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Stature and its Estimation Utilizing Arm Span Measurements in Kosovan Adults: National Survey

Estatura y su Estimación Utilizando Mediciones de Brazos en Adultos Kosovares: Encuesta Nacional

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SUMMARY: The purpose of this research is to examine stature in both Kosovan sexes as well as its association with arm span, as an alternative to estimating stature. A total of 1623 individuals (830 boys and 793 girls) participated in this research. The anthropometric measurements were taken according to the protocol of ISAK. The relationships between stature and arm span were determined using simple correlation coefficients at a ninety-five percent confidence interval. Then a linear regression analysis was carried out to examine extent to which arm span can reliably predict stature. Results displayed that Kosovan boys are 179.52±5.96 cm tall and have an arm span of 181.29±7.02 cm, while Kosovan girls are 165.72±4.93 cm tall and have an arm span of 165.60±5.87 cm. The results have shown that both sexes made Kosovans a tall nation but not even close to be in the top tallest nations. Moreover, the arm span reliably predicts stature in both sexes.

KEY WORDS: Prediction; Measurement; Body Height; Arm Span; Kosovo.

INTRODUCTION

Kosovo is a democratic, multi-ethnic and secular republic that has been a sovereign country since 2008, when it declared independence from Serbia. Shortly, it has gained diplomatic recognition by 112 states, including the United States and most European Union countries (KosovoThanksYou, 2016); however, Serbia refuses to recognize Kosovo as a state, although it has accepted the legitimacy of Kosovo institutions by the Brussels Agreement in 2013. Next to Serbia, Russia and a significant number of other countries (including some EU states) have not recognized it yet. Because of the mentioned disagreement at the international level, Kosovo was not directly admitted to the United Nations but it incorporates into its Constitution the UN Special Envoy, the plan that ensures protection and guarantees rights for all of Kosovo citizens (KosovoThanksYou). From the geographical point of view, Kosovo covers an area of 10,908 square kilometers and it spreads on the central Balkan Peninsula in southeast Europe. Kosovo is landlocked state and it borders with four countries; it shares its borders with Albania (112 km), Macedonia (160 km), Montenegro (76 km) and Serbia (366 km). From the demographic point of view, the total population of Kosovo is 1,883,018 inhabitants (Central Intelligence Agency, 2016). The country's specific historical events render the ethnic population of Kosovo a specific and very complex issue. According to the same source, the largest ethnicity in the country is the Kosovar ethnic group, representing 92.9 percent of the total population, followed by the Bosniaks, making up 1.6 percent of the total population, Serbs with 1.5 percent, Turk with 1.1 percent, Ashkali with 0.9 percent, Egyptian with 0.7 percent, Gorani with 0.6 percent, Roma with 0.5 percent, and other/unspecified with 0.2 percent.

The researches, carried out by European anthropologists a century ago, have proved the assumption that the tallest people living in the Dinarides (Pineau *et al*., 2005). As modern Kosovans, like other nations from former Yugoslavia, fall into this racial classification, it is believed by the researchers that Kosovan adults might be equally tall or at least a little bit shorter than the tallest populations in

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the Europe (Popovic, 2016), harmonious with the Bosnian and Herzegovinians (boys: 183.9 cm; girls: 171.8 cm), Dutch (boys: 183.8 cm; girls: 170.7 cm), Montenegrins (boys: 183.21 cm; girls: 168.37 cm) and Serbians (boys: 182.0 cm; girls: 166.8 cm). Compared to the Western European countries, Kosovo keeps poor records, and the expected data about the average stature among Kosovan populations are so beneficial as well as its relationship with arm span measurements, mostly by virtue of measurement of stature`s importance in many settings (Popovic *et al*., 2015).

Scientific literature provided us with the findings that the measurement of stature is a vitally important variable when assessing nutritional status (cited in Datta Banik, 2011), as well as, according to Golshan *et al*. (2003, 2007), Mohanty *et al*. (2001) and Ter Goon *et al*. (2011), when assessing the growth of children, evaluating the basic energy requirements, adjusting the measures of physical capacity and predicting the drug dosage and setting standards of physiological variables (e.g. muscle strength, metabolic rate, lung volumes and glomerular filtration). However, the exact stature, according to Quanjer *et al*. (2014), cannot always be identified and resolved in the usual way (e.g. paralysis, fractures, amputation, scoliosis and pain). Because of these factors, an estimate of stature has to be acquired from other reliable anthropometric indicators such as hand and foot lengths (Sanli *et al*., 2005; Agnihotri *et al*., 2007; Agnihotri *et al*., 2008; Kanchan *et al*., 2008; Rastogi *et al*., 2008; Uhrová *et al*., 2015), knee height (Hickson & Frost, 2003; Fatmah, 2010; Karadag *et al*., 2012; Fogal *et al*., 2014), length of the forearm (Ilayperuma *et al*., 2010), length of the sternum (Menezes *et al*., 2009; Menezes *et al*., 2011), vertebral column length (Nagesh & Pradeep Kumar, 2006), sitting height (Fatmah), length of scapula (Campobasso *et al*., 1998), arm span (Jarzem & Gledhill, 1993; Aggarwal *et al*., 2000; Mohanty *et al*.; Hickson & Frost; Fatmah; Datta Banik; Ter Goon *et al*.; Bjelica *et al*., 2012; Popovic *et al*., 2015; Vujovic *et al*., 2015) as well as cranial sutures (Rao *et al*., 2009), skull (Bidmos & Asala, 2005; Bidmos, 2006), facial measurements (Sahni *et al*., 2010) etc. Therefore, all these anthropometric indicators, which are used as an alternative to estimate stature, are very important in predicting loss in stature connected with aging. Also, to diagnose individuals with disproportionate growth abnormalities and skeletal dysplasia or stature loss during surgical procedures on the spine (Mohanty *et al*.), as well as to anticipate stature in many older people as it is very difficult to measure it precisely, and sometimes impossible because of mobility problems and kyphosis (Hickson & Frost).

As stated above, the researchers of this study believed it would be reasonable to find the benefit of using various body indicators in estimating stature in the Kosovan population. Additionally, couple of researches have reported the benefit of using various body parameters in predicting stature, and arm span happened to be the most reliable one (Jarzem & Gledhill; Mohanty *et al*.; Hickson & Frost; Ter Goon *et al*.). However, the relationship of arm span and stature was found to vary in different ethnic and racial groups (Steele & Chenier, 1990; Reeves *et al*., 1996; Brown *et al*., 2002; Bjelica *et al*.; Popovic *et al*., 2013; Popovic *et al*., 2015, 2016), while the research conducted by Quanjer *et al*. has reported that the arm span to stature ratio changes non-linearly with age and differs between boys and girls. Even though many studies are available on Western populations, only narrow data is available on Kosovan subjects. Considering rather sparse recent scientific literature, the purpose of this research was to examine the stature in both Kosovan sexes and its association with arm span.

MATERIAL AND METHOD

The nature of this research gave extension to 1623 last year high-school students (830 boys and 793 girls) from Kosovo to be subjects. Two reasons qualified the selected individuals, the first is related to the fact that the growth of an individual ceases by this age, while the second is related to the fact that there is no age-related loss in stature at this age. The average age of the male subject was 18.26±0.45 years old (range 18-20 years), while the average age of the female subject was 18.24±0.43 years old (range 18-20 years). It is important to underline that the researchers have excluded from the data analysis the individuals with physical deformities as well as those without informed consent. The exclusion criterion was also being non-Kosovan.

Although photogrammetric anthropometry is an accurate way nowadays, this is not valid for arm span measurement (Penders *et al*., 2015) and the anthropometric measurements, including stature and arm span, were taken according to the protocol of the International Society for the Advancement of Kinanthropometry (Marfell-Jones *et al*., 2006). The trained measurers have measured selected anthropometric indicators (same measurer for each indicator), while the quality of their performance was evaluated against the prescribed "ISAK Manual". Lastly, the age of the each subject was reached directly from the birth date.

The analysis was performed using the Statistical Package for Social Sciences (SPSS) version 20.0. Means and standard deviations (SD) were obtained for both anthropometric variables. A comparison of means of stature and arm spans within each sex group and between sexes

was performed using a t-test. The relationships between stature and arm span were determined using simple correlation coefficients at ninety-five percent confidence interval. Then a linear regression analysis was carried out to examine the extent to which the arm span can reliably predict stature. Statistical significance was set at $p<0.05$.

RESULTS

A summary of the anthropometric measurements in both sexes is shown in Table I. The mean of the arm span for boys was 181.20±7.02 cm which was 1.68±1.06 cm more than the stature and statistically significant (t=-5.724, p<0.000), and for girls it was 165.60±5.87 cm which was 0.12±0.94 cm less than the stature and statistically insignificant (t=0.445, p<0.656). The sex difference between stature and arm span measurements was statistically significant (stature: t=50.685; p<.000, and arm span: t=48.471; p<.000).

Table I. Anthropometric seasurements of the study subjects.

Subjects	Body Height Range (Mean±SD)	Arm span Range (Mean±SD)
Male	161.4-198.8 (179.52±5.96)	158.4-203.8 (181.20±7.02)
Female	153.3-185.0 (165.72±4.93)	148.9-195.0 (165.60±5.87)

In Table II, the simple correlation coefficients and their ninety-five percent confidence interval analysis between the anthropometric measurements are displayed. The associations between stature and arm span were significant (p<0.000) and high in this sample, regardless of sex (boys: 0.794; girls: 0.766).

Table II. Correlation between body height and arm Sspan of the study subjects.

Subjects	Correlation Coefficient	95% confidence interval	Significance p-value
Male	0.794	0.638–0.709	<0.000
Female	0.766	0.606–0.681	<0.000

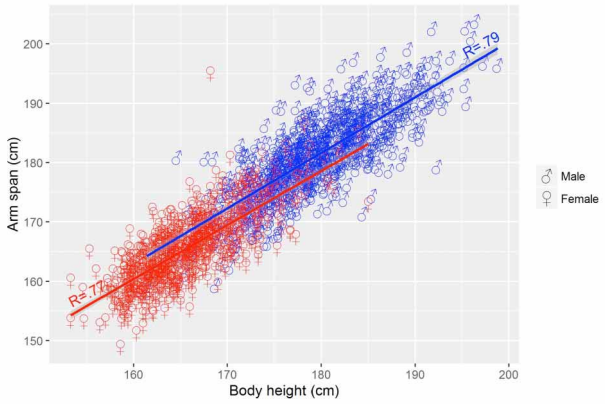

Fig. 1. Scatter diagram and relationship between arm span measurements and body height among both sexes.

The results of the linear regression analysis are shown in Table III. The first of all models were extracted by including age as a covariate. However, it was found that age was insignificant and therefore the age was dropped and estimations were derived as a univariate analysis. The high values of the regression coefficient (boys: 0.794; girls: 0.766) signify that arm span notably predicts stature in both Kosovan sexes (boys: t=17.674, p<0.000; girls: t=18.552, p<0.000), which confirms the R-square (%) for the boys (63.0) as well as for the girls (58.6).

The associations between arms span measurements and stature among the above models is sketched as a scatter diagram (Fig. 1).

DISCUSSION

This research enriches very important update of average stature among both Kosovan sexes. The results proved that Kosovan boys with an average height of 179.52 cm are almost as tall as the tallest subjects in European nations (Table IV), given 183.9 cm of the Bosnian and Herzegovinians (Popovic *et al.*, 2015), 183.21 cm of the Montenegrins measured in 2011 (Bjelica *et al.*), 182.4 cm of the Dutch measured in the lifestyle, preventive screening in 2010-2013 (Statistics Netherland, 2015), and 182.0 cm of the Serbians measured in 2012 (Popovic *et al.*, 2013), but

Table III. Results of linear regression analysis where the arm span predicts body height.

Subjects	Regression Coefficient	Standard Error	R-square (%)	t-value	p-value
Male	0.794	3.626	63.0	37.577	0.000
Female	0.766	3.175	58.6	33.469	0.000

Table IV. World`s Top 10 Nations with the tallest men.

#	Country	Average Body Height	Source
1	Bosnia and Herzegovina	183.9	Popovic *et al.,* 2015
2	Montenegro	183.2	Bjelica *et al.,* 2012
3	Netherland	182.4	Statistics Netherland, 2015
4	Serbia	182.0	Popovic *et al.,* 2013
5	Lithuania	181.3	Tutkuviene, 2005
6	Estonia	180.9	Kaarma *et al.,* 2008
7	Iceland	180.6	Dagbjartsson *et al.,* 2000
8	Croatia	180.5	Juresa *et al.,* 2012
9	Sweden	180.4	Werner & Bodin, 2006
10	Slovenia	180.3	Starc & Strel, 2011

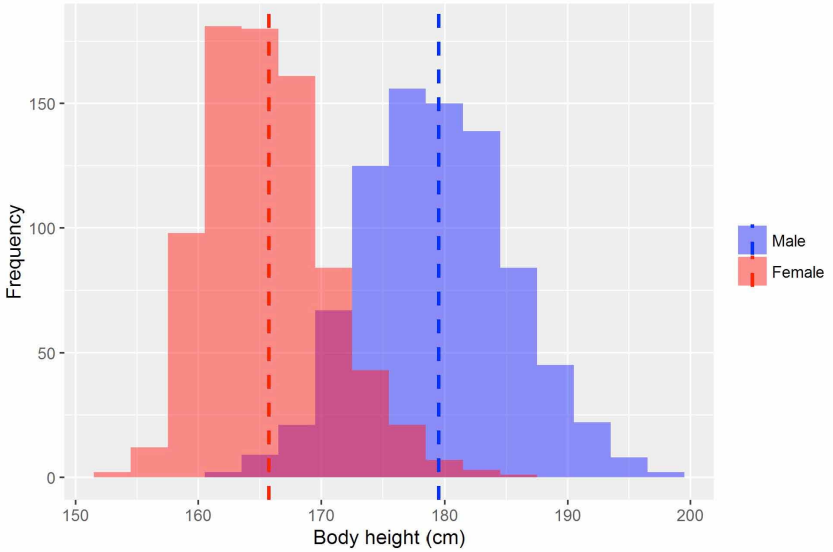

Fig. 2. Density of body height among both sexes.

Table V. World's Top 10 Nations with the tallest women.

#	Country	Average Body Height	Source
1	Bosnia and Herzegovina	171.8	Popovic *et al.,* 2015
2	Netherland	168.8	Statistics Netherland, 2015
3	Montenegro	168.3	Bjelica *et al.,* 2012
4	Germany	167.7	Hesse *et al.,* 1997
5	Lithuania	167.5	Tutkuviene, 2005
6	Slovenia	167.4	Starc & Strel, 2011
7	Iceland	167.2	Dagbjartsson *et al.,* 2000
8	Check Republic	167.2	Vignerová *et al.,* 2006
9	Latvia	167.1	Gerhards, 2005
10	Sweden	167.0	Werner & Bodin, 2006

not close enough. The average stature of Kosovan boys is still shorter than 181.3 centimeters of the Lithuanians (Tutkuviene, 2005), 180.6 cm of the Icelanders (Dagbjartsson *et al.*, 2000), 180.5 cm of the Croats (Juresa *et al.*, 2012), 180.4 centimeters of the Swedes (Werner & Bodin, 2006), 180.3 cm of the Slovenes (Starc & Strel, 2011), Danes (Statistics Denmark, 2011) and Czechs (Vignerová *et al.*, 2006) and several other nations, which indicated Kosovans are a tall nation, but are not close in height, to being in the top 10 nations worldwide.

With regards to the opposite sex, the average stature of Kosovan girls were 165.72 centimeters on average and this result proved that Kosovan girls are tall compared to the rest of the countries but not as tall as 171.8 cm of the Bosnian and Herzegovinians (Popovic *et al.*, 2015), 168.8 cm of the Netherlands (Statistics Netherlands, 2016), 168.3 cm of the Montenegrins (Bjelica *et al.*), 167.5 cm of the Lithuanians and several other nations ranked in the top 10 tallest female nations, according to the available sources (Table V).

However, there is a hypothesis that both sexes of Kosovo did not reach their full genetic potential yet, since various environmental factors controlled their development (wars in the former Yugoslavia, continued poor economic situation that is still a fact) in the last couple of decades. Consequently, the researchers are of the opinion that these circumstances had a negative bearing on the secular trend in Kosovo and surrounding countries alike, while it is expected that the secular changes influencing stature will ascend in the following two or three decades, comparing it to developed countries where this trend has already completed such as Dutch (Schönbeck *et al.*, 2013).

It is also interesting to mention that the frequency of very tall individuals appears to be distinctive for the Kosovan boys, since 5.1 percent measured 190 centimeters or more in stature. If a specified percent in Kosovo were to be compared to 20.2 percent in the Bosnian and Herzegovinians (Popovic *et al*., 2015), twenty percent in the Netherlands (Pineau *et al*.), fourteen percent in Serbia (Popovic *et al*., 2013) and thirteen percent in Montenegro (Bjelica *et al*.), it would imply that the frequency of very tall individuals in Kosovan boys does not appear likely in the Dinaric Alps in general and the Netherlands, this number is much closer to the non-Dinaric Alps nations such as 2.7 in Macedonia (Popovic *et al*., 2016) or 1.5 percent in France (Pineau *et al*.). With regards to the frequency of very tall female individuals, it does not appear to be characteristic of the Kosovan girls, since less than one percent (0.8 %) measured 180 cm or more in stature (Fig. 2).

The assessment of stature using various anthropometric measures is very typical from the past centuries and it has been attempted to be studied by many researchers. However, it is important to underline that the arm span has been determined as the most reliable body indicator for predicting the stature of an individual (Mohanty *et al*.; Ter Goon *et al*.). In parallel, it is important to emphasize that the individual and ethnic variations referring to stature, and its association with arm span were already examined in Europeans (Reeves *et al*.) and Africans (de Lucia *et al*., 2002), while Mohanty *et al*., have quoted that the estimating equation varies from ethnic group to ethnic group as well as race to race. In Steele & Chenier's research, the arm span was nearly 8.3 centimeters more than the stature for Blacks (105.36 % stature), whereas for Whites this difference was only 3.3 centimeters (102.04 % stature). Mohanty *et al*. have observed in their research that the arm span was nearly 2.5 centimeters more than the stature in South Indian girls (101.4 % body height), which is similar to that observed in the Whites. In Ter Goon *et al*.'s research, arm span was 5.8 centimeters more than stature for Nigerian boys (103.3 % stature observed in whites,), whereas for Nigerian girls this difference was only 4 centimeters (102.5 % stature), which is similar to that although they are black. The most recent research carried out by Bjelica *et al*. noted that the arm span was 2.5 centimeters more than stature for Montenegrin boys (101.4 % stature), whereas for Montenegrin girls this difference was only 0.24 centimeters but in favor of stature (99.9 % stature). Then Popovic at al. (2013), noted that arm span was 2.8 centimeters more than stature for Serbian boys (101.5 % stature), whereas for Serbians girls this difference was only 0.15 cm but also in favor of stature (98.7 % stature). Popovic *et al*. (2015), also noted that arm span was 0.73 centimeters more than stature for Bosnian and Herzegovinian boys (100.3 % body height), whereas for Bosnian and Herzegovinian girls this difference was only 1.97 centimeters but also in favor of stature (98.9 % stature). Popovic *et al*. (2016), have also confirmed that arm span was 0.68 centimeters more than stature for Macedonian boys (100.4 % body height), whereas for Macedonian girls this difference was only 0.17 centimeters but also in favor of stature (99.9 % stature), while Quanjer *et al*. has highlighted the stature estimated from the predicted arm span to stature ratio may differ by up to ten percent from actual stature. All above-mentioned have confirmed again the necessity for developing separate stature models for each population on account of ethnic differences, while some of latest studies found the regional differences among the same ethnic groups (Vujovic *et al*.; Milasinovic *et al*., 2016), which cause the need for additional caution. Therefore, the main goal of this research was to test the hypothesis if above-mentioned facts are true for the Kosovans, due to the previous scientific evidences (Mohanty *et al*.) that it might vary among various ethnic groups and races. Hence, in the present research it was remarked that the arm span was 1.68 centimeters more than the stature in boys (101.0 % stature), while it was 0.12 centimeters less than the stature in Kosovan girls (99.9 % stature). The arm span to stature ratio in Kosovan boys is quite low contrasting to other Europeans but it is very close to the data that was reached in the measurement of the Montenegrins (Bjelica *et al*.), as well as Serbians (Popovic *et al*., 2013), Bosnian and Herzegovinians (Popovic *et al*., 2015) and Macedonians (Popovic *et al*., 2016), while the arm span to stature ratio in Kosovan girls is an almost equal when compared with Montenegrins, Serbians, Macedonians, Bosnian and Herzegovinians and other Europeans.

The results of the previous research are also very similar to the correlation obtained in the present research (boys: r=0.794; girls: r=0.766). For instance, Hickson & Frost observed that the correlation was r=0.86, while in Mohanty *et al*. research, correlation was r=0.82, and in Zverev's research (2003) correlation was r=0.87 for boys and r=0.81 for the girls. In the most recent research, Ter Goon *et al*., noted that correlation was r=0.83, Bjelica *et al*., reported that the correlation was r=0.861 for boys and r=0.809 for girls, while in Popovic *et al*., research from 2013 correlation was r=0.814 for boys and r=0.822 for the girls and from 2016 correlation was r=0.879 for boys and r=0.839 for the girls. As the correlation between arm span and stature was high and significant in both Kosovan sexes, the arm span measure therefore seems to be a reliable indirect anthropometric indicator for estimating stature in both sexes of Kosovan population. Even though these relations are similar, the estimation equations, which are obtained in the Kosovans, considerably differ from other populations.

The results of this study confirm the necessity for developing separate stature models for both sexes in Kosovo at large; however, the researchers must underline that further

studies should consider dividing the population of this country to regional subsamples and analyze it separately, just to be sure there are no geographical differences (such as type of the soil) influencing the average stature in both Kosovan sexes as well as its association with arm span. This concern is based on the fact that entire Kosovo doesn't fall into Dinaric Alps racial classification. Next to this issue, the obvious constraint of this research might be the composition of the measured sample that consisted of high school students. This limitation is based on the fact there are some studies which assumed the growth of an individual doesn't cease by this age (Grasgruber, personal communication, 2016). This assumption might be supported by the fact that university-educated individuals have been founded to be taller than the high school population in Poland and Hungary. On the other hand, thiswasn't the truth in Montenegro and Bosnia and Herzegovina. Hence, some further studies might confirm if this is the truth in Kosovo or not. The obvious limitation of this study is the fact that both sexes of Kosovo did not reach their full genetic potential yet, since various environmental factors controlled their development. Further continuous monitoring is necessary, mostly due to the reason it is expected the secular changes influencing stature will ascend in the following two or three decades. Lastly, the body proportion measurement using photogrammetric anthropometry that is an accurate way nowadays but it is not valid for arm span measurement and it is recommended to keep the old fashion method of measuring this body proportion.

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AUTHOR CONTRIBUTIONS. Fitim Arifi collected the data, performed statistical analyses and wrote the manuscript; Dusko Bjelica, Sami Sermaxhaj and Miroslav Kezunovic overviewed previous studies and discussed the results; Jovan Gardasevic did the presentation of the results and discussed the results; Stevo Popovic designed the study, discussed the data and revised the manuscript.

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RESUMEN: El propósito de esta investigación fue examinar la talla en individuos kosovares de ambos sexos, así como su asociación con la extensión de brazo como una alternativa para la estimación de estatura. En la investigación participaron 1623 personas (830 hombres y 793 mujeres) . Las mediciones antropométricas se tomaron de acuerdo con el protocolo de ISAK. Las relaciones entre la talla y la extensión del brazo se determinó utilizando coeficientes de correlación simple con un 95 % de confianza. Se llevó a cabo un análisis de regresión lineal para examinar hasta qué punto la extensión de brazo puede predecir la estatura. Los resultados mostraron que los varones kosovares tienen 179.52 ± 5.96 cm de altura y tienen una extensión de brazo de 181.29 ± 7.02 cm, mientras que las mujeres kosovares tienen 165.72 ± 4.93 cm de altura y extensión de brazo de 165.60 ± 5.87 cm. Los resultados indicaron que los individuos kosovares de ambos sexos son una población alta, sin embargo las mediciones no se acercaron a poblaciones en las naciones de mayor altura. Además, la extensión de brazo fue predecible en cuanto a la estatura en ambos sexos.

PALABRAS CLAVE: Predicción; Medición; Peso corporal; Lapso del brazo; Kosovo.

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