Physical Activity Increases Synovial Fluid in Ankle Tendon Sheaths: an Adjustment of MR Criteria is Needed

Michel De Maeseneer (michel.demaeseneer@uzbrussel.be)
UZ Brussel
Seema Doering
UZ Brussel
Veerle De Grove
Brugmann University Hospital
Nico Buls
UZ Brussel
Maryam Shahabpour
UZ Brussel
Maryam Shahabpour
UZ Brussel
Steven Provyn
VUB
Inneke Willekens
UZ Brussel

Research Article

Keywords: Synovial effusion, Tenosynovitis, Ankle MRI

Posted Date: June 27th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1773245/v1

Additional Declarations: No competing interests reported.

Version of Record: A version of this preprint was published at Surgical and Radiologic Anatomy on January 17th, 2023. See the published version at https://doi.org/10.1007/s00276-022-03068-6.

Abstract

Objectives: To compare the amount of fluid in synovial sheaths of the ankle before and after running. Our hypothesis was that this amount would increase, and that the threshold for what is normally acceptable should be adjusted after physical activity.

Methods: Twenty-one healthy volunteers (n=42 ankles) ran for 40 minutes on a treadmill. They underwent 3T MRI before and immediately after running using a dedicated ankle coil. The images were stored and subsequently measured in a standardized way and independently read by two readers for fluid in the tendon sheaths in the retro and inframalleolar area. Statistics were performed for each tendon (Wilcoxon signed rank test), and also for the pooled data. Intraclass correlation coefficients were calculated.

Results: For reader 1, for all tendons the values after running increased without reaching statistical significance. For reader 2 this was not the case for all tendons but for most. When all the data were pooled (n=800 measurements), the statistical difference before and after running was significant ($p< 0.001$).

Conclusion: Data pre and post running show a trend of increasing synovial fluid, however not significant for each individual tendon. The pooled data for all tendons, (n=800) show a statistically significant increase after running ($p< 0.001$). The clinical implication is that the threshold for normally acceptable fluid should be adjusted if the patient undergoes an MR study after recent physical activity.

Key Points

- Synovial effusions are normally present in some of the ankle tendons
- Before running fluid is particularily common in the medial tendon group
- Data pre and post running show a trend of increasing synovial fluid, statistically significant after pooling the obtained data ($p< 0.001$).

Introduction

Tendons typically contain a synovial sheath. This is not the case everywhere, however. Examples where such a sheath is absent include the flexor carpi ulnaris, patellar tendon, Achilles' tendon, and the dorsal tendons at the fingers and toes [1-7].

One question that arises is what are the limits of normal tendon sheath fluid in the ankle. Too much fluid may indicate mechanical overuse, infection, or a rheumatological condition. A few studies have addressed this topic of normal synovial fluid especially in the ankle [1-7].

In this article we focus on the ankle tendons. Previous reports have given indications of the amount of fluid that can be expected in a normal person without any known underlying condition. Fluid was quite common and rather important around the medial tendons. It was minimal and usually absent around the peroneal tendons. In the normal situation fluid was never observed in the anterior tendon group. Reference values are available in several publications [2, 3, 4, 5, 8, and 9].

Our research question was whether increased athletic would increase tendon sheath fluid. Our hypothesis was that it indeed would increase tendon sheath fluid, and hence that the normal values could change [10, 11, 12, 13, 14]. We would try to demonstrate this with MR imaging.

To study this type of research question is rather complicated and an experimental context was designed. We decided to perform MR of both ankles in 21 volunteers before and after running for 40 minutes on a treadmill.

Materials and methods

Our study was approved by the IRB of our hospital. Written informed consent was obtained from the volunteers. They also filled out a questionnaire to make sure they had no underlying rheumatologic condition, ankle pain or trauma, or previous severe injury or surgery to the ankle. Conditions that would make the experiment unsafe were also assessed. The investigators were available to answer any questions and monitor the experiment.

The volunteers were also weighed and their length was obtained, allowing subsequent calculation of BMIs. MRI in the three orthogonal planes was obtained with a PD FS sequence on a Philips 3T Achieve system (Philips, Best, The Netherlands). Imaging parameters were as follows: TR 2969 ms; TE 30 ms; NA 2; slice thickness 2.5 mm. A dedicated ankle coil was used allowing maximum reproducibility of patient positioning before and after running.

After pre-exercise imaging the patient started running on a treadmill at intensity setting nr 3 (Domyus T520, Decathlon, Villeneuve-d'Ascq, France). The investigators continuously monitored the volunteers for injury, pain, or feeling unwell. After running, the same imaging sequences where repeated immediately with exactly the same imaging parameters. All images were stored on PACS (Agfa, Mortsel, Belgium). None of the investigators made any immediate assessments or interpretations of the obtained images. Positioning consistency and image quality were ascertained by a certified RT (three different RTs performed the studies; 15, 20, 25 years of work experience).

For the interpretation session the transverse images were used, however the other planes were used to ascertain that the measurements were performed in the most similar position possible for the pre and post images. The measurements that were obtained included TP, FD, FH, PL, and PB. For each tendon a retro- as well as inframalleolar measurement was obtained. The exact measurement positions are further detailed in Table 1. The largest dimension of fluid was used, in exactly the same position pre and post running. The images were interpreted by two MSK radiologists (8 and 20 years of experience) independently [Fig. 1-7].

The pre and post image set was analyzed simultaneously to make sure each measurement was performed in exactly the same location for both image sets. The readers were blinded to which image was pre and which was post. The images were thus presented to the viewers in a randomized fashion.

Results

All participants performed the experiment successfully without pain, injury, or becoming unwell.

Planning of imaging was organized as such that each participant immediately underwent MR when his running session ended.

There were 12 men (57 %) and 9 women (43%). The mean age was 24.7 years.

All the measurements obtained for all tendons pre and post are shown in table 2 and 3. The data were compared by a Wilcoxon signed rank test. This Table also shows the 95 % confidence intervals, the delta (and confidence interval), and the p-value for this specific tendon. Statistical significance was calculated for each tendon separately. Since the number of cases per tendon remained small, we also calculated statistical significance for all measurements pooled. This calculation thus related to 800 cases. The first table relates to reader 1, and the second table to reader 2 [Fig 1-7]. Intraclass correlation coefficients were calculated between both readers. BMI was calculated for each volunteer.

All the measurements pre and post were largest for both readers for the TP and FH, followed by the FD, and peroneal tendons but in their inframalleolar location.

For all tendons pooled the delta was small and ranged from 0.00 to 0.14 mm. None of the observed differences for both readers per tendon was statistically significant. For reader 1 all measurements post running showed a trend to be higher than pre-running. For reader 2 most values after running showed a trend to be higher, but not all. There was a trend for the post measurement to be larger, although not reaching statistical significance per tendon.

When the calculation was performed on the pooled data (n=800 cases) the result was significant, however ($p< 0.001$), with the measurement post running being higher.

The mean BMI of the volunteers was 23,2 (N). The BMI range was 19-32. Three individuals were in the obese range, and 3 in the overweight range, all the others having a BMI in the normal range.

Discussion

Several synovial sheaths, in the normal situation contain some synovial fluid. Generally, a sheath is present where the tendon(s) make a turn or are subject to increased mechanical forces. The presence of tendon sheath fluid therefore in itself is not necessarily abnormal.

The normal amount of fluid in tendon sheaths has been the subject of several investigations, some using MR, some US. In our opinion, the ones using US may have been flawed as it may be quite difficult to differentiate normal hypoechoic tendon retinacula from hypoechoic tendon fluid. This is less of a problem with MRI, where fluid is hyperintense and retinacula and sheaths exhibit hypointense signal on all pulse sequences.

Increased fluid may be the cause of mechanical issues, tendon damage, infection, and rheumatological disorders.

Our measurements pre-running is in accordance with those of previous investigations [1-6], pointing to the fact that fluid is particularly common in the medial tendons in the normal situation, and to a lesser degree in the peroneal tendons. In the anterior tendon group fluid is never present in the normal situation.

Our present investigation has a physiological implication, but more so a clinically relevant implication. If physical activity increases joint fluid our threshold for considering fluid as pathological should be adjusted following such activity.

Although it may be argued that for each tendon individually our pre and post imaging values were not statistically significant, significance was obtained when the data were pooled (to 800 cases). Our number of cases per tendon is not sufficient to show a significant difference per tendon. However, devising an experiment such as this is quite time consuming, and it would not be realistic to image e.g., 150 volunteers in this way. Probably an even better experiment would be to image this number of marathon runners before and after their contest, but this also is not realistic.

Our study has several limitations. Our number of volunteers was limited. Nevertheless, there was a consistent trend for the measurements to increase after running and when the data were pooled, they became statistically significant. Second, our set up was experimental using a treadmill. Running outside on uneven terrain or for longer distances would likely be more significant.

MR positioning before and after running may have changed slightly, although every effort was made to avoid this by meticulous positioning by highly experienced RTs.

The distribution of fluid in the sheath is a three-dimensional phenomenon and ideally the total volume in the entire sheath could have been measured. This would imply heavy computing and segmentation of images which was beyond our capabilities. It can be criticized that we obtained only one measurement in the transverse plane. However, we defined the measurement site precisely and also evaluated the paired images to measure exactly at the same location. Our study population was also rather heterogeneous, some individuals having a BMI out of the normal range. We believe, however, this in itself would not affect our measurements and is rather representative of a general population. We also omitted the anterior tendon group since it has been repeatedly shown that fluid never occurs in the normal situation. Finally, the observed differences were often small, and it could be argued that measurement bias played a role. Nevertheless, as mentioned before there was a quite consistent trend for an increase post running.

In conclusion, there was a statistically significant difference in synovial sheath fluid before and after running, when all obtained data were pooled (n=800).

Therefore, we suggest that if a patient is imaged after physical activity (such as running, jogging, fitness), the threshold of what can be accepted as a normal amount of synovial fluid should be adjusted.

Abbreviations

PL **peroneus longus**

PB **peroneus brevis**

TP **tibialis posterior**

FDL **flexor digitorum longus**

FHL **flexor halluces longus**

TA **tibialis anterior**

EDL **extensor digitorum longus**

EH **extensor halluces**

Pre **prior to running**

Post **following the running exercise**

Declarations

Ethics approval and consent to participate: ethical board approval and written consent was obtained

Consent for publication: approved by test subjects and authors

Availability of data and materials: provided in the tables of the manuscript

Competing interests: no competing interest to disclose

Funding: no funding

Authors' contributions

MD: study design, manuscript writing

SD: data collection

VDG: data collection

NB: statistical analysis

JDM: study design, manuscript review

MS: manuscript writing and review

SP: study design, data collection

IW: study design, experiment, data analysis

Acknowledgements: NA

References

1. Cheung Y, Rosenberg ZS, Magee T, Chinitz L. Normal anatomy and pathologic conditions of ankle tendons: current imaging techniques. Radiographics. 1992 May;12(3):429-44. doi: 10.1148/radiographics.12.3.1609136. PMID: 1609136
2. Teitz CC, Garrett WE Jr, Miniaci A, Lee MH, Mann RA. Tendon problems in athletic individuals. Instr Course Lect. 1997;46:569-82. PMID: 9144000.
3. Trevino S, Baumhauer JF. Tendon injuries of the foot and ankle. Clin Sports Med. 1992 Oct;11(4):727-39. PMID: 1358465.
4. Willekens I, Shahabpour M, Lenchik L, Buls N, De Mey J, Provyn S, De Maeseneer M. Fluid distribution in ankle tendon sheaths in healthy volunteers: MRI findings. Surg Radios Anat. 2019 Dec;41(12):1445-1449. doi: 10.1007/s00276-019-02355-z. Epub 2019 Oct 19. PMID: 31630237.
5. Nazarian LN, Rawool NM, Martin CE, Schweitzer ME. Synovial fluid in the hindfoot and ankle: detection of amount and distribution with US. Radiology. 1995 Oct;197(1):275-8. doi: 10.1148/radiology.197.1.7568837. PMID: 7568837.
6. Schmidt WA, Schmidt H, Schicke B, Gromnica-Ihle E. Standard reference values for musculoskeletal ultrasonography. Ann Rheum Dis. 2004 Aug;63(8):988-94. doi: 10.1136/ard.2003.015081. PMID: 15249327; PMCID: PMC1755091.
7. Schweitzer ME, van Leersum M, Ehrlich SS, Wapner K. Fluid in normal and abnormal ankle joints: amount and distribution as seen on MR images. AJR Am J Roentgenol. 1994 Jan;162(1):111-4. doi: 10.2214/ajr.162.1.8273647. PMID: 8273647.
8. Wang YX, Westwood FR. Fluid collection within the synovial sheath of the tendon of the flexor hallus longus muscle in the tarsal joint of rats: an anatomic variant detectable with magnetic resonance imaging. Lab Anim. 2006 Jan;40(1):58-62. doi: 10.1258/002367706775404381. PMID: 16460589.
9. Burke CJ, Alizai H, Beltran LS, Regatte RR. MRI of synovitis and joint fluid. J Magn Reson Imaging. 2019 Jun;49(6):1512-1527. doi: 10.1002/jmri.26618. Epub 2019 Jan 8. PMID: 30618151; PMCID: PMC6504589.

10. Akhbari P, Jaggard MK, Boulangé CL, Vaghela U, Graça G, Bhattacharya R, Lindon JC, Williams HRT, Gupte CM. Differences in the composition of hip and knee synovial fluid in osteoarthritis: a nuclear magnetic resonance (NMR) spectroscopy study of metabolic profiles. Osteoarthritis Cartilage. 2019 Dec;27(12):1768-1777. doi: 10.1016/j.joca.2019.07.017. Epub 2019 Sep 3. PMID: 31491490.
11. Pratt DJ. Mechanisms of shock attenuation via the lower extremity during running. Clin Biomech (Bristol, Avon). 1989 Feb;4(1):51-7. doi: 10.1016/0268-0033(89)90068-5. PMID: 23915960.
12. Otterness IG, Eskra JD, Bliven ML, Shay AK, Pelletier JP, Milici AJ. Exercise protects against articular cartilage degeneration in the hamster. Arthritis Rheum. 1998 Nov;41(11):2068-76. doi: 10.1002/1529-0131(199811)41:11<2068::AID-ART23>3.0.CO;2-L. PMID: 9811063.
13. Hoessly ML, Wildi LM. Magnetic Resonance Imaging Findings in the Knee Before and After Long-Distance Running-Documentation of Irreversible Structural Damage? A Systematic Review. Am J Sports Med. 2017 Apr;45(5):1206-1217. doi: 10.1177/0363546516656180. Epub 2016 Aug 20. PMID: 27519676.
14. Kingston AR, Toms AP, Ghosh-Ray S, Johnston-Downing S. Does running cause metatarsophalangeal joint effusions? A comparison of synovial fluid volumes on MRI in athletes before and after running. Skeletal Radiol. 2009 May;38(5):499-504. doi: 10.1007/s00256-008-0641-2. Epub 2009 Jan 30. PMID: 19183986.

Tables

Table 1. Measurement site of the different tendon parts

TP retro	5 mm above tip of medial malleolus	COR, SAG
TP infra	1 cm below tip of medial malleolus	COR, SAG
FD retro	same	same
FD infra	same	same
FH retro	same	same
FH infra	same	same
PL retro	3 mm above tip lateral malleolus	COR, SAG
PL infra	5 mm below tip of lateral malleolus	COR, SAG
PB retro	same	same
PB retro	same	same

Second column, measurement region, third column reference planes for determining measurement region

Table 2. Observations of reader 1 before and after running with 95 % confidence interval, delta (with 95 % confidence interval) and p-value.

TP retro	1.28 (1.07-1.49)	1.43 (1.20-1.66)	0.14 (-0.02-0.32)	0.098
TP infra	1.57 (1.30-1.85)	1.62 (1.33-1.91)	0.04 (-0.18-0.27)	0.56
FD retro	0.57 (0.26-0.87)	0.69 (0.39-1.00)	0.12 (-0.17-0.42)	0.38
FD infra	0.56 (0.33-0.79)	0.65 (0.42-0.88)	0.08(-0.13-0.30)	0.42
FH retro	1.53(0.98-2.09)	1.84(1.22-2.46)	0.30(-0.03-0.65)	0.07
FH infra	1.03(0.75-1.32)	1.11(0.78-1.45)	0.079(-0.13-0.29)	0.26
PL retro	0.07(-0.01-0.17)	0.16(0.03-0.29)	0.08(-0.00-0.17)	0.04
PL infra	0.41(0.20-0.63)	0.47(0.23-0.72)	0.06(-0.07-0.20)	0.37
PB retro	0.06(-0.00-0.13)	0.16(0.04-0.29)	0.10(-0.01-0.21)	0.09
PB infra	0.36(0.16-0.56)	0.48(0.23-0.72)	0.12(-0.05-0.29)	0.17

Table 3. Observations of reader 1 before and after running with 95 % confidence interval, delta (with 95 % confidence interval) and p-value.

TP retro	1.34(1.09-1.58)	1.39(1.15-1.62)	0.05(-0.15-0.26)	0.46
TP infra	1.31(0.98-1.63)	1.45(1.14-1.76)	0.14(-0.12-0.40)	0.34
FD retro	0.63(0.32-0.95)	0.77(0.43-1.11)	0.13(-0.06-0.33)	0.20
FD infra	0.43(0.20-0.65)	0.67(0.31-1.03)	0.24(-0.01-0.49)	0.06
FH retro	1.29(0.84-1.74)	1.31(0.87-1.75)	0.02(-0.24-0.28)	0.98
FH infra	0.56(0.20-0.92)	0.68(0.32-1.05)	0.11(-0.14-0.25)	0.08
PL retro	0.12(0.01-0.24)	0.08(-0.01-0.18)	-0.004(-0.11-0.03)	0.29
PL infra	0.14(-0.00-0.29)	0.14(-0.02-0.31)	0.00(-0.06-0.07)	0.94
PB retro	0.08(-0.01-0.18)	0.02(-0.02-0.08)	-0.05(-0.14-0.02)	0.17
PB infra	0.16(0.00-0.32)	0.09(-0.03-0.22)	-0.07(-0.18-0.04)	0.20

Figures

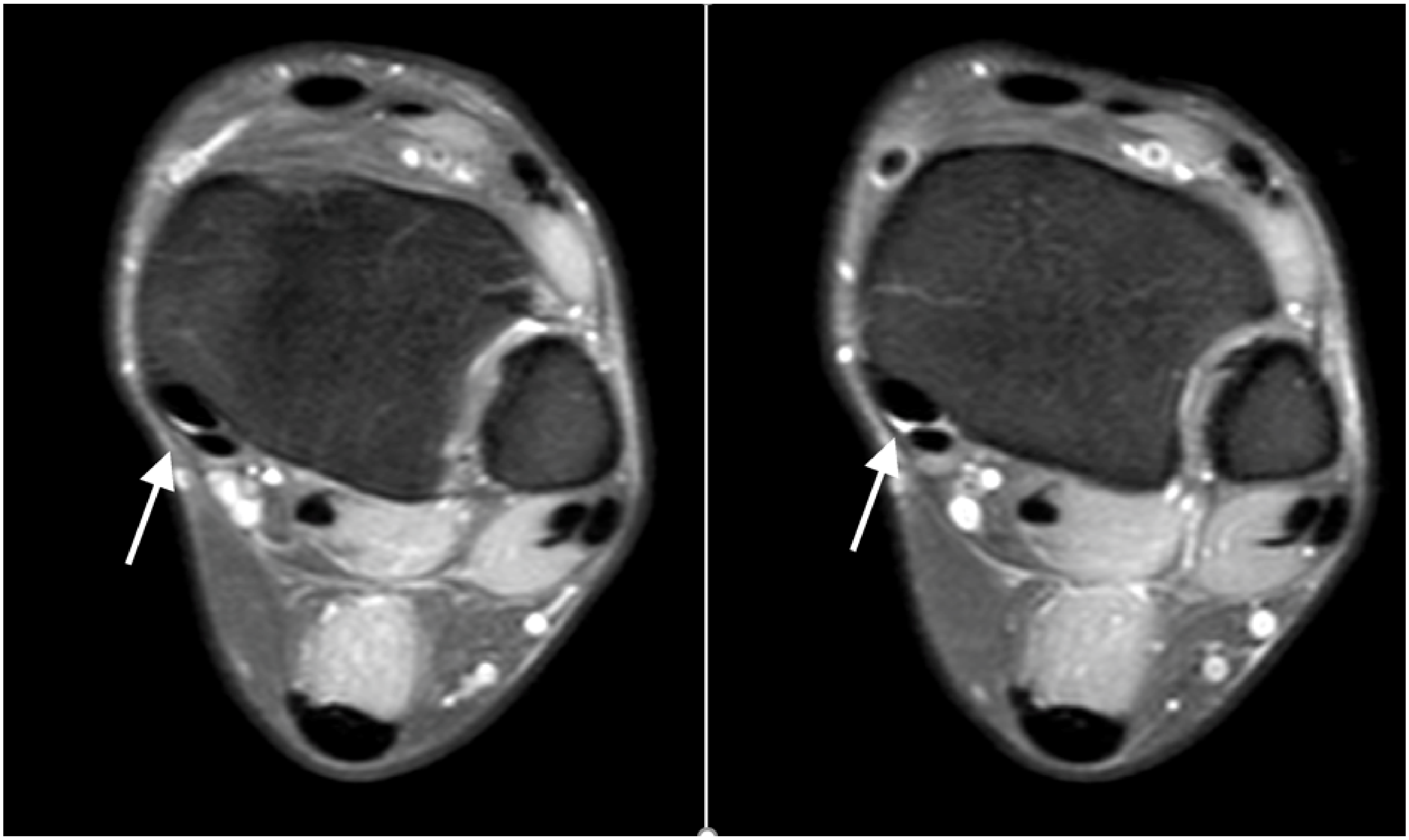

Figure 1

Tibialis posterior tendon retromalleolar. Left, before; right, after. Note slight increase in synovial fluid around tibialis posterior (arrows).

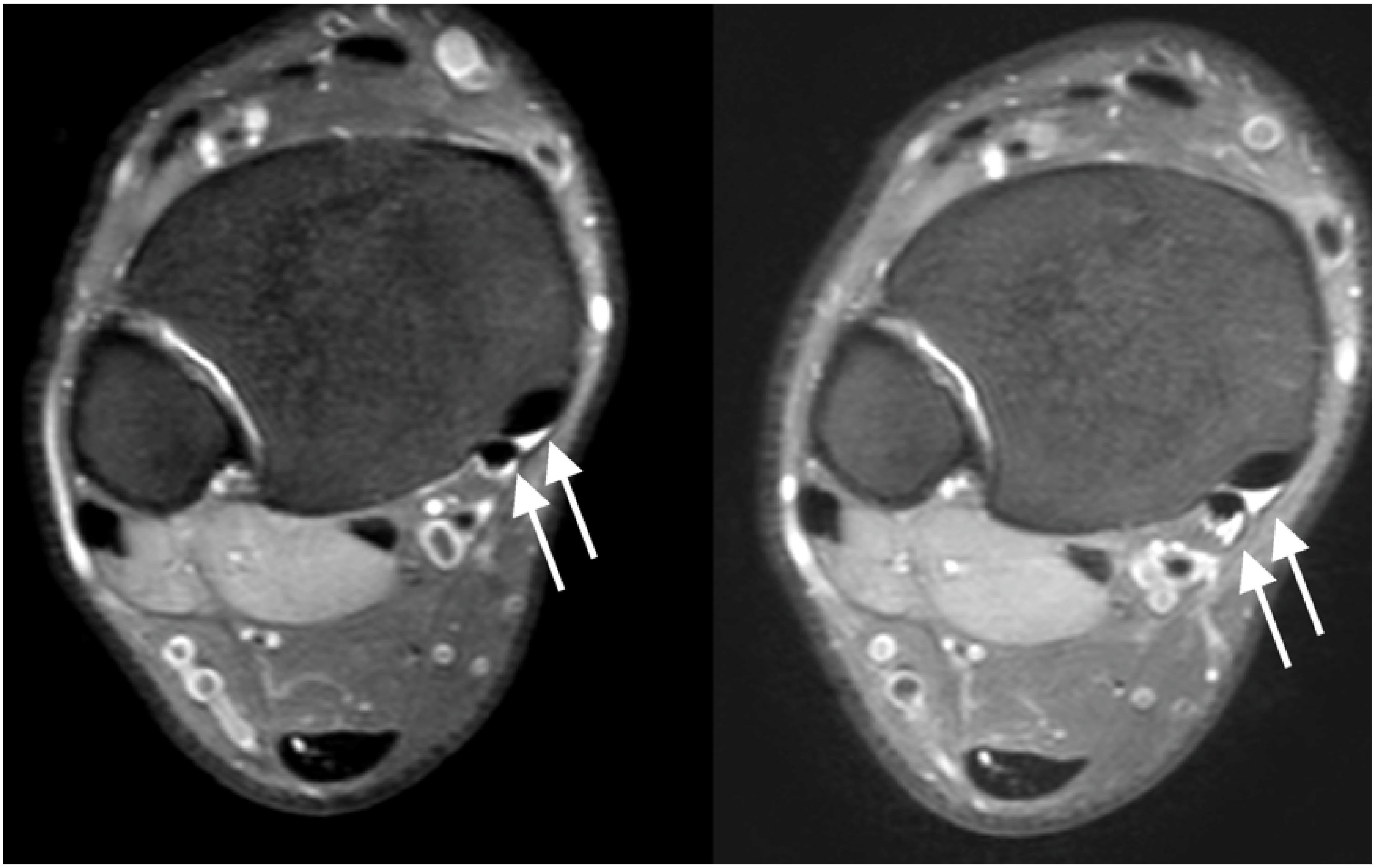

Figure 2

Tibialis posterior and flexor digitorum. Note quite obvious increase in fluid after running (arrows).

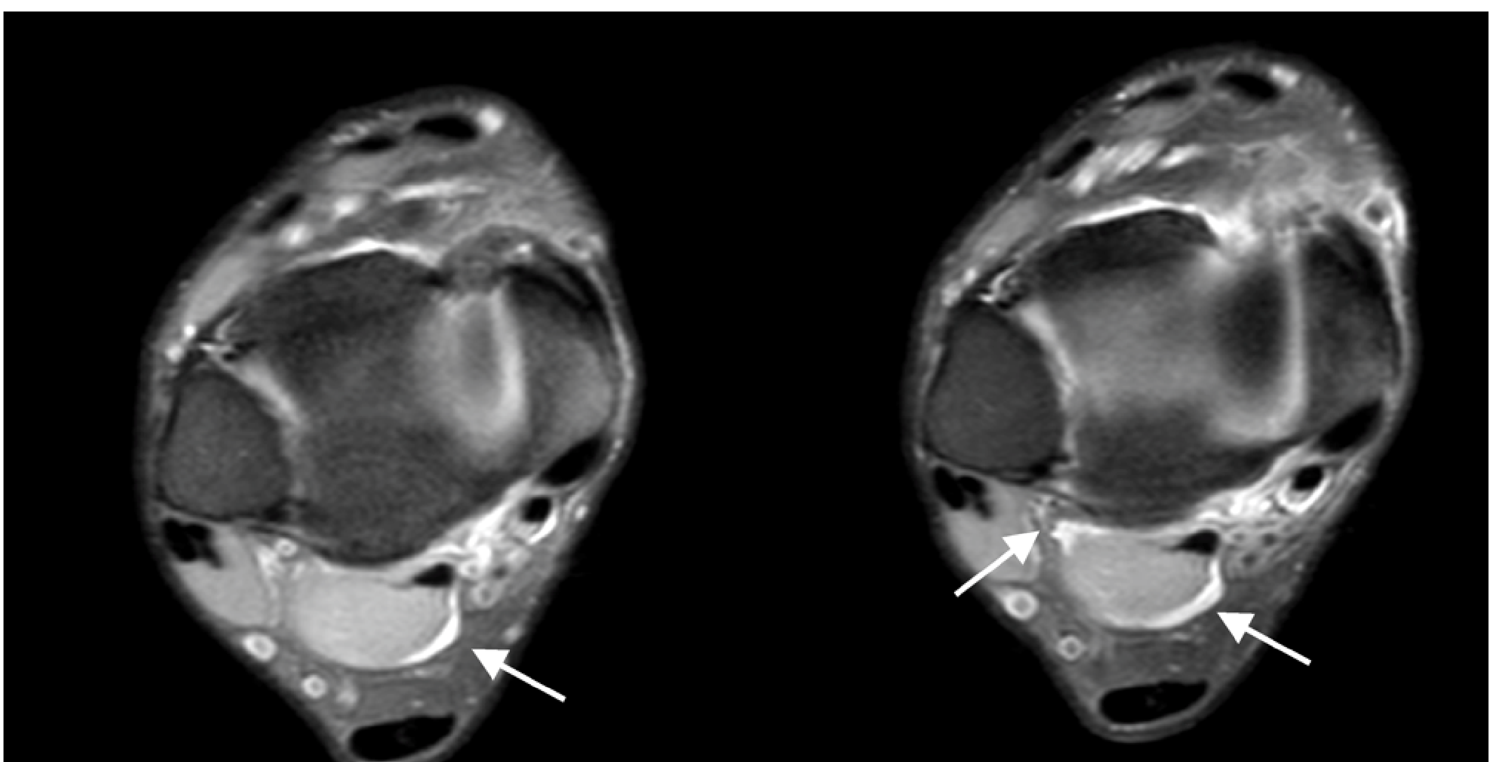

Figure 3

Flexor hallucis tendon. Note obvious increase of fluid after running along medial and lateral margin (arrows).

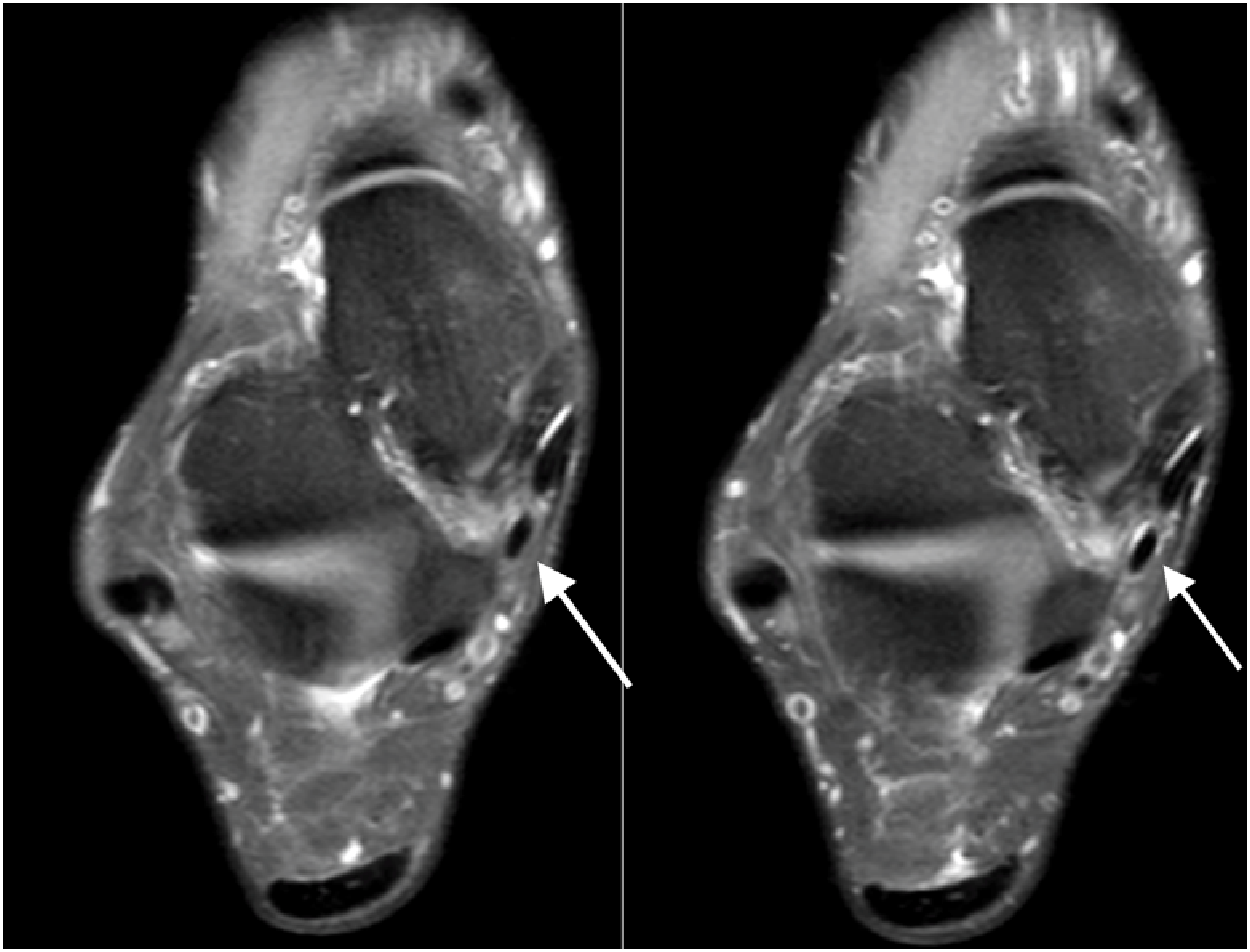

Figure 4

Flexor digitorum. Images in inframalleolar area. Note subtle increase after running in synovial fluid (arrows).

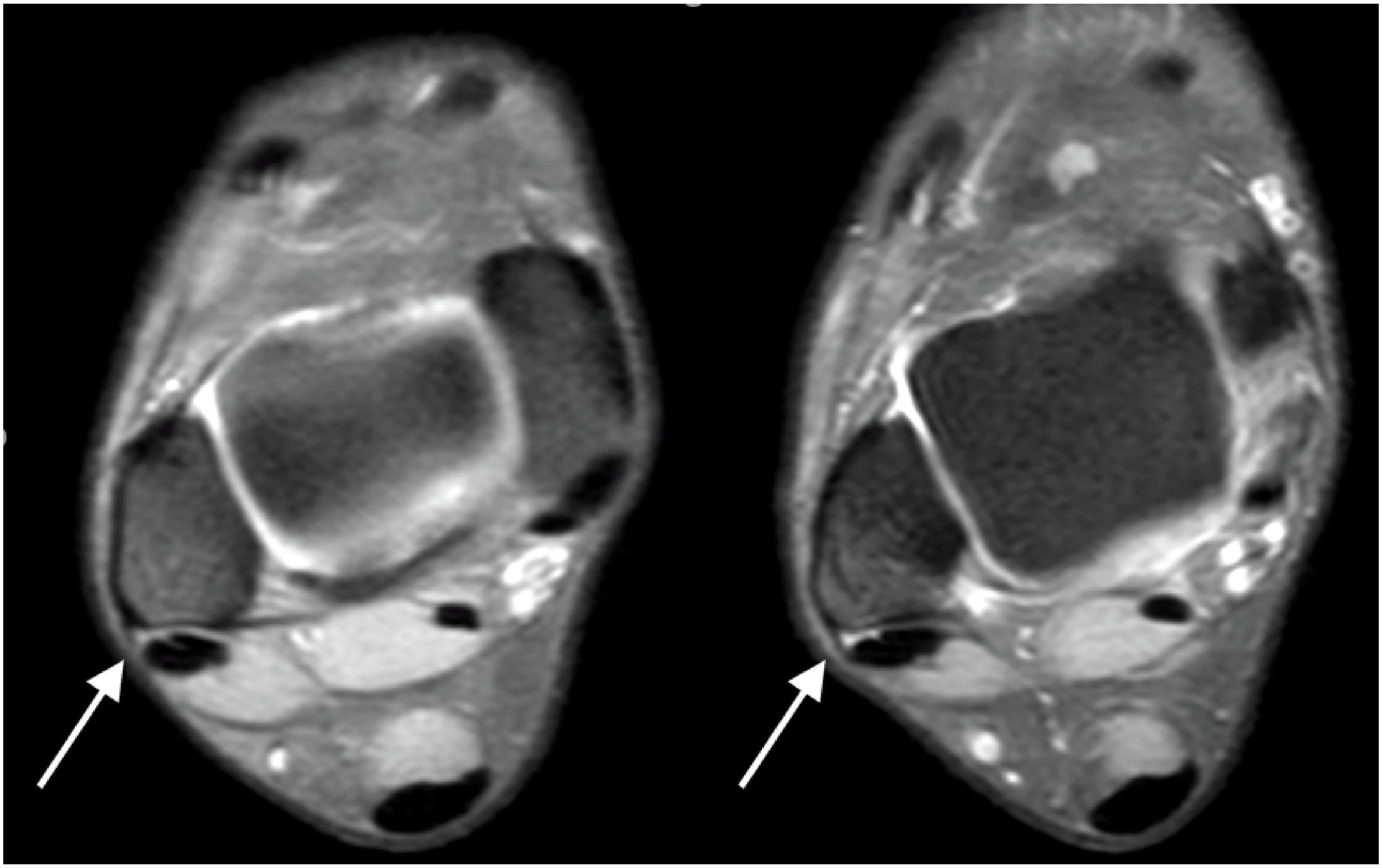

Figure 5

Peroneal tendons. Note slight increase in fluid in common sheath after running (arrows).

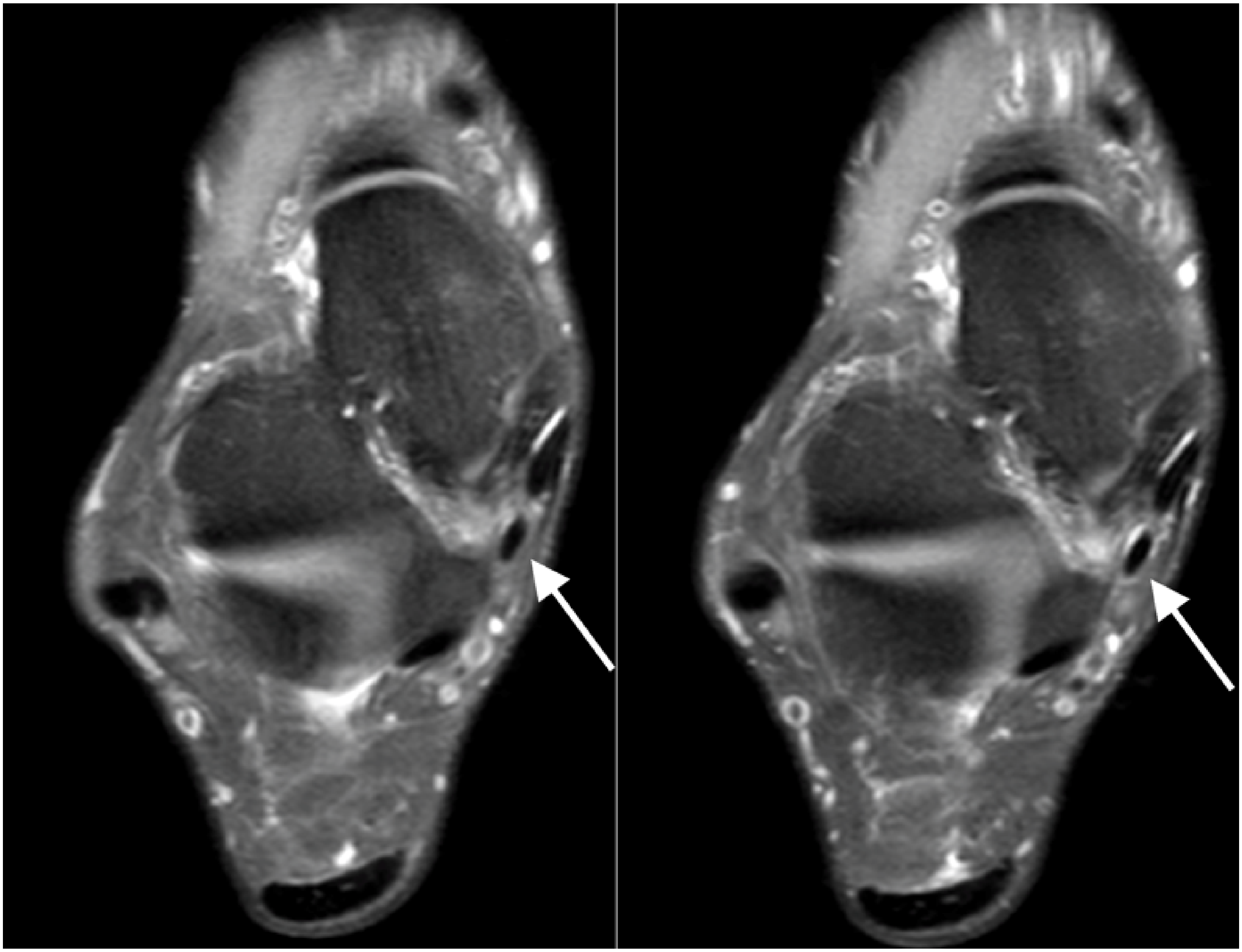

Figure 6

Flexor digitorum inframaleolar. Note slight synovial fluid increase. (arrows)