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Normative Values of Bone Mineral Content and Bone Mineral Density Assessed by Double X-ray Absorptiometry in Congolese Urban Women

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Abstract

Introduction: *The World Health Organization (WHO) have validated dual X-ray absorptiometry as the "gold standard" densitometric technique for assessing Bone Mineral Density (BMD) and Bone Mineral Content (BMC).*

The definitions of osteopenia and osteoporosis are based on its results Loss of bone mass with ageing or osteoprosis leads to decline of bone strength and fragility fractures. There are racial/ethnic differences in bone mass parameters for populations of different ethnic origins although living in the same environmental. WHO criteria for the diagnosis of osteoporosis and the associated risks of fractures are based on bone parameters assessed by dual x absorptiometry in postmenopausal Caucasian women. Studies have shown the necessity to establish reference data for bone mass measurements for each population according to habit and ethnicity.

These data are lacking for Congolese populations.

This study aims to establish spine and hip normative values in healthy Congolese women population and to compare them with those for Caucasian, Asian, and others ethnical groups.

Materials and methods: *604 bantus women aged from 18 to 92 years were recruited after public media advertising and undergoes DXA of spine and hip. To be included in the study, women must fulfill the conditions of absence of factor affecting bone metabolism.*

Results: *Bone mass parameters shows a growth up to the peak that is reached in the fourth decade followed by a slow decay that causes a loss of nearly 14.2% in BMD and BMC over a period of 20 years and, then a decrease more pronounced towards the sixtieth year (1.5% yearly), higher than among Caucasians Asians and Arabs. We found that the references curves for the lumbar spine and total hip are significantly differences from the Caucasian, Asean or Arab.*

Conclusion: *Spine and hip normatives values of BMD and BMC of Congolese urban women was etablished and were different to those of compared populations.*

Keywords

normative values, bone mass, DXA, Bone Mineral Density, Bone Mineral Content, Black women, Congolese

1. Introduction

The World Health Organization (WHO) has established Dual X-ray Absorptiometry (DXA) as the "gold standard" densitometric technique for assessing Bone Mineral Density (BMD) and the definitions of osteopenia and osteoporosis are based on its results (Cummings et al., 2002; IOF, 2011; Kanis et al., 2004; WHO, 1995; WHO, 2010). Bone is composed of collagen I as main organic phase and of hydroxyapatite crystals as the main inorganic phase, and a cellular component of osteoblasts and osteoclasts (Jager et al., 2010). Every year, the human body replaces not less than 10% of its bone mass by a resorption and formation process due to osteoclasts and osteoblasts. Formation of new bone is also related to synthesis of the organic matrix followed by deposition of calcium crystals, and a gradual maturation process (Kanis et al., 2004). Bone mass is a major determinant of bone strength and, after reaching peak values in the third decade of life, bone mass and density begins to decline until age 60-65 which results in low bone mass and decline of bone strength which is a risk factor for fragility fractures that occur with ageing and osteoporosis (Chami et al., 2006; Genant et al., 1999; Kabeya et al., 2017; Looker et al., 2013; WHO, 2010). The peak of bone mass and rate of decline seems related to ethnicity, environment and income level of nutritional habits (Wulan, 2010; Luckey at al., 2013).

Dual-energy X-ray Absorptiometry (DXA), which gives criteria for the diagnosis of osteoporosis and the associated risks of fractures, accurately provides information on bone mass and related indices of the axial and appendicular bone, according to values reported in postmenopausal Caucasian women (Borrud et al., 2010; Chami et al., 2006; Cipriani et al., 2017; Wulan et al., 2010).

Previous studies which investigated bio-anthropometrics (age, gender, height, weight) and ethnic group-specific differences in whole body and regional Bone Mineral Density (BMD in Europeans and overseas Caucasians, in Aseans, in South African Black and White populations in Middle-Eastern and Arab populations showed that there are racial/ethnic differences in BMD and BMC values of populations of different ethnic origins although living in the same environmental (Kelly et al., 2009; Kanis et al., 1997; Sangmo et al., 2011; Alacreu et al., 2017; Tracy et al., 2006; Luckey et al., 1996; Conradie et al., 2015; Muhamad et al., 2014; Aspray et al.,1995; Looker et al., 2013; Iki et al., 2001; El

Maghraoui et al., 2006) and shown the necessity to establish reference data for bone mass measurements for each population according to habit and ethnicity (WHO, 2004; Lewiecki et al., 2006; Ardawi et al., 2005; Kudlacek et al., 2003).

As osteoporosis is defined on the basis of the T-score, which is the difference between the measured BMD and the mean value of young adults expressed in Standard Deviations (SDs); the interpretation of the BMD data generated by DXA systems raises also many problems in clinical practice because it is a standard deviation from a normative population of the same ethnicity (Looker et al., 2013; Iki et al., 2001; El Maghraoui et al., 2006).

DXA machine manufacturers uses reference values based on an United States (U.S.) and/or northern European adult population, although some times providing data for some specifics ethnical groups.

If the reference values are not the ethnical one, there will be obvious consequences on the classification of subjects, what may lead in discrepancy of results. This literature review shows the necessity to establish reference data for bone mass measurements and patterns of bone loss for each particular population. Normative data for BMD and BMC for the Congolese population are lacking.

Thus, this study aims to establish spine and hip normative values in healthy Congolese female population and to compare them with those for Caucasian, Asian, and others ethical groups.

2. Materials and Methods

2.1 Subjects

A cross-sectional study of 604 women, selected in the urban area of Kinshasa, aged from 18 to 92 years of age was carried out to establish reference values of BMD. After a public media advertising call for check up, a total of 802 subjects were respondent from June 2016 to June 2017, whom 713 women and 89 men and our study group is constituted of 604 consecutives Black Bantoues women of Congolese origin who agreed to participate in the survey.

All the 802 subjects undergoes clinical examination by a physician, DXA, abdominal ultrasound, chest X-ray, head CT scanner, blood and urines samples were collected.

Results were given back to physician and Women were eligible for the study if they:

- were black Congolese from origin, living Kinshasa for, at least, 5 years.
- had no previous high or low energy vertebral fractures.
- had No diseases nor medications known to affect bone metabolism (cancer, diabetes, sicklanemia, prolonged diseases of the liver, kidney, thyroid gland, etc. or treatment using corticosteroids greater than or equal to 3 months, anticonvulsants, thyroid hormones, etc.).
- Have had a non perturbed menstrual and reproductive histories (Amenorrhea, anorexia nervosa, premature ovarian failure). Also excluded were women who had experienced an early menopause (before 40 years of age).
- Subjects from the postmenopausal group who had taken estrogens earlier (at least during the 2 years after menopause) or who still were taking estrogens were excluded, as well as those who had taken oral

corticosteroids for more than 6 months.

- Women using medications affecting calcium metabolism and those with medical conditions known to affect bone metabolism were excluded.

Thus, we excluded subjects with gastrectomy, intestinal resection, recent hyperthyroidism or hyperparathyroidism, treatment with corticosteroids, or recent severe immobilization.

We did not exclude individuals using inhalation steroids. We did not exclude subjects with certain lifestyle habits, such as heavy smoking, being sedentary, being athletic which are examples of voluntary factors that may have some impact on bone metabolism.

2.2 Measurements

- Anthropometric parameters (age, height, and weight) were collected according to standardized procedures. Weight was measured (kg) using portable digital scales to the nearest 0.1 kg (seca, Vivadia, Valbonne, France) and height was measured (cm) using a vertical stadiometer to the nearest 0.1 cm (seca, Vivadia, Valbonne, France).

- Body Mass Index (BMI) was calculated as follows: BMI was calculated by dividing weight in kilograms by height in meters squared [BMI in Kg/m^2 = w (Kg)/T^2 (m)].

A BMI ≥ 25Kg/m^2 defined the overweight and a BMI ≥ 30Kg/m^2 the obesity.

- The DXA examinations of the lumbar spine and proximal femurs were conducted with a QDR Discovery fan beam densitometer (Hologic, Inc., Bedford, MA, USA), in accordance with the procedures recommended by the manufacturer.

This Hologic QDR Discovery Densitometer is the first DXA machine installed in our country (1 DXA for at least 80 million people) installed in a private hospital of Kinshasa: The Harish Jagtani Hospital (HJ Hospital).

All subjects changed into light clothing and removed all jewelry and other things that could interfere.

The DXA Analysis was performed using Hologic Discovery software in its default configuration.

The examinations that revealed items with the ability to affect the accuracy of DXA results, such as prosthetic devices, implants, or other extraneous objects, were excluded. All BMD measurements were carried out by 2 trained technicians. The DXA instruments used in survey were calibrated according to the methods proposed by the manufacturer. At the time of the study, phantom measurements showed stable results. Patient BMD was measured at the lumbar spine (anteroposterior projection at L1 to L4 and L2 to L4) and the proximal femur region including the hip but only L2 to L4 and total hip results were used in the current study. The data sets include spine and hip DXA measurements of Bone Mineral Content (BMC, g), Bone Mineral Density (BMD, g/cm^2).

In total, from 713 women received, 109 individuals, were excluded from the study according to predetermined exclusion criteria, whereas 604, fully ambulatory, meets all inclusion criteria and were included in the study to consulate the reference population sample (220 premenopausal [36.42%] and 384 postmenopausal [63.57%] women). Data from men are not included in the present study.

2.3 Statistical Analysis

The statistical analysis was performed using commercially available software (SPSS version 21). The results were expressed as mean, standard deviation (mean ± SD), range (minimum and maximum values) and absolute (n) and relative (%) frequencies. The differences in BMD and BMC values between subgroups were analyzed using the Student's *t*-test. The threshold of significance was set at 0.05.

2.4 Ethics Statement

The study design was approved by the local ethics committee and the study was conducted in accordance with the declaration of Helsinki for human studies.

3. Results

3.1 Anthropometric and Biological Parameters

The anthropometric and biological characteristics of the 604 females studied are listed in Table 1.

Table 1. Anthropometrics and Biological Features of Our Subjects

	N	Minimum	Maximum	mean	Standard deviation
Age (years)	604	18	92	49,97	12,53
Weight (Kg)	604	31,00	133,99	79,93	16,79
Height (m)	604	1,46	1,83	1,65	0,065
BMI (Kg/m^2)	604	11,53	51,02	29,35	5,78
OHvitamine D (ng/ml)	604	13,30	59,20	29,53	8,96
Calcium (mg/dl)	604	8,1	11,0	9,35	,3980
Tsh3rd gen (µIU/ml)	604	0,32	8,93	1,77	1,12
Cholestérol (mg/dl)	604	101	393	201,70	42,26

Weight: From 16-25 years of age (mean 62.64 +- 15.99) to more than 75 years of age (mean 73.74 +- 13.96 Kg) an increase of +11.1 kg ($p < 0.001$) is observed.

Height: the size declined with age by 0.04 m ($p = 0.218$) from 16-25 years of age (mean 1.65+- 0.08 m) to more than 75 year age group (mean 1.61 +- 0.06). This decrease was not significant.

BMI: A significant increases ($p = 0.002$) is seen from 16-25 years of age (mean 22.92 +- 4.96 kg/m^2) to more than 75 years of age (mean 28.57 +- 5.12 kg/m^2) the BMI in women increased steadily until 65 years of age and then, remain stable.

Mean weight and BMI of our patients show high values and great proportion of our subjects are quoted over weight although the cholesterol mean level is in borderline. The TSH mean value seems normal. The CA++ level values which range from 8.1 to 11 mg/dl with mean value of 9.35 mg/dl in our study group are superimposable to worldwide accepted values (8.6 to 10 mg/dl for CA++). The OHvitamine

D mean level of 29.53 ng/ml is at the lower limit of worldwide normative values.

3.2 Spine BMC and BMD

Mean and Standard Deviation (SD) values of spine BMC and BMD according to age are presented in Table 2.

Table 2. Age-Related Variations of Values for Spine's BMC and BMD (L2 to L4) in Urban Congolese Female Adult

Age group		BMC		BMD	
	n	Mean	SD	Mean	SD
16-25	13	16,3490	5,70132	1,2155	0,26178
26-35	58	15,2566	2,76725	1,1199	0,19198
36-45	149	15,8508	2,96214	1,1353	0,15190
46-55	177	14,6251	2,97765	1,0521	0,16538
56-65	146	14,0314	3,79215	0,9749	0,19350
66-75	46	13,9308	3,59765	0,9713	0,19474
>75	15	11,1988	3,39455	0,8217	0,2062
Total	604				

The mean values of BMC and BMD on L2 to L4 vertebral spine shows a light increase to peak which is reached in the 36 to 45 years age group and then a decrease appears with age which is significative for BMD ($p = 0.012$) and BMC ($p = 0.008$). These data showed that mean BMD value of the spine of Congolese females was declining with age, especially in their post-menopausal period with accelerated decline after age 65 years. The peak BMD of the spine and proximal femurs was reached in the fourth decade of life. The spine BMD values between 36-45 years were defined as the peak bone mass values. Between 46 and 65 years, there was a linear decline of BMD (equivalent to a decrease of approximately 14.2% or 0.71% per year). The apparent decrease was higher between 66 and more than 75 years (15.7% or -1.57% per year). Congolese women exhibited a similar pattern of decrease in BMD that was also described for U.S., European, Lebanese, Saudi, and Kuwaiti reference values.

3.3 Total HIP BMC and BMD

Means and SD values of Surface, BMC and BMD on the hip according to age are presented in Table 3.

Table 3. The Age-Related Variations of Total Hip Bone Mass Indices and Standard Deviation

TOTAL HIP BONE MASS						
AGE GROUP		N	Minimum	Maximum	mean	SD
15-25 years	Surface (cm^2)	16	3,43	6,29	4,7766	1,09906
	BMC (gr)	16	3,72	5,69	4,6716	83848
	BMD (gr/cm^2)	16	0,71	1,63	1,0517	33638
26-35 years	Surface (cm^2)	45	2,22	6,66	4,5694	96549
	BMC (gr)	45	2,35	5,83	4,3526	93905
	BMD (gr/cm^2)	45	0,49	1,65	0,9859	27183
36-45 years	Surface (cm^2)	96	2,22	7,47	4,6127	77295
	BMC (gr)	96	1,89	6,23	4,4255	77171
	BMD (gr/cm^2)	96	0,43	1,63	0,9593	19557
46-55 years	Surface (cm^2)	92	3,48	17,94	4,8526	1,45178
	BMC (gr)	92	2,38	21,10	4,4700	1,87561
	BMD (gr/cm^2)	92	0,46	1,65	0,9300	17786
56-65 years	Surface (cm^2)	86	2,25	5,77	4,7500	51324
	BMC (gr)	86	1,71	6,03	3,8500	77981
	BMD (gr/cm^2)	86	0,38	1,14	0,8100	15443
66-75 years	Surface (cm^2)	25	2,00	5,65	4,6700	69017
	BMC (gr)	25	1,36	6,84	3,4600	1,07408
	BMD (gr/cm^2)	25	0,34	1,45	0,7200	20692
over 75 years	Surface (cm^2)	7	4,25	6,64	4,3900	75659
	BMC (gr)	7	2,00	6,72	3,5800	1,49646
	BMD (gr/cm^2)	7	0,40	1,01	0,6900	18356
Total		367				

The means values of surface, BMD and BMC of hip show very small differences between neighboring age groups, without significant statistical differences ($p > 0.5$).

The differences become significant when young adult subjects are compared with persons aged over 65 years of age ($p = 0.001$) where the loss became important.

3.4 Z-score

The age-related variations of means and standards deviation (means + SD, + 2.5 SD and minus 1 SD and minus 2.5 SD) of BMD assessed on L2 to L4 spine vertebrae in Congolese urban females are presented in Table 4 which enables to generate curves of Z-score.

Table 4. Age-Related Variations of Means BMD and SD in Congolese Female Subjects

Age group	15-25 years	26-35 years	36-45 years	46-55 years	56-65 years	66-75 years	over 75 years
+ 2.5 SD	1.86995	1.61985	1,49505	1,46555	1,45865	1,45815	1,3372
+ 1 SD	1,47728	1,33188	1,2672	1,21748	1,1684	1,16604	1,0279
Mean	1,2155	1,1399	1,1153	1,0521	0,9749	0,9713	0,8217
-1 SD	0,95372	0,94792	0,9634	0,88672	0,7814	0,77656	0,6155
-2.5 SD	0,56105	0,65995	0,73555	0,63865	0,49115	0,48445	0,3062

Note. Profile of parameters includes an increase, a peak and a decrease.

Figure 1 is a normogram for BMD showing the curves of the mean plus or minus 1 and 2.5 standard Deviations.

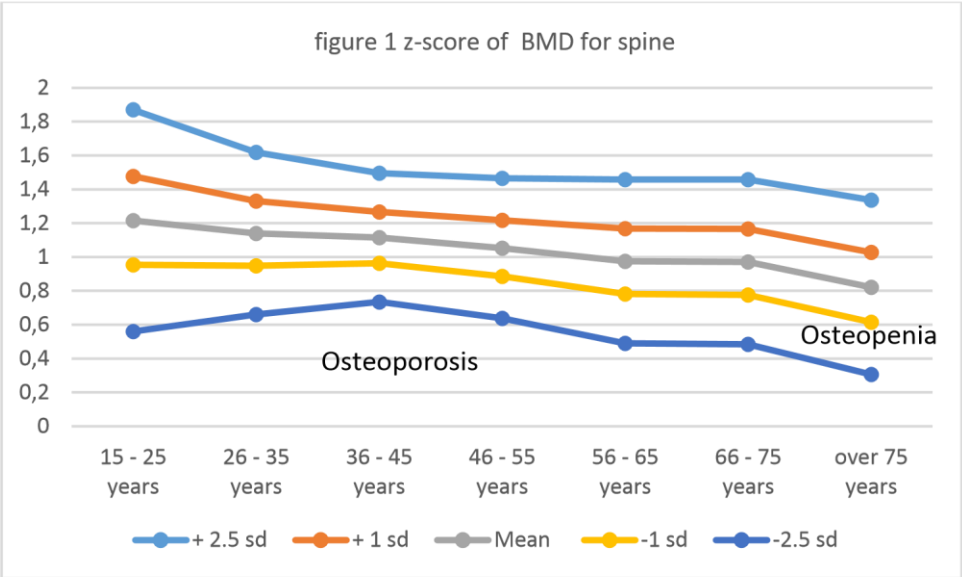

Figure 1. Z-score of BMD for Spine

The standard deviations are wide at the beginning of growth generating a fan-shaped profile. Osteopenia being defined between the curves mean minus 1 SD and the curve mean minus 2.5 SD. Osteoporosis is defined by the area below of the curve of mean minus 2.5 SD. The age-related variations of means and SD (means + 1SD,+ 2.5 SD and minus 1 SD and minus 2.5 SD) of BMC assessed on L2 to L4 spine vertebrae in congolese urban females are presented in Table 4 wich enables to generate curves of Z-score.

Table 5. Age-Related Variations of Means BMC and SD in Congolese Women

Age group	15-25 years	26-35 years	36-45 years	46-55 years	56-65 years	66-75 years	over 75 years
+2.5 SD	30.6022	22.1746	23.2560	22.0691	23.5116	22.9248	19.6850
+1 SD	22.0503	18.0238	18.8129	17.6027	17.8235	17.5285	14.5933
MEAN	16.3490	15.2566	15.8508	14.6251	14,0314	13.9308	11,1988
-1 SD	10.6477	12.4894	12.8887	11.6475	10.2393	10.3332	7.8043
-2.5 SD	2,0958	8.3386	8.4456	7.1811	4.5512	4.9368	2.7126

Figure 2 is a normogram for BMC showing the curves of the mean plus or minus 1 and 2.5 SD. Osteopenia being defined between the curves of mean minus one SD and the curve of mean minus 2.5 SD. Below the curve of the mean minus 2.5 standard deviation, osteoporosis is located.

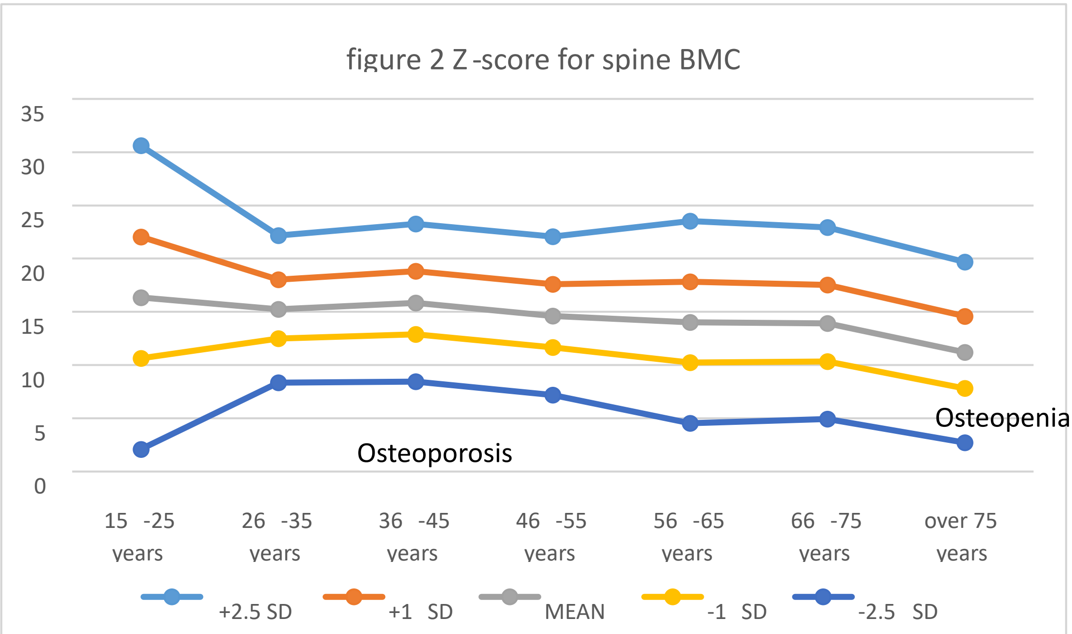

Figure 2. Z-score for Spine BMC

Osteopenia and osteoporosis are defined as reported for BMD.

3.5 T-score

Table 6 report means values, range and SD of parameters measured in young adult female subjects aged 30 to 40 years of age to assess T-score.

Table 6. Parameters in 30 to 40 Years Bantoues Female in Kinshasa

	n	mean	Std. d.	maximum	minimum
HEIGHT (m)	115	1.65	0.07	1.81	1.46
WEIGHT (kg)	115	75.31	13.83	114.99	31
BMI (kg/m^2)	115	27.68	4.85	41.31	11.53
BMC spine (gr)	115	16.58	2.81	25.55	11.45
BMD spine (gr/cm^2)	115	1.14	0.14	1.52	0.70
SURFACE spine (cm^2)	115	14.62	1.50	19.43	11.31
BMC total Hip (gr)	115	4.31	0.80	6.11	2.35
BMD total Hip (gr/cm^2)	115	0.94	0.17	1.27	0.49
SURFACE total Hip (cm^2)	115	4.43	0.62	5.19	2.22

4. Discussion

Many studies have assessed BMC and BMD, but a standard source for reference values for Congolese population were lacking. Data for these reference values were acquired using well-established DXA technology which is, for the first time installed in our country of not less 80 millions of people in the Harish Jagtani hospital (a private hospital of Kinshasa). These references values did not include the tutsi ethnic population of Congo whom only 4 individuals were respondant. Our subjects mean height (Table 1) is surimposable to others people although haven't shown the significant attended decrease in height, even in subjects aged over 75 years of age. This may be a consequence of rare vertebral fractures (Kabeya et al., 2017) or due to non-linearity of data in a cross sectional study like ours. Weight and BMI in our subjects (Table 2) are higher than others peoples and efhnicities (El Maghraoui et al., 2006: Luckey et al., 2013). These patterns possibly reflect the increase in the prevalence rate of severe obesity among the Congolese female. However, when we define overweightness and obesity according to Fat Mass Index (FMI) classification (Kelly et al., 2009), the rate of obesity and overweightness were similar to those of other ethnicities in the American's NHANES (Luckey et al., 2013). After a regular increase from 16-25 to 6th decade of life, there is not increase after 60 years of age.

Lack of increase of BMI after 60 years of age must be questioned. Is it due to the worldwide concern about sarcopenia (the degenerative loss of skeletal muscle mass with age)?

Although all subjects of our study group were ambulant and self-dependent, a study involving elderly subjects showed that sarcopenia was an indicator of self-reported physical disability in elderly independent of other covariates such as age, obesity, ethnicity, and income levels (Wulan et al., 2010).

Furthers studies on body composition are needed to give evidence based answers.

Among our subject, BMD and BMC in persons aged less than 46 years was significantly higher than in those aged 46-75, and significantly lower in persons aged over 75 than in those aged 46-75 as seen in ultrasound assessment in the same population (Kabeya et al., 2017).

All of these data are higher (about 2% to 11% more) than in Caucasians and non-hispanic black U.S. citizens of all ethnicities as seen in Figure 3 from Luckey et al. (2013), slight modified by us. Luckey et al. (2013) also reported that BMD was significantly higher in non-Hispanic black persons than in non-Hispanic white persons, regardless of age or sex.

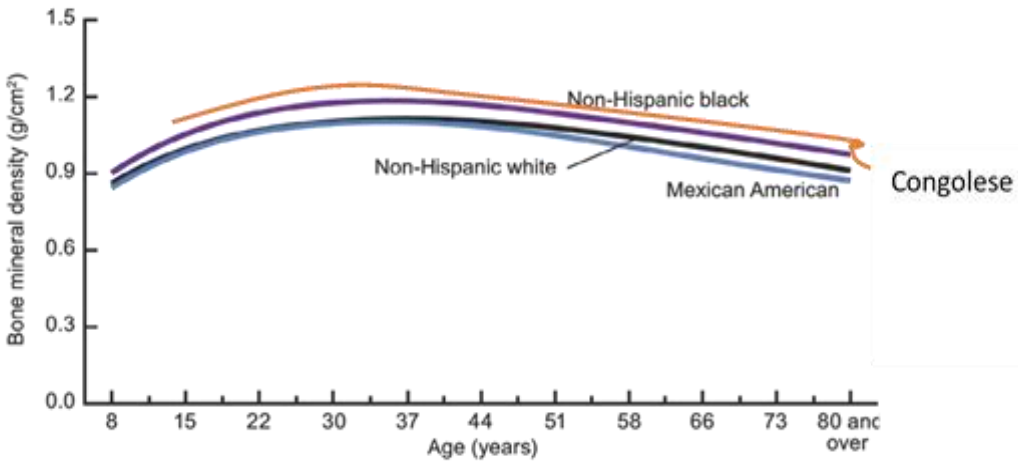

Figure 3. Comparative Curve of Spine BMD

When curves of Bone Mineral Density (g/cm^2) (Figure 4) of Congolese's total hip are compared to those of United States and European Caucasians, and Arab women especially Kuwaitis, Lebanon, Morocco, Saudi Arabia and Moroccans (El Maghraoui et al., 2006), Congolese women total hip have superimposable values up to 6th decade of life but thereafter, the decrease rate is higher in Congolese.

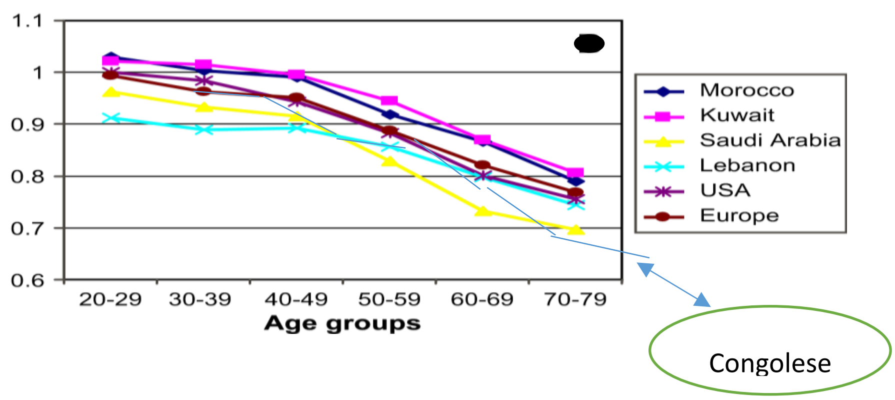

Figure 4. Comparative Values of Hip BMD

The differences in BMD values between women of differences ethnicities were thought to be a result of the differences in exercise, lifestyle and income level which interacts with body weight and obesity (Gougherty et al., 2001; Hammoudeha et al., 2005; Kelly et al., 2009). Body weight and obesity are also well known to correlate well positively with BMD (Chen et al., 1997; Kim et al., 2010; Leslie et al., 2017). Our population study had a mean BMI of 29.35 kg/m^2 which is higher than the values (about 24 in most series) reported in Caucasians, Arab and ASEANs populations (Albala et al., 1996; El Maghraoui et al., 2006; Sangmo et al., 2011; Leslie et al., 2017).

One must remark that a decrease in BMD is noted in our series after 65 year of age, concomitant with decrease in BMI. Life style seems not to be the principal factor of this difference, as U.S women of different ethnicity but same life style experience in different ways the hormonal privation (Luckey et al., 1996; Conradie et al., 2015). Furthermore, most of Kinshasa's women have a sedentary lifestyle and have experienced multiparity and lactation, which are well recognized as important osteoporosis risk factors although out-door activities are regular in ours women's life style. Our data demonstrate significant differences in spine and hip BMC and BMD between Congolese and Caucasians, ASEANs and Arab populations.

The present study is the first large-scale report on normative values on the BMD and BMC of the lumbar spine and the hip in healthy ambulatory Congolese women aged 16 to 92 years with defined exclusion criteria. The main limitation of our study lies in the cross sectional study of urban population to establish a reference database for the whole country whose rural inhabitants are in the majority.

5. Conclusion

A Congolese reference BMD and BMC for women has been established for the lumbar spine and hip on a selected sample of adequate size of the Urban population of Kinshasa. From the period of adolescence, we note a growth in bone mass parameters up to the peak that is reached in the fourth decade followed by a slow decay that causes a loss of nearly 14.2% in BMD and BMC over a period of almost 20 years and then a decrease towards the sixtieth year, which seems more pronounced (1.5% yearly), than among Caucasians Asians and Arabs. We found that the references curves for the lumbar spine and total hip are significantly differences from the Caucasian, ASEAN or Arab normative data. Further studies are needed to confirm linearity of phenomenon and best understanding of risk factors.

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