Acute exercise can induce oxidative stress and lower antioxidant status. When generation of reactive oxygen species (ROS) exceeds antioxidant capacity, lipids, proteins, and other cell components may be oxidised. Generation of ROS during exercise has been linked to increased oxygen consumption, but ROS could also be produced by alternative or additional mechanisms—for example, a respiratory burst of neutrophils or catecholamine auto-oxidation—when oxygen consumption is only moderately increased.

**Objectives:** To investigate noradrenaline concentrations, neutrophil counts, plasma antioxidants, and lipid oxidation products before and after acute resistance exercise.

**Methods:** 17 male participants undertook a submaximal resistance exercise circuit (10 exercises; 75% of the one repetition maximum; mean (SD) exercise time, 18.6 (1.1) minutes). Blood samples were taken before and immediately after exercise and analysed for plasma antioxidants, noradrenaline, neutrophils, and lipid oxidation products. Wilcoxon's signed-rank test and Pearson's correlation coefficient were used for calculations.

**Results:** Neutrophils, noradrenaline, fat soluble antioxidants, and lipid oxidation products increased after exercise. Noradrenaline concentrations were associated with higher antioxidant concentrations. Neutrophils were related to higher concentrations of conjugated dienes.

**Conclusions:** Submaximal resistance exercise increases plasma antioxidants. This might reflect enhanced antioxidant defence in response to the oxidative stress of exercise, though this is not efficient for inhibiting lipid oxidation. The correlation between noradrenaline concentrations and plasma antioxidants suggests a modulating role of the stress hormone. Neutrophils are a possible source of oxidative stress after resistance exercise.
The increase in noradrenaline concentrations after exercise correlated positively with the increase in concentrations. It has been suggested that there is a rapid flux of α tocopherol between plasma and tissue, and this could explain why we could not detect any association between plasma noradrenaline and α tocopherol. There is a large variability in the response of plasma ascorbic acid to resistance circuit training and thus no significant differences between before and after the exercise, but higher ascorbic acid concentrations were also associated with the increase in noradrenaline concentrations.

The association between noradrenaline concentrations and antioxidants could represent a physiological mechanism ensuring adequate antioxidant defence during physical activity. This type of study and statistical analysis do not prove causality between noradrenaline and antioxidant concentrations; the observed correlations could also reflect the possibility that both factors—noradrenaline and antioxidants—respond independently of each other to exercise. However, it has been speculated that the release of catecholamines leads to upregulation of antioxidant defence. It has been suggested that noradrenaline secretion induces antioxidant defence—for example, superoxide dismutase expression.

In our study no significant correlation between the stress hormone and the lipid oxidation products conjugated dienes and MDA could be observed after exercise, although it has been suggested that auto-oxidation of catecholamines, which generates a superoxide anion radical, could result in lipid oxidation. During short term resistance exercise, noradrenaline concentrations increase only moderately. We cannot rule out the possibility that during intensive endurance exercise, high noradrenaline concentration may contribute to oxidative stress. After short time resistance exercise there are other possible sources of free radicals causing lipid oxidation. For example, in our study there was a positive correlation between the neutrophil count and the concentrations of conjugated dienes; it is well known that neutrophils can

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Characteristics of the participants (n = 17)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td>Age (years)</td>
<td>29.5 (7.1)</td>
</tr>
<tr>
<td>Height (m)</td>
<td>1.82 (0.06)</td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td>82.1 (7.6)</td>
</tr>
<tr>
<td>Body fat (%)</td>
<td>16.8 (5.0)</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>24.8 (1.8)</td>
</tr>
</tbody>
</table>

BMI, body mass index.

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Plasma antioxidants, noradrenaline, neutrophils, and lipid oxidation products before and after exercise (n = 17)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before exercise</td>
</tr>
<tr>
<td>Noradrenaline (nmol/l)</td>
<td>1.46 (0.53)</td>
</tr>
<tr>
<td>Neutrophils (×10³ ml)</td>
<td>2.66 (1.01)</td>
</tr>
<tr>
<td>Ascorbic acid (µmol/l plasma)</td>
<td>50.6 (32.1)</td>
</tr>
<tr>
<td>α Tocopherol (µmol/l plasma)</td>
<td>1.72 (4.8)</td>
</tr>
<tr>
<td>γ Tocopherol (µmol/l plasma)</td>
<td>1.17 (0.44)</td>
</tr>
<tr>
<td>β Carotene (µmol/l plasma)</td>
<td>0.233 (0.58)</td>
</tr>
<tr>
<td>Lycopene (µmol/l plasma)</td>
<td>0.210 (0.159)</td>
</tr>
<tr>
<td>MDA (µmol/l plasma)</td>
<td>1.90 (0.98)</td>
</tr>
<tr>
<td>Conjugated dienes (mg/l plasma)</td>
<td>10.7 (5.2)</td>
</tr>
</tbody>
</table>

Values are mean (SD).

*After correction for plasma volume changes.

**Take home message**
- Acute submaximal resistance exercise increases absolute plasma antioxidant concentrations. This is not efficient at inhibiting the increase in lipid oxidation products in plasma.
- Noradrenaline concentrations are associated with higher plasma antioxidant concentrations, which could reflect a modulating role of the stress hormone.
generate ROS through an oxidative burst, which might worsen exercise induced damage and contribute to lipid peroxidation.18

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REFERENCES
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