Estimation of Femur Length From Its Fragments in an Iranian Population

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Abstract- Stature is one of the important variables to identify an individual, and the previous reports show that intact femur has the highest correlation with stature. But the femur is usually damaged in forensic cases. Hence in the present study, the femur length is estimated from proximal and distal femoral fragments in the Iranian population. Sixty-four dry femora (32 from each side) without sex determination were studied. The variables were measured by using the osteometric board and digital vernier caliper. The bones with visible abnormalities were excluded from the study. The measured values were analyzed by SPSS 25 software. The linear regression is used for estimating maximum femur length from the other measurements of femoral fragments. The result of this study showed that the value of segmental measurements was different between the right and left sides, but it was not statistically significant. All segmental measurements were positively correlated and found to have a linear relationship with the maximum femoral length ($P<0.05$) except for femoral neck circumference, which was not significantly different. The regression equation suggested that the intertrochanteric crest length is the best estimator of maximum femur length. The data of this study showed that the femoral length could be estimated from proximal and distal femoral fragments with the help of a regression equation. Then femoral length can be used to estimate the stature. The result of this study can be used in the analysis of forensic bone remains.

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Keywords: Maximum femur length; Femoral fragments; Intertrochanteric crest length; Regression equation

Introduction

In humans, stature is one of the important parameters. It could be estimated with long bones (1). The stature reconstruction from long bones is important in forensic identification anatomic and archaeological cases. It is also important in rebuilding lost parts in plastic surgery and in making bone prostheses (2).

On the other hand, the long bones are often damaged or fractured in forensic cases by motor vehicle accidents, natural disasters, and injuries. This makes it difficult to estimate the stature. In such cases, the ratio between a fragment of a long bone and the length of that bone can be beneficial for estimating the height of the individual (3).

The previous studies revealed that portions of a long bone could determine the total length of that bone (3,4). But the estimation of height from a limb bone fragment is difficult (5,6). Generally, Skeletal development is affected by environmental factors such as nutrition, physical development, and genetic factors. Also, factors such as age, sex, race can cause a variation in the length of bones and stature in different populations (7-10). Thus it seems essential to carry out specific studies to estimate the stature and length of long bones from their fragments on different populations (11).

Based on studies, the femur is one of the bones which has the highest correlation with stature and is more accurate for estimating height compared to the other long bones (3). Because of that, in this study, the femur length was determined in relation to the proximal and distal fragments of the femur among the Iranian population, and the regression equations were calculated for the estimation of femur length from the fragments. Therefore, in the partial presence of the femur length, it is possible to determine it through these equations, and

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consequently, the stature can be estimated.

Materials and Methods

In this study the data was obtained from direct measurement of dry bones. A total of 64 femora (32 right sided and 32 left sided) without sex distinctions from human Iranian cadavers were measured for the study. These bones were collected in the Department of Anatomical Sciences, Arak University Medical Sciences, Arak, Iran.

We excluded the bones with visible abnormalities and pathologies such as tumors, deformities, fractures and trauma. In present study, maximum length of femur along with five segmental measurements, three proximal and two distal measurements, were taken by using anthropometric instruments such as osteometric board and digital vernier caliper with precision of 0.01 mm.

The parameters were measured according to the standard procedure suggested by Trotter M and Glesser GC, including: (12)

1. Maximum Femoral Length (MFL): Distance from most proximal point of head of the femur to the most distal point of medial condyle (Figure 1)
2. Femoral Neck Length (FNL): The distance between the base of the head and the intertrochanteric line at the junction of the back of the neck with the shaft (Figure 2, A)
3. Femoral Neck Circumference (FNC): Circumference of the neck at the middle of femoral neck length (FNL) (Figure 2, B)
4. Intertrochanteric Crest Length (ICL): The most proximal point of the greater trochanter to the lowest point of the lesser trochanter (Figure 2, C)
5. Medial Condyle Length (MCL): The linear distance between the most anterior and the most posterior points on the medial condyle (Figure 3, A)
6. Lateral Condyle Length (LCL): The linear distance on the lateral condyle measured in an anteroposterior direction (Figure 3, B)

We considered the correlation coefficient between 0.00 and 0.30 as weak, between 0.30 and 0.70 as moderate, and above+0.70 as high (2).

Figure 1. Measurement of maximum femoral length (MFL)

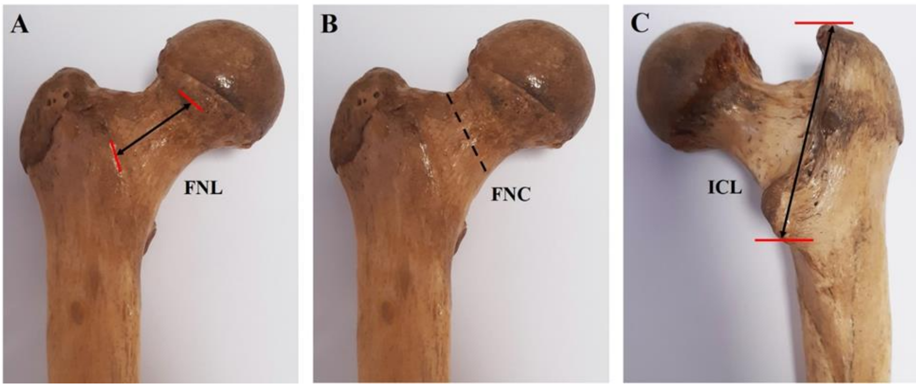

Figure 2. Measurement of (A) Femoral neck length (FNL), (B) Femoral neck circumference (FNC), and (C) Intertrochanteric crest length (ICL)

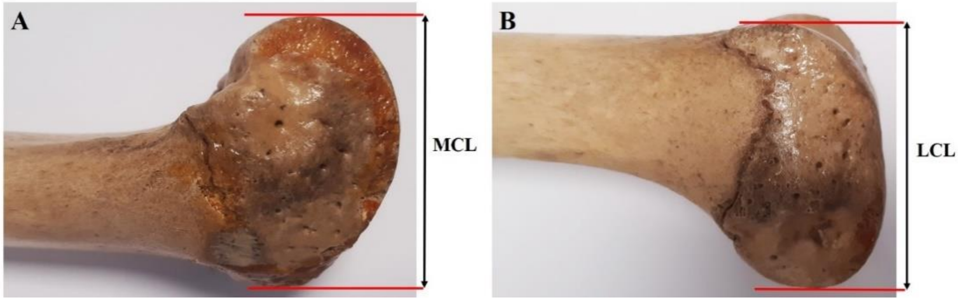

Figure 3. Measurement of (A) Medial condyle length (MCL) and (B) Lateral condyle length (MCL)

Statistical analysis

The data were analyzed by SPSS 25 software. The normality of data was tested by Kolmogorov-Smirnov test (K-S test). Independent-Samples T-Test was used to compare the value of segmental measurements between femurs of right and left sides. Results were expressed as mean±standard deviation (SD). $P<0.05$ was taken as statistically significant between the two groups.

Then, the relationship between quantitative data was assessed by Bivariate correlation (Pearson's correlation coefficient), and the linear regression equations were used to estimate the maximum femoral length (as dependent variable) from other measurements of the femoral fragments (as the independent variables).

Results

The present study was done among the 64 dry femora (32 right-sided and 32 left-sided) present in the Department of Anatomical Sciences, Arak University Medical Sciences, Arak, Iran. Results were analyzed by calculating the statistics of individual variables in total samples and between the right and left sides.

The mean of maximum femoral length (MFL) and other fragments in total samples and in the right and the left side is shown in Tables 1 and 2. There was no statistically significant difference between the right and left sides in all the parameters (Table 2).

Table 1. Comparison of mean of maximum femoral length and other parameters for total subjects (N=64)

Parameters	N	Mean ± SD
Maximum Femoral Length	64	42.675±2.857
Intertrochanteric Crest Length	64	7.328±0.637
Femoral Neck Length	64	4.450±0.543
Femoral Neck Circumference	64	10.292±0.942
Medial Condyle Length	64	3.658±0.359
Lateral Condyle Length	64	3.523±0.280

Table 2. Comparison of mean of maximum femoral length and other parameters between right and left side (N=32)

Parameters	N		Mean±SD		*P*	Significance
	Right side	Left side	Right side	Left side		
Maximum Femoral Length	32	32	43.018±2.668	42.331±3.038	0.340	NS
Intertrochanteric Crest Length	32	32	7.359±0.604	7.296±0.677	0.698	NS
Femoral Neck Length	32	32	4.435±0.536	4.464±0.558	0.838	NS
Femoral Neck Circumference	32	32	10.434±0.891	10.150±0.983	0.230	NS
Medial Condyle Length	32	32	3.667±0.328	3.650±0.392	0.850	NS
Lateral Condyle Length	32	32	3.556±0.240	3.490±0.316	0.354	NS

NS: Not Significant

According to the results, there was a correlation between the maximum femoral length and the various segmental measurements that were statistically significant ($P<0.05$) except for femoral neck circumference (Table 3).

Among all the fragments, the intertrochanteric crest length displayed the highest correlation with the MFL (r=0.620, *P*=0.000, and Table 3). The medial condyle length (r=0.304, *P*=0.015) and the lateral condyle length (r=0.309, *P*=0.013) showed moderate correlation with the MFL (Table 3). Also, there was a weak correlation between the femoral neck length with the MFL (r=0.237, *P*=0.059, and Table 3).

Based on the results, there is a moderate correlation between intertrochanteric crest length and maximum femoral length on the right side (r=0.584, *P*=0.000 and Table 3). In the left side, there is significant positive correlation between ICL (r=0.647, *P*=0.000), FNC (r=0.395, *P*=0.025) and LCL (r=0.415, *P*=0.018) with MFL (Table 3). The intertrochanteric crest length displayed the highest correlation with maximum femoral length on the left side.

Table 3. Correlation between maximum femoral length and other parameters in total samples and each side

Variables	Total (64)		Right (32)		Left (32)	
	Pearson correlation (r)	*P*	Pearson correlation (r)	*P*	Pearson correlation (r)	*P*
Maximum Femoral Length	1	-	1	-	1	-
Intertrochanteric Crest Length	0.620	0.000	0.584	0.000	0.647	0.000
Femoral Neck Length	0.237	0.059	0.216	0.236 NS	0.265	0.142 NS
Femoral Neck Circumference	0.219	0.083 NS	-0.035	0.848 NS	0.395	0.025
Medial Condyle Length	0.304	0.015	0.257	0.155 NS	0.336	0.060 NS
Lateral Condyle Length	0.309	0.013	0.127	0.487 NS	0.415	0.018

NS: Not Significant

Linear regression equations were used for the estimation of maximum femoral length (dependent variable) from each segmental measurement (independent variables). Accordingly, the regression equations derived from intertrochanteric crest length, femoral neck length, medial condyle length, lateral condyle length for estimating the MFL were statistically significant (Table 4). The regression equation from intertrochanteric crest length displayed a higher correlation coefficient (*P*=0.000, Table 4). Equations were derived from both right and left-sided femora individually to estimate MFL through intertrochanteric crest length was statistically significant (*P*=0.000, Table 5). Also, on the left side, the regression equations of femoral neck circumference (*P*=0.025) and lateral condyle length (*P*=0.018) were significant (Table 5). The correlation between maximum femoral length with other parameters is shown in Scatter graphs in all samples (Figure 4).

Table 4. Linear regression analysis for the studied population with maximum femoral length as the dependent variable and other parameters as independent variables in total samples (N=64)

Variables	R	R^2	Adjusted R^2	SE	B	*P*	Regression equations
Intertrochanteric Crest Length	0.620	0.385	0.375	0.446	22.310 2.779	0.000	MFL=22.310+2.779(ICL)
Femoral Neck Length	0.237	0.056	0.041	0.648	37.123 1.248	0.059	MLF=37.123+1.248(FNL)
Femoral Neck Circumference	0.219	0.048	0.032	0.376	35.852 0.663	0.083 NS	MLF=35.852+0.663(FNC)
Medial Condyle Length	0.304	0.092	0.077	0.963	33.839 2.415	0.015	MLF=33.839+2.415(MCL)
Lateral Condyle Length	0.309	0.096	0.081	1.229	31.589 3.146	0.013	MLF=31.589+3.146(LCL)

R: Pearson's correlation, R^2: Coefficient of Determination, SEE: Standard Error of the Estimate, B: Unstandardized Coefficients, NS: Not Significant, MLF: Maximum Femoral Length, ICL: Intertrochanteric Crest Length, FNL: Femoral Neck Length, FNC: Femoral Neck Circumference, MCL: Medial Condyle Length, LCL: Lateral Condyle Length

Table 5. Linear regression analysis for the studied population with maximum femoral length as the dependent variable and other parameters as independent variables in the right and left side, separately (N=32)

Variables	Side	R	R^2	Adjusted R^2	SE	B	*P*	Regression equations
Intertrochanteric Crest Length	Right	0.584	0.341	0.319	0.654	24.055 2.577	0.000	MFL=24.055+2.577(ICL)
	Left	0.647	0.419	0.400	0.624	21.141 2.904	0.000	MFL=21.141+2.904(ICL)
Femoral Neck Length	Right	0.216	0.047	0.015	0.886	38.261 1.072	0.236 NS	MLF=38.261+1.072(FNL)
	Left	0.265	0.070	0.039	0.957	35.890 1.443	0.142 NS	MLF=35.890+1.443(FNL)
Femoral Neck Circumference	Right	0.035	0.001	-0.032	0.546	44.120 -0.105	0.848 NS	MLF=44.120-0.105(FNC)
	Left	0.395	0.156	0.128	0.518	29.962 1.219	0.025	MLF=29.962+1.219(FNC)
Medial Condyle Length	Right	0.257	0.066	0.035	1.432	35.352 2.091	0.155 NS	MLF=35.352+2.091(MCL)
	Left	0.336	0.113	0.084	1.331	32.822 2.605	0.060 NS	MLF=32.822+2.605(MCL)
Lateral Condyle Length	Right	0.127	0.016	-0.017	2.009	37.990 1.414	0.487 NS	MLF=37.990+1.414(LCL)
	Left	0.415	0.172	0.145	1.594	28.424 3.984	0.018	MLF=28.424+3.984 (LCL)

R: Pearson's correlation, R^2: Coefficient of Determination, SEE: Standard Error of the Estimate, B: Unstandardized Coefficients, NS: Not Significant, MLF: Maximum Femoral Length, ICL: Intertrochanteric Crest Length, FNL: Femoral Neck Length, FNC: Femoral Neck Circumference, MCL: Medial Condyle Length, LCL: Lateral Condyle Length

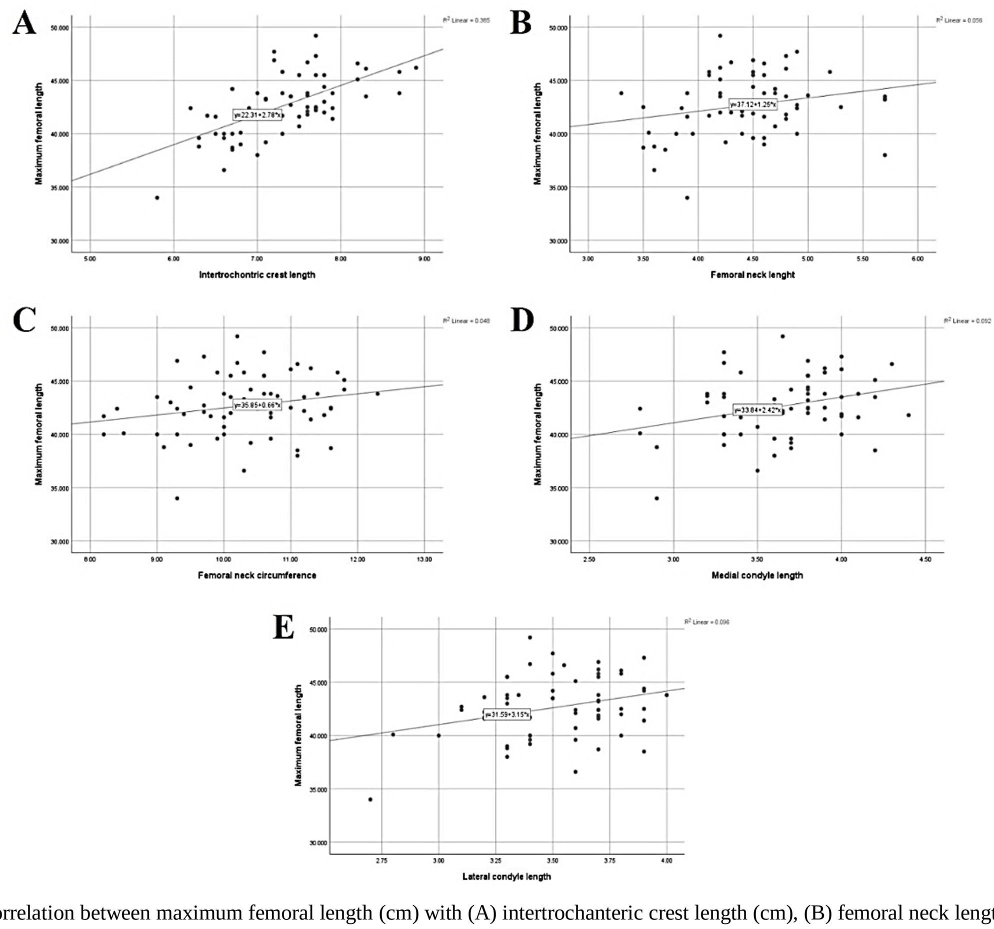

Figure 4. Correlation between maximum femoral length (cm) with (A) intertrochanteric crest length (cm), (B) femoral neck length (cm), (C) femoral neck circumference (cm), (D) medial condyle length (cm) and (E) lateral condyle length (cm)

Discussion

The present study was carried out among 64 dry femora (32 from each side). The maximum femoral length with three proximal and two distal fragments was measured.

The result of this study shows that the value of intertrochanteric crest length (ICL) in all samples was 7.328±0.637 cm which was higher than the study done among the Nepali population (5.04±0.71) and the Indian population (6.31±0.47) (13,14). ICL displayed the highest correlation with the MFL with a correlation coefficient of 0.620, which was more than that of Nepali (r= 0.275) and Indian populations (r=0.58) (13,14). Geographic, diet, and racial diversity might be the reason for different skeletal development (13).

Moreover, in our study, the proximal femoral fragment ICL had a high correlation with MFL in each of the right and left sides. Hence, the regression formula using the ICL measurement is proved to be more beneficial for estimating the maximum femoral length in the Iranian population.

According to the results, the mean femoral neck length (FNL) was 4.450±0.543 cm which was higher than the Nepali population (3.78±0.53), Chilean population (3.59±0.43 cm), and Tamil Nadu in Southern India (2.84±0.45 cm) (13,15,16). The correlation of FNL with MFL was 0.237, which was similar to the population of Nepali (r=0.290) and lower than Tamil Nadu in Southern India (r=0.474) (13,16).

A long femoral neck in the proximal part of femur increases the possibility of fracture (17).

In our study, FNL segment is the weakest predictor, consistent with Osorio's study and contrary to Prasad's study (13,16).

The femoral neck circumference (FNC) was also 10.292±0.942 cm in the present report, which is more than that of the Nepali population (9.37±0.75) and Chilean population (9.7±0.89) (13,15). While there is a significant correlation between FNC and MFL (r=0.427, *P*=0.001) in Nepali population, such a correlation was not found in our study (r=0.219, *P*=0.083) (13). Except for the left side, in which the proximal femoral fragment FNC had a moderate correlation to MFL (r=0.395, *P*=0.025).

Different shapes of femur following racial diversity is a determining factor for hip fracture in various populations (18).

The mean of medial condyle length (MCL) and lateral condyle length (LCL) were 3.658±0.359 cm and 3.523±0.280 cm, respectively, for the present study. They were lower than the findings of the study among the population of Nepali that MCL and LCL were 5.74±0.41 cm and 5.60±0.49 cm, respectively, Greek population that MCL was 5.87±0.41 cm and LCL was 5.85±0.40 cm, South African population that MCL and LCL were 6.12±0.36 cm and 6.22±0.39, respectively and Indian population (MCL=6.3±0.5 and LCL=6.2±0.5) (13,19-21).

In the present study, the mean of MCL was slightly higher than that of LCL, which was similar to the findings shown by Khanal *et al*., (in Nepali population), Terzidis *et al*., (in Greek population), and M. Chandran *et al*., (in Indian population) (13,19,21).

The correlation coefficient of MCL in present study was 0.304 which was less than that of Nepali (r=0.462), South African (r=0.71 for male and r=0.62 for female) and Indian population (r=0.81) (13,20,21). Also, the correlation of LCL with MFL was 0.309 which was more than that of Nepali (r=0.277) and less than South African (r=0.63 for male and r=0.71 for female) and Indian population (r=0.79) (13,20,21).

To design knee prostheses, the length of medial and lateral condyles are involved as key parameters (19).

Considering the result of this study, which showed no significant difference between the femoral measurements in the right and left sides, the femur fragments could be a surgical template for the opposite side.

The result of the current study revealed that the intertrochanteric crest length displayed the best correlation with MFL. The regression formula, using intertrochanteric crest length measurement, will prove to be more suitable compared with other fragments to estimate MFL in all samples and both sides individually among the Iranian population.

The current study showed that FNL has a poor correlation with the maximum femoral length, indicating the lower predictive efficiency of this variable, contrary to the Prasad *et al*., study (16). Also, there was no significant correlation between FNC and MFL in all samples. But FNC had a significant correlation with MFL in the left side, contrary to the Khanal *et al*., study (13).

The current study displayed those proximal and distal femoral fragments have correlations with the maximum femoral length. In the absence of intact long bones, regression equations derived from the present study can suggest a sensible estimate of femur length. Thus, the stature of the individual adults can be calculated from the length of the femur. The highest degree of correlation was found for ICL measurement with the MFL. Therefore, ICL is very effective in measuring the length of the femur. However, further studies in different races and in larger samples are required in order to get more accurate estimates in various populations, especially because nutrition, genetic variation, and hormones can have a serious effect on skeletal development.

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References

1. Hauser R, Smoliński J, Gos T. The estimation of stature on the basis of measurements of the femur. Forensic Sci Int 2005;147:185-90.
2. Timonov P, Fusova A. Reconstruction of femur length from its proximal fragments in a Bulgarian modern population. Aust J Forensic Sci 2018;50:403-13.
3. Parmar AM, Shah KP, Goda J, Aghera B, Agarwal G. Reconstruction of Total Length of Femur From its Proximal and Distal Fragments. Int J Anat Res 2015;3:1665-8.
4. Rother P, Jahn W, Hunger H, Kurp K. Determination of body height from fragments of the femur. Gegenbaurs Morphol Jahrb 1980;126:873-83.
5. McHenry HM. Femoral lengths and stature in Plio-Pleistocene hominids. Am J Phys Anthropol 1991;85:149-58.
6. Nath S. Reconstruction of tibial length and stature from fragmentary dimensions. J Hum Ecol 2000;11:167-76.
7. Giannecchini M, Moggi- Cecchi J. Stature in archeological samples from central Italy: methodological issues and diachronic changes. Am J Phys Anthropol 2008;135:284-92.
8. Bogin B, Varela-Silva MI. Leg length, body proportion, and health: a review with a note on beauty. Int J Environ Res Public Health 2010;7:1047-75.
9. Ruff CB, Holt BM, Niskanen M, Sladék V, Berner M, Garofalo E, et al. Stature and body mass estimation from skeletal remains in the European Holocene. Am J Phys Anthropol 2012;148:601-17.
10. Roseman CC, Auerbach BM. Ecogeography, genetics, and the evolution of human body form. J Hum Evol 2015;78:80-90.
11. Babu RU, Sadashiv R, Kiran J. Reconstruction of Femur Length from its Fragments. Indian J of Forensic Med Toxicol 2013;7.
12. Trotter M, Gleser GC. Estimation of stature from long bones of American Whites and Negroes. Am J Phys Anthropol 1952;10:463-514.
13. Khanal L, Shah S, Koirala S. Estimation of total length of femur from its proximal and distal segmental measurements of disarticulated femur bones of Nepalese population using regression equation method. J Clin Diagn Res 2017;11:HC01-5.
14. Singh S, Nair SK, Anjankar V, Bankwar V, Satpathy D, Malik Y. Regression equation for estimation of femur length in central Indians from inter-trochanteric crest. J Indian Acad Forensic Medi 2013;35:223-6.
15. Forenses AT. Proximal femoral epiphysis anatomy in Chilean population. Orthopedic and forensic aspects. Int J Morphol 2012;30:258-62.
16. Prasad R, Vettivel S, Jeyaseelan L, Isaac B, Chandi G. Reconstruction of femur length from markers of its proximal end. Clin Anat 1996;9:28-33.
17. Lamichhane AP. Osteoporosis-an update. JNMA J Nepal Med Assoc 2005;44:60-6.
18. Mikhail M, Vaswani A, Aloia J. Racial differences in femoral dimensions and their relation to hip fracture. Osteoporos Int 1996;6:22-4.
19. Terzidis I, Totlis T, Papathanasiou E, Sideridis A, Vlasis K, Natsis K. Gender and side-to-side differences of femoral condyles morphology: osteometric data from 360 Caucasian dried femori. Anat Res Int 2012;2012:679658.
20. Bidmos MA. Estimation of stature using fragmentary femora in indigenous South Africans. Int J Legal Med 2008;122:293-9.
21. Chandran M, Kumar V. Reconstruction of femur length from its fragments in South Indian males. J Forensic Leg Med 2012;19:132-6.