Anthropometric Tomographic Study of the Hip in a Brazilian Regional Population*

Estudo antropométrico tomográfico do quadril em uma população regional brasileira

Thiago Sampaio Busato[2] Taiuã Verdasca Milan[1] Gladyston Roberto Matioski Filho[2] Lucas Dias Godoi[2] Marcelo Gavazzoni Morozovski[2] Juan Rodolfo Vilela Capriotti[2]

[1] Specialization Course in Hip Surgery, Centro de Reconstrução e Instituto de Pesquisa Articular (CRIAr), Hospital Angelina Caron, Campina Grande do Sul, PR, Brazil
[2] Hip Group, Centro de Reconstrução e Instituto de Pesquisa Articular (CRIAr), Hospital Angelina Caron, Campina Grande do Sul, PR, Brazil

Address for correspondence Thiago Sampaio Busato, MD, Centro de Reconstrução e Instituto de Pesquisa Articular, Hospital Angelina Caron, Campina Grande do Sul, PR, Brasil (e-mail: tsbusato@hotmail.com).

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Abstract

Objective The present study aimed to determine the average hip anthropometry of a regional Brazilian population using measurements based on computerized axial tomography (CAT).

Methods Retrospective, descriptive analysis of hip measurements from 200 abdominal CATs from patients visiting a medical center. The tests were selected at random to determine 30 previously defined anthropometric measurements. The data were statistically analyzed and compared according to gender and age.

Results The prevalence of hip dysplasia was 6%. Signs suggesting femoroacetabular impingement were seen in 26% of cases. Patients over 50 years old presented significantly greater measures of horizontal acetabulum sectors, center-edge angle, and acetabular arch, as well as lower extrusion index, cervical-diaphyseal angle and vertical offset. Some measurements were significantly different according to gender: the lateral center-edge angle ($\mu = 35.5°$) and the acetabular arch ($\mu = 68.7°$) were higher in females. Males presented increased extrusion index ($\mu = 16\%$), lateral offset ($\mu = 38.3$ mm), depth ($\mu = 19.5$ mm), and neck diameter ($\mu = 26.4$ mm).

Conclusion The present study characterized the hip anthropometry of a regional Brazilian population. It also demonstrated significant morphological differences per age group and gender.

Keywords
- anthropometry
- arthroplasty
- hip joint
- tomography, x-ray computed

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Resumo

Objetivo Determinar a antropometria média do quadril de uma população regional brasileira através de medidas obtidas pela tomografia axial computadorizada (TAC).

Método Análise analítico-descritiva, retrospectiva, de medidas coxofemorais de 200 TACs do abdômen de pacientes atendidos em um centro médico. Foram selecionados aleatoriamente exames que permitissem a aferição de 30 medidas antropométricas previamente definidas. Os dados foram estatisticamente analisados e comparados quanto a sexo e idade.

Resultados A prevalência de displasia do quadril foi de 6%. Sinais sugestivos de impacto fêmoro-acetabular foram vistos em 26% dos casos. A análise dos resultados no grupo acima de 50 anos demonstrou medidas significativamente maiores dos: setores horizontais do acetábulo, do ângulo centro-borda e do arco acetabular, acompanhados de menor índice de extrusão, ângulo cérvico-diafisário e *offset* vertical. Algumas medidas foram significativamente diferentes em função do sexo: o ângulo centro-borda lateral ($\mu = 35.5°$) e o arco acetabular ($\mu = 68.7°$) se mostraram maiores no sexo feminino. No grupo masculino, foram maiores o índice de extrusão ($\mu = 16\%$), o *offset* lateral ($\mu = 38,3$ mm), a profundidade ($\mu = 19,5$ mm) e o diâmetro do colo ($\mu = 26,4$ mm).

Conclusão O presente estudo caracterizou a antropometria do quadril de uma população brasileira. Demonstrou ainda diferenças morfológicas significativas do quadril entre diferentes faixas etárias e sexos.

Palavras-chave
- antropometria
- artroplastia
- articulação do quadril
- tomografia computadorizada por raios X

Introduction

Knowledge on hip anthropometry, that is, the average anatomical measurements from a given population, is critical. It is known that bone structures dimensions and shape may vary according to age, gender, and ethnicity, among other factors.[1]

The mastery of these measures increases diagnostic accuracy and improves the treatment of conditions such as femoroacetabular impingement (FAI). In addition, anthropometry aids the development of implants for femoral fractures management.[2] This knowledge is also critical to total hip arthroplasty (THA), in which implants should be properly dimensioned to accommodate individual anatomical variabilities as accurately as possible; otherwise, complications resulting from dimensional incompatibility between implants and recipient bones can lead to early failure due to inadequate load transfer.[2–5]

Due to the lack of complete anthropometric studies on the Brazilian hip, we investigated the average hip joint anatomy of a regional population of the state of Paraná, using hip measurements obtained during abdominal computed tomography scans, and compared them with literature data from other populations. We also analyzed whether gender or age would have a significant correlation with measures range.

Material and Methods

Retrospective study based on anthropometric data obtained from 200 computed axial tomography (CAT) scans from patients visiting the imaging center of a tertiary hospital in Paraná, Brazil, from October 2014 to August 2018.

Abdominal CAT scans with axial and coronal planes reconstruction (i.e., sections from the acetabular roof, cranially, up to 2 cm below the base of the lesser trochanter, caudally) were included at random for anthropometric measurements determinations. Scans presenting hip fractures, hardware, or another condition that could result in distorted measurements, such as bone tumors or congenital deformities, were excluded. The study project was duly registered at Plataforma Brasil and approved by the institutional Ethics Committee (CAAE) under number 96182818.5.0000.5226.

Digitized images were obtained using a 16-channel Philips Model MX16EVO2 equipment (Philips, Amsterdam, Netherlands) and stored in an Aurora Picture Archiving and Communication System (PACS system, Pixeon, São Caetano do Sul, SP, Brazil). All evaluations and measurements were performed using the Arya software, from the same developer. The right hip was chosen for all measurements, which were made by the first coauthor. The data were statistically treated and compared with those of similar studies. ►**Figures 1**, **2**, and **3** show illustrative diagrams of the measurements.

The following parameters were evaluated in **coronal sections**:

1. **Sharp angle (acetabular index):** angle between a standard horizontal (bi-ischial) line and another line connecting the inferior-medial end to the superolateral acetabular end in its largest diameter.[6–8]
2. **Tönnis angle:** angle between a standard horizontal line and another line drawn from the most medial point to the most lateral point of the sourcil.[1,8–10]
3. **Acetabular depth:** orthogonal distance from the midpoint of the longest line connecting the inferior-medial

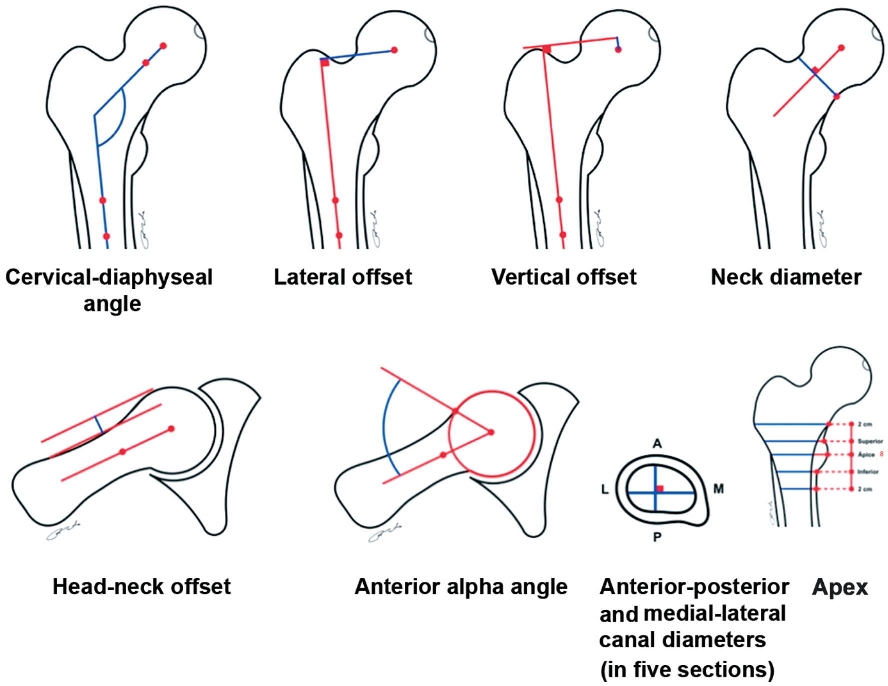

Fig. 1 Illustration of femoral measurements.

and superolateral acetabular ends to the bottom of the acetabulum in its largest diameter.[8,11]

4. **Wiberg (lateral center-edge) angle**: angle between a line drawn vertically through the center of the femoral head and another line drawn from the center of the femoral head to the most lateral edge of the sourcil.[12,13]
5. **Medial center-edge:** angle between a vertical line drawn through the center of the femoral head and another line connecting the center of the femoral head to the most medial edge of the sourcil.[9,14,15]
6. **Acetabular arc:** sum of the lateral center-edge and medial center-edge angles.[16,17]
7. **Delta (Notzli) angle:** angle between a line drawn from the center of the femoral head to the most medial part of the sourcil and another line drawn from the center of the head to the most lateral part of the femoral head fovea at the tomographic section in which its location is deeper.[18]
8. **Head extrusion index:** this index is measured at the largest diameter of the femoral head. It is determined using vertical, orthogonal lines to a standard horizontal line, drawn from the most lateral edge of the sourcil to the most lateral edge of the femoral head. The index is obtained by dividing the horizontal measurement of the extruded part by the cephalic diameter.[16]

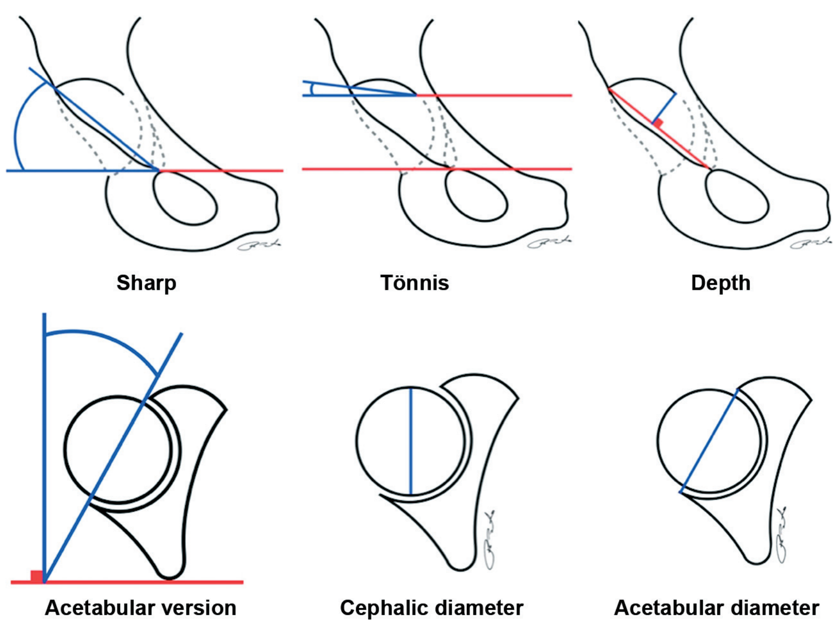

Fig. 2 Illustration of acetabular measurements.

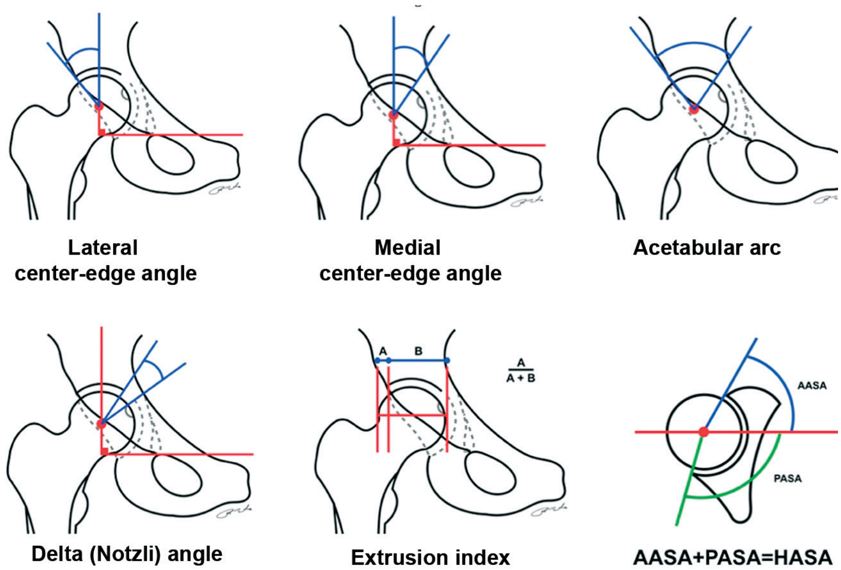

Fig. 3 Illustration of combined measurements.

9. **Cervical-diaphyseal angle:** angle between the anatomical axis of the femur (traced using points at the center of the medial-lateral diameter of the diaphysis in two distinct regions) and the axis of the neck (traced from a central point of the craniocaudal diameter of the femoral neck to the rotation center of the head).[1,2,7]
10. **Lateral offset:** orthogonal distance from the femoral head rotation center to the anatomical axis of the femur.[11,12]
11. **Vertical offset:** orthogonal distance from the center of the femoral head to a line touching the most cranial end of the greater trochanter.[12]
12. **Femoral neck diameter:** endosteal diameter orthogonal to the neck axis at its largest diameter section.[10]
13. **Femoral canal diameter:** medium-lateral endosteal diameter of the femoral canal. It is measured at 5 points, namely: 2 cm above the cranial edge of the lesser trochanter, at the level of the cranial edge of the lesser trochanter, at the level of the lesser trochanter apex, at the level of the caudal edge of the lesser trochanter, and 2 cm distal to the caudal edge of the lesser trochanter.[2]

The following parameters were evaluated in **axial sections**:

1. **Acetabular version:** angle between the ends of the anterior and posterior acetabular walls and an orthogonal line to another standard line that connects the posterior pelvic margins at the level of the largest diameter of the head.[13,14]
2. **Anterior acetabular sector angle (AASA):** angle between a line passing through the centers of the heads (in their largest diameters) and another line from the center of the head to the end of the anterior wall.[15]
3. **Posterior acetabular sector angle (PASA):** angle between a line passing through the centers of the heads (in their largest diameter) and another line drawn from the center of the head to the end of the posterior wall.[15]
4. **Horizontal acetabular sector angle (HASA):** AASA plus PASA.[15]
5. **Femoral head diameter:** largest diameter of the femoral head.[10]
6. **Acetabular diameter:** from the section with the largest head diameter.[10]
7. **Head-neck offset:**[10] three parallel lines are drawn: 1) axis of the femoral neck. 2) a line parallel to the first one, which touches the anterior cortex of the cervix. 3) a line parallel to the other two, which touches the anterior cortex of the femoral head. The offset is given by the distance between lines 2 and 3.
8. **Anterior alpha angle:** an angle between the axis of the femoral neck and a line connecting the femoral head rotation center to its point of sphericity loss.[16,19]
9. **Femoral canal diameter:** anteroposterior diameter of the femoral canal. It is measured at 5 points: 2 cm above the lesser trochanter, at the level of the upper border of the lesser trochanter, at the apex of the lesser trochanter, at the lower edge of the lesser trochanter and 2 cm distal to the lesser trochanter.[2]

Data was submitted to the Kolmogorov-Smirnov test to determine the normal distribution of anthropometric values. The Bartlett test was used to ascertain whether K variances in groups (anthropometric measurement types) were homogeneous. The chi-squared test for categorical variables was performed to identify trends in age and gender, whereas the analysis of variance (ANOVA) test compared means (considering a p-value < 0.05 as significant).

Results

This study analyzed CAT data from 200 patients. In each case, 30 measurements were collected, totaling 6,000 data for statistical analysis.

►**Table 1** shows the demographic data of the studied population. The mean age of the patients was 49 years old ($\mu = 48.90$), with a standard deviation of ± 20 years

Table 1 Sample demographic characterization

Characterization		n	%
Age range	≥ 50 years old	96	48%
	< 50 years old	104	52%
Gender	Female	86	43%
	Male	114	57%

Source: Research protocol (2019).

(σ = ± 20.25). The average (self-reported) ethnic composition of the population from this hospital unit was provided by inpatient system, and it is composed as follows: 69.2% white, 4.4% black, and 26.4% brown subjects.

►**Table 2** describes mean, standard deviation, minimum, and maximum values from the general sample. Mean values were usually deemed normal.

A lateral or anterior center-edge angle lower than 20°, suggesting hip developmental dysplasia, was found in 12 hips, resulting in a prevalence rate of 6%. Twenty-two hips, or 11% of the sample, presented alpha angles above 55°, suggesting cam-type femoroacetabular impingement (FAI). Twenty-three hips, or 11.5%, presented negative Tönnis angles, suggesting pincer-type FAI; in addition, 3.5% of this sample had findings suggesting mixed-type FAI. Thus, 26% of the sample had some sign suggestive of FAI.

►**Table 3** shows measurements by age group (< 50 or ≥ 50 years old). Measurements with statistically significant

Table 2 Anthropometric measurements of the general sample

Radiological measurement	Mean	Standard deviation	Minimum value	Maximum value
Sharp angle (degrees)	40.3	4.8	27.0	63.0
Tönnis angle (degrees)	3.4	6.8	−13.0	50.0
Depth (mm)	19.0	2.9	11.0	30.0
Lateral center-edge angle (degrees)	33.8	8.3	15.0	64.0
Medial center-edge angle (degrees)	33.4	8.6	13.0	66.0
Acetabular arc (degrees)	66.9	11.2	38.0	103.0
Delta angle (degrees)	27.8	8.8	5.0	52.0
Extrusion index (%)	14.0	9.8	0.0	52.0
Cervical-diaphyseal angle (degrees)	129.4	5.8	116.0	145.0
Lateral offset (mm)	37.6	3.4	28.0	45.0
Vertical offset (mm)	−1.3	8.8	−16.0	27.0
Neck diameter (mm)	25.2	4.0	17.0	37.0
Acetabular version (degrees)	21.2	6.5	7.0	47.0
AASA (degrees)	63.3	9.7	26.0	92.0
PASA (degrees)	105.9	14.0	71.0	159.0
HASA (degrees)	169.4	19.5	129.0	252.0
Cephalic diameter (mm)	41.8	4.0	32.0	52.0
Acetabular diameter (mm)	52.4	4.0	41.0	61.0
Head-neck diameter (mm)	9.4	2.7	4.0	28.0
Anterior alpha angle (degrees)	47.9	7.2	30.0	71.0
AP: + 2 cm (mm)	34.9	6.0	20.0	55.0
ML: + 2 cm (mm)	40.6	6.3	22.0	62.0
AP: superior (mm)	31.0	4.8	20.0	45.0
ML: superior (mm)	36.8	4.4	24.0	50.0
AP: apex (mm)	27.4	5.0	17.0	40.0
ML: apex (mm)	37.6	5.9	16.0	51.0
AP: inferior (mm)	22.6	4.0	12.0	35.0
ML: inferior (mm)	24.4	5.0	15.0	42.0
AP: - 2 cm (mm)	17.8	3.3	10.0	28.0
ML: - 2 cm (mm)	18.0	3.4	11.0	38.0

Abbreviations: AASA, anterior acetabular sector angle; PASA, posterior acetabular sector angle; HASA, horizontal acetabular sector angle; AP, anterior-posterior; ML, medial-lateral.
Source: Research protocol (2019).

Table 3 Anthropometric measurements per age range

Variable	Age (years old)	Mean	Standard deviation	Minimum value	Maximum value	*P*-value
Coronal Section						
Sharp angle (degrees)	≥ 50	39.1	5.5	27.0	63.0	0.000*
	< 50	**41.5**	3.8	28.0	49.0	
Tönnis angle (degrees)	≥ 50	3.4	6.8	−12.0	50.0	0.977
	< 50	3.4	6.8	−13.0	35.0	
Depth (mm)	≥ 50	18.7	2.8	12.0	28.0	0.187
	< 50	19.3	3.1	11.0	30.0	
Lateral center-edge angle (degrees)	≥ 50	**35.9**	8.1	22.0	62.0	0.001*
	< 50	31.9	8.0	15.0	64.0	
Medial center-edge angle (degrees)	≥ 50	32.6	7.1	13.0	50.0	0.188
	< 50	34.2	9.7	19.0	66.0	
Acetabular arc (degrees)	≥ 50	**68.6**	10.7	47.0	103.0	0.041*
	< 50	65.4	11.4	38.0	103.0	
Delta angle (degrees)	≥ 50	28.3	8.8	5.0	52.0	0.409
	< 50	27.3	8.8	5.0	42.0	
Extrusion index (%)	≥ 50	11.2	8.6	0.0	34.0	0.000*
	< 50	**16.7**	10.2	0.0	52.0	
Cervical-diaphyseal angle (degrees)	≥ 50	128.5	5.8	116.0	142.0	0.036*
	< 50	**130.2**	5.8	116.0	145.0	
Lateral offset (mm)	≥ 50	37.6	3.3	29.0	44.0	0.799
	< 50	37.5	3.5	28.0	45.0	
Vertical offset (mm)	≥ 50	−**2.8**	8.1	−15.0	24.0	0.028*
	< 50	0.0	9.2	−16.0	27.0	
Neck diameter (mm)	≥ 50	25.2	3.7	18.0	37.0	0.947
	< 50	25.2	4.2	17.0	37.0	
Axial section						
Acetabular anteversion (degrees)	≥ 50	**22.6**	6.5	7.0	44.0	0.003*
	< 50	19.9	6.3	8.0	47.0	
AASA (degrees)	≥ 50	**65.4**	10.5	35.0	87.0	0.002*
	< 50	61.3	8.6	26.0	92.0	
PASA (degrees)	≥ 50	**110.4**	14.8	80.0	159.0	0.000*
	< 50	101.6	11.7	71.0	159.0	
HASA (degrees)	≥ 50	**176.0**	20.9	132.0	234.0	0.000*
	< 50	163.2	15.8	129.0	252.0	
Cephalic diameter (mm)	≥ 50	41.5	3.7	32.0	50.0	0.337
	< 50	42.1	4.2	33.0	52.0	
Acetabular diameter (mm)	≥ 50	52.3	4.2	41.0	60.0	0.616
	< 50	52.6	3.9	42.0	61.0	
Head-neck offset (mm)	≥ 50	9.2	3.0	4.0	28.0	0.403
	< 50	9.5	2.5	5.0	21.0	
Anterior alpha angle (degrees)	≥ 50	48.2	7.6	30.0	71.0	0.526
	< 50	47.6	6.7	30.0	67.0	

Abbreviations: AASA, anterior acetabular sector angle; PASA, posterior acetabular sector angle; HASA, horizontal acetabular sector angle.
Source: Research protocol (2019).

Table 4 Anthropometric measurements per gender

Variable	Gender	Mean	Standard deviation	Minimum value	Maximum value	*P*-value
Coronal section						
Sharp angle (degrees)	Female	40.5	5.4	28.0	63.0	0.636
	Male	40.2	4.3	27.0	49.0	
Tönnis angle (degrees)	Female	2.7	6.8	−13.0	35.0	0.223
	Male	3.9	6.9	−11.0	50.0	
Depth (mm)	Female	18.3	2.7	12.0	25.0	0.004*
	Male	**19.5**	3.1	11.0	30.0	
Lateral center-edge angle (degrees)	Female	**35.5**	9.5	16.0	64.0	0.013*
	Male	32.6	7.1	15.0	54.0	
Medial center-edge angle (degrees)	Female	33.7	8.1	17.0	62.0	0.650
	Male	33.2	8.9	13.0	66.0	
Acetabular arc (degrees)	Female	**68.7**	12.2	47.0	103.0	0.046*
	Male	65.5	10.2	38.0	103.0	
Delta angle (degrees)	Female	28.4	9.2	5.0	52.0	0.372
	Male	27.3	8.5	5.0	47.0	
Extrusion index (%)	Female	11.4	9.6	0.0	52.0	0.001*
	Male	**16.0**	9.6	0.0	50.0	
Cervical-diaphyseal angle (degrees)	Female	129.0	6.3	116.0	142.0	0.390
	Male	129.7	5.5	116.0	145.0	
Lateral offset (mm)	Female	36.5	3.6	28.0	45.0	0.000*
	Male	**38.3**	3.1	30.0	45.0	
Vertical offset (mm)	Female	−2.1	7.8	−15.0	15.0	0.265
	Male	−0.7	9.4	−16.0	27.0	
Neck diameter (mm)	Female	23.7	3.6	17.0	32.0	0.000*
	Male	**26.4**	3.8	17.0	37.0	
Axial section						
Acetabular version (degrees)	Female	**22.5**	6.8	7.0	44.0	0.012*
	Male	20.2	6.1	8.0	47.0	
AASA (degrees)	Female	63.6	9.6	35.0	86.0	0.742ns
	Male	63.1	9.8	26.0	92.0	
PASA (degrees)	Female	107.8	13.6	73.0	159.0	0.086ns
	Male	104.4	14.1	71.0	159.0	
HASA (degrees)	Female	171.8	19.0	129.0	234.0	0.125ns
	Male	167.5	19.7	129.0	252.0	
Cephalic diameter (mm)	Female	39.4	3.2	32.0	50.0	0.000*
	Male	**43.6**	3.5	36.0	52.0	
Acetabular diameter (mm)	Female	50.0	4.0	41.0	60.0	0.000*
	Male	**54.2**	3.0	45.0	61.0	
Head-neck diameter (mm)	Female	8.9	2.3	4.0	14.0	0.055ns
	Male	9.7	3.0	4.0	28.0	
Anterior alpha angle (degrees)	Female	47.6	7.4	30.0	71.0	0.593ns
	Male	48.1	6.9	30.0	65.0	

Abbreviations: AASA, anterior acetabular sector angle; PASA, posterior acetabular sector angle; HASA, horizontal acetabular sector angle; ns, not significant.
Source: Research protocol (2019).

Table 5 Femoral canal anthropometric measurements per gender

Variable	Gender	Mean	Standard deviation	Minimum value	Maximum value	*P*-value
AP: + 2 cm	Female	33.1	5.5	22.0	52.0	0.000*
	Male	**36.2**	6.1	20.0	55.0	
ML: + 2 cm	Female	40.8	6.2	29.0	62.0	0.747
	Male	40.5	6.3	22.0	60.0	
AP: superior	Female	29.3	4.8	20.0	45.0	0.000*
	Male	**32.3**	4.4	22.0	44.0	
ML: superior	Female	35.6	4.2	24.0	50.0	0.001*
	Male	**37.7**	4.4	25.0	49.0	
AP: apex	Female	26.4	4.8	17.0	40.0	0.014*
	Male	**28.1**	5.0	18.0	40.0	
ML: apex	Female	36.3	5.1	19.0	50.0	0.008*
	Male	**38.6**	6.3	16.0	51.0	
AP: inferior	Female	22.2	4.2	14.0	32.0	0.147
	Male	23.0	3.8	12.0	35.0	
ML: inferior	Female	24.2	5.3	15.0	42.0	0.658
	Male	24.5	4.8	15.0	41.0	
AP: - 2 cm	Female	17.6	3.3	11.0	28.0	0.595
	Male	17.9	3.3	10.0	28.0	
ML: - 2 cm	Female	17.8	2.9	11.0	25.0	0.461
	Male	18.2	3.7	12.0	38.0	

Abbreviations: AP, Anterior-posterior; ML, medial-lateral.
Source: Research protocol (2019).

differences ($p < 0.05$) are in bold. Some anthropometric measurements were found to be significantly different depending on the age group.

In patients over 50 years old, the Sharp angle was greater, with a mean value of 41.5°; and the mean lateral center-edge angle ($\mu = 35.9°$) was also increased. Similarly, the acetabular arc was greater ($\mu = 68.6°$). Measurements from the axial sections revealed that mean the acetabular version ($\mu = 22.6°$), AASA ($\mu = 65.4°$), PASA ($\mu = 110.4°$), and HASA ($\mu = 176°$) were significantly higher in the older patient group.

In youngest patients, the mean extrusion index ($\mu = 16.7\%$) and the cervical-diaphyseal angle were higher ($\mu = 130.2°$).

Findings per gender

►**Table 4** shows measurements in both genders. Values with statistically significant differences ($p < 0.05$) are in bold. Some measurements were found to be significantly different comparing males and females.

Females presented significantly higher mean acetabular version angle ($\mu = 22.5°$), lateral center-edge angle ($\mu = 35.5°$), and acetabular arc ($\mu = 68.7°$).

Males presented higher mean extrusion index ($\mu = 16\%$), lateral offset ($\mu = 38.3$ mm), depth ($\mu = 19.5$ mm), neck diameter ($\mu = 26.4$ mm), head diameter ($\mu = 43.6$ mm), and acetabular diameter ($\mu = 54.2$ mm).

►**Table 5** shows that males presented significantly higher canal diameter compared to females. ►**Table 6** reveals that there was no significant difference in femoral canal measurements when comparing both age groups.

Discussion

The present study analyzed abdominal CAT scans containing segmentations at the hip joint level, allowing the characterization of average anthropometric measurements. Computed axial tomography studies of the abdomen were used to decrease the selection bias since they were probably not requested due to orthopedic complaints (and this study did not evaluate previous symptoms).

The modern concept of FAI was described by Ganz and subdivided into three types: pincer, when it results from acetabular changes, such as deep thigh, or global or focal retroversion; cam, when changes are at a femoral level, usually due to loss of the head-neck offset; and mixed, which is the most common type.

When investigating the prevalence of FAI-predisposing bone abnormalities in asymptomatic subjects, Kang et al.[6] noted that the acetabular version angle ranged from 5 to 29°, with an average value of 18°; this value is below the one found by our study, in which the acetabular version angle ranged from 7°to 47°, with an average of 21.2°. Other authors

Table 6 Femoral canal anthropometric measurements per age group

Variable	Age (years old)	Mean	Standard deviation	Minimum value	Maximum value	*P*-value
AP: + 2 cm (mm)	≥ 50	35.0	5.5	22.0	52.0	0.780
	< 50	34.8	6.5	20.0	55.0	
ML: + 2 cm (mm)	≥ 50	40.2	6.9	22.0	62.0	0.323
	< 50	41.0	5.6	28.0	57.0	
AP: superior (mm)	≥ 50	30.7	4.6	22.0	42.0	0.386
	< 50	31.3	5.0	20.0	45.0	
ML: superior (mm)	≥ 50	36.9	3.7	28.0	46.0	0.880
	< 50	36.8	5.0	24.0	50.0	
AP: apex (mm)	≥ 50	27.0	4.7	18.0	38.0	0.334
	< 50	27.7	5.2	17.0	40.0	
ML: apex (mm)	≥ 50	38.1	4.6	25.0	51.0	0.249
	< 50	37.1	6.9	16.0	50.0	
AP: inferior (mm)	≥ 50	22.5	3.8	12.0	35.0	0.725
	< 50	22.7	4.2	14.0	35.0	
ML: inferior (mm)	≥ 50	24.5	4.5	18.0	40.0	0.723
	< 50	24.3	5.4	15.0	42.0	
AP: − 2 cm (mm)	≥ 50	17.5	2.9	12.0	27.0	0.372
	< 50	18.0	3.7	10.0	28.0	
ML: − 2 cm (mm)	≥ 50	18.3	3.2	12.0	29.0	0.315
	< 50	17.8	3.6	11.0	38.0	

Abbreviations: AP, anterior-posterior; ML, medial-lateral.
Source: Research protocol (2019).

have evaluated measures potentially suggesting FAI. A measure widely described in the literature is the center-edge angle of Wiberg. In this same study,[6] these values ranged from 21 to 46°, with an average of 34°. In a case series evaluated by Murtha et al.,[8] this angle varied from 8.5°to 32.3°, whereas we found values ranging from 15° to 64°, with an average of 33.8°.

Tannast et al.[16] classified acetabula according to this measurement in 4 groups, in which angles lower than 22° indicated dysplastic hips, from 23 to 33° were normal hips, from 34 to 39° revealed overcovering hips, and higher than 40° showed severe overcovering. In our sample, the prevalence of hip developmental dysplasia was 6%, whereas 26% of the cases presented some sign suggestive of FAI. Regarding the high prevalence of signs suggesting FAI in our sample, it is extremely important to emphasize that FAI syndrome diagnosis is not contingent on imaging data alone. Since we did not collect data about any symptom presented by these patients, this finding must be only considered from a morphological point of view, not a pathological one.

In gender-related analysis, Lepaage-Saucier et al.[14] and Kang et al.[6] found higher mean center-edge angles in men compared to women. Curiously, only Mineta et al.[10] observed no differences between genders. Our sample was consistent with the previous literature, showing greater angles in females when compared to males (35.5° and 32.6°, respectively). Kang et al. also described a mean alpha angle of 45.5°, consistent with our study, which revealed a value of 47.9°.

The delta angle is described as a sign of dysplasia. In normal hips, Beltran et al. reported mean values of 22.7°, with standard deviation (SD) values of 12.6°. In our study, the mean delta angle was 27.8°, with a SD value of 8.8°. This finding is probably related to the greater acetabular coverage in comparison to the aforementioned studies.

Lepaage-Saucier et al.[14] reported a mean Tönnis angle 6°, with no differences between genders. In contrast, Mineta et al.[10] found lower values in men and elderly patients. In our sample, the Tönnis angle showed no significant differences in both age groups.

Another research[1] revealed the following mean values: Sharp angle, 39.2° (smaller compared to our result of 40.3°), lateral-center edge angle, 32.7 ° (smaller compared to our result of 33.8°), cervical-diaphyseal angle, 139.5 ° (greater compared to our result of 129.4°), acetabular version, 18.2° (inferior to our finding of 21.2°), acetabular depth, 25 mm (much lower compared to our result of 19 mm).

Anda et al.[15] described the anterior and posterior sectorial arcs of the hip, reporting mean values consistent with our study, with a difference of only 0.3° in AASA and 0.9° in PASA.

Our population presented lower mean acetabular and femoral head diameter, at 41.8 and 52.4 mm, respectively, compared to 45.3 and 52.6 mm according to Hauser et al.[20]

Lateral offset is a measure of direct interest for biomechanical reconstruction in hip arthroplasty. Husmann et al. showed a mean lateral offset of 40.5 mm, while our population presented an average value of 37.6 mm, with lateral offsets ranging from 28 to 45 mm.

The joint analysis of our results, specifically in the group over 50 years old, indicated the acetabular deepening related to aging. This fact was demonstrated by the significantly greater horizontal acetabular sectors angles, the center-edge angle, and the acetabular arc, along with a lower extrusion index. In addition, a varusing was noted, with reduced cervical-diaphyseal angle and vertical offset, the latter with a negative mean value in this subsample.

Our data on endosteal femoral canal diameter allows us to outline the average shape of the metaphyseal region, which would be critical to build a custom prosthetic implant. Although the mean values from our study are consistent with those obtained by Noble et al.,[17] our measurements presented higher variability compared to most previous studies. In addition, there were differences regarding femoral neck diameter measurements. Noble reported an average diameter of 16.5 mm, ranging from 10 to 22 mm, while we found an average value of 25.2 mm and measurements ranging from 17 to 37 mm. We believe that this difference may be due to the ethnic multitude found in Brazil. Such variability has a direct impact on the design of cephalomedullary implants with antirotating screws. The anatomical variety of our population would require a wide range of device sizes.

The current study has limitations inherent to its retrospective design, and we have not analyzed whether these subjects had any symptoms or what was the reason for the imaging test. In addition, measurements performed by a single examiner may be susceptible to variation even though CAT scans have shown good intra and interobserver confidence in some analysis. As positive points of this research, we emphasize that it demonstrated, in an unprecedented way, detailed anthropometric mean values of the hip joint from a Brazilian population. We have also shown that there are variations in patients from different age groups. Our protocol may be replicated promptly in multicenter studies, which we deem necessary to cover a larger, more diversified sample from other regions of Brazil.

Conclusions

The present study characterized in detail the anthropometry of the hip joint of a regional Brazilian population. It also demonstrated significant morphological differences of the hip between different age groups and genders.

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Conflicts of Interests

The authors declare that there were no conflicts of interests.

References

1 Saikia KC, Bhuyan SK, Rongphar R. Anthropometric study of the hip joint in northeastern region population with computed tomography scan. Indian J Orthop 2008;42(03):260–266

2 Sengodan VC, Sinmayanantham E, Kumar JS. Anthropometric analysis of the hip joint in South Indian population using computed tomography. Indian J Orthop 2017;51(02):155–161

3 Abbas K, Murtaza G, Umer M, Rashid H, Qadir I. Complications of total hip replacement. J Coll Physicians Surg Pak 2012;22(09):575–578

4 Banerjee S, Faizan A, Nevelos J, et al. Innovations in hip arthroplasty three-dimensional modeling and analytical technology (SOMA). Surg Technol Int 2014;24:288–294

5 Parratte S, Flecher X, Vesin O, Brunet C, Aubaniac J, Argenson J. Anatomy of the hip before total hip arthroplasty: A tridimentionnal Ct study of 469 patients. Orthop Proc 2018; 92-B Supp II. Disponível em: https://online.boneandjoint.org.uk/doi/abs/10.1302/0301-620X.92BSUPP_II.0920274d

6 Kang AC, Gooding AJ, Coates MH, Goh TD, Armour P, Rietveld J. Computed tomography assessment of hip joints in asymptomatic individuals in relation to femoroacetabular impingement. Am J Sports Med 2010;38(06):1160–1165

7 Abel MF, Sutherland DH, Wenger DR, Mubarak SJ. Evaluation of CT scans and 3-D reformatted images for quantitative assessment of the hip. J Pediatr Orthop 1994;14(01):48–53

8 Murtha PE, Hafez MA, Jaramaz B, DiGioia AM III. Variations in acetabular anatomy with reference to total hip replacement. J Bone Joint Surg Br 2008;90(03):308–313

9 Stem ES, O'Connor MI, Kransdorf MJ, Crook J. Computed tomography analysis of acetabular anteversion and abduction. Skeletal Radiol 2006;35(06):385–389

10 Mineta K, Goto T, Wada K, et al. CT-based morphological assessment of the hip joint in Japanese patients: association with radiographic predictors of femoroacetabular impingement. Bone Joint J 2016;98-B(09):1167–1174

11 Husmann O, Rubin PJ, Leyvraz PF, de Roguin B, Argenson JN. Three-dimensional morphology of the proximal femur. J Arthroplasty 1997;12(04):444–450

12 Pasquier G, Ducharne G, Ali ES, Giraud F, Mouttet A, Durante E. Total hip arthroplasty offset measurement: is C T scan the most accurate option? Orthop Traumatol Surg Res 2010;96(04):367–375

13 Dandachli W, Ul Islam S, Tippett R, Hall-Craggs MA, Witt JD. Analysis of acetabular version in the native hip: comparison between 2D axial CT and 3D CT measurements. Skeletal Radiol 2011;40(07):877–883

14 Lepage-Saucier M, Thiéry C, Larbi A, Lecouvet FE, Vande Berg BC, Omoumi P. Femoroacetabular impingement: normal values of the quantitative morphometric parameters in asymptomatic hips. Eur Radiol 2014;24(07):1707–1714

15 Anda S, Terjesen T, Kvistad KA. Computed tomography measurements of the acetabulum in adult dysplastic hips: which level is appropriate? Skeletal Radiol 1991;20(04):267–271

16 Tannast M, Hanke MS, Zheng G, Steppacher SD, Siebenrock KA. What are the radiographic reference values for acetabular under-

and overcoverage? Clin Orthop Relat Res 2015;473(04):1234–1246

17 Noble PC, Alexander JW, Lindahl LJ, Yew DT, Granberry WM, Tullos HS. The anatomic basis of femoral component design. Clin Orthop Relat Res 1988; ((235):148–165

18 Beltran LS, Mayo JD, Rosenberg ZS, et al. Fovea alta on MR images: is it a marker of hip dysplasia in young adults? AJR Am J Roentgenol 2012;199(04):879–883

19 Tannast M, Fritsch S, Zheng G, Siebenrock KA, Steppacher SD. Which radiographic hip parameters do not have to be corrected for pelvic rotation and tilt? Clin Orthop Relat Res 2015;473(04):1255–1266

20 Hauser DL, Fox JC, Sukin D, Mudge B, Coutts RD. Anatomic variation of structural properties of periacetabular bone as a function of age. A quantitative computed tomography study. J Arthroplasty 1997;12(07):804–811

