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# Achilles Tendon and Paratendon Microcirculation in Midportion and Insertional Tendinopathy in Athletes

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**Background:** Neovascularisation can be detected qualitatively by Power Doppler in Achilles tendinopathy. Quantitative data regarding tendon microcirculation have not been established and may be substantial.

**Purpose:** To assess the microcirculation of the Achilles tendon and the paratendon in healthy volunteers as well as in athletes with either midportion or insertional tendinopathy.

**Study Design:** Cohort study; Level of evidence, 2.

**Methods:** In 66 physically active volunteers, parameters of Achilles tendon and paratendon microcirculation, such as tissue oxygen saturation, relative postcapillary venous filling pressures, and microcirculatory blood flow, were determined at rest at 2-mm and 8-mm tissue depths. Forty-one patients never had Achilles pain (25 men, 27 ± 8 years), 14 patients had insertional pain (7 men, 29 ± 8 years), and 11 patients had midportion tendinopathy (7 men, 38 ± 13 years, not significant).

**Results:** Achilles tendon diameter 2 cm and 6 cm proximal to the insertion was increased in symptomatic tendons. Compared with the uninvolved opposite tendon, deep microcirculatory blood flow was significantly elevated at insertional (160 ± 79 vs 132 ± 42, $P < .05$) as well as in midportion tendinopathy (150 ± 74 vs 119 ± 34, $P < .05$). The microcirculation in the uninvolved opposite tendon and the normal athlete controls were not significantly different from each other (132 ± 42 insertional asymptomatic vs 119 ± 34 mid-portion vs 120 ± 48 healthy tendon). Insertional paratendon deep microcirculatory flow was elevated in all groups, whereas tissue oxygen saturation and relative postcapillary venous filling pressures were not significantly different.

**Conclusion:** Microcirculatory blood flow is significantly elevated at the point of pain in insertional and midportion tendinopathy. Postcapillary venous filling pressures are increased at both the midportion Achilles tendon and the midportion paratendon, whereas tissue oxygen saturation is not different among the studied groups. We found no evidence of an abnormal microcirculation of the asymptomatic limb in Achilles tendinopathy.

**Keywords:** Achilles tendon; tendinopathy; Doppler; pain; microcirculation

Achilles tendinopathy is a common condition of yet unknown origin and pathogenesis.[21] Treatment is currently very difficult and often anecdotal without large, evidence-based controlled intervention trials. When studying patients with Achilles tendinopathy, one has to differentiate among insertional pain, commonly found in both elite and recreational athletes, pain adjacent to the calcaneus, and midportion tendinopathy, found 2 to 6 cm proximal to the tuber calcanei.

Recently, clinical studies using modern ultrasound-based technology, such as Power Doppler sonography, have demonstrated increased blood flow and perfusion in patients with chronic Achilles tendinopathy, most likely as a reaction to hypoxic, degenerative lesions.[28] Furthermore, in an immunohistochemical cadaveric study[29] using laminin antibodies, a component of the basement membrane, a different vascular density throughout the Achilles tendon, with 57 vessels/cm$^2$ at the insertional site, 28 vessels/cm$^2$ at the midportion, and 73 vessels/cm$^2$ in the proximal part of the tendon, could be detected, indicating the importance of the vascular system in tendons. Thus, current available data give rise to a possible link between neovessels and

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TABLE 1
Patient Characteristics of 66 Patients, Group A Without Previous or Current Tendinopathy, Group B With a History of or a Current Insertional Tendinopathy, and Group C With a History of or a Current Midportion (2-6 cm) Tendinopathy[a]

| | Group A (n = 41) | Group B (n = 14) | Group C (n = 11) |
|---|---|---|---|
| Males, n | 25 | 7 | 7 |
| Females, n | 16 | 7 | 4 |
| Age | 27 ± 8 | 29 ± 8 | 38 ± 13 |
| Height | 177 ± 11 | 175 ± 5 | 177 ± 8 |
| Weight | 73 ± 14 | 68 ± 8 | 77 ± 12 |
| BMI | 23.17 ± 3 | 22.2 ± 1.6 | 24.0 ± 3.4 |
| Training | | | |
| Aerobic | 9 (21%) | 9 (64%) | 6 (55%) |
| Hours per week | 3 (0.5-13) | 6 (1-11.5) | 7 (1-20) |
| Ballgames | 11 (27%) | 4 (29%) | 4 (36%) |
| Hours per week | 5 (0.5-7) | 5 (1.5-14) | 5 (1-12) |
| Gymnastics | 6 (15%) | 2 (14%) | 1 (9%) |
| Hours per week | 6 (2.5-15) | 1.5 (1-2) | 4 |
| Cycling/inliner | 10 (24%) | 3 (21%) | 6 (55%) |
| Hours per week | 5 (1.5-14.5) | 11 (4-24) | 3 (1-9) |
| Fitness/Gymnasium | 16 (39%) | 3 (21%) | 4 (36%) |
| Hours per week | 5 (1.5-11) | 1.5 (0.5-2.5) | 2 (0.5-4) |
| Swimming | 5 (12%) | 1 (7%) | 1 (9%) |
| Hours per week | 2 (1-4) | 3 | 0.75 |
| Equestrian | 3 (7%) | 2 (14%) | 0 |
| Hours per week | 2 (1-2) | 3.5 (2-5) | 0 |

[a]Values for age, height, weight, and BMI (body mass index) are presented as mean ± SD; values for training are presented as no. (%) and no. (range).

TABLE 2
Patients' History

| | Group A (n = 41) | | Group B (n = 14) | | Group C (n =11) | |
|---|---|---|---|---|---|---|
| | n | % | n | % | n | % |
| Smoking | | | | | | |
| Never/stopped | 31 | 76 | 13 | 93 | 6 | 55 |
| Cigarettes <5/d | 5 | 12 | 1 | 7 | 2 | 18 |
| Cigarettes >5/d | 5 | 12 | 0 | 0 | 3 | 27 |
| Medication during past 6 mo | | | | | | |
| Antibiotics | | | | | | |
| Chinolones | 0 | 0 | 1 | 7 | 0 | 0 |
| Others | 6 | 15 | 1 | 7 | 0 | 0 |
| Anabolic steroids | 0 | 0 | 0 | 0 | 0 | 0 |
| Other corticoids | 0 | 0 | 0 | 0 | 0 | 0 |
| Corticoids per inhalation | 1 | 2 | 1 | 7 | 1 | 9 |
| Nonsteroidal antirheumatic drugs | 1 | 2 | 2 | 14 | 2 | 18 |
| Oral contraceptives | 12 | 29 | 4 | 29 | 1 | 9 |
| Diseases | | | | | | |
| Arterial hypertension | 0 | 0 | 0 | 0 | 2 | 18 |
| Coronary artery disease | 0 | 0 | 0 | 0 | 0 | 0 |
| Stroke | 0 | 0 | 0 | 0 | 1 | 9 |
| Peripheral occlusive disease | 0 | 0 | 0 | 0 | 0 | 0 |
| Diabetes mellitus | 0 | 0 | 0 | 0 | 1 | 9 |
| Renal insufficiency | 0 | 0 | 0 | 0 | 0 | 0 |

pain in Achilles tendinopathy. Nevertheless, up to now, no quantitative technique has been established to assess the amount of neovascularization in tendons in vivo.

We hypothesized that the parameters of Achilles tendon and paratendon microcirculation are different in healthy athletes versus in athletes with insertional or midportion tendinopathy. For quantitative determination of this issue, we used a novel combined laser Doppler flowmetry system, or oxygen-to-see (O2C) system (LEA Medizintechnik, Giessen, Germany), to evaluate noninvasively microcirculation at 2 distinct tissue depths.

## METHODS

One hundred thirty-two tendons of 66 patients who gave informed consent orally have been included in the study. Depending on the clinical status of the Achilles tendon, the tendons were assigned to 3 different groups: healthy Achilles tendons (group A), current insertional Achilles pain (group B), and current midportion Achilles tendon pain 2 to 6 cm proximal to the tuber calcanei (group C). None of the patients had received prior surgical therapy to the Achilles tendon or to the lower limbs. Patients' characteristics are listed in Table 1. Medical history and history of chinolone administration, corticoids, or anabolic steroids are documented in Table 2.

The same experienced examiner performed all examinations with the O2C system under equal conditions in ambient lighting after 30 minutes of equilibration on both tendons at 12 positions on each side. Four consecutive positions were placed longitudinally on the Achilles tendon, starting at the insertion site, leading proximally every 3 cm, with corresponding paratendon longitudinal positions at the medial and lateral sides at the same level.

### Determination of Vital Parameters of the Microcirculation

The determination of hemoglobin and the principle of blood flow measurement[3,23] are combined in the O2C system. The local oxygen supply parameters, blood flow, oxygen saturation of hemoglobin, and the amount of local hemoglobin relative postcapillary venous filling pressures were recorded by an optical fiber probe. The fiber probe incorporates both the laser Doppler method and the broadband light spectrometry technique.

### Laser Doppler Flowmetry

The tissue is illuminated with coherent laser light of 830 nm and 30 mW from a laser diode through a fiber optic light guide. Backscattered light is collected by the same probe, and frequency shifted light is extracted by heterodyne light beating technique. The power-spectral density of shifted light is a linear function of the mean velocity of moving cells within the tissue. As laser Doppler flowmetry detects all moved particles of certain velocity, it measures blood flow. We described the use of the O2C system in regard to the sternal microcirculation after harvesting of the pedicled left internal thoracic artery,[11] palmar microcirculation after radial artery harvesting,[12] and clinical myocardial preconditioning in cardiac off-pump bypass surgery.[16] Regarding the intraobserver reliability of the laser Doppler in the O2C system, a 5% intrasubject variability was determined,[8] indicating that a laser Doppler is a reliable method under sufficient standardized test conditions.

### Statistics

The data are presented as median and range for continuous variables or number and percentages for dichotomous variables. Univariate analysis of categorical data was performed using the $\chi^2$ or Fisher exact tests. To avoid a mixture of dependent and independent number samples in groups B and C, a *t* test was not used. A 1-way analysis of variance test was performed for all microcirculatory data for intergroup comparisons. Furthermore, a post hoc analysis according to least squares difference was applied for the intergroup comparison for A versus B, B versus C, and A versus C for both the symptomatic and the asymptomatic limbs in tendinopathy versus the control group. A *P* value less than .05 was considered to indicate statistical significance. The SPSS statistical software package 11.5 for Windows (SPSS Inc, Chicago, Ill) was used for statistical analysis.

## RESULTS

### Tendon Diameter

The opposite Achilles tendon diameter 2 cm proximal from the insertion was increased in symptomatic tendons in insertional tendinopathy (20 ± 3 mm vs 18 ± 3 mm, not significant [NS]) and 5 cm proximal to the tuber calcanei in tendons with midportion tendinopathy (18 ± 4 mm vs 15 ± 2 mm, $P < .05$).

### Achilles Tendon Microcirculation in Healthy Athletes

Deep tissue oxygen saturation at 8-mm tissue depths was significantly elevated versus superficial depths, as was relative postcapillary venous filling pressures, microcirculatory blood flow, and velocity. Neither superficial nor deep tissue oxygen saturation was different throughout the tendon (positions 1-4), nor was the corresponding medial or lateral paratendon. No side differences were evident in healthy athletes regarding microcirculatory flow parameters (Figure 1).

### Achilles Tendon Microcirculation in Insertional Achilles Tendinopathy

In 14 patients, insertional problems of the Achilles tendon were evident. Tissue oxygen saturation was not significantly different at superficial or at deep tissue determination at all 12 positions (Table 3). Postcapillary venous filling pressures were significantly increased at medial and lateral paratendon positions at 8-mm tissue depths. Microcirculatory blood flow was significantly increased at the insertional tendon site versus the asymptomatic limb at 2-mm and 8-mm tissue depths (49 ± 44 vs 31 ± 17 relative units at 2 mm; 160 ± 79 vs 132 ± 42 relative units at 8 mm; $P < .05$, respectively) (Table 3).

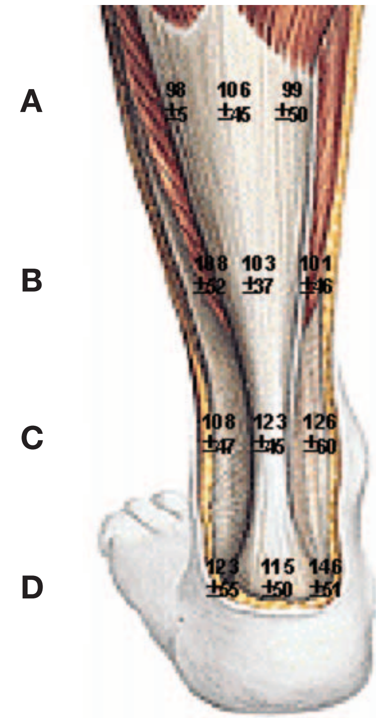


**Figure 1.** Distribution of deep microcirculatory blood flow on 4 positions on the Achilles tendon and 8 corresponding locations on the paratendon in 41 healthy athletes (mean ± SD). Paratendons and tendons represented in this figure, which are found in Tables 3 and 4, are as follows (from left to right): (A)12, 4, 8; (B)11, 3, 7; (C)10, 2, 6; and (D) 9, 1, 5.

### Achilles Tendon Microcirculation in Midportion Achilles Tendinopathy

In 11 patients, midportion problems at 2 to 6 cm proximal to the insertion of the Achilles tendon were evident. Tissue oxygen saturation was not significantly different at superficial or at deep tissue determination at all 12 positions (Table 4). Deep postcapillary venous filling pressures were significantly increased beginning 6 cm proximal to the insertion at the tendon and the paratendon positions. Microcirculatory blood flow was significantly increased within the midportion tendon sites 2 and 6 cm proximal to the insertion site at 8-mm tissue depths (150 ± 74 vs 119 ± 34 relative units at 2 cm proximal to the insertion; 142 ± 61 vs 101 ± 28 relative units at 6 cm proximal to the insertion; $P < .05$, respectively) (Table 4).

### Tendinopathy—A Simultaneous Disease of the Asymptomatic Contralateral Tendon?

We found no significant differences between the parameters of microcirculation in healthy athletes versus the asymptomatic side in either patients with insertional (group B) or midportion tendinopathy (group C).

TABLE 3
Parameters of Microcirculation Measured With the Oxygen-to-See (O2C) System at the Injured Versus Control Achilles Tendon and Paratendon at 12 Positions in Patients With Insertion Tendinopathy (Group B)[a]

| | Tissue Oxygen Saturation | | Postcapillary Venous Filling Pressures | | Flow | | Velocity | |
|---|---|---|---|---|---|---|---|---|
| | 2 mm | 8 mm | 2 mm | 8 mm | 2 mm | 8 mm | 2 mm | 8 mm |
| Tendon 1 | 47 ± 20 vs 38 ± 22 | 75 ± 6 vs 76 ± 6 | 41 ± 14 vs 47 ± 17 | 78 ± 23 vs 75 ± 20 | 49 ± 44 vs 31 ± 17[b] | 160 ± 79 vs 132 ± 42[b] | 16 ± 5 vs 13 ± 2 | 21 ± 7 vs 18 ± 5[b] |
| Tendon 2 | 39 ± 18 vs 31 ± 18 | 72 ± 8 vs 72 ± 7 | 46 ± 14 vs 46 ± 11 | 77 ± 27 vs 69 ± 15 | 34 ± 18 vs 31 ± 15 | 130 ± 54 vs 129 ± 40 | 14 ± 3 vs 13 ± 2 | 19 ± 5 vs 17 ± 3 |
| Tendon 3 | 42 ± 14 vs 42 ± 23 | 69 ± 9 vs 68 ± 7 | 56 ± 13 vs 54 ± 10 | 80 ± 31 vs 79 ± 30 | 30 ± 33 vs 29 ± 17 | 116 ± 55 vs 112 ± 54 | 13 ± 4 vs 14 ± 3 | 18 ± 5 vs 17 ± 4 |
| Tendon 4 | 38 ± 15 vs 35 ± 17 | 69 ± 6 vs 66 ± 12 | 56 ± 10 vs 57 ± 9 | 81 ± 32 vs 79 ± 44 | 25 ± 22 vs 20 ± 13 | 109 ± 53 vs 97 ± 56 | 14 ± 4 vs 13 ± 4 | 18 ± 5 vs 17 ± 5 |
| Paratendon 5 | 42 ± 19 vs 32 ± 23 | 72 ± 6 vs 70 ± 6 | 44 ± 11 vs 45 ± 16 | 110 ± 16 vs 102 ± 19 | 42 ± 36 vs 33 ± 25 | 178 ± 95 vs 171 ± 97 | 16 ± 5 vs 15 ± 5 | 25 ± 8 vs 23 ± 8 |
| Paratendon 6 | 33 ± 15 vs 34 ± 10 | 69 ± 6 vs 66 ± 6 | 55 ± 11 vs 62 ± 6 | 98 ± 15 vs 91 ± 19 | 28 ± 18 vs 24 ± 18 | 143 ± 66 vs 140 ± 54 | 15 ± 4 vs 13 ± 3 | 21 ± 5 vs 19 ± 5 |
| Paratendon 7 | 39 ± 18 vs 32 ± 18 | 69 ± 7 vs 66 ± 6 | 56 ± 9 vs 58 ± 7 | 71 ± 16 vs 86 ± 36[b] | 24 ± 17 vs 25 ± 15 | 111 ± 58 vs 137 ± 76 | 13 ± 3 vs 14 ± 3 | 18 ± 4 vs 20 ± 6 |
| Paratendon 8 | 41 ± 21 vs 30 ± 20 | 68 ± 8 vs 68 ± 8 | 52 ± 11 vs 57 ± 9 | 74 ± 19 vs 85 ± 35 | 38 ± 40 vs 25 ± 17 | 118 ± 54 vs 107 ± 45 | 16 ± 5 vs 13 ± 3 | 19 ± 4 vs 19 ± 5 |
| Paratendon 9 | 33 ± 21 vs 26 ± 17 | 71 ± 6 vs 67 ± 8 | 50 ± 18 vs 50 ± 16 | 107 ± 24 vs 96 ± 22 | 36 ± 18 vs 32 ± 17 | 166 ± 69 vs 147 ± 59[b] | 15 ± 3 vs 15 ± 3 | 23 ± 6 vs 21 ± 5[b] |
| Paratendon 10 | 35 ± 9 vs 40 ± 9 | 68 ± 5 vs 64 ± 12 | 56 ± 11 vs 61 ± 8 | 92 ± 16 vs 94 ± 16 | 27 ± 16 vs 31 ± 19 | 121 ± 36 vs 156 ± 50 | 14 ± 3 vs 14 ± 2 | 21 ± 4 vs 21 ± 4 |
| Paratendon 11 | 44 ± 15 vs 39 ± 9 | 65 ± 9 vs 64 ± 10 | 59 ± 9 vs 59 ± 9 | 77 ± 16 vs 105 ± 85[b] | 24 ± 19 vs 23 ± 13 | 105 ± 43 vs 131 ± 51 | 14 ± 3 vs 14 ± 2 | 20 ± 4 vs 20 ± 5 |
| Paratendon 12 | 39 ± 18 vs 41 ± 16 | 65 ± 10 vs 63 ± 14 | 58 ± 7 vs 57 ± 8 | 70 ± 14 vs 67 ± 12[b] | 26 ± 16 vs 26 ± 16 | 103 ± 47 vs 112 ± 53 | 16 ± 5 vs 13 ± 2 | 19 ± 4 vs 18 ± 4 |

[a]Values are presented as mean ± SD.
[b]Significantly different, $P < .05$.

TABLE 4
Parameters of Microcirculation Measured With the Oxygen-to-See (O2C) System at the Injured Versus Control Achilles Tendon and Paratendon at 12 Positions in Patients With Midportion Tendinopathy (Group C)[a]

| | Tissue Oxygen Saturation | | Postcapillary Venous Filling Pressures | | Flow | | Velocity | |
|---|---|---|---|---|---|---|---|---|
| | 2 mm | 8 mm | 2 mm | 8 mm | 2 mm | 8 mm | 2 mm | 8 mm |
| Tendon 1 | 38 ± 25 vs 44 ± 21 | 73 ± 6 vs 75 ± 7 | 44 ± 17 vs 47 ± 17 | 87 ± 26 vs 79 ± 30 | 23 ± 18 vs 24 ± 19 | 120 ± 60 vs 112 ± 53 | 12 ± 3 vs 12 ± 3 | 18 ± 6 vs 16 ± 3 |
| Tendon 2 | 41 ± 25 vs 34 ± 15 | 70 ± 4 vs 72 ± 5 | 47 ± 17 vs 44 ± 13 | 84 ± 31 vs 73 ± 27 | 31 ± 25 vs 31 ± 24 | 150 ± 74 vs 119 ± 34[b] | 13 ± 4 vs 12 ± 2 | 20 ± 6 vs 17 ± 2 |
| Tendon 3 | 54 ± 14 vs 44 ± 22 | 68 ± 5 vs 69 ± 6 | 60 ± 12 vs 58 ± 14 | 95 ± 44 vs 69 ± 16[b] | 42 ± 31 vs 28 ± 14 | 142 ± 61 vs 101 ± 28[b] | 16 ± 5 vs 12 ± 2 | 21 ± 6 vs 16 ± 2[b] |
| Tendon 4 | 43 ± 23 vs 40 ± 14 | 68 ± 5 vs 70 ± 7 | 59 ± 9 vs 58 ± 8 | 94 ± 40 vs 81 ± 23[b] | 28 ± 25 vs 24 ± 18 | 109 ± 46 vs 111 ± 54 | 14 ± 5 vs 14 ± 3 | 18 ± 4 vs 18 ± 5 |
| Paratendon 5 | 38 ± 15 vs 29 ± 23 | 70 ± 4 vs 73 ± 9 | 44 ± 16 vs 42 ± 18 | 108 ± 31 vs 105 ± 43 | 23 ± 11 vs 29 ± 14 | 142 ± 90 vs 131 ± 46 | 13 ± 4 vs 14 ± 4 | 22 ± 9 vs 20 ± 4 |
| Paratendon 6 | 40 ± 15 vs 39 ± 19 | 68 ± 4 vs 68 ± 5 | 59 ± 12 vs 64 ± 7 | 112 ± 22 vs100 ± 34[b] | 25 ± 24 vs 21 ± 8 | 139 ± 74 vs 116 ± 32 | 14 ± 4 vs 12 ± 1 | 22 ± 7 vs 18 ± 3 |
| Paratendon 7 | 37 ± 20 vs 42 ± 24 | 67 ± 4 vs 71 ± 6 | 58 ± 10 vs 57 ± 9 | 98 ± 27 vs 86 ± 27[b] | 21 ± 13 vs 24 ± 11 | 110 ± 32 vs 103 ± 22 | 13 ± 3 vs 14 ± 3 | 18 ± 3 vs 17 ± 2 |
| Paratendon 8 | 36 ± 17 vs 36 ± 18 | 68 ± 4 vs 72 ± 5 | 56 ± 12 vs 55 ± 9 | 92 ± 36 vs 78 ± 26[b] | 23 ± 16 vs 22 ± 13 | 112 ± 52 vs 118 ± 52 | 14 ± 5 vs 13 ± 3 | 19 ± 5 vs 19 ± 6 |
| Paratendon 9 | 33 ± 21 vs 35 ± 17 | 67 ± 4 vs 68 ± 5 | 51 ± 13 vs 46 ± 17 | 109 ± 34 vs 93 ± 28 | 21 ± 12 vs 27 ± 13 | 115 ± 44 vs 155 ± 93[b] | 13 ± 2 vs 15 ± 4 | 18 ± 4 vs 22 ± 11[b] |
| Paratendon 10 | 37 ± 22 vs 39 ± 19 | 67 ± 4 vs 66 ± 2 | 60 ± 13 vs 62 ± 12 | 101 ± 13 vs 95 ± 23[b] | 24 ± 18 vs 23 ± 21 | 124 ± 63 vs 111 ± 38 | 13 ± 4 vs 13 ± 2 | 20 ± 6 vs 20 ± 5 |
| Paratendon 11 | 44 ± 24 vs 36 ± 20 | 65 ± 4 vs 66 ± 5 | 62 ± 10 vs 65 ± 10 | 101 ± 28 vs 82 ± 27[b] | 28 ± 18 vs 18 ± 4 | 119 ± 64 vs 104 ± 52 | 14 ± 3 vs 15 ± 6 | 20 ± 6 vs 22 ± 9 |
| Paratendon 12 | 48 ± 21 vs 41 ± 19 | 66 ± 4 vs 66 ± 6 | 63 ± 11 vs 59 ± 8 | 88 ± 20 vs 79 ± 24 | 19 ± 11 vs 13 ± 8 | 100 ± 43 vs 82 ± 39[b] | 13 ± 2 vs 12 ± 2 | 20 ± 5 vs 19 ± 7 |

[a]Values are presented as mean ± SD.
[b]Significantly different, $P < .05$.

## DISCUSSION

The crucial findings of our work are that parameters of microcirculation of the Achilles tendon are significantly different among healthy athletes, athletes with midportion tendinopathy, and athletes with insertional tendinopathy at the point of pain. Microcirculatory flow was significantly elevated at the point of pain in patients with insertional and midportion tendinopathy, which for the first time could be detected by quantitative means. Postcapillary venous filling pressures were increased at both the midportion Achilles tendon and the midportion paratendon. No differences between healthy athletes and the asymptomatic limb in athletes with either insertional or midportion tendinopathy indicate that, in our cohort, no contralateral disease of the asymptomatic Achilles tendon was evident.

Achilles tendinopathy, as an acute or chronic manifestation of tendon pain, is common among elite athletes as well as among recreational athletes. Although nomenclature is not clear cut yet, *tendinopathy* or *tendinitis* are often used interchangeably. Insertional pain syndromes have to be differentiated from tendinopathy of the midportion (2-6 cm) of the Achilles tendon. Insertional pain is often caused by retrocalcaneal or subcutaneous bursitis or problems in the tendon insertion.[7] In insertional pain syndromes, no signs of inflammation are evident, but apparent tendinosis of the distal part of the Achilles tendon may be evident.[1] Furthermore, Haglund deformity may cause chronic Achilles tendon insertional pain as a tender swelling with a localized posterolateral prominence at the calcaneus, probably because of impingement.[26] In a recent biomechanical cadaveric study, a complex strain behavior of the Achilles tendon with a significant strain increase in the posterior aspect of the tendon after dorsiflexion has been shown.[17] Implications for physical exercise are still to be drawn after accumulating biomechanical data.

Although normal tendons are avascular with no detectable flow either on color flow or on Power Doppler examination, one may detect neovascularity in chronic but not acute tendinopathy.[8,9] Power Doppler examination detects blood flow from deep tissues without causing aliasing, which decreases the signal quality, independent of angle of incident beam and reduced background noise compared to color flow Doppler machines, thus improving the machines' sensitivity.[22] Power Doppler has been found to be 3 to 4 times more sensitive than color Doppler in tiny vessels, detecting flow tubes at a diameter of 0.3 mm.[27]

Especially in the midportion of the Achilles tendon, vessels are only rarely encountered histologically. This area is the typical rupture location, as has already been proposed more than 40 years ago,[14] and recently has been demonstrated quantitatively with laminin antibodies by Zantop et al.[29] Local hypoxia may weaken the tendon by myxoid degeneration, which may facilitate thickening of the tendon and possibly aggravate local hypoxia in a vicious circular fashion. Local hypoxia increases lactate levels, stimulating vessel proliferation.[15]

Increased Power Doppler blood flow and perfusion in symptomatic Achilles tendinopathy in proportion to the increased size of the tendon are correlated with an abnormal signal on MRI in a T2-weighted signal pattern.[10,20] Experimental data using a needle-based laser Doppler flowmetry system (Periflux PF2b, Perimed, Stockholm, Sweden) demonstrated increased microvascular flow in symptomatic chronic Achilles tendinopathy,[2] similar to our findings in either midportion or insertional tendinopathy using a laser Doppler. Laser Doppler flowmetry was found to be harmless and minimally invasive in the needle-based system. Near-infrared spectroscopy was introduced to measure tissue oxygen saturation noninvasively, becoming applicable in the determination of oxygenation of muscles, brain, and connective tissues.[4] We used a totally noninvasive O2C system, which combines noninvasive laser Doppler flowmetry with spectrophotometry, thus allowing determination of several parameters of microcirculation of the tendon and the paratendon at 2 distinct tissue depths.

Astrom and Westlin[2] found lower laser Doppler-determined blood flow at the calcaneal insertion of the Achilles tendon in healthy volunteers, with an equal distribution at the midportion and the musculotendinous location. Symptomatic patients in Astrom and Westlin's[2] study had a significantly higher blood flow in the middle and proximal parts of the Achilles tendon, which was shown in our patient cohort, depending on the type of tendinopathy, either insertional or midportion. Unfortunately, the authors failed to define symptomatic tendinopathy regarding the duration of symptoms and to differentiate between insertional and midportion tendinopathy, which, in our view, is far more important. Furthermore, data on the medial and lateral paratendons were lacking. Up to now, no quantitative technique has been established to assess the amount of neovascularization in tendons. Using the O2C system, we could assess quantitatively both the tendon and the paratendon in asymptomatic and symptomatic patients with tendinopathy of either origin, midportion or insertional, with increased microcirculatory blood flow at the site of pain, as well as increased capillary venous filling pressures.

### Sclerosing Therapy in Tendinopathy

Several preliminary studies have been performed to treat neovascularization with hyperemia and inflammation, alone or in combination, in chronic Achilles tendinopathy. In midportion chronic tendinosis, good clinical results have been achieved by sclerosing the area of neovascularization with a mean of 2 injections of polidocanol and 6 months of follow-up.[18] Recently, Konig et al[13] found that even intratendinous corticoid injection is associated with quick pain relief and neovascularization disappearance in a preliminary study in 5 patients. Nevertheless, an intratendinous corticoid injection is not applicable in every country because of a perceived risk of tendon rupture.

### Physical Therapy in Achilles Tendinopathy

Physical exercise has been applied in patients with chronic Achilles tendon problems in insertional as well as midportion tendinopathy.[25] Eccentric training has been found to be associated with reasonably good results in a preliminary study not differentiating between conditions.[24] A prospective controlled trial published on this issue demonstrated good clinical results after 12 weeks of eccentric calf-muscle training in patients with midportion tendinopathy (2-6 cm) but not in patients with chronic insertional problems of the Achilles tendon.[5] After a follow-up of 3.8 years and eccentric calf-muscle training in patients with midportion chronic tendinopathy (mean, 17 months), ultrasonography could demonstrate a localized decrease in tendon thickness and a normalized tendon structure in most of the participating patients.[19] The good clinical effects of painful eccentric calf-muscle training regarding midportion Achilles tendinopathy are thought to be mediated through action on the area with neovascularization.[19] It is speculated that during foot dorsiflexion, the flow in those neovessels is stopped, thus facilitating occlusion of those neovessels and resolution of the pain.

## Limitations

Technical deficits, which have been described in needle-based laser Doppler flowmetry systems, are randomly occurring motion artifacts, which we minimized as much as possible by the patients' stable position throughout the measurements, which were a mean of a 10-second period at each location. Nonetheless, micromovements may have affected the measurements to an uncertain degree. Regarding those patients with 1-sided tendinopathy, either insertional or midportion, we assumed the clinically asymptomatic tendon as the control and found no significant difference between the microcirculation of healthy athletes and the asymptomatic tendon in either the insertional or midportion tendinopathy group.

## CONCLUSION

We found parameters of microcirculation of the Achilles tendon significantly different among healthy athletes, athletes with midportion Achilles tendinopathy, and athletes with insertional Achilles tendinopathy. Microcirculatory flow is significantly elevated at the point of pain in both insertional and midportion tendinopathy. Postcapillary venous filling pressures were increased at both the midportion Achilles tendon and the midportion paratendon, whereas tissue oxygen saturation was not different among the studied groups. We found no evidence of an abnormal microcirculation of the asymptomatic limb in patients with Achilles tendinopathy at the insertional or the midportion level versus the healthy control tendons. Further studies focusing on the convincing effects of eccentric training in Achilles tendinopathy in a microcirculatory perspective are mandatory to further evaluate this novel, noninvasive laser Doppler system.

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