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Jeffrey Williams
Butler University, jwilliams4@butler.edu

Megan Battles
University of Mississippi

Rachel Bowden
Wake Forest University

Cameron Greene
University of Wisconsin Green Bay

Arbin Thapaliya
Franklin College

See next page for additional authors

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Authors

Jeffrey Williams, Megan Battles, Rachel Bowden, Cameron Greene, Arbin Thapaliya, and Justin Stanek

Relationship Between Posterior Tibial Artery Blood Flow and Lower Leg Flexibility Among Collegiate Runners

Jeffrey Williams PhD, LAT, ATC[*]; Megan Battles MS, LAT, ATC[#]; Rachel Bowden MS, LAT, ATC[†]; Cameron Greene MS, LAT, ATC[§]; Arbin Thapaliya PhD[‡]; Justin Stanek EdD, LAT, ATC[||]
Butler University[*]; University of Mississippi[#]; Wake Forest University[†]; University of Wisconsin Green Bay[§]; Franklin College [‡]; Illinois State University[||]

Purpose: Understanding relationships between blood flow and muscle inflexibility in the lower leg can support improved healthcare competency. Sports medicine practitioners might use the reference ranges and knowledge of relationships among these variables to support effective health screenings among their competitive runners. These variables have been linked in other areas of the body where inflexibility in the pectoralis minor and scalene muscles have been associated with diminished blood flow to the upper limb. No studies, however, have examined the relationship between vascular and mobility characteristics in the lower legs of runners. Therefore, the purpose of this study was to examine the relationship between blood flow in the posterior tibial artery and ankle range of motion (ROM) among competitive runners. **Methods:** Blood flow in the posterior tibial artery and ankle ROM were measured bilaterally on twenty-five, asymptomatic collegiate track athletes (15 males, 10 females, age = 20.0±1.2 years, height = 171.5±10.2 cm, mass = 66.7±13.7 kg) using diagnostic ultrasound and standard goniometry, respectively. Pearson correlation analysis was used to analyze the relationship between blood flow in the posterior tibial artery and ROM of the ankle joint. **Results:** Findings revealed no significant relationship between blood flow in the dominant leg's posterior tibial artery and dorsiflexion (r=.14, P=.52, $CI_{95\%}$ = -0.27 – 0.51) or plantar flexion (r=-.32, P=.12, $CI_{95\%}$ = -0.63 – 0.09) and no significant relationship between blood flow in the non-dominant leg's posterior tibial artery and dorsiflexion (r=-.02, P=.93; $CI_{95\%}$ = -0.41 – 0.38) or plantar flexion (r=-.02, P=.92; $CI_{95\%}$ = -0.41 – 0.38). **Conclusion:** While muscle inflexibility is associated with compromised blood flow in other body regions, findings of this study demonstrated no relationship between the variables within the lower legs of a sample of competitive runners. Sports medicine practitioners should consider these findings in their efforts to predict, prevent, and manage potential vascular and musculoskeletal adaptations among clients/patients who are competitive runners. ***Key Words:*** *posterior tibial artery, range of motion, vascularity, running*

INTRODUCTION

Being a competitive runner requires one to be fast and as such, runners train and develop their skills to improve performance. Running speed can be increased in various ways but runners tend to use their lower limbs to push on the ground with increasingly greater force as the principle means of increasing speed.[1] The increased ground contact force facilitates greater running speed by causing larger stride lengths and more time in the air during the gait cycle.[1,2]

The kinetics of this speed-enhancing strategy rely on forceful contractions of numerous lower extremity muscles including the ankle plantar flexors represented by the gastrocnemius and soleus muscles.[2,3] These muscles are responsible for the majority of vertical and propulsive forces that increase the runner's speed across the surface.[2] This performance-enhancing strategy is advantageous and used by runners who train and compete at various speeds ranging from jogging to medium-paced running.[1]

Producing more force to improve speed might be beneficial for performance, but the strategy does not come without consequences. Running has historically been associated with hypertrophy and inflexibility of the plantar flexors.[4] For example, runners tend to experience tightness in their soleus muscles compared to non-runners.[4] Passive muscle stiffness of the plantar flexors has also demonstrated being increased and correlated to changes in ROM among runners compared to non-runners.[5, 6]

Previous research has been aimed at investigating the unique characteristics and adaptations in the lower extremities of runners. Variables such as injury history,[7] Q-angle, lower limb alignment, and subtalar angle have been studied.[8] However, no studies have investigated the relationship between peripheral vascular characteristics and range of motion in competitive runners' lower legs.

Vascular and muscular adaptations have been linked in other areas of the body where hypertrophy and/or passive tightness in the pectoralis minor and scalene muscles have been associated with diminished blood flow to the upper limb—a condition known as thoracic outlet syndrome.[9,10] Among baseball pitchers, specifically, adaptations in blood flow have been shown to be diminished and thought to be caused by adaptations in surrounding soft-tissues resulting from the repetitive and forceful shoulder motions of the sport.[11]

Gaining a similar understanding of the connections between blood flow and muscle flexibility in the lower limb may support sports medicine practitioners' prevention and management of running injury. For example, some of the most common injuries in the lower limbs of runners include chronic exertional compartment syndrome,[12] Achilles tendinopathy, medial tibial stress syndrome, and plantar fasciitis[13]—each directly or indirectly involving tissues supplied by the posterior tibial artery coursing near and through the potentially inflexible plantar flexors. As such, examining the relationship between blood flow and tissue inflexibility may illuminate factors clinicians could consider in their efforts to prevent and manage multiple conditions suffered by runners. Therefore, the purpose of this study was to examine the relationship between blood flow in the posterior tibial artery and sagittal plane ankle range of motion (used as a proxy measure of tissue flexibility of the gastroc-soleus complex) among a sample of collegiate runners.

METHODS

Participants

An Institutional Review Board (IRB) approved informed consent form was reviewed and signed by all participants prior to participating in the study. Exclusion criteria consisted of having any history of a lower extremity surgery, or any lower extremity injury diagnosed by a licensed healthcare provider within the last 6-months which was causing (or caused) restriction from participation in sport for more than 1-week. Participants consisted of a convenience sample of asymptomatic, National Collegiate Athletic Association (NCAA) Division III track runners (15 males, 10 females) (age = 20.0 ± 1.21 years, height = 171.5 ± 10.2 cm, mass = 66.7 ± 13.7 kg).

Instrumentation

Blood flow measurements were collected bilaterally from participants' posterior tibial arteries using a GE LOGIQ P5 ultrasound unit (GE Medical Systems, Milwaukee, WI). A standard, 12-inch goniometer (Fabrication Enterprise Inc., White Plains, NY) was used to measure sagittal plane ROM of participants' talocrural joints.

Procedures

A cross-sectional, observational design was used for this study. All measurements were performed within a functioning biomedical physics laboratory. All participants were instructed to abstain from exercise or physical activity for 12-hours prior to being measured to ensure they were all examined in physiologically rested states. Participants were also instructed to wear loose fitted shorts during the measurement sessions to limit clothing from interfering with blood flow and allowing exposure of the target body areas. Main outcome measures included bilateral measurements of blood flow within the posterior tibial artery, as well as bilateral ankle range of motion in the sagittal plane for all participants.

Measuring and Operationalizing Blood Flow

Blood flow was measured by a formally trained, experienced technician of the ultrasound unit. Participants were positioned supine on a standard treatment table with their hips relaxed in slight abduction and external rotation and their knees slightly flexed.[14] The posterior tibial pulse was palpated coursing posterior to the medial malleolus and the ultrasound transducer was placed atop that landmark (Figure 1).[14]

Figure 1. Placement and Positioning for Ultrasound Movement

The transducer was held parallel to the artery, enabling the examiner to view and measure *vessel diameter* (Figure 2) and *velocity of blood* moving through the vessel (Figure 3).

Figure 2. View and Measurement of Vessel Diameter

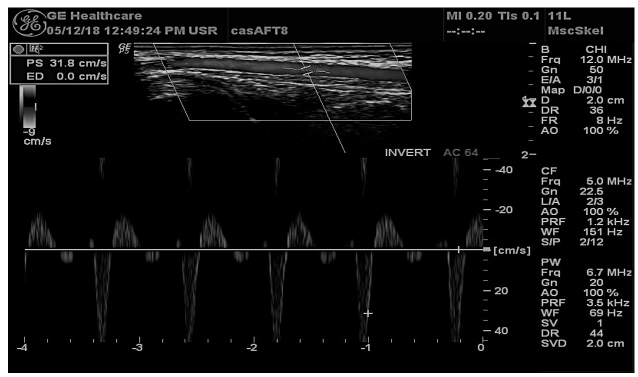

Figure 3. View and Measurement of Blood Velocity

The intra-rater reliability and standard error of measurement (SEM) of performing sonographic measurements of vessel *diameter* and *velocity* of blood moving through the vessel were, ICC=.84 and SEM=.02, and ICC=.60 and SEM=2.53, respectively. Diameter and velocity measurements were recorded and used to operationalize/compute the dependent variable, “blood flow (BF).” Blood flow (mL/min) was calculated by multiplying the velocity of blood moving through the vessel with its cross-sectional area. This area was calculated using $\pi/4 \times (diameter)^2$. Reliability of this transformed variable to be used as a main outcome measure was good (ICC = .85, SEM=14.7 mL/min). Measurements were performed and computed bilaterally on each participant.

Measuring Ankle Range-of-Motion (ROM)
Bilateral sagittal plane ankle ROM measurements were performed by an experienced certified athletic trainer. This examiner was blinded from the ultrasound operator's blood flow measurements as the ultrasound and ROM measurements were performed in physically separated areas of the laboratory and without access to one another's findings. ROM measurements were performed prior to blood flow measurements for all participants.

To measure ROM, participants were positioned hooked seated at the edge of a standard treatment table. A standard, 12-inch goniometer was positioned with its fulcrum aligned just inferior to the lateral malleolus, stationary arm fixed along the midline of the fibula, and the moveable arm positioned parallel to a line formed by the midline of the participant's fifth metatarsal bone.[15] Participants were instructed to actively move the ankle to the end-range of plantar flexion and dorsiflexion where the ROM measurements were recorded on a single trial. *A priori* intra-rater reliability and SEM of dorsiflexion and plantar flexion measurements was ICC=.85 (SEM=2.79°) and ICC=.58 (SEM=5.44°), respectively.

Statistical Analysis
Pearson correlation analysis was used to analyze the direction and degree of relationship between blood flow in the posterior tibial artery, as well as dorsiflexion and plantar flexion ROM of the dominant and non-dominant limbs. All analyses were performed using SPSS statistical software (version 27; IBM Corporation, Armonk, NY).

RESULTS
Descriptive statistics of ROM and BF measures are provided in Table 1. No significant relationship was observed between blood flow in the dominant leg's posterior tibial artery and dorsiflexion (r=.14, P=.52, $CI_{95\%}$ = -0.27 – 0.51) or plantar flexion (r=-.32, P=.12, $CI_{95\%}$ = -0.63 – 0.09) and no significant relationship between blood flow in the non-dominant leg's posterior tibial artery and dorsiflexion (r=-.02, P=.93; $CI_{95\%}$ = -0.41 – 0.38) or plantar flexion (r=-.02, P=.92; $CI_{95\%}$ = -0.41 – 0.38).

	N	Mean	Std. Deviation	$CI_{95\%}$
*Blood Flow$_{Dominant}$	25	123.3	43.7	106.2 – 140.4
† Blood Flow$_{Non\text{-}Dominant}$	25	112.6	40.3	96.8 – 128.4
‡Dorsiflexion ROM$_{Dominant}$	25	7.7	6.7	5.1 – 10.3
†† Plantar Flexion ROM$_{Dominant}$	25	59.4	9.3	55.8 – 63.1
‡‡ Dorsiflexion ROM$_{Non\text{-}Dominant}$	25	7.9	7.8	4.8 – 11.0
** Plantar Flexion ROM$_{Non\text{-}Dominant}$	25	57.9	7.6	54.9 – 60.9

Table 1. Descriptive Statistics for Blood Flow in Posterior Tibial Artery (mL/min) and Ankle ROM (degrees) Measurements.
(Blood Flow$_{Dominant}$ = blood flow in the dominant limb's posterior tibial artery*
† Blood Flow$_{Non\text{-}Dominant}$ = blood flow in the non-dominant limb's posterior tibial artery
‡ Dorsiflexion ROM$_{Dominant}$ = dorsiflexion ROM in the dominant limb
†† Plantar Flexion ROM$_{Dominant}$ = plantar flexion ROM in the dominant limb
‡‡ Dorsiflexion ROM$_{Non\text{-}Dominant}$ = dorsiflexion ROM in the non-dominant limb
*** Plantar Flexion ROM$_{Non\text{-}Dominant}$ = plantar flexion ROM in the non-dominant limb)*

DISCUSSION

Previous research has explored unique characteristics and adaptations in the legs of runners including Q-angle, lower limb alignment, and subtalar angle,[8] but none have examined the relationship between ROM (as a proxy measure of inflexibility) and blood flow. Testing this relationship was important because similar adaptations are associated with compromised blood flow in other areas of the body and may influence function of the limb.[16–18] The findings of our study, however, suggest little relationship between ROM and blood flow in the lower leg. These findings are the first of their kind and begin a line of inquiry exploring peripheral vascular adaptations in the lower limbs of running athletes.

The findings are valuable as they represent contradictory data to typical theory and findings in rehabilitation science, whereby blood flow has been shown to be restricted by tightness in surrounding musculature.[9,10,11] Therefore, this study provides preliminary evidence of how blood flow and surrounding soft tissues may not have consistent predictable relationships throughout the body. However, working toward a comprehensive understanding of the body's responses to running is essential to advancing evidence-based practices that optimize care for this sport population. As such, we suggest sports medicine practitioners should include examinations of blood flow, and reference the ranges demonstrated by our sample of healthy asymptomatic runners, when performing preparticipation health screenings of their runners. In doing so, their capacity to screen and detect potentially abnormal ranges of blood flow in their runners' lower legs would be enhanced.

Considering Normal Ranges of ROM and Blood Flow.

The mean ROM measurements in this study demonstrated participants having tight plantar flexor muscles represented by limited amounts of dorsiflexion ROM compared to normative ranges.[15] Participants had an av erage of approximately 7° of dorsiflexion compared to an expected normal range of 20°.[15] The amount of blood flow in the posterior tibial arteries were clinically reasonable but cannot be compared to values of blood flow in previous studies because of known variability of flow measurements within millimeter-sized vessels.[19]

Contribution to Contemporary Sports Medicine Theory

This study was born out of similar clinical questions and substantiated theory in the upper extremity. Blood flow in the upper limbs of pitchers, for example, has been shown to be diminished as consequence of soft-tissue adaptations incurred from forceful, repetitive motions of throwing over the course of a competitive season.[11] Moreover, thoracic outlet syndrome (TOS), a known neurovascular condition of the upper limb, is caused by compression of vascular supply to the arm.[9] The diminished blood flow to the arm in TOS can be caused by hypertrophy or tightness in pectoralis minor or scalene muscles.[16–18] Because this etiology exists (e.g., muscle tightness causing diminished blood flow) in the upper limb, the same could conceivably occur in other body regions that experience similar tissue demands and adaptations.

We hypothesized blood flow through the posterior tibial arteries of competitive runners may be associated with inflexibility of the plantar flexor musculature it courses near and through. Those muscles were anticipated to be and were in fact, inflexible. We contend this was due to the excessive and forceful contraction cycles they undergo during training and competitions.[4] This finding was consistent with other studies documenting tightness and inflexibility of the lower legs of runners.[4] Despite the sample having inflexibility in their lower leg musculature, there was no association between it and blood flow. To that end, the findings were incongruent with typical sports medicine theory of muscular inflexibility being associated with blood flow.

Implications for Practice

Exploring a relationship between ROM and blood flow has implications for clinical practice because of the potential etiological connection between limited blood flow in the posterior tibial artery and common injuries suffered by runners. Those injuries include chronic exertional compartment syndrome,[12] Achilles tendinopathy, medial tibial stress syndrome, and plantar fasciitis[13]—some of which involve tissues necessitating blood supply from the posterior tibial artery.

While the findings of our study demonstrated no relationship between blood flow and ROM, we encourage practitioners to monitor both variables among their clients and patients. Because our study only captured cross-sectional measures of BF and ROM, and only included asymptomatic runners, practitioners should interpret the findings with caution and avoid generalizing them to any clients/patients who have pathology or signs and symptoms of pathology. In other words, it remains possible that BF and ROM may be related under different clinical circumstances (e.g., among injured individuals and at different times throughout a runner's training cycles).

We also believe that although the posterior tibial artery exists near and in typically "tight" musculature, it may maintain effective levels of perfusion from several connecting arterial branches of nearby anterior tibial and peroneal arteries.[20] This may be an underlying reason why the sample's inflexibility of plantar flexor musculature had no significant relationship with posterior tibial artery blood flow. It is important to reiterate that the relationship between these variables may be different among injured populations. In runners with lower extremity injuries, the system of angiosomes supplying blood to different areas of the posterior tibial artery and subsequent musculoskeletal structures of the lower leg could be compromised, which would influence overall blood flow.

Limitations and Future Research

During this study, we positioned participants according to procedures used in previous work.[14] However, we may not have observed significant relationships between the variables because of the ankle being in a rested position during the blood flow measurement. This resting position may have reduced tension in the musculature of the lower leg and mitigated relationship between the surrounding musculature on the posterior tibial artery. This phenomenon has been seen in professional baseball players' upper limbs where they have less blood flow when in "provocative" overhead positions compared to when their arms are resting at their side.[21] The provocative position is suspected to increase tension in the pectoralis minor muscle and alter tension in the scalenes, thereby causing decreased blood flowing through the axillary and subclavian arteries.[16–18,21] To that end, future researchers and practitioners with access to diagnostic ultrasound, should examine blood flow in the lower legs of runners while in resting, and in more provocative positions such as having the ankle in end-ranges of sagittal plane motion.

Examining the variables used in this study but among injured runners will also extend the line of inquiry. This would supply the sports medicine community with reference ranges of blood flow for both injured and non-injured running athletes. Clinicians could screen their patients, during preparticipation exams for example, and compare their findings with those of injured and healthy subjects in the literature. In doing so, their screening and prediction of potentially injurious adaptations would be improved. Examining blood flow in different arteries (the anterior tibial and peroneal arteries, for example) would also advance future research. It would support a more comprehensive understanding of vascular perfusion in the lower leg and how the system of vessels may be influenced by the demands of running. Finally, studying blood flow in different ankle and knee positions, along with using direct measures of tissue stiffness instead of ROM alone, would extend the findings of this study. Testing tissue stiffness and blood flow at different joint angles would help reveal if changes in passive tension accrued during different joint angles relate to blood flow in the leg.

CONCLUSION

We hypothesized muscle inflexibility would be related to blood flow. However, our findings demonstrated little relationship between the two variables among a sample of competitive runners. This study provides preliminary evidence of how blood flow and surrounding soft tissues may not have consistent predictable relationships throughout the body. We suggest sports medicine practitioners should include examinations of blood flow, and reference the ranges demonstrated by our sample of healthy asymptomatic runners, when performing health screenings of their running athletes. Their capacity to screen and detect potentially abnormal ranges of blood flow would be enhanced and would inform more effective injury prevention strategies. Future research should continue examining blood flow in the lower limb as one of the many physical adaptations runners might experience from training. Further research should also work toward determining if and how blood flow in the lower legs of runners may be related to common injuries suffered by this patient population.

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