SHORT COMMUNICATION

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Age related blood flow around the Achilles tendon during exercise in humans

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Abstract Injuries due to the overuse of tendons increase with age, and it has been suggested that this correlates with hypovascularity of the tendon. In the present study, the peritendinous blood flow was determined using xenon-133 washout at rest and during standardised intermittent exercise of the calf muscle (1.5 s contraction, 1.5 s rest, 40 min) in young (n = 6; 26 years), middle-aged (n = 6; 48 years), and older (n = 6; 74 years) individuals. At rest, the older individuals had a lower peritendinous blood flow compared with the two other age groups. During exercise, blood flow in all three groups rose 2.5–3.5-fold to reveal similar blood flows [2.7 (SEM 0.5) to 7.8 (SEM 1.0) ml·100 g tissue⁻¹ min⁻¹ (young group); 3.0 (SEM 0.4) to 7.3 (SEM 1.6) ml·100 g tissue⁻¹ min⁻¹ (middle-aged group); 1.6 (SEM 0.2) to 5.5 (SEM 1.1) ml·100 g tissue⁻¹ min⁻¹ (older group)]. The findings demonstrated that the peritendinous blood flow to the zone of the tendon with the highest incidence of injury from overuse is unaltered by age during exercise, and indicates that factors other than blood flow are important for the increased incidence with age of injuries from overuse.

Key words Young · Older · Connective tissue · Muscle contraction

Introduction

Injuries resulting from the overuse of tendons are major problems both in the workforce and in sport, but little is known of the aetiology of tendon inflammation and degeneration. An inadequate blood supply has been suggested to play an important role in the development of the symptoms of the overuse of the Achilles tendon (Carr and Norris 1989). As an indirect validation of this hypothesis a specific zone of the Achilles tendon having a reduced vasculature has been identified corresponding to the region most prone to injuries (Carr and Norris 1989). The local tissue blood flow (BF) to this region has been found to be compromised by age, and chronic Achilles tendinopathy has furthermore been found to increase with age (Hastad et al. 1958; Moller et al. 1996). Despite the coexistence of hypovascularity and a high incidence of injury no evidence of any cause-effect relationship between the two phenomena has ever been demonstrated. Interestingly, all studies addressing this question in older individuals and athletes have focused on measurements in the resting state and on anatomical observations rather than on physiological flow determinations (Jasperse et al. 1994; Floridi et al. 1981). It would be expected that any reason for a region with reduced perfusion to be exposed to tissue inflammation or degradation would be due to its hypoperfusion during exercise. Thus studies determining BF during exercise were needed. Recently it has been demonstrated in healthy young adults that the peritendinous BF to all regions of the Achilles tendon rose three to fourfold during exercise (Langberg et al. 1999). It is however unknown whether the exercise-induced increase in peritendinous BF is maintained with increasing age. Thus, the aim of the present study was to investigate the effects of age on BF to the Achilles tendon during rest and exercise.

Methods

Subjects

In the present protocol, three groups of healthy volunteers with no histories of previous injuries to the Achilles tendon were included in a study approved by The Ethics Committee of Copenhagen [approval no. (KF) 01-065/98] (Table 1). The subjects were told not to do any kind of exercise during the 24 h prior to the experiments, except for ordinary daily working activities.

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Table 1 The number of subjects (women, W, men, M) in the three groups as well as subject data for age, body mass and training status (including all exercise performed)

<table>
<thead>
<tr>
<th>Group</th>
<th>Sex (W/M)</th>
<th>Age (years)</th>
<th>Body mass (kg)</th>
<th>Training status (h·week⁻¹)</th>
<th>Training experience (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean</td>
<td>Range</td>
<td>Mean</td>
<td>Range</td>
</tr>
<tr>
<td>Young</td>
<td>2/4</td>
<td>26</td>
<td>22–33</td>
<td>78</td>
<td>66–85</td>
</tr>
<tr>
<td>Middle-aged (&gt; 45 years)</td>
<td>3/3</td>
<td>48</td>
<td>41–56</td>
<td>71</td>
<td>57–77</td>
</tr>
<tr>
<td>Older (&gt; 70 years)</td>
<td>6</td>
<td>74</td>
<td>72–78</td>
<td>87</td>
<td>73–96</td>
</tr>
</tbody>
</table>

Procedure

The BF of the tissue ventral to the Achilles tendon 50 mm proximal to the tendon insertion on both right and left sides was determined using radioactive xenon-133 as has been previously described (Langberg et al. 1999).

Calculations of BF

From the rate of clearance of ¹³³Xe it was possible to calculate BF in ml·100 g tissue⁻¹·min⁻¹:

\[ BF = 100 \cdot \frac{\lambda}{\kappa} \]

The partition coefficient tissue/blood (\( \lambda \), in \( \mu \)C·g tissue⁻¹·(\( \mu \)C·ml blood⁻¹) was set at 10 for all three age groups in the present study; \( \kappa \) is the elimination rate constant for the monoexponential washout of ¹³³Xe.

Experiment design

A ¹³³Xenon depot was positioned in the tissue and after 30 min the clearance rate was measured. This delay ensured that the risk of the trauma of the insertion influencing the calculated BF was reduced. The BF at rest was measured during 40 min with the subjects supine and the ankle joints in a relaxed neutral position. The rest period was followed by a period of exercise lasting 40 min. During exercise the subjects were seated in a specially constructed experimental set-up, with the trunk perpendicular to the seat and the knees extended. The extension of the knees ensured that the torque moment measured was generated by the triceps surae muscle alone and that the extensor muscles of the thigh were excluded. Both feet were positioned on a vertical sheet with the axis of the sheet aligned with the axis of plantar/dorsal flexion in the ankle joint. The torque moment developed by the triceps surae muscle of the two legs in the plantar direction was measured using a precalibrated (range 0–2000 N) strain gauge (lever arm 28 cm). The torque was amplified by a custom-built AC amplifier and displayed on-line to the subject (Langberg et al. 1999). The subjects were told to generate a plantar flexor torque corresponding to their respective body weights (1 body weight), simulating the workload of the triceps surae muscles during normal walking. Intermittent contractions were performed continuously for 1.5 s followed by a rest period of 1.5 s for a total of 40 min. The protocol ended with a final recovery period of 40 min of rest.

Statistics

Non-parametric ranking sum tests were used to detect significant differences in the BF between rest and exercise (Wilcoxon). The Kruskal-Wallis test was used to detect significant differences among the three groups during both rest and exercise. If the Kruskal-Wallis test indicated significant differences, these were determined using non-parametric ranking sum tests (Mann–Whitney). A probability of \( P < 0.05 \) (two tailed test) was considered significant.

Results

Peritendinous BF at rest was similar in the young [2.7 (SEM 0.5) ml·100 g tissue⁻¹·min⁻¹] and the middle-aged group [3.0 (SEM 0.4) ml·100 g tissue⁻¹·min⁻¹]. In contrast BF at rest in the older group [1.6 (SEM 0.2) ml·100 g tissue⁻¹·min⁻¹] was approximately 50% lower compared to the two other age groups (\( P < 0.05 \); Fig. 1). With intermittent static exercise BF increased significantly (\( P < 0.05 \)) in all three groups to 7.8 (SEM 1.0) ml·100 g tissue⁻¹·min⁻¹ (young group), to 7.3 (SEM 1.6) ml·100 g tissue⁻¹·min⁻¹ (middle-aged group), and 5.5 (SEM 1.1) ml·100 g tissue⁻¹·min⁻¹ (older group). During exercise no significant differences among the three groups were detected. In all three groups, BF returned within a few minutes to the level determined at rest prior to exercise.

Discussion

In the present study, BF flow in the peritendinous area around the Achilles tendon was studied in young, middle-aged and older subjects, and it was demonstrated that at rest BF was significantly lower in the older subjects compared to the other two groups (Fig. 1). In spite of this, peritendinous BF increased significantly in all three groups with intermittent static calf muscle exercise, and achieved values that did not reveal any significant

![Fig. 1 Mean blood flow values during rest and intermittent isometric exercise determined by xenon washout in three age groups. Error bars indicate SEM. *Significant increase in blood flow during exercise compared to rest. **Significant difference in blood flow in the old compared to the young and middle-aged groups (\( P < 0.05 \))](Image)