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The Calibers of the Common Femoral, Popliteal, and Posterior Tibialis Arteries: A Statistical Investigation in 100 Healthy Subjects by Color Doppler ultrasonography

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SUMMARY

One hundred healthy subjects (50 men, 50 women; age range: 18 to 90 years) with no history of occlusive arterial disease of the lower extremities were examined. In each, the principal arteries of the lower extremities were measured by Doppler ultrasound. The difference between the dimensions of the arteries of the right with those of the left was generally not significant, although those of the right were consistently larger. The only exceptions were the common femoral arteries in both sexes and the posterior tibialis arteries in the men, where there was a statistically significant predominance of the right. As compared to those of the females, the arterial calibers of the male subjects were significantly larger ($p < 0.01$) for all the arteries examined. In both sexes, there was a statistically significant direct relationship between vessel caliber and age. There was no correlation between arterial dimension and body index.

INTRODUCTION

Until the early 1900s, gross anatomical studies of the blood vessels were performed predominantly on cadavers, both to study the vessels' course and pattern of ramification and to determine their dimensions (Poirier and Charpy, 1904; Adachi, 1928). Among the more interesting studies are those of Fazzari (1929), whose laws characterizing the arterial tree were subsequently confirmed in a variety of vascular districts (Pacini *et al.*, 1977; Gulisano *et al.*, 1982).

Although never completely abandoned (Ciardi Duprè, 1938; Gremigni, 1968), characterization of the human vasculature has until recently subsequently commanded less interest. In the past few years (Macchi *et al.*, 1993), this topic has experienced a significant surge of interest. There are several reasons for the increased attention, principally its clinical relevance (Gulisano *et al.*, 1982; Macchi *et al.*, 1993). Both the higher incidence of vascular disease and the corresponding technical advances in vascular surgery demand greater precision in identifying significant lesions and distinguishing normal from pathological, as well as greater knowledge of normal anatomy in all its possible variants.

The findings of cadaveric investigations are of course limited by distortions produced by tissue preservation, but also by the pathological processes themselves; thus, not only are the data that derive from such studies questionable insofar as they are reflections of *in situ* anatomical data, it is unclear to what extent such data reflect normal anatomy. Alongside cadaveric studies using either direct measurement (Fazzari, 1929; Gremigni, 1968; Gulisano *et al.*, 1982) or injection corrosion casting (Wolfe, 1966; Michelet *et al.*, 1966; Huu *et al.*, 1972), other studies have used a variety of other methods, sometimes extremely complex (Czopek and Blaszynski, 1965; Michelet *et al.*, 1966; Wolfe, 1966; Granata *et al.*, 1966; Van der Shee *et al.*, 1981).

At present, the most promising approaches employ imaging techniques, including arteriography, ultrasonography, CT, and MR (Gaux and Blery, 1974; Cronier *et al.*, 1980; Zamir, 1981; Gulisano *et al.*, 1982). By allowing examination of the arteries of healthy, living subjects, they are not influenced by distortions related to either the manipulation of autopsy specimens or the pathological processes leading to death (Pacini *et al.*, 1977).

To be sure, these diagnostic imaging techniques themselves also have inherent disadvantages that limit their usefulness. For example, high cost and discomfort restrict the large-scale utilization of CT and MR, thus impeding the collection of a cohort of subjects large enough to validate a statistical analysis. Furthermore, radiation exposure and the risks associated with the administration of contrast media limit the use of CT and arteriography, even in healthy subjects. Finally, radiographic images, especially those that require the use of contrast media, are also affected by morphological distortions which may limit the value of morphologic studies based exclusively on them (Zamir, 1981). These distortions affect the measurement of arterial dimensions in particular.

In view of these limitations, Doppler ultrasound would seem to be technically the best solution. It combines relatively low cost with no risk to the patient, while the morphological and dimensional distortions of its images are negligible.

The present study thus proposes the use of Doppler ultrasound to investigate the dimensions of the arterial vessels of the lower extremities. Characterization of these vessels is particularly relevant, because the high incidence of vascular disease in this vascular system, which is subject to intense hemodynamic stress (Klingerhofer and Meyer, 1962; Granata *et al.*, 1966; Jelinek and Wolfmann, 1969), frequently obliges the clinician to evaluate the adequacy of the arterial perfusion of the lower extremities. Nonetheless, despite its clinical importance, the literature on this subject is relatively sparse.

Anatomical dissections of the femoral artery tend to emphasize the extreme variability of its branches (Adachi, 1928; Olivier, 1953; Sanders, 1963; Videau, 1968; Cronier *et al.*, 1980), while those studies that concern its dimensions are few in number and predominantly limited to cadaveric dissections (Poirier and Charpy, 1904; Gremigni, 1968).

There are also studies on the vascularization of the thigh muscles, which are primarily aimed at characterizing the principal modes of branching (Adachi, 1928; Konig, 1970). Studies of the popliteal artery focus on its topographical anatomy (Khudaiberdyev, 1956; Tazishinsky, 1957; Sarlier and Torlois, 1958; Welti and Sels, 1960; Bzinov, 1961; Huu *et al.*, 1972) and its clinical importance for the vascularization of the knee and leg (Kagan, 1964; Konig, 1970; Becquemin *et al.*, 1984). The few studies of the lower branches are not very recent (Poirier and Charpy, 1904; Adachi, 1928). In particular, reports concerning the posterior tibialis artery are scarce and generalized, notwithstanding their importance for the locomotor structures, such as the muscles, joints, and ligaments of the foot (Adachi, 1928; Manukyan, 1967; Testut and Latarjet, 1971; Chiarugi-Bucciante, 1972)

We believe that Doppler ultrasound can provide reliable and important information about the arterial system of the lower extremity in an anatomical study of a large population of normal subjects with good hemodynamic status. With the aim of filling a significant gap in the literature on normal arterial dimensions, we turned out attention to: 1) the femoral artery as the principal vessel of the lower extremity; 2) the popliteal artery as its direct continuation and the source of perfusion of the leg; and 3) the posterior tibialis artery.

MATERIALS AND METHODS

This study was performed on 100 subjects (50 men, 50 women; age range: 18 to 90 years) with good arterial circulation in the lower extremities. Each subject gave informed consent to participate in the research protocol.

The height and weight of each subject were obtained. Each subsequently underwent a Doppler ultrasound examination of the arteries of both lower extremities. In particular, the following were studied: 1) the common femoral artery, 1 cm proximal to its bifurcation; 2) the popliteal artery, 1 cm proximal to its trifurcation; and 3) the posterior tibialis artery, just distal to the medial malleolus, in each vessel, the internal luminal caliber (in millimeters) was measured. The results are reported in *Tables 1* and *2* and *Figure 1*. The means and standard deviations of the calibers of the arteries of both sides (in millimeters) were calculated, both with respect to the totality of cases and separately by sex (*Tab. 3*).

TABLE 1 - *Females. Age, weigth, height, body index and calibre of the arteries. post. tib. a. = posterior tibial artery; poplit. a. = popliteal artery; com. fem. a. = common femoral artery.*

FEMALES			post. tib. a.		poplit. a.		com. fem. a.		body index
age	weigth	height	right	left	right	left	right	left	
18	55	162	1,5	1,4	4,6	4,6	6,3	6,3	33,95
19	56	162	0,8	0,7	3,8	3,6	5,3	5	34,57
19	56	165	1,1	1,3	3,8	3,7	5,9	6	33,94
32	72	165	1,6	1,6	4,6	4,5	6,3	6,2	43,64
36	55	162	1,4	1,3	4,9	4,9	6,4	6,3	33,95
38	64	165	1,5	1,5	4,8	4,9	7	6,9	38,79
44	58	163	1,5	1,5	4,6	4,7	6,5	6,4	35,58
45	69	165	1,6	1,6	4,6	4,5	7,2	7,5	41,82
48	53	162	1,5	1,3	4,6	4,5	6,3	6,2	32,72
48	65	153	1,3	1,3	4,6	4,4	6,9	6,5	42,48
49	53	160	1,4	1,6	4,8	4,8	6,5	6,3	33,13
49	82	182	1,2	1,2	3,9	3,9	5,2	5	45,05
51	52	154	1,6	1,5	4,8	4,6	6,8	6,5	33,77
54	67	154	1,5	1,5	4,7	4,6	6,8	6,6	43,51
54	68	173	1,6	1,5	4,7	4,8	7,5	7,5	39,31
56	75	165	1	1,4	4,5	4,7	6,6	6,7	45,45
56	84	166	1,8	1,7	4,9	5,1	7,7	7,9	50,60
60	64	152	1,3	1,2	4,7	4,8	6,3	6,2	42,11
62	73	167	1,5	1,5	4,2	4,3	6,3	6,1	43,71
62	102	180	1,5	1,5	4,4	4,4	6,9	6,9	56,67
63	65	160	1,2	1,3	4,6	4,5	6,5	6,4	40,63
63	73	159	1,6	1,5	4,8	4,5	7,3	7,2	45,91
63	75	169	1,5	1,4	4,7	4,9	6,6	6,4	44,38
65	53	168	1,6	1,5	4,6	4,6	7	6,8	31,55
65	58	164	1,5	1,4	4,4	4,5	6,8	6,7	35,37
65	59	167	1,6	1,5	4,4	4,3	6,6	6,6	35,33
65	68	165	1,4	1,4	4,6	4,5	6,6	6,5	41,21
65	83	167	1,8	1,6	4,9	5,1	6,8	6,8	49,70
66	70	165	1,4	1,3	4,8	4,9	7,3	7,5	42,42
66	72	165	1,8	1,8	4,6	4,8	7,7	8	43,64
67	69	157	1,7	1,6	4,6	4,5	6,9	6,8	43,95
68	58	163	1,7	1,6	4,7	4,7	6,9	6,4	35,58
68	70	164	1,6	1,5	4,8	4,7	6,5	6,4	42,68
68	78	166	1,6	1,6	4,8	4,7	6,8	6,7	46,99
68	78	183	1,8	1,6	4,9	5	7	6,9	42,62
69	53	156	1,7	1,4	5	5,1	6,6	6,6	33,97
70	92	176	1,2	1,4	4,8	4,9	6,1	6,2	52,27
71	52	154	1,7	1,7	4,6	4,6	6,7	6,5	33,77
71	54	156	2	2,1	5,2	5	6,9	7	34,62
71	62	165	1,4	1,6	4,5	4,7	6,2	6,5	37,58
71	70	163	1,7	1,7	4,8	4,5	6,8	6,8	42,94
72	58	170	1,7	1,8	5,2	5	7,1	7,2	34,12
72	74	166	1,7	1,6	4,9	4,7	6,9	6,9	44,58
73	82	165	1,6	1,7	4,8	4,7	6,5	6,4	49,70
77	51	156	1,9	1,7	4,9	4,8	7,2	7,1	32,69
80	63	162	1,7	1,6	4,7	4,7	6,5	6,6	38,89
81	49	152	1,5	1,4	4,5	4,5	6,5	6,3	32,24
81	54	159	1,6	1,4	4,6	4,5	6,8	6,6	33,96
87	49	150	1	0,9	3,6	3,6	5,7	5,8	32,67
90	62	163	2,2	2,2	5,4	5,6	8,3	8,2	38,04

TABLE 2 - *Males. Age, weigth, height, body index and calibre of the arteries. post. tib. a. = posterior tibial artery; poplit. a. = popliteal artery; com. fem. a. = common femoral artery.*

MALES			mall. a.		poplit. a.		com. fem. a.		body index
age	weigth	height	right	left	right	left	right	left	
24	61	166	1,9	2	5,4	5,2	6,9	7	36,75
26	58	164	2,4	2,2	5,5	5,4	7,3	7,2	35,37
30	93	189	1,9	1,7	5	4,8	6,9	6,8	49,21
38	86	182	2,4	2,2	5,5	5,5	7,8	7,6	47,25
39	78	169	2	2,1	6,1	5,8	8,3	7,7	46,15
44	80	194	2,5	2,6	5,9	6,3	8,2	8,2	41,24
44	89	179	2	1,8	5	4,7	6,9	7,2	49,72
49	60	158	1,9	1,8	5,1	5	7,3	7,2	37,97
49	75	169	2,2	2,2	6	5,9	8	7,9	44,38
49	89	176	2	1,8	5	5,1	7,3	7,2	50,57
51	82	173	1,9	2,1	4,7	4,4	7,5	7,2	47,40
52	69	174	1,8	1,8	4,9	5	7,2	7,2	39,66
52	69	170	1,8	1,7	4,5	4,5	6,9	6,7	40,59
54	83	178	2,3	2,3	5,8	5,5	8,1	8	46,63
54	92	188	2	2	5,5	5,2	8,1	7,8	48,94
55	70	170	1,5	1,6	4,7	4,9	6,4	6,7	41,18
55	75	169	2,1	2	5,3	5,3	7,9	7,7	44,38
56	73	165	1,8	1,9	5	4,9	7,5	7,4	44,24
57	87	184	2,1	2	5,8	5,8	8	8,1	47,28
58	69	171	1,8	1,8	5	4,9	7,9	7,9	40,35
59	88	173	2,2	2,1	5,4	5,6	8	7,9	50,87
62	65	163	2	2	5,1	4,9	7,8	8,1	39,88
63	62	164	2,1	2,1	5	5	7,8	7,6	37,80
63	63	164	2,1	1,9	5,3	5,3	7,8	7,5	38,41
63	88	192	1,9	1,7	5	4,8	7,8	7,9	45,83
63	89	177	1,8	1,6	4,9	4,9	7	6,9	50,28
65	58	159	1,9	1,9	4,8	5	7,6	7,4	36,48
65	59	160	1,7	1,6	5	5,6	7,3	7	36,88
65	65	174	1,6	1,5	5	4,8	6,4	6,2	37,36
65	102	179	2,2	2,1	5,3	5,2	7,7	7,7	56,98
65	112	189	2,3	2	5,5	5,4	7,5	7,6	59,26
68	72	180	1,9	1,8	4,9	4,8	7,2	7,1	40,00
69	64	159	2,1	2	5,3	5,2	7,8	7,8	40,25
70	69	168	2,2	1,6	5	4,9	7,5	7,3	41,07
70	80	173	2	2,1	5,4	5,3	7,9	7,9	46,24
70	99	188	2	2	4,9	4,7	7,3	7	52,66
71	69	169	1,9	1,9	5	4,9	7,7	7,8	40,83
71	88	184	2,4	2,2	5,6	5,6	8,4	8,2	47,83
72	85	183	2,5	2,5	5,8	5,6	8	7,7	46,45
72	94	184	1,9	2,2	5,1	4,8	7,7	7,6	51,09
73	57	161	2,2	2	5,6	5,7	8	8,2	35,40
73	61	178	2,3	2,2	5,4	5,3	8	7,9	34,27
73	65	174	1,5	1,4	4	4,1	5,9	5,8	37,36
73	72	173	1,9	1,9	5	4,9	7,4	7,2	41,62
76	64	172	2	1,9	5,2	5	7,3	7,4	37,21
78	79	173	1,9	1,8	4,9	5	7,1	6,9	45,66
80	69	173	2,1	2	5,3	5,3	7,9	7,9	39,88
80	89	177	1,5	1,5	4,6	4,6	7,2	7,3	50,28
81	69	170	1,8	1,8	4,7	4,7	7,3	7,3	40,59
83	73	168	1,6	1,5	4,7	4,9	7,4	7,5	43,45

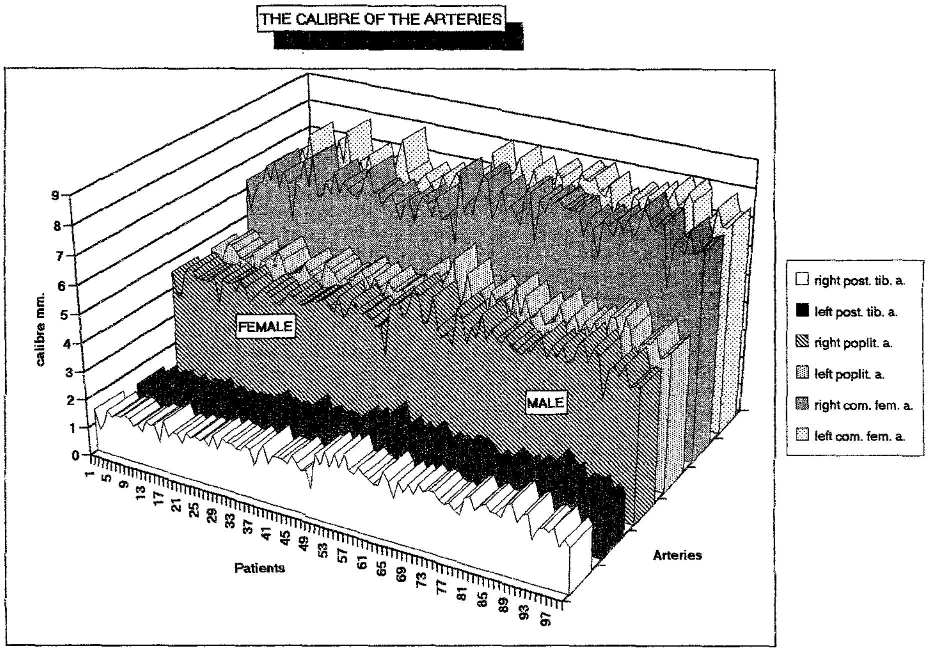

Fig. 1

TABLE 3 - *Age, weigth, height of each sex and mean calibres ± standard deviation of posterior tibial artery, popliteal artery and common femoral artery.*

		age	weigth	height	post. tib. a.		poplit. a.		com. fem. a.	
					right	left	right	left	right	left
TOTAL	mean				1,82	1,76	4,97	4,94	7,22	7,16
100 cases	± sd				0,32	0,31	0,43	0,43	0,61	0,61
FEMALES	mean	60,42	65,54	163,44	1,53	1,50	4,64	4,63	6,70	6,64
50 cases	± sd				0,26	0,24	0,34	0,37	0,55	0,60
MALES	mean	60,74	76,14	173,78	2,00	1,93	5,17	5,12	7,52	7,45
50 cases	± sd				0,25	0,25	0,41	0,42	0,51	0,51

These data were subjected to statistical analysis. In each vessel, the measurements of the right and left were compared, and the statistical significance of this difference was assessed using the Student's t test and a calculation of the probability (Pr) that the association occurred by chance (*Tab. 4, Figs. 2, 3,* and *4*). Using the same method, we compared the values found in the males with those in the females (*Tab. 5*).

The Body Index (B.I.) of each subject was calculated according to the formula: B.I. = weight / height. The regression equation was calculated according to the model: $y = kx + n$, and the coefficient of correlation r was determined, with the probability (Pr) that this relationship occurred by chance (*Tab. 6*). Applying the

TABLE 4 - *Relationship between two sides of each sex. t = Student's t; P = probability.*

Females		*t*	*P*
Posterior Tibial Artery			
right	left		
1,53 ± 0,25	1,50 ± 0,24	1,89	ns
Popliteal Artery			
right	left		
4,64 ± 0,34	4,63 ± 0,37	0,82	ns
Common Femoral Artery			
right	left		
6,70 ± 0,55	6,64 ± 0,60	2,55	< 0,05
Males		*t*	*P*
Posterior Tibial Artery			
right	letf		
2,00 ± 0,25	1,93 ± 0,25	3,42	<0,01
Popliteal Artery			
right	left		
5,17 ± 0,41	5,12 ± 0,42	1,95	ns
Common Femoral Artery			
right	left		
7,52 ± 0,51	7,45 ± 0,51	3,04	< 0,01

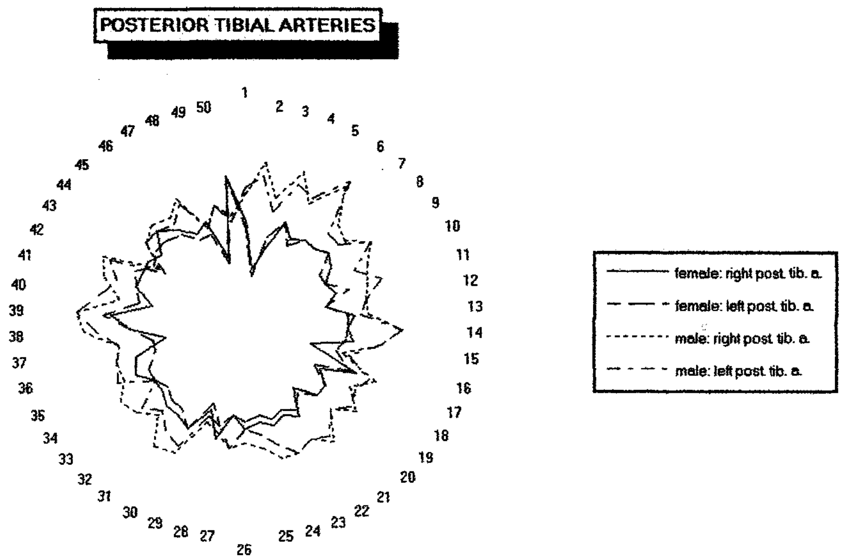

Fig. 2

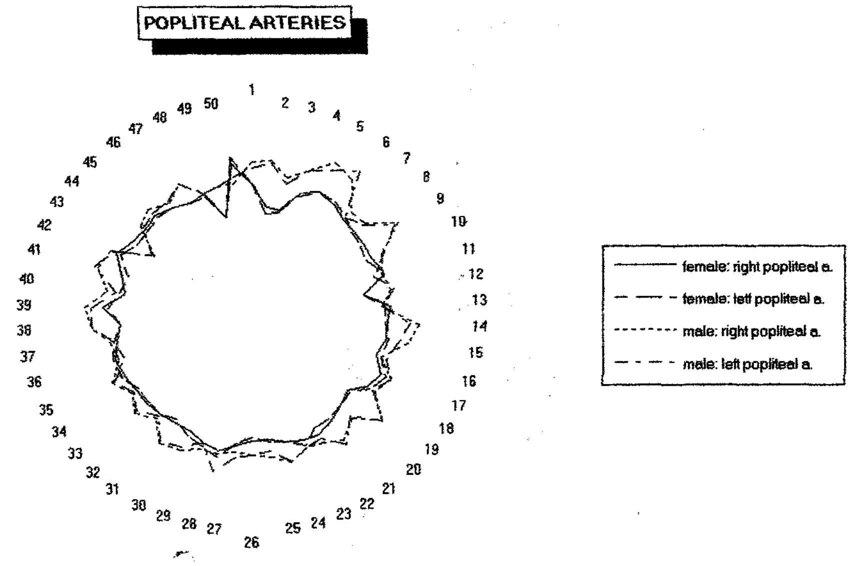

Fig. 3

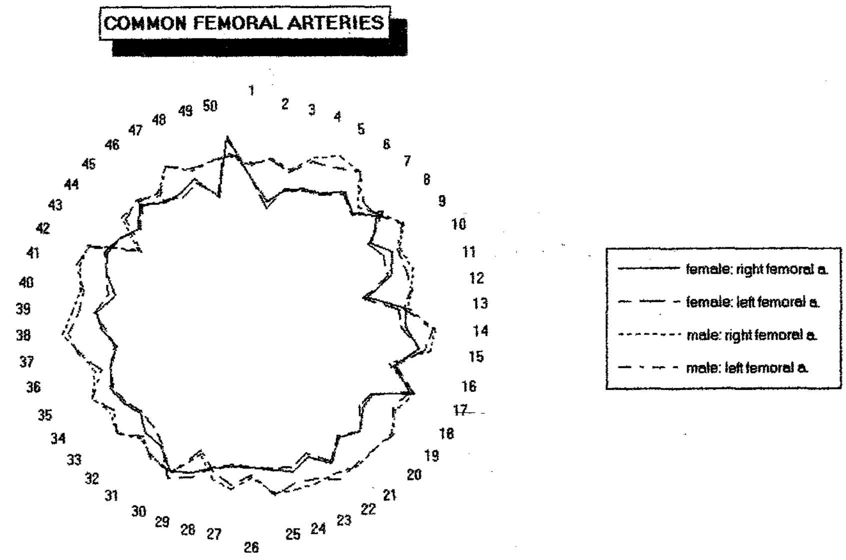

Fig. 4

same approach, the possible significance and type of correlation between arterial dimension and age were assessed (*Tab. 7*).

For the Doppler ultrasound examinations, an Acuson 128XP color Doppler ultrasound device with a 5 MHz probe was used. A Sony UP-850 thermal printer and a Sony UP-3030P color video printer were used for documentation.

TABLE 5 - *Student,s t between the calibres of the right side arteries in female and male sex and between the calibres of the left side arteries in female and male sex.*

SEX	Females	Males	*P*
Right Com. Fem. A.			
mean ± sd	6,70±0,55	7,52±0,51	<0,01
Left Com. Fem. A.			
mean ± sd	6,64±0,60	7,45±0,51	<0,01
Right Popliteal A.			*P*
mean ± sd	4,64±0,34	5,17±0,41	<0,01
Left Popliteal A.			
mean ± sd	4,63±0,37	5,12±0,42	<0,01
Right Malleolar A.			*P*
mean ± sd	1,53±0,26	2,00±0,25	<0,01
Left Malleolar A.			
mean ± sd	1,50±0,24	1,93±0,25	<0,01

TABLE 6 - *Relationship between the body index and the calibres of the arteries. r = correlation coefficient. t = Student's t. P = probability.*

Females		*P*
Right Post. Tib. A.		
r = 0,014	t = 0,141	ns
Left Post. Tib. A.		
r = 0,12	t = 1,194	ns
Right Popliteal A.		
r = 0,102	t = 1,014	ns
Left Popliteal A.		
r =0,154	t = 1,548	ns
Right Com. Fem. A.		
r = 0,142	t = 1,425	ns
Left Com. Fem. A.		
r = 0,188	t = 1,891	ns
Males		***P***
Right Post. Tib. A.		
r = 0,157	t = 1,578	ns
Left Post. Tib. A.		
r = 0,144	t = 1,445	ns
Right Popliteal A.		
r = 0,148	t = 1,482	ns
Left Popliteal A.		
r =0,033	t = 0,326	ns
Right Com. Fem. A.		
r = 0,158	t = 1,586	ns
Left Com. Fem. A.		
r = 0,146	t = 1,46	ns

TABLE 7 - *Relationship between the age and the calibres of the arteries. r = correlation coefficient. t = Student's t. P = probability.*

Females		*P*
Right Post. Tib. A.		
r = 0,453	t = 5,033	<0,01
Left Post. Tib. A.		
r = 0,406	t = 4,401	<0,01
Right Popliteal A.		
r = 0,337	t = 3,547	<0,01
Left Popliteal A.		
r = 0,349	t = 3,687	<0,01
Right Com. Fem. A.		
r = 0,366	t = 3,894	<0,01
Left Com. Fem. A.		
r = 0,362	t = 3,848	<0,01
Males		*P*
Right Post. Tib. A.		
r = 0,21	t = 2,127	<0,05
Left Post. Tib. A.		
r = 0,235	t = 2,395	<0,05
Right Popliteal A.		
r = 0,315	t = 3,287	<0,01
Left Popliteal A.		
r = 0,238	t = 2,423	<0,05
Right Com. Fem. A.		
r = 0,045	t = 0,444	ns
Left Com. Fem. A.		
r = 0,087	t = 0,779	ns

RESULTS

The results are presented in the above-mentioned Tables and Figures. The difference between the dimensions of the right- and left-sided arteries was generally not significant, although there was a consistently slight predominance of the right side. The exceptions were the common femoral artery, in both the males and females, and the posterior tibialis artery of the males, where the greater dimension of the right-sided vessel was statistically significant. Comparing males and females, vessel caliber was found to be consistently larger in the males by a large, statistically significant margin ($p < 0.01$). This was not explained by differences in body size alone, though, since the relationship between B.I. and arterial dimension was not significant. However, there was a statistically significant direct relationship ($p < 0.01$) between arterial caliber and subject age.

DISCUSSION AND CONCLUSIONS

A consideration of the mean dimensions of the arteries under study reveals several interesting findings. For example, the ultrasonographically measured caliber of the common femoral artery, which just exceeds a mean of 7 mm, is slightly lower than the cadaveric measurements of 9-10 mm generally reported by a variety of investigators (Adachi, 1928; Chiarugi, 1972). A similar discrepancy is observed in measurements of the popliteal artery (Poirier and Charpy, 1904; Adachi, 1928). In the posterior tibialis artery, the lack of precise data regarding dimensions precludes direct comparison.

These discrepancies could be explained by the differences in distortion associated with the different methods. For example, the measurement of cadaveric specimens often requires variable degrees of traction on the measured vessel (Orlandini, 1968): less traction is required if the circumference of the straightened vessel is measured and more if the caliber is measured (Pacini *et al.*, 1977), but it may nonetheless cause an increase of the measured dimensions. An analogous problem arises when arteriography is used, because of the distortion intrinsic to this method (Zamir, 1981)

Ultrasonography would seem to be uninfluenced by these drawbacks, since it measures only the effective caliber in the living subject. Furthermore, the case series of this study comprised apparently healthy subjects with no known vascular disease of the lower extremities, which cannot be confirmed in the case of the cadaveric studies.

The finding of a consistent predominance of the right-sided arteries with respect to those of the left in terms of size agrees with observations in other vascular districts (Gulisano *et al.*, 1982). The fact that this predominance is statistically significant only in certain arteries (the common femoral artery in both sexes and the posterior tibialis artery in males) does not alter the value of the observation; however, the case series will probably have to be enlarged to draw definitive conclusions.

On the other hand, it is extremely interesting to note that, in the vessels examined, the values obtained in males was significantly higher than those obtained in females. This observation completely contradicts the reports of other workers (Orlandini, 1968; Gulisano *et al.*, 1982). This finding could be explained by the fact that males, who generally lead more active lives, need a larger blood supply for the large muscles of the lower extremities.

Nevertheless, this finding requires further analysis. In particular, cadaveric studies (Pacini *et al.*, 1976) have shown that the external iliac arteries, of which the common femorals are the direct continuation, do not conform to this trend. Not even the larger body volume of the male sex in general is a valid explanation of the discrepancy, especially because the dimensions of the arteries do not appear to be in any way related to the Body Index. Even recalling the extreme variability of the vessels under examination (Adachi, 1928), the difference is nonetheless difficult to interpret and will require accurate confirmation, performed by means of a comparison with a homogeneous comparative case series in cadavers.

Finally, the finding of a significant increase in vascular dimensions with age agrees with the reports of all workers (Pacini *et al.*, 1977; Gulisano *et al.*, 1982). It is opportune to recall that vessel dimensions are subject to change with age. This process may be expressed by an «age power function» of the type y = kx n < 1 (Gulisano *et al.*, 1977), in which dimensions tend to increase with the passage of time, although not indefinitely.

In conclusion, ultrasonography can be an extremely useful tool in anatomic studies of the vascular system. Not only is the method practical and innocuous for the subject, it yields precise measurements. Further, this method is of considerable importance insofar as it can provide data regarding normal values which can serve as an indispensable resource for further clinical studies.

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