Blood flow in chronic Achilles tendinosis

Radioactive microsphere study in rabbits

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Cerium-labeled microspheres were used for blood-flow measurements in 7 New Zealand white rabbits with exercise-induced chronic Achilles paratenonitis and tendinosis. The blood flow increased 1.9 times more on the exercised side as compared with the contralateral, unexercised (control) side with respect to both the tendon and the paratenon. The blood flow of the tendon of the exercised leg showed a strong correlation with the blood flow in the paratenon of the ipsilateral side ($r = 0.81$). We concluded that the relative contribution of blood from the paratenon to the tendon remained unaltered in the exercised tendon and that degeneration of the tendon cannot be primarily explained by chronic circulatory impairment.

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We have studied the circulation of the Achilles tendon during development of chronic Achilles paratenonitis with tendinosis in the rabbit using the microsphere technique (Heyman et al. 1977, Morris and Kelly 1980, Jansson et al. 1981). Special attention was paid to the relative contribution of blood flow via the paratenon to the tendon.

Animals and methods

The experiment was carried out on 7 New Zeeland white rabbits that weighed 2.8 to 4.1 kg. Before and after exercise, the animals were kept in ordinary cages with free access to food and water.

To accomplish the chronic Achilles paratenonitis with tendinosis, the animals were exercised in a specially designed kicking machine (Backman et al. 1990). In this setup the animals were exercised with active and passive movements of the ankle at a frequency of 150 flexion and extension movements per minute. The exercise was carried on for 2 hours three times a week for 5.5 weeks. The right leg was exercised, and the left leg served as the control.

One day after the final exercise bout, the animals were anesthetized with fentanyl fluanisone (0.3 mL/kg) and diazepam (2 mg/kg). The right carotid artery was cannulated, and a PE90 catheter was introduced for the infusion of microspheres, as well as for the recording of the systemic mean arterial blood pressure. Following confirmation of a steady arterial blood pressure, approximately 5×10^6 cerium-141 labeled radioactive microspheres (Dupont, Dreieich, Germany) with a diameter of 16.5 ± 0.1 were infused for 30 s in the left ventricle of the heart. Through a catheter in the left brachial artery, blood was withdrawn from 15 s before until 15 s after the infusion of the spheres. A Harvard pump was used to withdraw the reference sample from the brachial artery (Jansson et al. 1981). During the infusion, the animal was under anesthesia and the legs were at rest.

After infusion, the animals were killed with an overdose of pentobarbital, and the Achilles tendons of both legs were exposed. The paratenon, here defined as the loose areolar tissue surrounding the tendon, was dissected separately, leaving the tendon with its epitenon intact. The tendon was cut just distal to the musculotendinous junction and proximal to its insertion in the calcaneus. Biopsies from the right and left kidneys were taken to determine if there was any difference in the blood distribution between the left and the right side.

The specimens were weighed and put into separate vials for counting in a scintillation counter (Packard Autogamma, Åbo, Finland). Reference blood samples and standards containing known numbers of spheres from the actual batches were counted at the same time as the samples.

Statistical methods

Counts per minute/sample weight (specific activity) values on the right and left sides were compared using the Wilcoxon nonparametric technique for each group. The correlation between samples was tested using simple regression analysis. $P < 0.05$ was considered significant.

Results

The arterial blood pressure was not affected by the

Table 1. Ratios of specific activity between the right and left sides in the tendon (A), paratenon (B), and whole tendon (C)

Animal	A	B	C
1	1.2	1.9	1.7
2	1.8	1.9	1.8
3[a]	13	18	21
4	5.3	1.2	1.8
5	1.9	1.2	1.5
6	6.0	2.1	3.9
7	1.1	1.3	1.5
Median	1.9[b]	1.9[b]	1.8[b]

[a]The high ratio between the right and the left tendon and the paratenon in animal number 3 is due to the relative proximity of the left control tendon and paratenon to background scintillation.
[b] $P < 0.05$

infusion of microspheres. The left and right kidneys had identical specific activities. The tendon and paratenon values were higher on the exercised side as compared with control values (Table 1).

The specific activity of the right tendon correlated well with ipsilateral paratenon values ($r = 0.81$, $P = 0.028$). A strong tendon-paratenon correlation was noted in the control legs ($r = 0.94$, $P = 0.002$).

Discussion

This study demonstrated an increased concentration of microspheres—reflecting differences in blood distribution—in the chronically inflamed Achilles tendon following repeated bouts of long-term dynamic exercise.

It is unknown whether an increased number of capillaries or dilatation of vessels is the most important factor related to blood flow changes (Lundberg et al. 1982). Using an identical experimental setup as in the present study, a recent morphologic study demonstrated both increased vascularity and dilatation in the paratenon (Backman et al. 1990). This suggests that the increase in exercise-induced paratenon blood flow is due to both of these factors. The strong correlation between tendon and paratenon blood distribution suggests that there is an increased blood flow through the communicating vessels in the mesotenon and paratenon. These communicating vessels have been described by Bergljung (1968); however, this study did not determine whether the increase in blood flow was uniformly distributed throughout the tendon.

We therefore conclude that shunting of blood to the tendon from the paratenon accompanies a state of chronic paratenonitis with tendinosis.

Increased blood flow in the tendon of the exercised leg suggests that the degenerative alterations, as shown previously (Backman et al. 1990), are not due to a chronic circulatory impairment. We cannot, however, exclude that there is a circulatory impairment during exercise or focal blood-flow changes causing the degenerative alterations in the tendon.

The exercised Achilles tendon of the rabbits showed chronic inflammatory alterations in the paratenon and degenerative changes of the tendon (Backman et al. 1990). These observations are in concert with previous studies of chronic Achilles paratenonitis (Kvist et al. 1987) and paratenonitis with tendinosis (Clancy et al. 1976, Puddu et al. 1976).

To eliminate the effect of muscle stimulation on the blood flow, we chose to investigate the blood flow of the tendons the day after the last exercise (Randall et al. 1952).

Acknowledgements

This work has been supported by grants from the research council of the Swedish Sports Federation. Professor Damber and Dr. Robert Pedowitz have made valuable suggestions and linguistic revision.

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