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Morphometric studies of the nutrient foramen in lower limb long bones of adult black and white South Africans

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SUMMARY

The present study analyzed the direction, number, location and position of the nutrient foramina in 1080 lower limb long bones of 20th century adult black and white South Africans. In each population 90 complete skeletons were used resulting in 360 femora, 360 tibiae and 360 fibulae being analyzed. The majority of the nutrient foramina pointed away from the growing end of the diaphysis in the lower limb bones with a few pointing in the opposite direction in both black and white populations. A single nutrient foramen was common on the shafts of the tibia and fibula in both populations, while, in the femur, double nutrient foramina were most frequent in the white population as opposed to one in the black counterparts.

Nutrient foramina were located most frequently on the *linea aspera* of the femur and the posterior surface of both the tibia and the fibula in both black and white populations. The mean foraminal indices were as follows: in the black population, 41.87% for the femur, 31.66% for the tibia and 43.33% for the fibula, and in the white population, 44.58% for the femur, 33.15% for the tibia and 46.86% for the fibula. These foraminal indices represent the relative positions of the nutrient foramina on the shaft of the bone. The information about direction, number, location and position of the nutrient foramina is important clinically during free vascularized bone grafting to preserve the blood supply of the graft, during fracture repair, joint replacement surgeries, and also in medico-legal cases.

Key words: Foraminal index – Fracture repair – Long bone – Nutrient artery – Nutrient foramina

INTRODUCTION

Nutrient foramina are cavities which allow passage of nutrient arteries and peripheral nerves into the diaphysis of the long bones (Pereira et al., 2011). The principal source of blood supply to long bones originates from the nutrient arteries, and is particularly important during its active growth period and also during embryonic stages (Lewis, 1956; Patake and Mysorekar, 1977; Forriol Campos et al., 1987; Sendemir and Çimen, 1991; Gümüsbrun et al., 1994). Trueta (1974) reported that 70 to 80% of intraosseous blood supply to long bones in childhood is provided by nutrient arteries, and when this flow is compromised medullary bone ischemia occurs, resulting in less vascularization of both the metaphysis and the growth plate. In cases where nutrient arteries are absent, periosteal vessels become the sole source of blood to the diaphysis of long bones (Schulman, 1958; Mysorekar, 1967; Patake and Mysorekar, 1977; Forriol Campos et al., 1987). The nutrient blood supply is very important in free vascularised bone grafting, and it must be preserved to promote fracture repair, with a good blood supply being necessary for osteoblast and osteocyte cell survival, as well as for facilitating graft healing in the recipient (Longia et al., 1980; Gümüsburun et al., 1994).

The nutrient foramen is also important in the de-

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velopment of longitudinal stress fractures, as they either develop from it or from its surrounding areas (Craig et al., 2003). Clinically, long bone fractures are accompanied by rupture of nutrient arteries and periosteal vessels leading to local bleeding (Trueta, 1974). Knowledge of the nutrient foramina morphometry is therefore important in some orthopedic surgical procedures, such as joint replacement therapy, fracture repair, bone grafts, vascularized bone microsurgery and also in medico-legal cases (Trueta, 1974; Longia et al., 1980; Guo, 1981; Forriol Campos et al., 1987; Sendemir and Çimen, 1991; Nagel, 1993; Gümüsbrun et al., 1994). Regarding the nutrient foramina, Shulman (1959) demonstrated that their location does not have a significant relationship with bone age, but that the development of the nutrient artery is primarily responsible for the form of the nutrient canal, rather than for bone development. In addition, Patake and Mysorekar (1977) reported that the number of nutrient foramina does not seem to have a significant relationship with bone length and number of ossification centers. Information on the blood supply to the long bones has been, and continues to be a major factor in the development of new transplantation and resection techniques in orthopedics (Kirschner et al., 1998).

The present study was undertaken to investigate the location, position, number and direction of the nutrient foramina in lower limb long bones in black and white South African population with known age, population affinity and sex.

MATERIALS AND METHODS

A total of 1080 lower limb long bones of 20th century black and white South Africans were analyzed. The dry skeletons were obtained from the Raymond A. Dart Collection of Human Skeletal Specimens housed in the School of Anatomical Sciences, University of the Witwatersrand. The following parameters, age, sex and population affinity, were known since the osteological collections are documented. Age ranged from 18-90 years for males and 20-87 years for females. In each population, 50 male and 40 female complete skeletons were used leading to 90 skeletons for each population. In total 360 each of femur, tibia and fibula were analyzed and measured. Bones with notable physical and pathological signs were excluded from the study. The location, number, position and direction of nutrient foramen were observed and analyzed. The total bone length of each bone and the distance between the dominant nutrient foramina and its most proximal point were measured using an osteometric table (Fig. 1) and a venier caliper respectively. Nutrient foramina were calibrated using hypodermic needles, and a dominant nutrient foramen was defined as that which admits a largest hypodermic needle (18-20 gauge). Any foramen which could admit a 25 gauge hypodermic was considered a nutrient foramen and also recorded in the study (Carroll, 1963). The position of the nutrient foramen was expressed as the percentage of the total bone length and was calculated by the formula according to (Hughes, 1952): **FI=DNF/TL×100**, where **FI** is the foraminal index; **DNF** the distance from the proximal end of the bone to the nutrient foramen and **TL** the total length of the bone. Statistical analysis was done using SPSS version 11, and P≤ 0.05 was used to infer on the level of statistical significance. The following statistical analyses were undertaken: frequency tables were used to calculate measures of central tendency (mean, range and standard deviation); Chi-squared test were used to test for association between nutrient foramina parameters and sex, sidedness and population affinity; and lastly, student T test for comparisons of means between the two population groups. This work was undertaken in accordance with the University of Witwatersrand ethics committee on the use of human cadaver and skeletal remains for teaching and research.

Fig. 1. The osteometric board used to measure the maximum length of the bones.

RESULTS

Femur

The mean length of the femur in black South Africans was found to be significantly smaller (p ≤ 0.05) than that of white South Africans as shown in Table 1. There was also a significant difference (p ≤ 0.05) in the mean length of the femur between males and females in both populations, but no side differences were observed.

The nutrient foramina pointed away from the *growing end* (the end of the bone that grows at least twice faster than the other end) in the majority of the femora (99.4% in blacks and 98.8% in whites) while a few femora (0.6% in blacks and 1.1% in whites) had nutrient foramen pointing towards the growing end of the bone (Table 2).

In black South Africans the majority of the femora had one (64.4%) followed by two (34.4%) nutrient foramina on their surfaces. One femur (0.6%) had

Table 1. The mean length (cm) of the lower limb long bones in black and white South Africans

Bone	Mean length									
	Male		Female			Male		Female		
	R	L	R	L	Mean	R	L	R	L	Mean
Femur	45.74	45.90	42.50	42.50	44.34	46.63	46.66	42.85	42.87	44.96
Tibia	39.50	39.43	36.23	36.16	38.44	38.51	38.56	35.44	35.25	37.12
Fibula	38.10	38.18	35.0	35.10	36.76	37.52	37.56	34.29	34.20	36.07

R: right; L: left.

Table 2. Direction of nutrient foramen in lower limb long bones

Bone	Race	Away from the growing end	Towards the growing end	Both directions	No foramen
Femur	Black	179 (99.4%)	-	-	1 (0.56%)
	White	178 (98.8%)	-		2(1.1%)
Tibia	Black	179 (99.4%)	1 (0.6%)	-	-
	White	176 (97.8%)	3 (1.7%)	1 (0.5%)	-
Fibula	Black	154 (85.6%)	5 (2.8%)	2 (1.1%)	14 (7.8%)
	White	150 (83.3%)	10 (5.6%)	7 (3.9%)	8 (4.4%)

Table 3. Number and location of the nutrient foramina on the femur

			0	1	2	3	4	5	6	LA	MLA	LLA	PMS	PLS
Black	Male	Right	-	33	16	1	-	-	-	38	9	-	2	1
		Left	1	33	16	-	-	-	-	38	6	-	4	1
	Female	Right	-	25	15	-	-	-	-	35	1	-	4	-
		Left	-	25	15	-	-	-	-	37	1	-	2	-
	Population %		**0.6**	**64.4**	**34.4**	**0.56**	**-**	**-**	**-**	**82.7**	**9.5**		**6.7**	**1.1**
White	Male	Right	1	25	24	-	-	-	-	37	5	1	4	2
		Left	1	26	23	-	-	-	-	40	-	2	7	-
	Female	Right	-	16	22	1	-	-	1	30	2	-	8	-
		Left	-	14	25	-	1	-	-	34	-	1	5	-
	Population %		**1.1**	**45**	**52.2**	**0.6**	**0.6**	**-**	**0.6**	**79.2**	**3.9**	**2.2**	**13.5**	**1.1**

LA: linea aspera; MLA: medial lip of linea aspera; LLA: lateral lip of linea aspera; PMS: posteromedial surface; PLS: posterolateral surface.

no nutrient foramina on its diaphysis. A maximum of three (0.6%) nutrient foramina were observed in one femur in black South Africans. In white South Africans two nutrient foramina were the most common (52.2%), followed by one (45%) and multiple nutrient foramina (Fig. 2) up to six were also recorded (Table 3). The majority of the femora studied in both populations (82.7% in blacks and 79.2% in whites), had their nutrient foramina located on the *linea aspera*, and the rest were found on the medial and lateral lips of the *linea aspera*, posteromedial surface and the posterolateral surfaces (Table 3).

Fig. 2. (A) Femur with six nutrient foramina pointing away from the growing end of the diaphysis. **(B)** A clearer view on the nutrient foramina on the femur. **(C)** A single nutrient foramina on tibia pointing towards the growing of the diaphysis. **(D)** Tibia with double nutrient foramina pointing both directions (away and towards the growing end). **(E)** Fibula with three nutrient foramina, two of which points towards the growing end and one of them pointing away from the growing end of the diaphysis. White thick arrows show the direction of the nutrient foramina. Hypodermic needles show the different sizes of the nutrient foramens.

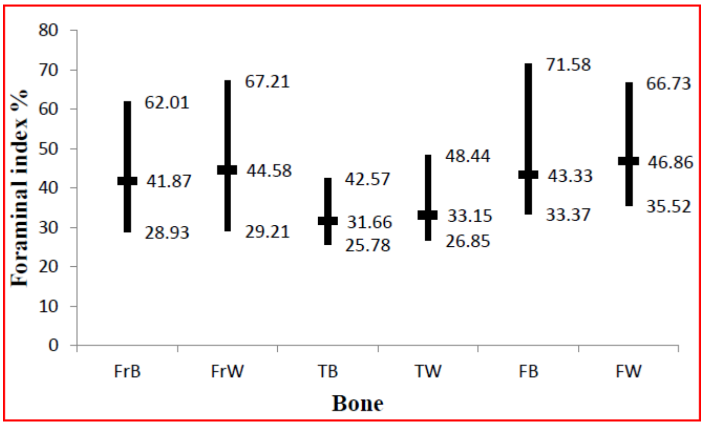

Fig. 3. Range of positions of the nutrient foramina based on the foraminal index (FI) of the femur, tibia and fibula in black and white South Africans. Abbreviations: Frb: black femur; Frw: white femur; TB: black tibia; TW: white tibia; FB: black fibula; Fw: white fibula.

There was no significant difference on the number and locations of nutrient foramina with regards to sex and sidedness (P≥0.05). There were no significant associations between the following nutrient foramina parameters (number and location) with population affinity. The nutrient foramina were distributed more on the middle third of the shaft of the femora in both black and white South African populations (Fig. 3). The mean foramen index (FI) for the femur was 41.87% in blacks and 44.58% in whites as shown in in Fig. 3. The FI of the femur was compared between the populations, sex and sidedness and it was found to be higher in whites than in blacks ($p \leq 0.05$) and no statistically significant differences were recorded between sex and sidedness respectively (Table 4).

Tibia

The mean length of tibia was found to be 38.44cm in blacks and 37.12 cm in whites. When the mean length of the bone was compared between the two populations and also with sidedness, it was observed that the mean length of the tibia in blacks was higher that of whites ($p \leq 0.05$) but there was no statistically significant difference between mean length of the right and left tibiae (Table 1). Males had longer tibiae than females. In black South Africans, the majority of the tibiae (99.4%) had nutrient foramina pointing away from the growing end of the bone. One tibia (0.6%) had the nutrient foramen pointing towards the growing end of the bone. In white South Africans, most of the tibiae (97.8%) had nutrient foramina pointing away from the growing end, three (1.7%) tibiae had their nutrient foramen pointing towards the growing end, and in one case (0.5%) the tibia had two nutrient foramina, one pointing towards the growing end and the other away from the growing end (Table 2). A single nutrient foramen was observed in the majority of the tibiae in both populations (99.4% in blacks and 98.3% in

Table 4. Statistical analysis of positions of nutrient foramina on lower limb long bones expressed by means and ranges of the foraminal index.

Bone	Population	Sex	Side	Number	FI Range	Mean	SD
Femur	Black	Male	Right	50	29.11-59.61	40.35	7.61
			Left	49	31.36-62.86	43.98	9.02
		Female	Right	49	27.44-62.02	40.83	9.48
			Left	49	27.84-63.57	42.33	8.91
	White	Male	Right	40	30.12-68.55	43.79	9.59
			Left	40	29.25-67.52	44.91	8.95
		Female	Right	40	29.67-66.46	44.43	11.20
			Left	40	30.89-66.29	45.19	10.80
Tibia	Black	Male	Right	50	27.35-35.91	31.33	2.26
			Left	50	25.53-39.17	31.23	2.83
		Female	Right	40	25.12-40.00	31.57	2.79
			Left	40	28.25-55.19	32.51	4.43
	White	Male	Right	50	26.23-59.73	33.85	4.33
			Left	50	25.85-36.33	32.52	2.32
		Female	Right	40	27.24-38.57	32.89	2.50
			Left	40	28.06-59.13	33.35	5.33
Fibula	Black	Male	Right	49	34.09-72.97	46.12	9.44
			Left	48	31.33-73.98	46.60	9.03
		Female	Right	33	34.28-64.70	43.93	6.63
			Left	36	33.77-74.86	44.66	8.89
	White	Male	Right	50	34.79-67.09	46.53	7.98
			Left	48	35.30-66.93	47.51	7.73
		Female	Right	39	37.12-68.79	47.17	8.62
			Left	35	34.88-64.14	46.58	7.27

FI: Foraminal index; SD: Standard deviation whites). Double nutrient foramina where also observed on one tibia (0.6%) in blacks and on three tibiae (1.7%) in white South Africans (Table 5).

Regarding the location of the nutrient foramina, in black South Africans 75.6% of the tibiae had their nutrient foramina located on the posterior surface, 22.8% on the posterolateral surface and 1.7% on the lateral surface. The situation in white South Africans was 77.8% of the tibia had nutrient foramina located on the posterior surface, 20.6% on the posterolateral surface and 1.7% on the lateral surface (Table 5). The mean FI of the tibia was 31.66% and 33.15% for both blacks and whites respectively. The majority of the nutrient foramina were found in the upper third, and the remainder in the middle third of the total bone length (Fig. 3). In the white population the mean FI of the tibia was significantly higher ($p \leq 0.05$) than that of the black population and no differences were observed between sex and sidedness (see Fig. 3 and Table 4 for distribution of foraminal indices).

Fibula

The mean length of the fibula was 36.76cm in blacks and 36.07cm in whites, and, when compared between the two populations and also between left and right sides, it was found to be significantly larger in blacks than in whites ($p \leq 0.05$) but there was no differences between the sides (Table 1). The mean length of the fibula was significantly higher in males than in females as well. In black South Africans 85.6% of the fibulae had their nutrient foramina pointing away from the growing end of the bone, 2.8% pointed towards the growing end and 1.1% had two nutrient foramina pointed in both directions. In white South Africans 83.3% of the fibulae had nutrient foramina pointing away from the growing end of the diaphysis, 5.6% pointed towards the growing end, 3.9% had two nutrient foramina pointed in both directions (Table 2). The majority of the fibulae in black South Africans (87.2%) had a single nutrient but cases of zero (7.2%), two (5.0%) and up to three (1.3%) nutrient foramina were also present (Table 6). The situation in white South Africans was 86.1% of the fibulae had one, 8.9% had two and 5% had no nutrient foramina on their diaphysis as shown in Table 6.

The location of the nutrient foramina on the fibula in black South Africans was as follows: 64.5% of the fibulae had nutrient foramina on the posterior surface, and 32.5% on the medial surface and 3% on the lateral surface. In white South Africans the situation was 70.3% of the fibulae had nutrient foramina on the posterior surface, 22.7% on the medial surface, 5.2% on the lateral surface and 1.7% on the medial crest (Table 6). The mean FI was 43.33% in blacks and 46.86% in whites and the nutrient foramina were found mainly in the middle third and to lesser extent in the lower third of the bone in both populations (Fig. 3). The mean FI was also found to be higher in whites than in black population ($p \leq 0.05$).

Table 5. Number and location of nutrient foramina on the tibia

Population	Sex	Side	No. of nutrient foramina				Location of nutrient foramina		
			0	1	2	3	PS	PL	LS
Black	Male	Right	-	50	-	-	33	17	-
		Left	-	50	-	-	35	15	-
	Female	Right	-	39	1	-	36	4	-
		Left	-	40	-	-	32	5	3
	Population %		-	**99.4**	**0.6**	-	**75.6**	**22.8**	**1.7**
White	Male	Right	-	50	-	-	43	6	1
		Left	-	50	-	-	39	11	-
	Female	Right	-	39	1	-	30	9	1
		Left	-	38	2	-	28	11	1
	Population %		-	**98.3**	**1.7**	-	**77.8**	**20.6**	**1.7**

PS: posterior surface; PL: posterolateral surface; LS: lateral surface

Table 6. Number and location of nutrient foramina on the fibula

Population	Sex	Side	No. of nutrient foramina				Location of nutrient foramina			
			0	1	2	3	PS	MS	LS	MC
Black	Male	Right	1	45	4	-	30	19	-	-
		Left	2	43	4	1	31	14	3	-
	Female	Right	6	33	1	-	22	9	2	-
		Left	4	36	-	-	24	12	-	-
	Population %		**7.2**	**87.2**	**5.0**	**1.3**	**64.5**	**32.5**	**3**	-
White	Male	Right	-	39	11	-	30	13	6	1
		Left	2	45	3	-	32	14	2	-
	Female	Right	2	38	-	-	26	12	1	-
		Left	5	33	2	-	33	-	-	2
	Population %		**5.0**	**86.1**	**8.9**	-	**70.3**	**22.7**	**5.2**	**1.7**

PS: posterior surface; Ms: medial surface; LS: lateral surface; MC: medial crest.

DISCUSSION

Femur

The mean length of the femur was 44.34cm in blacks and 44.96cm in white South Africans. The mean femoral length of the black South Africans was significantly smaller ($p \leq 0.05$) than that of white South Africans counterparts. This finding was in agreement with reports by Macho (1991), who found that white South Africans had longer femoral length than black South Africans. On the contrary, many researchers concur that individuals from African populations have longer limb segments than those from European populations, possibly due to differences in biological ancestry and climatic conditions (Eveleth and Tanner, 1990; Katzmarzyk and Leonard, 1998; Holliday, 1999; Holliday and Ruff, 2001). The causes of the current discrepancy may be partly because of poor nutrition, health and lifestyle which were common in African populations, and their effects were found to negatively impact on total stature and leg length (Steckel, 1995; Stephensen, 1999; Bogin et al., 2002). The current femoral measurements were similar to 44.3 cm in Turkish population (Sendemir and Çimen, 1991) and approximately 10% longer than 40.1cm in Americans (Nagel, 1993), 40.8cm in Germans (Kirschner et al., 1998) and 42.6 cm in Turkish (Kizilkanat et al., 2007). The majority of the nutrient foramina on the femur in both black and white South African populations were directed towards the hip joint (away from the growing end of the bone). The direction of the nutrient foramen is determined by unequal growth rates at the two diaphyseal ends of the bone during growth and development (Mysorekar, 1967). The nutrient foramina in adults are usually directed away from the fast growing ends of the bone (Mysorekar, 1967). This has led to the description of the direction of the nutrient foramina in long bones as being directed towards the elbow in the upper limbs and away from the knees in lower limbs (Mysorekar, 1967).

In the present study the majority of the femora in black South Africans had one nutrient foramen, followed by two on their surfaces while the situation was different in white South Africans where double nutrient foramina were commonest followed by a single nutrient foramen. In addition, multiple foramina up to six were also identified in white South Africans. The results in black South Africans were in agreement with reports from other studies, Longia et al. (1980) in Indians, and Kizilkanat et al. (2007) in Turkish population, who reported that a single nutrient was the commonest on the shaft of the femur. Like in white South Africans, other studies also found that double nutrient foramina were commonest on the shafts of the femur and the reported incidences were 55% by Laing and Kent (1953) in unknown population; 50% by Mysorekar (1967) in Indians; 60% by Forriol Campos et al. (1987) in Spanish and 46% by Sendemir and Çimen (1991) in Turkish populations. In support of the present findings on multiple nutrient foramina on the femur, Mysoreka (1967) found three while Sendemir and Çimen (1991) recorded a maximum of nine nutrient foramina. With regards to the location of the nutrient foramina, the majority of the nutrient foramina were found on the *linea aspera*, and the rest were unevenly distributed on the medial lip, lateral lip, posteromedial and posterolateral surfaces of the femur in both black and white populations. Similarly, Lütken (1950) reported that 71.1% of the nutrient foramina were located on the linea aspera of the femur. There is however a consensus that majority of the nutrient foramina are associated with the linea aspera spreading into its lips (Laing and Kent, 1953; Mysorekar, 1967; Sendemir and Çimen, 1991; Forriol Campos et al., 1987; Kizilkanat et al., 2007). In line with most reports, the majority of the nutrient foramina in the current study were found occupying the middle third of the shaft of the femur and the FI ranged between 25-70% of the total bone length (Mysorekar, 1967; Longia et al., 1980; Sendemir and Çimen, 1991; Nagel, 1993; Gümüsburun et al., 1994; Kirschner et al., 1998; Kizilknat et al., 2007). In the current study, the mean FI of the femur was significantly higher in whites than in black South Africans ($p \leq 0.05$).

Tibia

In the current study, the mean length of the tibia was 38.44cm in blacks and 37.12 cm in whites South Africans. The current measurements are approximately 10% longer than 34.8 and 35,8cm reported in Americans by Nagel (1993) and in Turkish by Kizilkanat et al. (2007) respectively. Contrary to the mean length of the femur which was larger in white South Africans than in black South Africans, the mean length of the tibia was larger in black South Africans than in white South Africans ($p \leq 0.05$). Many researchers concur with these findings that on average black individuals have longer legs (tibia and fibula lengths) than white individuals both in adults and even in foetuses (Eveleth and Tanner, 1990; Katzmarzyk and Leonard, 1998; Holliday, 1999; Holliday and Ruff, 2001; Trotter and Hixon, 1974). This characteristic variation in the length of the distal limb segments between blacks and whites can be as a result of genetic (Eveleth and Tanner, 1990), environmental (Bogin et al., 2002, Silventoinen, 2003) and climatic factors (Ruff, 2002; Frelat and Mittereocker, 2011). Climatic adaptation in particular is often believed to be the primary cause of these differences (Ruff, 2002; Steegmann, 2005; Stock, 2003, 2006). Allen's rule predicts that limbs are elongated under warmer climates, and shortened under colder ones, because longer limbs increase the surface area exposed to the environment for heat dissipation relative to the volume of the organism

(Allen, 1877). This rule has been confirmed in humans (Ruff, 1994, 2002; Tilkens et al., 2007; Frelat and Mittereocker 2011), although in modern human populations this effect may be partly obscured by the influence of nutrition, lifestyle and other environmental factors on growth (Bogin et al., 2002; Bogin and Rios, 2003; Silventoinen, 2003; Weinstein, 2005).

In the majority of the tibiae (99.4% in blacks and 97.8% in whites), the nutrient foramina pointed away from the growing end of the diaphysis towards the ankle joint, as observed by Mysorekar (1967). There were few cases in both black and white populations where the nutrient foramina pointed towards the growing end of the diaphysis contrary to the growing end theory. In addition to this variation, in one case the tibia had two nutrient foramina pointing in both directions, a situation which poses questions as to how the direction of the nutrient foramina is determined during growth and development. In the present study, a single nutrient foramen was the commonest and rarely a second in both black and white populations and this observation was in accordance with many researchers (Mysorekar, 1967; Longia et al., 1980; Forriol Campos et al., 1987; Sendemir and Çimen, 1991; Nagel, 1993; Gümüsburun et al., 1994; Kizilkanat et al., 2007). Cases of none (0.9%) and three (2.8%) nutrient foramina were also reported on the tibia among the Indian population (Gümüsburun et al., 1994). The nutrient foramina were located more on the posterior surface followed by posterolateral surface and to lesser extent on lateral surface in both Black and white South Africans. Similar findings were reported in previous studies, where the majority of the nutrient foramina were located on the posterior surface of the shaft of the tibia and were reported as 74% by Mysorekar (1967); 80.4% by Longia et al. (1980); 100% by Forriol Campos et al. (1987); 90.8% by Sendemir and Çimen (1991); 88.6% by Gümüsburun et al. (1994); 99% by Kizilkanat et al. (2007) and 93.7% by Pereira et al. (2011). All the foramina in this study were positioned in the proximal third of the bone below the soleal line, ranging from 25-50% of the total bone length and the mean foraminal indices were 31.66% and 33.15% for both blacks and whites respectively. This was consistent with previous studies by (Mysorekar, 1967; Longia et al., 1980; Forriol Campos et al., 1987; Sendemir and Çimen, 1991; Gümüsburun et al., 1994). However, in Indian (Mysorekar, 1967) and Spanish populations (Forriol Campos et al., 1987), some nutrient foramina were also found in the middle third of the bone.

Fibula

The mean length of the fibula was 36.76cm in blacks and 36.07cm in whites. Like for the tibia, it was larger in black South Africans than in their white counterparts. The mean lengths of the fibula in both black and white populations were similar to that reported in previous studied populations: Turkish (Gümüsburun et al., 1994; Kizilkanat et al., 2007), in Chileans (Collipal et al., 2007), and in southern Brazilians (Pereira et al., 2011). The majority of the fibulae (85.6% in black and 83.3% in white South Africans) had their nutrient foramina pointing away from the growing end of the bone towards the ankle joints, and few bones had nutrient foramina pointing towards the growing end in both populations. Cases of double nutrient foramina pointing in both directions were also present in both black and white South Africans. Mysorekar (1967) reported that the majority of the fibulae had their nutrient foramina pointing away from the growing end of the bone towards the ankle joints among the Indian population. In the present study, a single nutrient foramen was the most frequent, followed by two in both black and white population. Fibulae with up to three nutrient foramina were present in black South Africans while cases of none were prevalent in both studied populations. Mckee et al. (1984) reported similar findings in Canadian Caucasians: out of 323 fibulas, 5.6% had none, 86.4% had one, 7.7% had two and only one fibula had three nutrient foramina. In general, the occurrence of a single nutrient foramina on the fibula was the commonest (Longia et al., 1980; Mckee et al., 1984; Forriol Campos et al., 1987; Gümüsburun et al., 1994; Sendemir and Çimen, 1994; Kizilkanat et al., 2007; Pereira et al., 2011) followed by two (Guo, 1981; Gümüsburun et al., 1994; Kizilkanat et al., 2007) and then none (Mysorekar, 1967; Mkee et al., 1984; Sendemir and Çimen, 1991; Gümüsburun et al., 1994) but rarely three as observed by Mckee et al. (1984).

They are conflicting reports on the location of the nutrient foramina on the surfaces of the fibula. In the present study, most of the nutrient foramina were located on the posterior surface, followed by the medial surface, the lateral surface in both black and white South Africans and least on the medial crest in whites only. The posterior surface of the fibula was reported to harbor the majority of the nutrient foramina in some previous studies and was reported as 100% by Kizilkanat et al. (2007) among the Turkish; 67.5% by Mckee et al. (1984) in Canadian Caucasians; 53.9% by Gümüsburun et al. (1994) in Turkish population. On the contrary, nutrient foramina were observed most frequently on the medial surface (Forriol Campos et al., 1987; Sendemir and Çimen, 1994), lateral surface (Pereira et al., 2011) and the medial crest (Mysorekar, 1967).

The nutrient foramina occupied the middle third of the shaft of the fibula with a few spreading into its lower third ranging between 30-80% of the total bone length. The mean foraminal indices were 43.33% in blacks and 46.86% in whites. Most studies reported similar findings on the position of the nutrient foramina on fibula (Forriol Campos et al., 1987; Gümüsburun et al., 1994; Kizilkanat et al., 2007; Pereira et al., 2011). On the contrary, Guo (1981) and Fen (1981) reported that the majority of the nutrient foramina occupied the upper third of the diaphysis of the fibula.

Conclusion

The present study confirms information on the direction, number, location and position of the nutrient foramina on the lower limb long bones of the black and white South African populations. There was no significant association between nutrient foramina parameters with population affinity. Differences in length and foraminal indices identified between black and white South Africans were attributed to differences in genetic composition, environment and to a larger extent on climatic adaptation. The current study also supports the contention that nutrient foramina in long bones occupy their flexor surfaces, that is, the posterior surfaces in the lower limb bones. The parameters of the nutrient foramina in the femur, tibia and fibula as reported will be useful to prevent intra operative injuries and poor prognosis during procedures such as vascularised bone grafting, fracture repair, tumour resections and any other orthopaedic interventions among the two South African populations.

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