Children Are Less Susceptible to Exercise-Induced Muscle Damage Than Adults: A Preliminary Investigation

José M.C. Soares, Paulo Mota, José A. Duarte, and Hans J. Appell

The aim of the present study was to investigate whether children showed similar signs of muscle overuse like adults after intense exercise. One child group \( (n = 10) \) and one adult group \( (n = 10) \) of males both had to perform five series of bench press exercises at an intensity of 80% of maximum strength until exhaustion. Maximum isometric strength, subjective perception of muscle pain, was measured before, immediately after, 48 hr, 72 hr, and 1 week after the exercise. Serum creatine kinase (CK) activity was measured before, 48 hr, 72 hr, and 1 week after the exercise. The adults showed all symptoms of muscle overuse: reduced strength, muscle pain, and elevated CK activities until 3 days after the exercise. In contrast, the children experienced only some light muscle pain, but neither showed reduced strength nor elevated CK activities. It is concluded that children’s muscles can easier withstand physical stress than adult muscles.

It is well established that intense, prolonged, or unaccustomed exercise produces damage to muscle tissue \( (1, 8) \). Four stages of exercise-induced muscle damage have been described \( (2) \). The sequence of these events are accompanied by a sequence of morphological and functional alterations that can be divided into direct and indirect signs of damage \( (5) \). Direct signs includes structural and ultrastructural alterations observed in muscle tissue such as mitochondrial swelling, myofibrillar ruptures, cellular infiltration, and central nuclei. \( (7, 17) \). Delayed soreness, prolonged reduction in muscle strength, alterations in the range of motion, and efflux of muscle proteins into the blood are the most commonly assessed indirect indicators of damage \( (5) \).

These morphological, biochemical, and functional alterations are well described in different subjects with different exercise protocols, especially with eccentric exercise that is known to produce muscle damage because of its mechanically aggressive character \( (8) \). However, there has been little research concerning the

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effects of exercise-induced muscle damage in children, in spite of the importance of such knowledge for designing training programs that promote health and fitness in children. Some animal studies have described a lower susceptibility of juvenile muscles to injury (4, 21), but such results are difficult to transfer to humans. Webber et al. (20) reported a less pronounced creatine kinase (CK) response, but a similar degree of muscle soreness in children compared to adults after a downhill run (i.e., with a typical eccentric exercise protocol).

Children are subjected to strength training in many youth sports that require muscular power (e.g., gymnastics). It is anecdotally reported that children involved in strength training do not suffer severely from muscle soreness, which may lead to the assumption that children are less susceptible to muscle damage. Since eccentric exercise protocols are rather aggressive and do not reflect common types of training with a mixture of concentric and eccentric contractions, the aim of this study was to evaluate the effects of a typical strength exercise on some indirect indicators of muscle damage in children and adults.

Material and Methods

Subjects

Ten boys (age = 12.1 ± 0.2 years, weight = 52.2 ± 3.2 kg, height = 148 ± 4.2 cm) and 10 male adults (age = 28.3 ± 3.5 years, weight = 73.2 ± 3.1 kg, height = 174 ± 5.8 cm) volunteered to participate in the study. A signed informed consent form was required from each parent of the children and from each subject for the adult group, before participation in the study. According to interrogation, none of the participants were "weight trained," nor had they exercised for at least 2 months before the experiments.

Exercise Protocol

The strength exercise was done using bench press in supine position. Individual strength was determined during one maximum repetition (RM) 1 week before the actual exercise; after a warm-up with low resistance, the load was gradually increased, allowing determination of RM within six to eight trials (3, 10, 16) with complete recovery between the trials. For the strength-exercise bouts, all subjects had to perform five sets (separated by rest periods of 90 s) of bench press at 80% of their individual RM until subjective exhaustion. The subjects were verbally motivated by the experimenter and other group members during the sets in order to ensure termination of the exercise at comparable exhaustion.

Test Protocol

Maximum isometric force (MIF) of arm muscles was assessed using the Nicholas Manual Muscle Tester (Model 1116, Lafayette Instrument Company, Indiana, USA). After warm-up, three trials were performed (10) using the best one for further evaluation. The perception of delayed muscular soreness was estimated, with and without palpation (DMS, DMS-P), by using an interval perception scale (ranging from 1 = not sore to 7 = extremely sore). These evaluations were done before, immediately after, 48 hr, 72 hr, and 1 week after exercise. Blood was collected from the antecubital vein before, 48 hr, 72 hr, and 1 week after exercise, and serum
CK activity was measured enzymatically using a commercial kit (CK NAC Activated, Boehringer).

**Statistical Analysis**

The statistical significance of the data was tested using a repeated-measures ANOVA to assess changes over time and between groups. A significant difference was determined at $p < .05$ and further analyzed using a Scheffé’s post hoc analysis.

**Results**

The number of repetitions the subjects were able to perform in each set decreased similarly in adults and children (Figure 1), indicating a comparable degree of exhaustion. The total amount of work during all sets was similar in both groups (adults: ~25 repetitions; children: ~27 repetitions, see Figure 1).

The maximum isometric force decreased significantly immediately after exercise and recovered completely only 1 week later in the adult group; the children did not show significant changes in this respect (Table 1). The perception of DMS, with and without palpation, increased slightly, yet significantly, in children. In contrast, the adults experienced pronounced muscle soreness 2 and 3 days after exercise (Table 1).

![Figure 1 — Number of repetitions in each set of exercise.](image)
Table 1  Maximum Isometric Force (MIF) and Perception of Delayed Muscle Soreness Without (DMS) and With Palpation (DMS-P)

<table>
<thead>
<tr>
<th></th>
<th>Before</th>
<th>0 hours</th>
<th>48 hours</th>
<th>72 hours</th>
<th>1 week</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MIF (kg)</strong></td>
<td></td>
<td></td>
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<tr>
<td>Children</td>
<td>8.9 ± 2.3</td>
<td>7.6 ± 3.4</td>
<td>8.2 ± 2.1</td>
<td>7.8 ± 2.1</td>
<td>7.8 ± 1.4</td>
</tr>
<tr>
<td>Adults</td>
<td>18.3 ± 5.7</td>
<td>12.7 ± 4.8</td>
<td>13.7 ± 5.5</td>
<td>15.3 ± 4.1</td>
<td>18.9 ± 6.4</td>
</tr>
<tr>
<td><strong>DMS</strong></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Children</td>
<td>1.0 ± 0.0</td>
<td>1.4 ± 0.5</td>
<td>1.5 ± 0.5</td>
<td>1.5 ± 0.8</td>
<td>1.0 ± 0.0</td>
</tr>
<tr>
<td>Adults</td>
<td>1.0 ± 0.0</td>
<td>1.7 ± 0.7</td>
<td>3.4 ± 1.4</td>
<td>2.7 ± 1.2</td>
<td>1.3 ± 0.4</td>
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<tr>
<td><strong>DMS-P</strong></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Children</td>
<td>1.0 ± 0.0</td>
<td>1.6 ± 0.5</td>
<td>1.7 ± 0.6</td>
<td>1.8 ± 0.0</td>
<td>1.0 ± 0.0</td>
</tr>
<tr>
<td>Adults</td>
<td>1.0 ± 0.0</td>
<td>1.9 ± 0.9</td>
<td>4.9 ± 1.5</td>
<td>4.0 ± 1.8</td>
<td>1.4 ± 0.5</td>
</tr>
</tbody>
</table>

Note. Values are $M \pm SD$.
$p < .05$ vs. before. $b p < .05$ vs. adults at same period of time.

Table 2  Serum Creatine Kinase Activity

<table>
<thead>
<tr>
<th></th>
<th>Before</th>
<th>48 hours</th>
<th>72 hours</th>
<th>1 week</th>
</tr>
</thead>
<tbody>
<tr>
<td>Children</td>
<td>32.2 ± 14.5</td>
<td>48.5 ± 24.8</td>
<td>55.5 ± 41.2</td>
<td>39.3 ± 19.2</td>
</tr>
<tr>
<td>Adults</td>
<td>41.7 ± 16.8</td>
<td>266.1 ± 27.24</td>
<td>1,190.1 ± 1,522.7</td>
<td>727.1 ± 308.0</td>
</tr>
</tbody>
</table>

Note. Values are $M \pm SD$.
$p < 0.5$ vs. before. $b p < .05$ vs. adults at same period of time.

The development of CK activities showed completely different patterns in the two groups during the week after exercise (Table 2). In children, only normal CK activities were detected. The adults showed an elevation in CK activities until 72 hr and still higher activities 1 week after exercise. The elevated CK activities after 48 hr were not significant, probably because of large variations within this group, since some subjects were low and others high CK responders (Figure 2).

**Discussion**

It was evident that the children showed less indirect indicators of muscle overuse after strength exercise compared to the adult group. To understand the differences observed between the two groups, one might suspect that the children had exercised at a lower intensity due to a lower ability to voluntarily activate their muscles (12) and therefore had a better endurance. However, the method used to determine the repetition maximum, and therefore the setting of work intensity (80% of RM),
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Figure 2 — Individual creatine kinase activities in the adult group.

During the trials is widely acknowledged (3, 10, 16). Moreover, the similar number of total repetitions and a comparable decrease in the number of repetitions in each set (Figure 1) suggest that all subjects experienced a similar relative work load and consecutive fatigue (19); therefore, the engagement in the exercise was comparable in all subjects. In adults, we observed a marked decrease in strength immediately after exercise and a very slow recovery during the following week compared with that observed in the child group (Figure 1). Technical and methodological problems in evaluating strength should not account for this difference. Although simple, the Nicholas Manual Muscle Tester, represents a quick and reliable testing instrument for determining maximal isometric force in children (6) and adults (18).

There are several probable explanations for the results concerning the differences in acute prolonged strength loss between the child and adult groups, but the most suggestive one described in other similar protocols, concerns the muscle damage induced by exercise (13). Given that the exercise protocol was performed with the same relative intensity for all subjects, the lack of a decrease in strength observed in the child group suggests less muscle injury induced by the exercise.

The alterations in CK support these assumptions. If CK elevations after exercise indicate overuse and muscle damage, without being biased by body weight (14) nor muscle mass (15), one could conclude that muscle damage in children was not as intense as that observed in adults. However, others (20) have related a lower CK response relatively to body weight in children. Generally, assumptions based on CK activities should be done with some caution because of a marked intersubject variability in response (5). This variability was shown in adults (Figure 2), as in previous
Soares, Mota, Duarte, and Appell studies (9), but surprisingly, was not found in children. Although some adults were high responders, all children were nonresponders. In adults, a low response has been attributed to the presence of CK inhibitors in the blood, different CK release velocities from the muscle, and clearance of CK by the reticuloendothelial system (5). However, in our experiment, as in other studies, the low CK responders showed other indirect signs of muscle overuse, such as a decrease in strength, muscle pain, and stiffness (5). These signs were only negligibly observed in the child group at any point in the protocol. One of those indicators of muscle damage is the delayed onset of muscle soreness (2). In the adult group, as described by other authors (5), muscle soreness appeared 24 hr after exercise, peaked at 2 days postexercise, and slowly dissipated. Moreover, and in accordance with other authors (11), DMS was more pronounced with palpation. In the child group there was no relevant difference in DMS compared with the preexercise state, although the difference did achieve significance.

The reader should keep in mind that our exercise protocol was designed to mimic a typical high-intensity strength training rather than to provoke muscle damage by forced eccentric contractions, as was done in other studies (20). The present results confirm the practical observation that children rarely experience muscle discomfort during such a training, in contrast to adults. Taking into account all of the indirect indicators of muscle overuse dealt with in this study, the results suggest that children are less susceptible to muscle injury induced by exercise when compared to adults exerting similar workloads. The reasons for this peculiarity in children currently remain unknown. In accordance with a hypothesis about the occurrence of the overuse syndrome (1), it can be speculated that muscle fibers in children are more able to withstand physical stress, and that they have a greater ability to recover. The higher susceptibility of adult muscles may depend on a higher percentage of muscle fibers being near the end of their life cycle and becoming more easily damaged. However, further research is needed to explain the underlying mechanisms.

References


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