. This may be explained in part by the fact
that IL-6 is a pleiotropic cytokine produced not only by immune cells, but also by neuroendocrine ones (Zhou, Kusnecov, Shurin, Depaoli, & Rabin, 1993).

The IL-12 levels did, however, show the predicted effect, with plasma levels diminishing for the hardiness unbalanced group as stress increased. In contrast, the hardiness balanced group showed no decrease in IL-12 levels as stress increased. IL-12 is considered a major proinflammatory cytokine and plays a critical role in cellular immunity (Elenkov & Chrousos, 2002).

Our results show the predicted increase in anti-inflammatory cytokines (IL-4 and IL-10) for the hardiness unbalanced group, and a concomitant decrease (IL-4) or smaller increase (IL-10) for the balanced group.

**Neuropeptide-Y**

A significant interaction effect indicated the hardiness balanced group showed a greater increase in NY levels compared to the hardiness unbalanced group. These results suggest a more adaptive stress response for the hardiness-balanced group.
findings are in with previous studies which have indicated a stress-buffering effect of NY (Morgan et al., 2002; Yehuda et al., 2006).

**General discussion**

Knowledge about who will show a more resilient and adaptive response to stress can be beneficial in recruitment and selection to professions or positions prone to stress. For the present study, we were unable to examine high-vs. low-hardiness groups, since all subjects scored in the high-hardiness range. However, similar to Bartone, Valdes, Spinoza and Robb (2011), we identified a sub group of subjects who showed an unbalanced hardiness profile of high scores on hardiness commitment and control, but relatively low scores on challenge. Our study found that those with this unbalanced hardiness profile, when exposed to stressful conditions that involve surprising and unexpected developments, show a more reactive and potentially unhealthy immune and
neuroendocrine response, as compared to their balanced and high-hardiness counterparts.

The results of our study also highlight the immune system as a biological system through which hardiness can have beneficial stress-buffering effects, and hence contribute to explaining the biophysical processes underlying the hardiness concept. This strengthens the theoretical foundation and justification for hardiness as a psychological valid concept.

The findings of this study should be considered in light of the limitations of a small homogenous military sample.

Note
1. Analyses were also obtained for Vasoactive Intestinal Peptide and β-endorphin, but no significant association to hardiness was found, so the results were omitted from this short report.

References


