Stress reactivity after maximal exercise: The effect of manipulated performance feedback in endurance athletes

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This study was designed to assess the effect of performance feedback on stress reactivity after recovery from maximal exercise. Forty competitive athletes were recruited to complete a maximal exercise test. Performance feedback was manipulated after the exercise test to give four groups: (1) high performance, (2) low performance, (3) accurate feedback and (4) no exercise control. Cardiovascular reactivity was assessed during psychological stress. The results indicate that accurate feedback participants experienced lower relative reactivity to stress (lower mean arterial pressure) than their no-exercise counterparts. These results demonstrate that the stress-buffering effect of exercise extends to maximal exercise. In addition, high-performance participants experienced lower relative reactivity than low-performance participants. Thus, low-performance feedback was sufficient to remove the buffering effect of exercise. There were no differences between the high-performance and accurate feedback conditions, or between the low-performance and control conditions.

Keywords: heart rate, mean arterial pressure, public speaking, stress reactivity.

Introduction

Participation in exercise has long been associated with a reduced physical response to stress (Crews and Landers, 1987). As a result, exercise training has been suggested as a useful, non-pharmacological treatment for the management of stress (Berger, 1994). In contrast to the suggestions for exercise training, early research failed to support the usefulness of an acute bout of exercise in buffering the cardiovascular response to stress (Russel et al., 1983; Roth, 1989). However, this research either used a relatively low to moderate dose of exercise (Roth, 1989) or did not utilize blood pressure as an indicator of stress reactivity (Russel et al., 1983). These limitations became clear in later work in which trained cyclists performed either 60 min of aerobic exercise at 80% of maximal oxygen uptake ($\dot{V}O_{2max}$) or 30 min of exercise at 50% of $\dot{V}O_{2max}$ (Rejeski et al., 1991). Cardiovascular reactivity was indicated by changes in mean arterial pressure and heart rate relative to an attitudinal control. Results indicated that, although there were no differences in heart rate reactivity, mean arterial pressure reactivity was significantly lowered for those participants who completed the high dose of aerobic exercise. Moderate exercise did not significantly reduce reactivity. Similarly, 80 low to moderately trained women were asked to complete aerobic exercise at 70% of $\dot{V}O_{2max}$ for 10, 25 or 40 min by Hobson and Rejeski (1993). Only those women who completed 40 min of exercise showed lower mean arterial pressure reactivity when compared to attentional controls. This effect has also been demonstrated in untrained women (Rejeski et al., 1992) and sedentary males (Ebbesen et al., 1992; Steptoe et al., 1993). It is clear, therefore, that people who complete a relatively high dose of aerobic exercise will experience lower reactivity to subsequent psychological stress.

Although stress-related anxiety is also reduced after exercise (Rejeski et al., 1992), explanations for the exercise-induced reduction in stress reactivity have generally ignored a cognitive component. Instead, it has been suggested that the completion of a large dose of

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aerobic exercise imparts a direct change in physiological response that results in lower cardiovascular reactivity to stress. Specifically, aerobic exercise is known to produce a short-term reduction in blood pressure (Kenney and Seals, 1993). It has been suggested that this hypotensive effect also serves to dampen the increase in blood pressure that is expected to occur during stress (Boone et al., 1993). Because it is based on a direct physiological response to exercise, this explanation is independent of any thoughts about either the exercise bout or the period of stress. However, the completion of intense exercise is likely to impact several personal judgements.

Intense exercise is, by definition, challenging to perform. When done well—for example, completing the full dose of exercise or doing so without excessive effort—it is likely to result in positive self-perceptions, including a sense of mastery and increased self-efficacy (Simons et al., 1985). In contrast, a poor performance—for example, an inability to complete all exercise or having completed it with an exhaustive effort—might result in negative self-perceptions. This is the basis of the mastery hypothesis, which has been suggested to underlie several psychological benefits that accrue from exercise, including reduced depression (Simons et al., 1985) and improved affect (Tuson and Sinyor, 1993).

The mastery hypothesis can also be used to explain the impact of acute exercise on stress reactivity, perhaps in combination with Lazarus and Folkman’s (1984) conception of stress appraisal. Lazarus and Folkman suggested that the experience of stress is based on a primary appraisal of the threat faced, as well as a secondary appraisal of one’s ability to meet the demands of that challenge. Although it is not likely to impact primary appraisal of threat, exercise, particularly successful exercise, may increase the perception that a person can meet the demands of a subsequent challenge. Specifically, the effort and determination needed to be successful at exercise would produce a sense of accomplishment that might generalize to subsequent challenges. Because positive self-perceptions would be maximized with the completion of a relatively challenging task, this effect is most likely to occur after a high dose of exercise. The ability to complete 1 h of exercise at 80% of $\dot{V}O_{2\text{max}}$ is more likely to produce a sense of accomplishment that would generalize to subsequent challenges than would a small dose of exercise.

Although suggested as a mechanism for many of the mental health benefits of exercise, relatively little work has tested directly the contribution of mastery experiences to any of the mental health benefits of exercise. One method of testing the mastery hypothesis would be to correlate perceived success with the reduction in stress reactivity. However, limitations to psychological self-report and correlational studies limit the ability to infer causality (Cook and Campbell, 1979). The preferred method of testing the mastery hypothesis would be to manipulate performance feedback relative to pre-exercise goals (Tuson and Sinyor, 1993). In this design, the mastery hypothesis would be fully supported if the benefits of exercise are limited to those who receive feedback of success. Partial support for the hypothesis would be inferred if the benefits of exercise are relatively greater in those who receive success feedback about success than for those who receive feedback about failure. The lack of research testing the mastery hypothesis is surprising, as support for this hypothesis would strongly impact the prescription of exercise as a stress management tool. Not only would exercise need to be of a relatively high dose to reduce reactivity to stress, it would also need to be perceived positively.

What is clearly needed is a series of experiments that manipulate people’s perceptions about their exercise performance while holding intensity constant. If mastery experiences underlie some component of the relationship between exercise and reactivity, then differential feedback about exercise success would be expected to moderate the ability of exercise to buffer stress reactivity.

To address this issue, endurance athletes were asked to perform a maximal exercise test to determine aerobic fitness ($\dot{V}O_{2\text{max}}$). Post-exercise feedback was then manipulated to create high- and low-performance conditions, together with accurate feedback and no-exercise conditions. Although the buffering effect of acute exercise has been demonstrated with highly trained endurance athletes (Rejeski et al., 1991), the response to a maximal exercise test has yet to be determined. As a result, the main aim of this study was to compare the accurate feedback and no-exercise conditions to determine if the stress-buffering effects of aerobic exercise extend to maximal exercise trials. In addition, a comparison of the high- and low-performance feedback conditions provides a powerful test of the mastery hypothesis. This design, however, also limits the ability to generalize the results. Clearly, the sample does not represent a large segment of the population or include exercise of training intensities. Further experimentation will be required before applying the results to a larger population. In addition, the no-exercise controls differed from the experimental groups in that they did not receive either exercise or feedback. They do, however, provide an indication of the general response of trained athletes to the selected stressors. Given the stated goal of providing an initial powerful test of the mastery hypothesis, the strengths of the design were judged to outweigh the weaknesses.
Methods

Participants

The participants were 40 competitive athletes (17 males, 23 females) aged 18–25 years. They were recruited from varsity university rowing \((n = 16)\) and cross-country \((n = 14)\) teams, as well as from a local competitive running club \((n = 10)\), to determine the effects of exercise on mood and cognitive functioning. They had a mean age of 21.2 years and a mean \(\dot{V}O_2\text{max}\) of 60.0 ml \(\cdot\) kg\(^{-1}\) \(\cdot\) min\(^{-1}\).

Procedure

Full exercise procedures were explained, written informed consent was obtained, and questionnaires were completed. Next, the participants were provided with the population norms for aerobic fitness and \(\dot{V}O_2\text{max}\) and asked to predict their \(\dot{V}O_2\text{max}\) on the upcoming test. To encourage accurate predictions, the predicted \(\dot{V}O_2\text{max}\) values were referred back to the population norms and the participants were asked to verify their accuracy. After these predictions, the participants were randomly assigned to one of four conditions: (1) exercise, accurate feedback; (2) exercise, low-performance feedback; (3) exercise, high-performance feedback; and (4) no exercise, control. The exercise participants completed the graded exercise test, whereas the controls were asked to complete a series of body composition measurements. For the controls, the results of the body composition measures were provided after the experiment had ended. For the exercise participants, performance feedback was provided by the lead experimenter within 2 min of the end of the exercise bout. By limiting the knowledge of the feedback to the lead experimenter, the assistants who oversaw the exercise and recovery periods were kept blind to the experimental conditions. Questionnaires of psychological state were completed before and 10, 25 and 40 min after exercise. The participants were then taken to a separate room to complete the test of cognitive function that served as the source of psychological stress. The manipulation check and measurements of baseline blood pressure and pulse were performed after 40 min of recovery but before receiving the directions for the stress task. Blood pressure and pulse were measured 30 s after the start of the mental challenge as well as 30 s after the start of the speech test.

Exercise manipulation

A graded aerobic exercise test served as the exercise procedure. All exercise was completed on a treadmill; heart rate was monitored continuously using a three-lead electrocardiograph and oxygen consumption was monitored using a Sensormedics 2900 metabolic cart. Maximal oxygen uptake was considered to have been reached when there was: (1) a plateau in oxygen consumption despite increases in exercise intensity; (2) a rating of perceived exertion > 18 on Borg’s 6–20 scale (Borg, 1985); or (3) a heart rate within 10 beats of the participant’s age-predicted maximum.

Feedback manipulation

Performance feedback was manipulated as a function of (a) pre-exercise predictions and (b) the duration of exercise before exhaustion. The high-performance participants were told that their \(\dot{V}O_2\text{max}\) was 12% higher than their prediction and that they were able to cycle for 2–3 min beyond the norm for other participants before reaching exhaustion. The low-performance participants were told that their \(\dot{V}O_2\text{max}\) was 12% lower than their prediction and that they were able to cycle 2–3 min less than the norm for other participants before reaching exhaustion. Accurate feedback participants were given accurate information concerning their \(\dot{V}O_2\text{max}\) after the end of the exercise test. These manipulations were selected based on pilot testing that revealed them to be powerful and believable. After completion of the experiment, all participants were fully debriefed about the manipulation and informed of their true exercise performance.

Stress reactivity procedure

Stress was induced by a mental challenge and a speech task, which are among the most common methods of experimental stress induction. The mental challenge consisted of mental arithmetic and the Stroop colour word task (Frankenhaeuser and Johansson, 1976), which were presented by computer. The participants responded verbally to 70 trials of the mental challenge, equally divided between Stroop and mental arithmetic problems, for approximately 2 min. They were then allowed 1 min to prepare a 2-min speech on an assigned topic of local concern. The participants were led to believe that the speech was videotaped for later evaluation, although no videotaping actually took place. To maintain the threat and thus maximize the induced reactivity, the participants were told that the mental challenge and speech task constituted a modified intelligence test. However, no performance data were collected.

Dependent variables

Heart rate and blood pressure were assessed automatically using a Colin blood pressure monitor (model
STBP-680), with the participant in a semi-reclined position. The performance manipulation was checked with two 5-point Likert scales. The first asked participants to rate their performance relative to their expectations and was anchored with ‘far exceeded’ and ‘fell far short of’. The second asked participants to describe their performance and was anchored with ‘very successful’ and ‘very unsuccessful’. The participants also completed a series of questionnaires of psychological state before and 10, 25 and 40 min after exercise. These questionnaires were collected to assess the psychological response to a maximal exercise test. These self-report data relate to an issue that is distinct from that of the present study. These data, therefore, require a separate theoretical justification, literature review and analysis. As a result, these data will be reported elsewhere.

**Statistical analysis**

Stress reactivity was assessed in terms of mean arterial pressure and pulse. Because reactivity is defined as a change from baseline values, a comparison of absolute differences in mean arterial pressure and heart rate between conditions is considered inappropriate. The preferred method of analysis would be an analysis of covariance (ANCOVA), with pre-stress scores serving as the covariate. However, ANCOVA requires homogeneity of regression slopes across the groups (Pedhazur, 1982). This assumption was not met in the present data, indicating differences among the regression slopes for mean arterial pressure. Difference scores were therefore calculated for mean arterial pressure and heart rate, and analysed using separate analyses of variance. Follow-up comparisons were corrected for alpha-inflation using the modified Bonferroni adjustment (Keppel, 1991).

**Results**

**Participants and manipulation check**

Descriptive data for the participants are presented in Table 1. The only difference among the conditions was the age of the participants ($F_{1,34} = 4.78, P < 0.05$); the participants in the two control conditions were slightly older than those in the experimental ones. The conditions did not differ in terms of $\dot{V}O_{2max}$ ($P = 0.61$) or prediction of $\dot{V}O_{2max}$ ($P = 0.76$). One member of the no-exercise control and one participant in the accurate feedback condition failed to complete all questionnaires and were eliminated from the analysis.

An examination of the manipulation check indicated that one participant in the high-performance condition reported relatively low performance ratings, and one participant in the low-performance condition reported relatively high performance ratings. These individuals were therefore excluded from the analysis because they did not experience the manipulation as intended. This left nine participants in each condition, with a relatively equal distribution of males within each group (i.e. 3–5 per cell). The remaining sample size resulted in a power of 0.63 to detect a moderate effect. For the remaining participants, there was a significant difference in ratings for both of the exercise performance questions ($F_{2,21} = 52.42, P < 0.05$ and $F_{2,21} = 14.97, P < 0.05$ respectively). These data are presented in Table 1. The high-performance participants rated their performance higher in relation to expectations than the low-performance and accurate feedback participants. Similarly, the high-performance participants rated their performance as more successful than the low-performance participants, although not different from the accurate feedback participants.

**Cardiovascular reactivity**

Cardiovascular reactivity was defined as the change in mean arterial pressure and heart rate during the stressor. The mean arterial pressure data are presented in Table 2. There were no significant main effect differences between groups for heart rate reactivity to either the mental challenge ($F_{3,32} = 0.62, P > 0.10$) or the speech tasks ($F_{3,32} = 0.16, P > 0.10$). There were also no main effect differences between groups for mean arterial pressure reactivity to the mental challenge ($F_{3,32} = 1.57, P > 0.10$). There was, however, a significant main effect difference between groups for mean arterial pressure reactivity to the speech task ($F_{3,32} = 2.92, P < 0.05$). *Post-hoc* comparisons between the difference scores revealed lower mean arterial pressure for the accurate feedback participants than the no-exercise controls (effect size, ES = 0.85), but no difference between the accurate feedback and high-performance groups (ES = 0.18). In addition, mean arterial pressure reactivity to the speech was reduced in the high-performance group compared with the low-performance participants (ES = 0.90), with no differences between the low-performance and no-exercise control participants (ES = 0.23).

**Discussion**

This experiment was primarily designed to assess the general impact of maximal exercise on cardiovascular reactivity to psychological stress. The results indicate that maximal exercise does reduce relative reactivity to stress. Although there were no differences in heart rate reactivity, accurate feedback participants responded to
Table 1. Descriptive characteristics of the participants (mean ± s)

<table>
<thead>
<tr>
<th></th>
<th>No exercise</th>
<th>Accurate feedback</th>
<th>High performance</th>
<th>Low performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>22.44 ± 2.51</td>
<td>22.22 ± 1.56</td>
<td>20.11 ± 1.05</td>
<td>20.11 ± 1.62</td>
</tr>
<tr>
<td>Height (m)</td>
<td>1.73 ± 0.10</td>
<td>1.74 ± 0.08</td>
<td>1.68 ± 0.10</td>
<td>1.71 ± 0.07</td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td>67.2 ± 13.6</td>
<td>66.8 ± 11.9</td>
<td>59.9 ± 4.9</td>
<td>62.9 ± 8.8</td>
</tr>
<tr>
<td>Predicted $\dot{V}O_{2\max}$ (ml·kg⁻¹·min⁻¹)</td>
<td>58.2 ± 10.8</td>
<td>59.2 ± 10.3</td>
<td>58.2 ± 10.8</td>
<td>58.8 ± 4.7</td>
</tr>
<tr>
<td>Actual $\dot{V}O_{2\max}$ (ml·kg⁻¹·min⁻¹)</td>
<td>57.8 ± 6.4</td>
<td>61.6 ± 9.2</td>
<td>58.9 ± 10.4</td>
<td>62.3 ± 9.2</td>
</tr>
<tr>
<td>Performance rating</td>
<td>3.22 ± 0.41</td>
<td>4.33 ± 0.71</td>
<td>4.22 ± 0.67</td>
<td>4.33 ± 0.71</td>
</tr>
<tr>
<td>Exercise success</td>
<td>3.56 ± 0.53</td>
<td>4.22 ± 0.67</td>
<td>3.22 ± 0.41</td>
<td>3.22 ± 0.41</td>
</tr>
</tbody>
</table>

Note: Within each measure, means without a common superscript are significantly different ($P < 0.05$).

Table 2. Mean arterial pressure (mmHg) and heart rate (beats·min⁻¹) before and during stress (mean ± s)

<table>
<thead>
<tr>
<th></th>
<th>No exercise</th>
<th>Accurate feedback</th>
<th>High performance</th>
<th>Low performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean arterial pressure</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-stress, actual</td>
<td>89.5 ± 8.6</td>
<td>86.7 ± 9.2</td>
<td>88.4 ± 7.6</td>
<td>90.5 ± 9.9</td>
</tr>
<tr>
<td>Mental challenge, actual</td>
<td>100.3 ± 10.3</td>
<td>92.9 ± 9.3</td>
<td>98.8 ± 6.3</td>
<td>102.0 ± 12.4</td>
</tr>
<tr>
<td>Difference</td>
<td>10.8</td>
<td>6.2</td>
<td>10.4</td>
<td>11.5</td>
</tr>
<tr>
<td>Speech task, actual</td>
<td>108.6 ± 10.3</td>
<td>100.0 ± 8.7</td>
<td>102.9 ± 6.3</td>
<td>111.2 ± 13.9</td>
</tr>
<tr>
<td>Difference</td>
<td>19.1</td>
<td>15.1</td>
<td>14.8</td>
<td>19.1</td>
</tr>
</tbody>
</table>

|                          |             |                  |                  |                 |
| Heart rate               |             |                  |                  |                 |
| Pre-stress, actual       | 65.1 ± 8.0  | 69.7 ± 10.5      | 69.7 ± 10.5      | 76.6 ± 18.4     |
| Mental challenge, actual | 74.4 ± 8.8  | 76.7 ± 15.5      | 76.7 ± 15.5      | 85.8 ± 18.3     |
| Difference               | 9.3         | 13.5             | 7.0              | 9.2             |
| Speech task, actual      | 78.1 ± 14.9 | 82.8 ± 12.2      | 82.8 ± 12.2      | 91.3 ± 20.8     |
| Difference               | 13.0        | 16.2             | 13.1             | 14.8            |

Note: Means without a common superscript are significantly different ($P < 0.05$).

the speech task with a smaller increase in mean arterial pressure than no-exercise controls. Previous experiments have shown a similar pattern of effects for relatively high doses of exercise (Rejeski et al., 1991; Hobson and Rejeski, 1993). However, this is the first study to assess stress reactivity after maximal exercise. The present results serve to extend our understanding of the exercise-reactivity relationship to include maximal exercise.

The experiment was also designed to test the mastery hypothesis by assessing the impact of manipulated performance feedback on post-exercise stress reactivity. The results supported the mastery hypothesis. High-performance feedback participants responded to the speech task with a smaller increase in mean arterial pressure than the low-performance feedback participants. In fact, those individuals who received low-performance feedback responded no differently than non-exercising controls. Thus, in this instance, the presence of low-performance feedback was sufficient to negate any benefit for stress reactivity that is provided by an acute bout of maximal aerobic exercise. High-performance feedback, however, was not sufficient to further reduce mean arterial pressure relative to accurate feedback participants. There were no differences in reactivity between these groups. This may be because the participants in the accurate feedback condition generally met their performance predictions for the maximal exercise test. In support of this, their ratings of exercise success were not significantly different from those of the high-performance participants.

Although it is clear that low-performance feedback removed the buffering effect of exercise in this sample, several issues limit the ability to generalize these findings. A primary concern is the use of competitive athletes on a maximal exercise test. The results from
such a test are likely to have greater meaning for competitive athletes than for recreational athletes or sedentary individuals. Manipulation of performance feedback has been shown to moderate post-exercise mood states in non-athlete, resistance exercisers (Bartholomew et al., 1996) and in interpersonal competition during cycle ergometry (McAuley and Duncan, 1989). However, this manipulation has not yet been applied to acute bouts of aerobic exercise in non-athletes or in conjunction with any stress reactivity measures. Thus, it is clear that this design needs to be replicated with a non-athlete sample before the results can be generalized beyond endurance athletes.

The pattern of results for the speech task were not replicated with the mental challenge. Although the power to detect a moderate effect was relatively low, the group differences in mean arterial pressure for this task were not great. Thus, it is unlikely that a different result would have been realized with a larger sample. It is more likely that the mental challenge was not sufficiently stressful. Previous experiments have shown a 20% increase in mean arterial pressure during similar protocols (Rejeski et al., 1991; Hobson and Rejeski, 1993). However, only the speech task produced a 20% increase in mean arterial pressure in the present experiment. In contrast, the mental challenge produced an increase of only 12%. The relatively modest increase in mean arterial pressure during the mental challenge may have produced a floor effect, obscuring any benefits of exercise in reducing mean arterial pressure during stress. That there wasn’t a reduction in heart rate reactivity is also not surprising. The buffering effect of exercise appears to be limited to measures of blood pressure (Rejeski et al., 1991). The lack of a positive finding for either heart rate or the mental challenge does not reduce the importance of the data collected during the speech task. In this instance, low-performance feedback was sufficient to remove the stress-buffering effect of exercise. With replication, this result impacts our thinking about why acute bouts of exercise buffer stress and, as a result, the appropriate prescription of exercise to achieve this end.

It is clear that exercise provides an opportunity to demonstrate competence and thus enjoy a mastery experience. However, few studies have assessed the role of these experiences on subsequent psychological health. By manipulating and randomly assigning performance feedback, this is the first study to test directly the role of mastery experiences with respect to the relationship between exercise and reactivity. The results support the importance of performance feedback in the buffering effects of an earlier bout of aerobic exercise. Despite the limitations discussed above, the results suggest both the usefulness of maximal exercise in reducing reactivity to stress as well the viability of the mastery hypothesis as an explanation for the relationship between exercise and reactivity.

References

