



## The Böhler's angle in population of central Serbia – a radiological study

Vrednosti Böhler-ovog ugla u populaciji centralne Srbije – radiološka studija

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### Abstract

**Background/Aim.** The values of the Böhler's angle (BA) are relevant parameters for diagnosis, management and prognosis of the calcaneal fracture and the outcome. Range of normal values of Böhler's angle (BA) in adults varies depending on the examined population, age, gender or ethnicity. The aim of this study was to determine the range of normal values of the Böhler's angle in the central part of Serbia. **Methods.** The lateral foot radiographs of 225 subjects (111 males and 114 females) without calcaneal fractures, divided into 6 age groups were observed to determine the normal values of the Böhler's angle by using the IMPAX 6.5.2.114 Enterprise software. Obtained values for Böhler's angle were compared among gender and groups using appropriate statistical tests. **Results.** The mean of Böhler's angle in observed population was 34.06°, ranging from 25.1° to 49.5° and was higher in males than in females included in our study. Gender difference was statistically significant. The distribution of the mean BA across the age groups showed tendency of decreasing with age and the highest BA was found in the youngest group. **Conclusion.** The findings presented in this paper confirmed the existence of wide range of BA values as well as its gender and age differences.

### Key words:

calcaneus; anatomy; anthropology; gender identity; serbia; orthopedics.

### Apstrakt

**Uvod/Cilj.** Određivanje Böhler-ovog ugla (BA) ima važnu ulogu u dijagnostici, određivanju načina lečenja, prognozi preloma kalkaneusa kao i proveru uspeha operativnog lečenja preloma. Raspon normalnih vrednosti BA kod odraslih varira u zavisnosti od ispitivane populacije, starosti, pola ili etničke pripadnosti. Cilj ovog istraživanja bio je da se utvrdi opseg normalnih vrednosti BA u centralnom delu Srbije. **Metode.** Böhler-ov ugao određivan je na profilnim radiografskim snimcima 225 ispitanika, oba pola (111 muških i 114 ženskih), podeljenih u 6 starosnih grupa, bez uočenih fraktura, korišćenjem IMPAKS 6.5.2.114 Enterprise softvera. Korišćenjem statističkih testova upoređene su dobijene vrednosti BA u muškoj i ženskoj populaciji, kao i između različitih starosnih grupa. **Rezultati.** Prosečna vrednost BA u posmatranoj populaciji iznosila je 34,06°, u rasponu od 25,1°–49,5°. Srednja vrednost ovog ugla kod muškaraca bila je veća nego kod žena, a razlika vrednosti ugla između polova bila je statistički značajna. Srednja vrednost BA pokazuje tendenciju opadanja sa godinama, a najveća srednja vrednost BA uočena je u najmlađoj starosnoj grupi. **Zaključak.** Rezultati ovog istraživanja potvrdili su širok opseg normalnih vrednosti BA u ispitivanoj populaciji, kao i postojanje polnih i starosnih razlika.

### Ključne reči:

kalkaneus; anatomija; antropologija; pol; srbija; ortopedija.

## Introduction

Calcaneus is the most common site of tarsal bones fractures<sup>1</sup>. These fractures have very variable patterns<sup>2</sup>; can be divided into intra- and extra-articular and they present the most common fractures of tarsal bones (up to 75%) and thus account for 2% of all fractures<sup>3,4</sup>. The posterior articular surface of calcaneus is usually depressed as a result of the fracture. The Böhler's angle (BA) can be used for evaluation of the loss of calcaneal inclination when this angle is reduced and indicates the degree of proximal displacement of the calcaneal tuberosity. It is a relevant parameter for diagnosis, management and prognosis of the calcaneal fracture outcome<sup>5</sup>. Böhler's angle is named after surgeon Dr. Lorenz Böhler<sup>6</sup> (1885–1973), who introduced this angle in 1931 as a radiological method in the diagnosis of compression fractures of the calcaneus. It was noted in earlier studies that there was a reduction of this angle in intra-articular but also in the most of extra-articular fractures of the calcaneus<sup>7</sup>. Böhler's angle is otherwise called tuber joint angle, calcaneal angle or salient angle. The range of the normal values in adults, without presence of fractures, is from 25° to 40°, but this value varies depending on the examined population and is found to be in the range of 14° to 58.1°<sup>1,5</sup>. In the first paper about BA, the angles of 30°–35° were mentioned as normal values. In some other textbooks, ranges from 20° to 45° were reported as normal values of this angle<sup>8–14</sup>. The range of normal BA varies depending on the gender, age and the ethnicity of the observed population. The assessment of the BA is important in the diagnosis, determining ways of treatment and prognosis of calcaneal fractures and it can be an indicator of operative treatment success<sup>5</sup>. The measurement is usually performed on lateral foot radiographs at the intersection of two lines or it can be determined using computed tomography (CT). The first line that is important in the construction of this angle is obtained by merging the highest points of the anterior and the posterior articular surface of the calcaneus. Another line connects the same point on the posterior articular surface and the most prominent (the most superior) point of the tuberosity of the calcaneus. Some earlier studies have reported difficulties in precise measurement of the BA on lateral foot radiographs and the possibility of variation of its value in increasing obliquity on the lateral fluoroscopic image<sup>1</sup>. The aim of this study was to determine the range of normal values of the Böhler's angle of the population in the central part of Serbia.

## Methods

This study included 225 randomly taken subjects (111 males and 114 females) in order to determine the normal values of the BA in the population of central Serbia. The weight-bearing lateral foot and ankle joint radiographs were observed. The recordings were made with foot placed on solid surface. The subjects were without calcaneal fractures. The average age in the study sample was 43 years (ranging from 15 to 75). The subjects were divided into 6 age groups in order to examine the changes of the BA values with age and statistical significance of differences among the groups.

The exclusion criterion was any congenital or acquired deformity of the foot or arthritic change. The study was conducted in the Clinical Centre "Kragujevac" from 1st January 2014 to 31st March 2016.

The computed radiographs were obtained on Digital x-ray system (Duo Diagnost, Philips Medical Systems, the Netherlands). Images were reviewed on a Picture Archiving and Communication System (PACS) and angles were obtained by using the IMPAX 6.5.2.114 Enterprise software (Agfa Healthcare, Belgium). The Böhler's angle was measured from the intersection of the line passing through the most prominent points of posterior and anterior articulating calcaneal facet and the line connecting posterior articulating calcaneal facet to the most prominent point of the calcaneal tuberosity (Figure 1). The precision of measurement was 0.1. All radiographs were analyzed by two independent observers. The intra-class correlation coefficient (ICC) was used for evaluation of inter-observer reliability and ICC > 0.8 was considered as excellent agreement.



Fig. 1 – Measurement of Böhler's angle.

The results were analyzed using the statistical program (IBM SPSS Statistics 20). The analysis included descriptive and analytical statistical methods. Normality of data distribution was tested by Kolmogorov-Smirnov and Shapiro-Wilk test. Mann-Whitney was applied to compare significance of difference between genders, because variables in one of the individual groups (male group) were not normally distributed (Shapiro-Wilk test:  $p = 0.014$ ). One way ANOVA test was used in comparing the different age groups. Pearson's coefficient of correlation was used for measuring the correlation between the age and the value of the BA. The level of statistical significance was set at 0.05.

## Results

This study included 225 participants of both gender who were classified into the different age groups. The mean Böhler's angle in total observed population was  $34.1 \pm 4.2^\circ$

and ranged from 25.1–49.5°. The mean of this angle in males included in our study was  $35.3 \pm 3.9^\circ$  (ranging from 27.7° to 49.5°), while its mean value in female participants was  $32.8 \pm 4.1^\circ$  (ranging from 25.1° to 43.5°). Gender difference was statistically significant ( $U = 4174.5$ ;  $p < 0.05$ ) (Table 1).

Analysis of the angle distribution showed that the highest frequency (41.33%), was in the range of angles between 30–34.9° as expected and it was according to results of other studies. The lowest frequency was (1.3%) in the range between 45–49.5°.

The values of the BA were compared among different age groups. As it was expected, the highest mean of the BA was in the youngest group (15–24 years) due to anatomical

characteristics of calcaneus in the pre-adolescent ages (mean:  $39.8^\circ \pm 4.9$ ). The distribution of mean BA across the age groups showed tendency of decreasing with age and the lowest values were found in the group between 65 and 74 years, and the highest in the youngest age group. There was statistically significant difference among some of age groups regarding the mean BA (ANOVA;  $p < 0.05$ ) (Table 2). The correlation between angle and age was significant (Pearson correlation;  $r = 0.581$ ;  $p < 0.01$ ).

There were several earlier studies of normal BA in different populations and the mean values and ranges of BA are given in Table 3.

Table 1

The mean value of the Böhler's angle in males and females						
Gender	n (%)	Böhler's angle (°)			Mann-Whitney U test	p
		Mean	SD	Range		
Male	111 (49.33)	35.3	3.9	27.7–49.5		
Female	114 (50.67)	32.8	4.1	25.1–43.5		
Total	225 (100)	34.1	4.2	25.1–49.5		
Gender difference					4174.5	< 0.05

SD – standard deviation.

Table 2

The mean value and the range of the Böhler's (BA) angle in different age groups							
Age groups (years) (range)	Böhler's angle (in degree)						Range of BA (in degree)
	Male (n)	Female (n)	Total (n)	Male mean $\pm$ SD	Female mean $\pm$ SD	Total mean $\pm$ SD	
65–74	13	15	28	$33.1 \pm 3.3$	$29.7 \pm 3.1$	$31.3 \pm 3.6$ *a	25.1–40.9
55–64	21	22	43	$33.4 \pm 3.0$	$30.2 \pm 2.6$	$31.7 \pm 3.2$ *a	27.6–34.1
45–54	18	21	39	$33.0 \pm 2.1$	$31.3 \pm 3.6$	$32.1 \pm 3.1$ *a	25.1–34.1
35–44	33	30	63	$35.4 \pm 2.8$	$34.5 \pm 3.1$	$35.0 \pm 3.0$ *b	26.5–40.8
25–34	15	17	32	$38.2 \pm 2.4$	$35.2 \pm 3.2$	$36.6 \pm 3.2$ *c	31.3–42.7
15–24	11	09	20	$41.5 \pm 3.2$	$37.6 \pm 5.2$	$39.8 \pm 4.9$ *d	28.9–49.5

\*  $p < 0.01$  – statistically significant difference: a – compared to the age groups 35–44, 25–34 and 15–24; b – compared to the age groups: 65–74, 55–64, 45–54 and 15–24; c – compared to the age groups: 65–74, 55–64 and 45–54; d – compared to the age groups: 65–74, 55–64, 45–54 and 35–44.  
SD – standard deviation.

Table 3

The comparison of the mean calcaneal angles to the previous studies					
Study	Population	Sample size	Age group (years) range	Böhler's angle (in degree) mean $\pm$ SD	Böhler's angle (in degree) range
Chen et al. <sup>19</sup>	USA	120	16–81	$30 \pm 6.0$	14–50
Udoaka and Didia <sup>18</sup>	Nigerians	302	Not mentioned	$32.8 \pm 2.8$	28–38
Igbigbi and Msamati <sup>21</sup>	Malawian	220	18–54	$30.3 \pm 7.2$	14–45
Igbibi and Mutessaira <sup>20</sup>	Ugandans	206	20–40	36.4	20–50
Schepers et al. <sup>25</sup>	Dutch	33	18–65	32	25–40
Seyahil et al. <sup>23</sup>	Turkish	268	18–79	$33.8 \pm 4.8$	20–46
Boyle et al. <sup>26</sup>	New Zeland	100	30–70	39.2	26.2–54.9
		763	0–14	35.2	14.3–58.1
Shoukry et al. <sup>24</sup>	Egyptian	220	20–40	$30.1 \pm 4.2$	22–40
Willmott et al. <sup>8</sup>	British	127	16–92	$36.4 \pm 4.2$	24.65–48.85
Isaacs et al. <sup>7</sup>	Australian	212	Not mentioned	$29.4 \pm 4.1$	20–38
Khoshhal et al. <sup>22</sup>	Saudi Arabians	229	15–72	$31.2 \pm 5.6$	16–47
Ramachandran et al. <sup>5</sup>	Indian	184	17–75	$31.3 \pm 5.0$	18.7–46.2
Present study	Serbian	225	15–75	$34.1 \pm 4.2$	25.1–49.5

SD – standard deviation.

## Discussion

The assessment of the BA is of great importance in determining the indications for operative or non-operative treatment of the fractured calcaneus<sup>15</sup> and the surgical restoration with minimal anatomical and functional reduction<sup>7</sup>. According to the recommendation of AO Foundation, conservative treatment is indicated for the nondislocated calcaneal fractures with preserved values of BA<sup>15</sup>. Preoperative BA significantly correlated with the seriousness of injury and its postoperative value has a significant role in the prediction of functional recovery of the patient and the need for further surgery (e.g. subtalar fusion)<sup>16</sup>. It is an important prognostic factor for the outcomes of calcaneal fractures regardless of the treatment modality<sup>17</sup>.

This angle, known as Böhler's, calcaneal-, tuber-joint- or salient angle, is also important for anthropometry and varies among the different populations<sup>18</sup>. Although some studies did not show any difference, the majority of evaluations of normal BA showed the gender, racial, territorial or the age differences of its values. This angle is usually measured using the lateral and axial radiographs. The variations of its normal values drew our attention to the assessment of BA in Serbian population, since the similar study has not yet been performed and this research may contribute to better knowledge of foot anatomy in this population. Taking this into consideration, findings of our study may be important in diagnosis and reconstructive surgery of calcaneal fractures and in anatomical and anthropometric studies.

Chen et al.<sup>19</sup> conducted the study in population of North Carolina<sup>18</sup>. There was no statistically significant difference between males and females, and it was not related to the side of the body. The reported mean BA and the lowest value of BA were lower than observed in this research.

Radiological study conducted in Nigerian population did not show significant gender dimorphism of BA<sup>18</sup>. The mean of the total population value of BA was lower than in our study.

Calcaneal angle in Ugandans was significantly sex dimorphic and it was similar to our findings. Authors also emphasized statistically significant difference between African populations of Nigeria and Uganda. There were no data about the age variations<sup>20</sup>.

The reported values of BA in Malawian males and females were not statistically significant. The BA of the majority of examined Malawian subjects was in the 30–34° class. Statistically significant difference was found between Malawians and Nigerians, between Malawians and the Uganda population, but not between Malawians and Caucasians<sup>21</sup>. In agreement with this study, the majority of subjects from our study were in the 30–35° class, but the lowest value of BA was significantly higher.

The mean value of the Böhler's angle in Saudi population was not significantly related to age, gender or side of the body. The highest mean value of this angle was in the 15–20 years age group (33.1°), and the lowest one was in 21–30 age group (29.2°)<sup>22</sup>. In comparison to this population, Serbian subjects had higher mean and minimal BA, and the highest BA was in the youngest age group in both studies.

In Turkish population the highest mean value was in the 41–50 years age group (35.2°), and the lowest was in the group of 61–83 years (32.3°). There were no statistically significant gender differences and the significance was found neither among age groups nor between right and left foot. Comparing to the earlier studies, there was a significant difference among Turkish, Nigerian and Saudi populations. The value of the mean BA in Turkish population is in agreement with our findings, and the difference was not statistically significant. Opposite to findings of Seyahi et al.<sup>23</sup> statistically significant difference was found between mean BA of males and females as well as among age groups in our study. According to our results, the lowest mean BA was in the age group between 65–75 years and this is in agreement with the findings in Turkish population.

In the study conducted in Egyptians, it was concluded that the values of BA were reduced with aging. The sex dimorphism of BA was not statistically significant. The side of the body, occupation, residence and body mass index were not significantly related to the value of the BA<sup>24</sup>.

The lower mean BA was also reported in Indian population. There was no report on the gender or the age variations<sup>5</sup>.

The lower mean BA was also found in the study conducted in the Sydney Hospital among the patients with and without calcaneal fracture. The Böhler's angle in the group of patients with fracture of calcaneus was significantly reduced<sup>7</sup>.

The Böhler's angle in British population was higher than in Serbians. Opposite to our findings, there were neither significant differences between the angles in males and females nor between the left and the right foot. Age was not a significant parameter for the value of the calcaneal angle<sup>8</sup>.

According to Schepers et al.<sup>25</sup>, the mean BA of the uninjured foot in the population of the Netherlands, was significantly higher than in the injured group. The mean BA in our study was higher and the lowest value of the BA, important for the fracture diagnosis, was equal.

The obtained results from the study conducted in New Zealand adult population showed that they were significantly different in comparison with our findings. The study also included children between 0–14 years and the mean BA was lower than in adults<sup>26</sup>.

Previous studies showed that the BA in children is lower than in adults, but this is not of general importance. This angle rapidly increases with age until adolescence. This angle has its highest values in the age of six or seven, because of the rapid growth of the posterior articular facet of calcaneus and its disproportion in relation to calcaneal tuberosity<sup>14</sup>. The highest BA in our study was indeed found in the youngest age group.

Results of this study revealed the sex dimorphism of the BA in examined population, with the higher mean value in males. This was in agreement with the findings in Ugandan population<sup>20</sup>, although the male Ugandan subjects had lower BA than female ones (opposite to our results). The other studies did not find the statistically significant gender differences, although the mean BA was higher in males<sup>8, 18, 19, 21–24</sup>.

The mean values of BA were also significantly different between the age groups in Serbian population, with a negative correlation between the BA and age. This was also found in earlier studies in Egyptian and Ugandan population<sup>20,24</sup>. Results reported in other studies, showed the same tendency, but the difference was not significant.

Considering the interpopulation differences, the mean BA in Serbians as well the range of this angle, our results were the most consistent with values reported for the Turkish population. In the observed population, the range of the BA value was from 24.1° to 49.5°.

The clinically important lowest value of the BA obtained from this study was similar to minimal BA in British, Dutch and Egyptian population and notably lower in the USA, Malawian and Indian population.

The limitation of this study may be the fact that measurements were not done on both feet of all the observed subjects. The reason is that the results of earlier studies as well as our small-sample test showed that difference was not statistically different.

### Conclusion

The findings presented in this paper confirmed the existence of a wide range of gender and age differences in values of Böhler's angle. These findings about the Böhler's angle in Serbian population are important for the diagnostics and reconstructive surgery of the calcaneal fractures. Besides, results obtained in this study are important for anthropometric studies and forensic medicine.

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