

## Research Article

# A New Definition of Hip Geometry Measures to Evaluate Hip Fracture Risk

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## Keywords

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- Femoral neck fracture
- Trochanter fracture
- Fracture risk assessment

## Abstract

**Background:** Our goal was to test the influence of the anatomical position of the head in relation to the femoral neck on the quality of Hip Geometry (HG) for a better diagnosis of people running risk of femoral neck and trochanter fractures. The previously used measures of HG are defined by the position of the neck in relation to the femoral diaphysis.

**Methods:** We tested HG measures with an anatomical (CN axis) and non-anatomical relation of the femoral neck and head (NN'axis). The test we have performed on a clearly defined sample of 171 white females.

**Results:** Femoral neck fracture: CNAL  $\geq$  78.88 mm, AUC 0.67, 95% CI 0.64-0.84, sensitivity 0.76 and specificity 0.58,  $p < 0.001$ ; CNTMA  $\geq$  47.33 mm, AUC 0.70; 95% CI 0.56-0.82, 0.69 and 0.67,  $p = 0.001$ ; CNS angle  $\geq$  127.5°, AUC 0.66, 95% CI 0.55-0.77, 0.57 and 0.69,  $p = 0.01$ .

NN'AL  $\geq$  79.12 mm, AUC 0.66; 95% CI 0.55-0.78, 0.55 and 0.69,  $p = 0.008$ ; NN'TMA  $\geq$  44.20 mm, AUC 0.53; 95% CI 0.41-0.65, 0.43 and 0.67  $p = 0.668$ . NS angle  $\geq$  123.50°, AUC 0.59; 95% CI 0.47-0.72, 0.57 and 0.58,  $p = 0.149$ . Neither the measures CN axis nor NN' axis don't diagnose the risk of a trochanter fracture.

**Conclusion:** The measures of HG defined by an anatomical relation between the neck and head are better at diagnosing people running risk of femoral neck fractures than previously used measures. Hip Geometry doesn't influence the biomechanics of trochanter fractures. Anatomical measures better evaluate the risk of femoral neck fractures than the previous. These measures are usable in lowering the amount and severity of femoral neck fractures.

## INTRODUCTION

The fracture of the hip joint is a significant personal, familiar, and public health issue which deteriorate the patient's and his family's living quality, and it also raises the cost the Health system has. The mortality rate of hip fractures is between 20 to 36% in the first year since the fracture. About 50% of the patients with a hip joint fracture do not nearly recover the functional state of movement and all round physical activity they had before the fracture [1-3].

Hip geometry (HG) measures are usable in lowering the amount and severity of fractures [4-10]. However, by reviewing current literature on HG (see the Reference section) on the prediction on hip fracture we came to the conclusion that the anatomical relationship of the femoral head and neck are not included in the definition of HG measures such as Femoral axis length (FAL), Neck-shaft (NS) angle and True moment arm (TMA). The stated measures are defined by the neck axis whose position is visually estimated and the head are centered,

a passive extension without any influence on the definition of the stated measures. Because of these reasons measure-tests of HG, as a variable independent of the Bone Mineral Density (BMD) (Faulkner et al. 1993), in the diagnosis of those running risk of a hip fracture, have a questionable statistical and clinical-medical credibility. HG determines the direction and the size of the fracture force created during the fall [4,6-9,10-14]. We have compared the diagnostically value of in such a way determined measures of hip geometry with measures which are defined by the relationship of the active position of the head's center towards the neck's base. The test we have performed on a clearly defined sample of 171 white females, of a similar age, BMD, Body Mass Index (BMI), social and economical position and similar conditions of maturing, diet, intake of medicine and an average number of births.

We have separated the femoral neck fractures from the trochanter fractures. This kind of testing has so far not been conducted. The listed criteria of inclusion and exclusion of

patients, as also the construction of HG measures which include the anatomical relationship of the femoral head and neck, will increase, we assume, the sensitivity and specificity of HG measures in the diagnosis of women running risk of neck and trochanter fractures.

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## PATIENTS AND METHODS

### Patients

We have only included 171 white females born in the geographical area defined by the position of the Požega-Slavonia County, Republic of Croatia. The gathering of data happened in the County General hospital Požega, between January 2011 and end of December 2015. Included criteria: patients with an injury sustained by falling from a standing, sitting or lying height. In the fracture group we included women with a trochanteric fracture (according to the AO/ASIF classification 31.A1 and A2), and neck fracture (31.B1, B2, B3) [15-18].

In the control group are included women with a contusion of the glutei region and/or a fracture but not in the area of the pelvis or hip.

Excluded criteria: patients with inherent hip anomalies, major rheumatic diseases, metabolically disturbances, malign illnesses and paralysis, used estrogens longer than 6 months, anabolic steroids, calcitonin, bisphosphonates or glucocorticoids longer than 3 months.

Patients with hip fractures sustained through high energy, younger than 65 years or older than 90 years we have not taken in consideration. Not included immigrants, men, persons of another race, or patients with a previous hip and/or pelvis fracture and patients with sub trochanter fractures (AO/ASIF 31.A3).

For further research we have picked patients from fracture and control groups which have not statistically differed in BMD or neck hip or trochanteric area, and BMI more than one standard deviation (1SD).

### RTG imagines

Patients have been scanned with the same rtg machine - axion luminous drf-digital polyvalent teledirigated rtg machine from a distance of 100cm from the simphisis to the camera of the rtg machine. In a lying position (spine position), with spread medial edges of heels on the length of the feet with an inwards rotation and mutually fixed toes [19]. The scanning was done within a week after the reception and/or surgical treatment of the hip fracture.

For purposes of measure calibration, a metal ball was placed on the skin of healthy hip for patients of the fracture group and on the right hip for patients of the control. The position of the ball for all patients is nearly the same in the position in the area of the femoral neck or trochanter area determined by palpation and/or a control rtg scan.

### Determining measures

The CN axis is defined by the junction of the head's center (C) and the center of the neck (N) respectively equally distant (equidistant) points from the upper and lower edge to the narrowest part of the neck's shadow on the radiogram in the AP projection. The center of the head (C) is determined with software - Software picture archiving communication system (Impacs 6,5).

The axis NN' is determined with two equally distant points. The N' point is the middle point on the line parallel with the line on which lies the point N, 10 mm away on paper print of the radiogram toward lateral. 10 mm is calibrated by the coefficient of the real size of the metal ball and the measured size of the ball on each radiogram specially.

The axis of the diaphysis (Shaft Axis, S axis) has been determined on 3 cm from the lower edge of the small trochanter and 10 mm below that as is the NN' axis.

The length of the CNAL (caput-neck axis length) is on the CN axis determined by the lateral edge of the trochanter and the medial edge of the femur's head.

The length of the NN'AL (neck axis length) is on NN' axis determined with the lateral edge of the trochanter and the medial edge of femur's head

The lengths have been measured to two tenths of a millimeter with the help of a digital measuring instrument - Standard Gage 2013. The real lengths of the stated measures (a) we got by multiplying the measured length (b) with the coefficient of the real (c) and measured size of the ball (d),  $a = b \times c / d$ .

The angle between the Shaft axis and the CN axis is marked as the CNS angle. The NS angle is the angle between the Shaft axis and the NN' axis. The angles have been measured with a goniometer scaled by 1°. We calculated the CNTMA =  $\sin(\text{CNS angle} - 90^\circ) \times \text{CNAL}$ , and NN'TMA =  $\sin(\text{NS angle} - 90^\circ) \times \text{NN'AL}$  (14).

SOS and IOS are vertical distances of two parallel lines with the NN' axis, and the tangencial are with the neck's concavity and convexity of the femur's head. From these two lengths we have calculated the translation coefficient, SOS/IOS (Figure 2).

The examinees had their height and weight measured - a scale with a height meter M130. Calculated BMI - ( $\text{kg}/\text{m}^2$ ), with a device for densitometry - DMS stratus, determined BMD, ( $\text{g}/\text{cm}^2$ ) for the neck hip and trochanter.

### Statistical analysis

The measurements repeated in 3 volunteers to evaluate the precision of the technique for geometry hip measurements revealed that coefficient of variation (CV %) was 0, 9%, 0, 8%, 1, 5%, 1, 7%, 2, 0% for CNAL, NN'AL, CNS angle, NS angle, SOS/IOS. The examiners did not know if the patients had hip fractures and which type or not and they were not able to comment the results amongst themselves. All used measure values for statistical processing are mean values 3 repeated measures.

Means and standard deviations were used to describe continuous variables. Control and fracture groups were compared with an independent sample t-test. A receiver operating characteristic (ROC) curve was constructed for measured

indicators to test the effectiveness of various cutoff points in predicting hip fracture. The area under the ROC curve calculated as well as sensitivity and specificity on the most appropriate cutoff points.

The sample of 80 examinees per cohort is sufficient that with a 90% of probability in a statistical test on 95% border level of significance we make a type I (alpha) error is less than 5% and to make a type II (beta) error is less than 10%. Statistical significance was defined as a p value <0.05. All analyses were conducted using IBM SPSS 20.0.

## RESULTS

In these cohorts prospective study for the last 5 years we have tracked a total of 171 white women. They are of the same gender, race, geographical origin; they have a similar economical and social position, and have similar habits in terms of diet, physical activity and intake of medicine. There is no differences between control and fracture groups on age, BMI and BMD for neck or trochanteric. The patients in the neck cohort are older than those of the trochanter cohort; also they are shorter and lighter and have a lower BMD

Within the cohorts there is no difference in hip stress based on carry weight. The fractures were caused by a fall from the same level. We assume that the amount of kinetic energy caused by the fall is also the same. The amount of mineral matter (g/cm<sup>2</sup>) is of no significance within the group. Of course, except for the presence of a fracture, the experimental and control group probably only differ by HG measures.

Statistically significant differences between control and neck's fracture groups were observed on following variables: NN'AL (p=0.001), CNAL (p<0.001), CNS-angle (p=0.004), CNTMA (p<0.001 (Table 2). NS angle is a measure which assumes the center of the head on the neck axis and it does not differentiate the control and neck fractures angles. HG based on lengths, no matter the anatomical correctness, does a good job at differentiating a neck fracture from control. But, there is an obvious difference in angles quality, based on the influence of the head's position in relation to the neck, in differentiating within a group. The difference in quality between the anatomical and non-anatomical HG measures in highlighted in the calculation of TMA (NN'TMA p=0.368, CNTMA p<0.001).

The CNS angle is smaller in the trochanter group then he is in the control group, p = 0.025. All other variables do not differ well the control from the trochanter fracture group (Table 1,2).

This leads as to a possible conclusion that HG measures do not have influence on the distribution of size and direction of breaking force in the creation of a trochanter region fracture as they have on femoral neck fractures.

The qualities of HG have an influence on sensitivity and specificity of observed variables in the differentiation of fracture from control.

In Table (3) the comparison of sensitivity and specificity of parameters for neck fracture is shown. This find also confirms that lengths are equally good for diagnostics. The angle defined by the anatomical position of the head in relation to the neck is a better test than the angle defined by the position of the head in relation to the neck as an ordinary extension.

No matter the way of defining HG, the observed measures are neither specific nor sensitive for a diagnostic of listed trochanter fractures (AO 34-A1 and 2) (Table 4). SOS/IOS (p=0.047) barely differs in the neck group patients with a fracture from the control ones. Nominally, it shows that the head in the neck fracture group is more laid up. This quotient is nearly identical in the trochanter cohort (Table 3,4). Figures (3) and (4) show the distribution of ROC curves of tested HG.

For the neck cohort, the curves are relatively high above the reference line, especially for measures defined by the CN axis (Figure 3). ROK curves are, however, for the trochanter cohort stationed very close to the reference line. Classification based on these indicators is similar to the classification based on chance.

Neither the measures NN'axis nor CN axis do not diagnose the risk of a trochanter fracture (Figure 4).

## DISCUSSION

In this study we have tested the influence of the femur's head position in relation to the neck on diagnosing people running risk of neck and trochanter fractures, independent from the influence of BMD .We have tested the position of the head in relation to the femur's neck with two axes. The determined measures of hip geometry in the described way and the used methodology have so far not been used in reviewing the current literature on hip geometry on the prediction of hip fracture.

**Table 1:** Comparison between control and fracture groups on control variables.

Neck fractures	Control (M ± SD) (n=45)	Fracture (M ± SD) (n=42)	p*
Age	76.31 ± 4.45	77.07 ± 4.51	0.431
BMI	26.51 ± 2.18	26.95 ± 4.28	0.552
BMD	0.75 ± 0.06	0.76 ± 0.08	0.481
Trochanter fractures	Control (n=40) (Mean ± SD)	Fracture (n=44) (Mean ± SD)	p*
Age	73.47 ± 5.35	73.20 ± 5.18	0.815
BMI	28.73 ± 2.88	28.94 ± 3.28	0.754
BMD	0.79 ± 0.09	0.80 ± 0.08	0.567

\*ANOVA;

### Abbreviations

BMI: Bone Mineral Index; BMD: Body Mass Index

**Table 2:** Comparison between control and fracture groups on study variables.

Neck fractures	Control (n=45) (M ± SD)	Fracture (n=42) (M ± SD)	p*
NN'AL	77.84 ± 4.21	81.81 ± 6.40	0.001
CNAL	77.93 ± 4.38	83.01 ± 6.09	<0.001
NS angle	122.69 ± 6.08	124.52 ± 7.04	0.196
CNS angle	124.36 ± 6.73	128.38 ± 6.02	0.004
NN'TMA	41.82 ± 7.85	43.55 ± 9.95	0.368
CNTMA	43.45 ± 8.86	50.00 ± 5.86	<0.001
SOS/IOS	1.09 ± 0.34	1.27 ± 0.33	0.047
Trochanter fractures	Control (n=40) (Mean ± SD)	Fracture (n=44) (Mean ± SD)	p*
NN'AL	87.25 ± 8.82	87.95 ± 9.40	0.726
CNAL	90.57 ± 11.90	89.83 ± 8.95	0.746
NS angle	121.80 ± 4.64	122.18 ± 6.82	0.763
CNS angle	123.48 ± 5.58	126.32 ± 5.80	0.025
SOS/IOS	1.23 ± 0.32	1.23 ± 0.33	0.915
NN'TMA	45.94 ± 8.32	46.84 ± 10.12	0.659
CNTMA	50.06 ± 11.54	53.59 ± 9.91	0.668

\*ANOVA

**Abbreviations**

NN'AL- NN'Axis Length; CNAL- CN Axis Length; NS angle- Neck Shaft angle; NN'TMA- NN' True Moment Arm; CNTMA- CN True Moment Arm; SOS/IOS- Superior ossal segment/Inferior ossal segment

**Table 3:** The comparison of sensitivity and specificity for necks fracture and control.

	Cut-off point	AUC	95% CI (AUC)	Sensitivity	Specificity	p
NN'AL	≥ 79.12	0.666	0.551-0.781	0.548	0.689	0.008
CNAL	≥ 78.88	0.739	0.636-0.842	0.762	0.578	0.001
NS Angle	≥ 123.50	0.590	0.468-0.712	0.571	0.578	0.149
CNS Angle	≥ 127.50	0.661	0.548-0.775	0.571	0.689	0.010
SOS/IOS	≥ 1.13	0.597	0.476-0.717	0.548	0.677	0.121
NN'TMA	≥ 44.20	0.527	0.403-0.651	0.429	0.669	0.668
CNTMA	≥ 47.33	0.701	0.595-0.820	0.690	0.669	0.001

\*ROC

**Abbreviations:** NN'AL: NN'Axis Length; CNAL: CN Axis Length; NS angle: Neck Shaft angle; NN'TMA: NN'True Moment Arm; CNTMA: CN True Moment Arm; SOS/IOS: Superior Ossal Segment/Inferior Ossal Segment

**Table 4:** The comparison of sensitivity and specificity parameters for trochanter fractures and control groups

	Cut-off point	AUC	95% CI (AUC)	Sensitivity	Specificity	p*
NN'AL	89.31	0.524	0.399-0.648	0.523	0.550	0.710
CNAL	81.07	0.488	0.361-0.614	0.773	0.350	0.847
NS Angle	121.50	0.506	0.381-0.631	0.500	0.550	0.922
CNS Angle	121.50	0.630	0.511-0.749	0.773	0.400	0.040
SOS/IOS	1.118	0.513	0.389-0.638	0.727	0.275	0.883
NN'TMA	44.193	0.530	0.406-0.654	0.614	0.450	0.635
CNTMA	47.970	0.608	0.485-0.730	0.705	0.475	0.089

\*ROC

**Abbreviations**

NN'AL: NN'Axis Length; CNAL: CN Axis Length; NS angle: Neck Shaft angle; NN'TMA: NN' True Moment Arm; CNTMA: CN True Moment Arm; SOS/IOS: Superior Ossal Segment/Inferior Ossal Segment

The first axis we have named NN'axis. It is different from the previous definitions of neck axis insofar as its position is not visually estimated, but their common mistake is that they both define the head's position towards the neck as a centered extension [21].

The second axis, which we named as CN axis, although axis is not lingual correct, maybe junction, in defining hip geometry

measures includes the position of the head's center above or below the neck axis, but under no circumstances on the neck axis as the previously described axes.

According to the listed axes we have measured the lengths, angles and the true moment arm. The main find of this study is that HG measures do not diagnose people running risk of trochanter fractures. Also, the measures defined with CN axis are



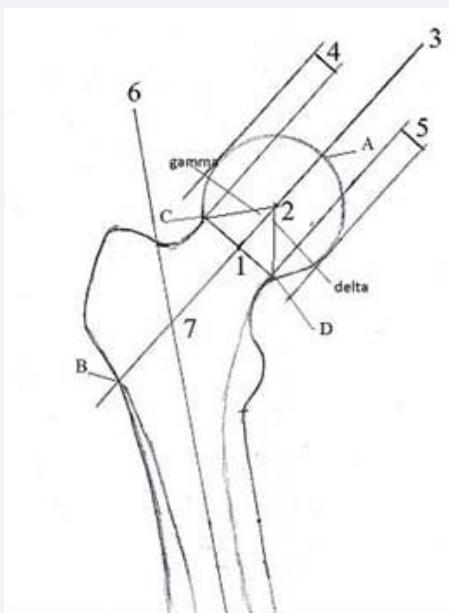
more sensitive and specific at diagnosing people running risk of a femoral neck fractures than the measures defined with NN' axis.

Through the entire history of HG there stretches an unclear definition of neck axis and it's relation with the head's center. In previous literature we found the following definitions of the neck's axis: middle line of the neck [15-17]; the neck axis was defined by a densitometer [4-9,11,15]; the examiner has visually estimated the position of the neck's axis [10,12]; the neck axis passes through an equally distant point on the narrowest part of the neck which has to be vertical on the neck axis [14-16]; the neck axis is a line equally distant from the upper and lower edge of the neck shadow in the ap projection [20]. On a in such a ways defined neck axis, the femoral head is a centered extension with a coefficient of SOS/IOS=1, an equal gamma and delta angles and scar of the head's epiphysis vertical to the axis (Figure 1). Or with the possibility of such a presentation. Such a find is not part of the human anatomy [20]. On the basis of definitions of the neck's axis determined are the Hip Axis Length, FAL and NS angle and the TMA in previous papers on HG.

Our construction of the NN' axis with two equally distant points from the edge of the neck's shadow on the radiogram is one of the modifications on previously shown neck axes whose definition contains a mistake. The mistake consists of the explicit presentation of the head's center on the axis or the sheer possibility of such an occurrence.

CN axis puts the position of the head in relation to the neck in an active position during the determination of the length (CNAL) and angle (CNS angle) and the calculation of CNTMA.

We analyzed SOS/IOS although it is not a HG measure.



**Figure 1** Non anatomical display of the proximal femur (Gašpar et al. 2017).

Description of Figure 1: 1-On which lies; 2-The center of the head. Superior offset; 3-neck axis defined by a line passing through the middle point of the neck; 4-and inferior offset; 5-are equal as are also the gamma and delta angles of concavity. The scar of the epiphysis (CD-narrowest part of the neck) is perpendicular to the neck axis in the anterior posterior projection. AB- Femoral Axis Length.



**Figure 2** The original construct of two axes whose value in determining HG measures we have compared in this study (Gašpar et al. 2017).

Description of Figure 2: NN'axis (3) defined by the points 1 and 2. 4 - Superior offset. 5 - Inferior offset. 4 and 5 is the distance between two parallel lines with 3. 6 - The diaphyseal axis is equally apart from the edges of the diaphysis. 7 - The angle between 3 and 6. 8 - The angle of CN axis and 6. CN axis - the junction of the head's center and the femoral neck. The position of the ball is visible on the neck of the femur.

According to the results the head is displaced more upward relative to the neck fractures of the control group. The coefficient of translation (SOS/IOS) is 1.27 and 1.09. And in the trochanter group the head is displaced upwards, identical to the control, 1.23. Although there is no difference between groups, those running risk of femoral neck fractures have the head leaned more towards the femoral neck than the control and trochanter group. Gamma and delta angles of concavity follow the values of SOS/IOS [20]. The AP epiphiseal angle we have not analyzed because it is often faulty presented in the observed age [20-22] (Figure 2). The finding of FAL (herein marked as NN'AL) as a better diagnostically tool than the TMA (NN'TMA) does not fit with the finding of Ulusoy et al. 2008, where the finding is reverse.

So far in literature appear intuitive explanations of biomechanics trochanter region fractures because of the longer FAL (NN'AL) through which the trochanter is more exposed to contact with the surface [5-7,9-12]. We have not confirmed that. This clinical trial is in vitro, with a high error possibility which can lead to wrong results but also wrong interpretation of results. The suggested methodology of inclusion and exclusion of female patients is more rigorous than in previous papers.

We have given special attention to the differentiation of neck and trochanter fractures. In previous works this was not the case [4-10,12,13,15-17]. The results of this study show that that leads to a heavy warp of the results.

## CONCLUSION

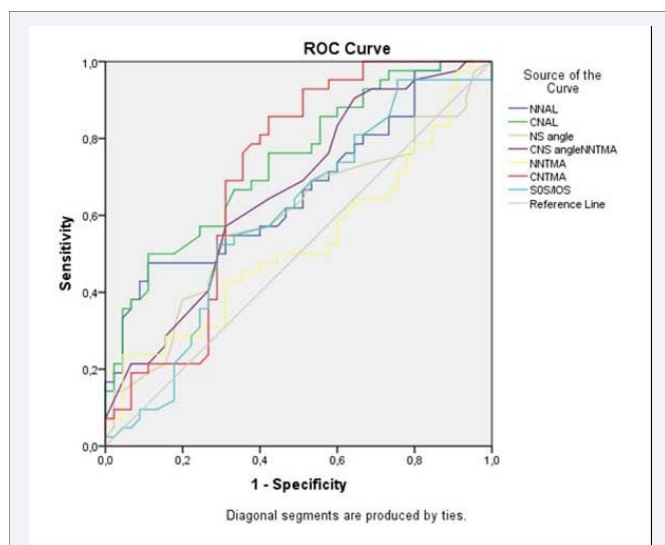
We have not in relevant HG literature found a similar study. Previous HG studies have studied the relationship of diaphysis and femoral neck. This study highlights the previously unknown fact that the value of HG measures in diagnosing people running risk of femoral neck fractures is determined by the position of the head towards the neck of the femur. That position is not on the neck axis. Also it confirms that HG measures, be they anatomical or non-anatomical; don't have any role in diagnosing people running risk of trochanter fractures.

Previously used hip geometry measures are not anatomically defined. Anatomical measures better evaluate the risk of femoral

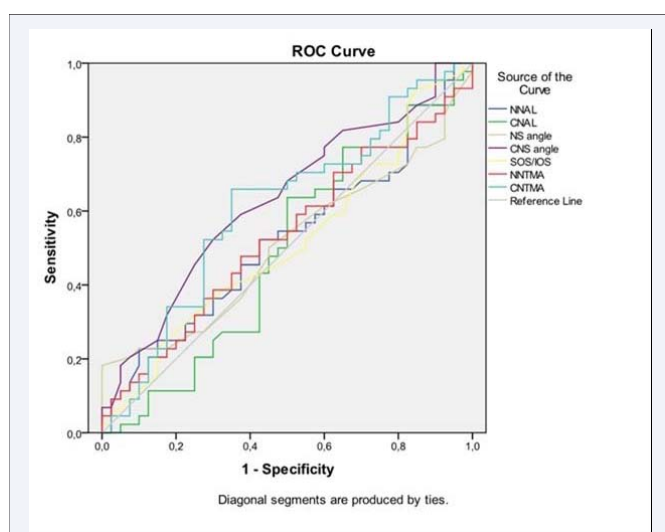
neck fractures than the previous. These measures are usable in lowering the amount and severity of femoral neck fractures. Hip Geometry doesn't influence the biomechanics of trochanter fractures. The biomechanics of neck and trochanter fractures must be studied separately. HG probably doesn't determine the break vector for trochanter fractures. By continuing Hip Geometry research, including the finds of this study, we can gain a useful instrument for diagnosing people running risk of femoral neck fractures. For further research of HG in diagnosing people running risk of fractures, we strongly recommend the inclusion of the anatomical position of the head in relation to the neck of the femur.

## REFERENCES

- Cummings SR, Melton LJ. Epidemiology and outcomes of osteoporotic fractures. *Lancet*. 2002; 359: 1761-1767.
- Osnes EK, Lofthus CM, Meyer HE, Falch JA, Nordsletten L, Cappelen I, et al. Consequences of hip fracture on activities of daily life and residential needs. *Osteoporos Int*. 2004; 15: 567-574.
- Mackenzie EJ, Fowler CJ. Epidemiology. In: Feliciano D, Mattox KL, Moore EE. *Trauma 6<sup>th</sup> ed*. New York: The McGraw-Hill companies; 2008; 26- 42.
- Faulkner KG, Cummings SR, Black D, Palermo L, Glüer CC, Genant HK. Simple measurement of femoral geometry predicts hip fracture: the study of osteoporotic fractures. *J Bone Miner Res*. 1993; 8: 1211-1217.
- Crabtree NJ, Kroger H, Martin A, Pols HA, Lorenc R, Nijs J, et al. Improving risk assessment: hip geometry, bone mineral distribution and bone strength in hip fracture cases and controls. The EPOS study. *European Prospective Osteoporosis Study*. *Osteoporos Int*. 2002; 13: 48-54.
- Partanen JI, Jämsä T, Jalovaara P. Influence of the upper femur and pelvic geometry on the risk and type of hip fractures. *J Bone Miner Res*. 2001; 16: 1540-1546.
- Gómez Alonso C, Díaz Curiel M, Hawkins Carranza F, Pérez Cano R, Díez Pérez A; Multicenter Project for Research in Osteoporosis.. Femoral bone mineral densiti, neck shaft angle and mean femoral neck width as predictors of hip fractures in men and women. *Osteoporos Int*. 2000; 11: 714-720.
- Center JR, Nguyen TV, Pocock NA, Noakes KA, Kelly PJ, Eisman JA, et al. Femoral neck axis length, height loss and risk of hip fracture in males and females. *Osteoporos Int*. 1998; 8: 75-81.
- Gnudi S, Ripamonti C, Gualtieri G, Malavolta N. Geometry of proximal femur in the prediction of hip fracture in osteoporotic women. *Br J Radiol*. 1999; 72: 729-733.
- Michelotti J, Clark J. Femoral neck length and hip fracture risk. *J Bone Miner Res*. 1999; 14: 1714-1720.
- Bergot C, Bousson V, Meunier A, Laval-Jeantet M, Laredo JD. Hip fracture risk and proximal femur geometry from DXA scans. *Osteoporos Int*. 2002; 13: 542-550.
- Wang MC, Aguirre M, Bhudhikanok GS, Kendall CG, Kirsch S, Marcus R, et al. Bone mass and hip axis length in healthy Asian, black, Hispanic, and white American youths. *J Bone Miner Res*. 1997; 12: 1922-1935.
- Ulusoy H, Bilgici A, Kuru O, Sarica N, Arslan S, Erkorkmaz U. A new value of proximal femur geometry to evaluate hip fracture risk: true moment arm. *Hip Int*. 2008; 18: 101-107.
- Calis HT, Eryavuz M, Calis M. Comparison of femoral geometry among cases with and without hip fractures. *Yonsei Med J*. 2004; 45: 901-907.



**Figure 3** Receiver operating characteristic curve showing the relationship between sensitivity and false positives at various cutoff points of NNAL, CNAL, NS angle, CNS angle, SOS/IOS, NNTMA, and CNTMA to predict hip fracture (Gašpar et al. 2017).



**Figure 4** Not a single of hip geometry measures does not do a good job at differing the control group from the trochanter fracture group (Gašpar et al. 2017).

15. Glüer CC, Cummings SR, Pressman A, Li J, Glüer K, Faulkner KG, et al. Prediction of hip fractures from pelvic radiographs: the study of osteoporotic fractures. The Study of Osteoporotic Fractures Research Group. *J Bone Miner Res.* 1994; 9: 671-677.
16. Patron MS, Duthie RA, Sutherland AG. Proximal femoral geometry and hip fractures. *Acta Orthop Belg.* 2006; 72: 51-54.
17. Pulkkinen P, Eckstein F, Lochmüller EM, Kuhn V, Jämsä T. Association of geometric factors and failure load level with the distribution of cervical vs. trochanteric hip fractures. *J Bone Miner Res.* 2006; 21: 895-901.
18. Muller ME, Nazarian S, Koch P, Schatzker J. *The AO classification of fractures of long bones.* Berlin; Springer-Verlag; 1990.
19. Bradley M, Shaw M, Fox D. The Bristol Hip View: a new hypothetical radiographic projection for femoral neck fractures. *Br J Radiol.* 2006; 79: 216-220.
20. Toogood PA, Skalak A, Cooperman DR. Proximal femoral anatomy in the normal human population. *Clin Orthop Relat Res.* 2009; 467: 876-885.
21. Siebenrock KA, Wahab KH, Werlen S, Kalhor M, Leunig M, Ganz R. Abnormal extension of the femoral head epiphysis as a cause of cam impingement. *Clin Orthop Relat Res.* 2004; 54-60.
22. Nötzli HP, Wyss TF, Stoecklin CH, Schmid MR, Treiber K, Hodler J. The contour of the femoral head-neck junction as a predictor for the risk of anterior impingement. *J Bone Joint Surg Br.* 2002; 84: 556-560.

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