

# Research Paper: The Diagnostic Value of Radius Bone in Forensic Identification Using Radiographic Images in Iranian Population

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**Citation:** Karimi Jeshni S, Akhlaghi M, Varzandeh M. The Diagnostic Value of Radius Bone in Forensic Identification Using Radiographic Images in Iranian Population. *International Journal of Medical Toxicology & Forensic Medicine*. 2018; 8(1):29-36.  
[http://dx.doi.org/10.22037/ijmtfm.v8i1\(Winter\).19382](http://dx.doi.org/10.22037/ijmtfm.v8i1(Winter).19382)

**doi:** [http://dx.doi.org/10.22037/ijmtfm.v8i1\(Winter\).19382](http://dx.doi.org/10.22037/ijmtfm.v8i1(Winter).19382)

## Article info:

Received: 27 Jun. 2017

Accepted: 13 Sep. 2017

## Keywords:

Forensic science, Sex determination, Maximum length of radius bone, Maximum distal width of radius bone, Radiography, Forensic identification

## ABSTRACT

**Background:** Identification is an important and difficult part of forensic medicine. This study investigated the accuracy of using Maximum Length of Radius (MLR) and Maximum distal Width of Radius (MWR) measurements in radiographic images to determine sex in Iranian population. Moreover, the correlation between these parameters was evaluated.

**Methods:** This study was carried out on radiographic images of 90 adults (45 men and 45 women) over 20 years old. The sample population was divided into three age groups of 20-34, 35-49, and  $\geq 50$  years old. Maximum length and width of radius were measured digitally and then analyzed.

**Results:** The mean values of both measurements in men were more than those in women and radius length decreased with increasing age. The accuracy of these two measured parameters in determining sex was similar (83.3%). Moreover, the correlation values ( $r$ ) between MLR and MWR were 0.49 ( $P < 0.0001$ ) in total studied population.

**Conclusion:** Sex can be determined using MLR or MWR with relatively high accuracy. However, regarding the intermediate correlation between these values, it is not enough to estimate the corresponding MLR from MWR.

## 1. Introduction

Identification is an essential part of forensic medicine. In cases like natural disasters, explosions, or mutilation, identification must be done using a part of a body or skeletal remains which are often crushed, fragmented, or incomplete. Forensic

medicine scientists have reported that sex determination accuracies varies from 90% to 100% using the whole skeleton, 95% for pelvic bone, 80% to 92% for the skull, 98% for the pelvis plus skull, 80% for long bones, and 98% for long bones plus pelvis [1].

Radius bone is relatively resistant to environmental corruption and degradation. Therefore, it is more

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likely to be retrieved for forensic investigations. Several studies have investigated different races and geographical regions to investigate gender differences in radius bone length, width, diameter, circumference, and trabecular structure using various methods [2-15]. Also, some studies investigated the relationship between body stature and length of radius bone because stature estimation is useful in identification [2-6]. Furthermore, few studies have considered that linear intra-bone geometric dependencies of radius bone could be useful for identification [16].

Because the diagnostic value of radius bone for forensic identification had not been studied in Iranian population, the purpose of this study was to evaluate radius bone measurement for sex determination in this society using radiographic images. We also examined the correlation between maximum length and maximal distal width of radius to find possible linear relationships between these parameters for the same population. If such a relationship exists it is useful to estimate maximum radius length and ultimately body stature from the maximum distal width of this bone when only the distal part of the bone is available.

## 2. Materials and Methods

This study was conducted on 90 Iranian patients over 20 years old, (45 males and 45 females). These individuals were referred by their physicians for right side forearm radiography to Sina Hospital of Tehran over one year from November 2015 to November 2016. The participants had already signed the informed consent for research utilization of their images. The studied population were divided into three age groups of 20-34 (Group A: 14 males and 18 females), 35-49 (Group B: 17 males and 14 females), and over 50 years old (Group C: 14 males and 13 females) to compare the recorded measurements in different age groups [17]. Exclusion criteria were any sign of present or past forearm fracture, any acquired or congenital skeletal abnormalities and underlying bone diseases except osteoporosis, chromosomal abnormalities, and hermaphrodite cases, non-standard and low-quality radiographic images, and those people with invalid identification cards.

Our sample size was calculated based on Baumbatch et al. study [16]. Maximum length and maximum distal width of radius were measured digitally using Picture Archiving and Communication System (PACS). In order to minimize error, all measurements were done by two independent investigators (one Forensic medicine specialist and one radiology technician) blinded to the

study and to each other. Then we used the mean value of two reported measures in our study. Figure 1 shows an example of the measured parameters. The obtained data were analyzed using SPSS version 19. Sex difference and the relation between the length and distal width of radius bone were tested using the paired t test, Receiver Operating Characteristic (ROC) curve, and regression relations.  $P < 0.05$  was considered as statistically significant.

## 3. Results

Mean (SD) age of total sample population, men, and women were respectively 42.59(16.09), 43.42(16.67), and 41.76(15.63) years. Table 1 summarizes the age-sex characteristics of the studied population and shows no statistically significant difference in the mean age between males and females ( $P > 0.626$ ).

Mean (SD) values of the maximum length and maximum distal width of radius were 24.3(1.9) cm and 3.3(0.3) cm in the total sample population. These values were 25.6(1.3) cm and 3.5(0.3) cm in men, and 22.9(1.3) cm and 3.1(0.2) cm in women, respectively. These results showed that the maximum length and distal width of radius were significantly longer in males than females ( $P < 0.001$ ). Therefore, sensitivity, specificity, Negative Predictive Value (NPV), Positive Predictive Value (PPV), and accuracy of measured parameters for sex determination on Roc curve (Figure 2) were calculated. In 24 cm demarking point for the maximum length of radius, calculated sensitivity, specificity, NPV, PPV, and accuracy were 91.1%, 75.56%, 89.5%, 78.8%, and 83.3%, respectively. The corresponding values for the maximum distal width in 3.3 cm demarking point were 77.8%, 88.9%, 80%, 87.5%, and 83.3%, respectively.

We categorized the total studied population into three age groups of 20-34, 35-49, and  $\geq 50$  years. Maximum radius length and distal width mean values in total population and two genders of each age group are presented in Table 2. Regarding significant differences between men and women of each age groups for these values ( $P < 0.001$ ), sensitivity, specificity, positive and negative predictive values, and the accuracy of measured parameters for sex determination in obtained demarking points were calculated (Table 3). The accuracy of these measured parameters ranged from 77.4% to 90.6%.

Moreover, correlation coefficient ( $r$ ), and linear regression graphs between the maximum length and maximum width of radius for men, women, and total population

**Table 1.** Age (year) distribution of the studied sample according to sex

Sex	Mean	Median	Mode	SD	95% Confidence Interval		P
Male	43.42	43.00	35	16.674	38.41	48.43	0.626
Female	41.76	40.00	24	15.632	37.06	46.45	
Total	42.59	40.50	35	16.09	39.22	45.9	

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**Table 2.** Comparison of mean, Standard Deviation (SD), Maximum Length (MLR) and Maximum distal Width of Radius (MWR) between two sexes in different age groups

Parameter	Age Group, y	Male, cm				Female, cm				P	Total, cm			
		Mean	SD	Min	Max	Mean	SD	Min	Max		Mean	SD	Min	Max
MLR	20-34 (A)	26.2	1.1	24.0	28.0	23.4	1.2	21.2	25.8	<0.001	24.7	1.8	21.2	28.0
	35-49 (B)	26.0	1.2	23.5	27.9	23.0	1.3	21.1	25.1	<0.001	24.7	2	21.1	27.9
	≥50 (C)	24.6	0.9	22.9	26.0	22.1	1.1	20.3	24.3	<0.001	23.4	1.6	20.3	26.0
MWR	20-34 (A)	3.5	0.4	2.8	3.9	3.0	0.3	2.4	3.9	<0.001	3.2	0.4	2.4	3.9
	35-49 (B)	3.4	0.27	3.1	4.1	3.1	0.2	2.8	3.5	<0.001	3.3	0.3	2.8	4.1
	≥50 (C)	3.6	0.26	3.0	4.0	3.1	0.1	2.9	3.3	<0.001	3.4	0.3	2.9	4.0

All measurements were in cm and P<0.05 was statistically significant.

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were investigated that are presented in Figure 3. As shown, there were significant relationships between the maximum length and distal width of radius bone in the total sample population, the total population of different age groups, and over 50 years old men.

#### 4. Discussion

In this study, we attempted to examine the accuracy of maximum length and width of radius measurements in

sex determination of adult Iranians using radiographic images. Also, the correlation between these parameters was investigated. Table 4 shows the mean values of maximum length and width of radius, type of samples and geographical zones of similar studies. In all studies, the mean values of maximum length and width of radius in men were longer than those in women. The MLR measurement mean (SD) in our study (24.3 [1.9] cm), was relatively similar to Baumbach et al. study with radiographic images in Austrian population (24.65 cm).

**Table 3.** Sensitivity, specificity, Positive Predictive Value (PPV), Negative Predictive Value (NPV), and accuracy of Maximum Length of Radius (MLR), and Maximum Width of Radius (MWR) for sex determination in different age groups

Age, Y	Parameter	Demarking Point	Sensitivity, %	Specificity, %	PPV, %	NPV, %	Accuracy, %
20-34	MLR	25.2	85.7	94.4	92.3	89.4	90.6
	MWR	3.2	78.6	88.9	84.6	84.2	84.4
35-49	MLR	24.4	82.4	78.6	82.3	78.6	80.6
	MWR	3.3	70.6	85.7	85.7	70.6	77.4
≥50	MLR	23.4	85.7	84.6	85.7	84.6	85.18
	MWR	3.3	85.7	92.3	92.3	85.7	88.8

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**Table 4.** The maximum length and distal width of radius in similar studies

Parameter Reference	Population	Year	Type of Sample	MLR (cm)			MWR (cm)		
				Male	Female	Total	Male	Female	Total
Celbis et al. [2]	Turkey	2006	Fresh bone	24.5	21.7	----	----	----	----
Petrovich et al. [6]	Croatia	2007	Radiography	24.8	22.7	----	----	----	----
Akhlaghi et al. [3]	Iran	2012	Fresh bone	24.49	20.87	22.9	----	----	----
Torimitsu et al. [5]	Japan	2014	CT scan	23.1	20.79	21.96	----	----	----
Mall et al. [4]	Germany	2001	Fresh bone	24.6	22	----	3.6	3.2	----
Barrier et al. [7]	South Africa	2008	Dry bone	25.5	23	----	3.46	3.1	----
Uzun et al. [8]	Turkey	2011	Fresh bone	24.36	21.79	----	3.37	2.99	----
Chairisi et al. [10]	Greek	2011	Dry bone	24	21	----	3.27	2.8	----
Baumbach et al. [16]	Germany	2012	Dry bone	24.57	22.04	23.17	3.62	3.21	3.4
	Austria		Radiography	24.6	23.32	24.65	3.34	3.21	3.1
Je-Hun Lee et al. [9]	Korea	2014	Fresh bone	23.1	20.7	----	----	----	----
The present study	Iran	2016	Radiography	25.6	22.9	24.3	3.5	3.1	3.3

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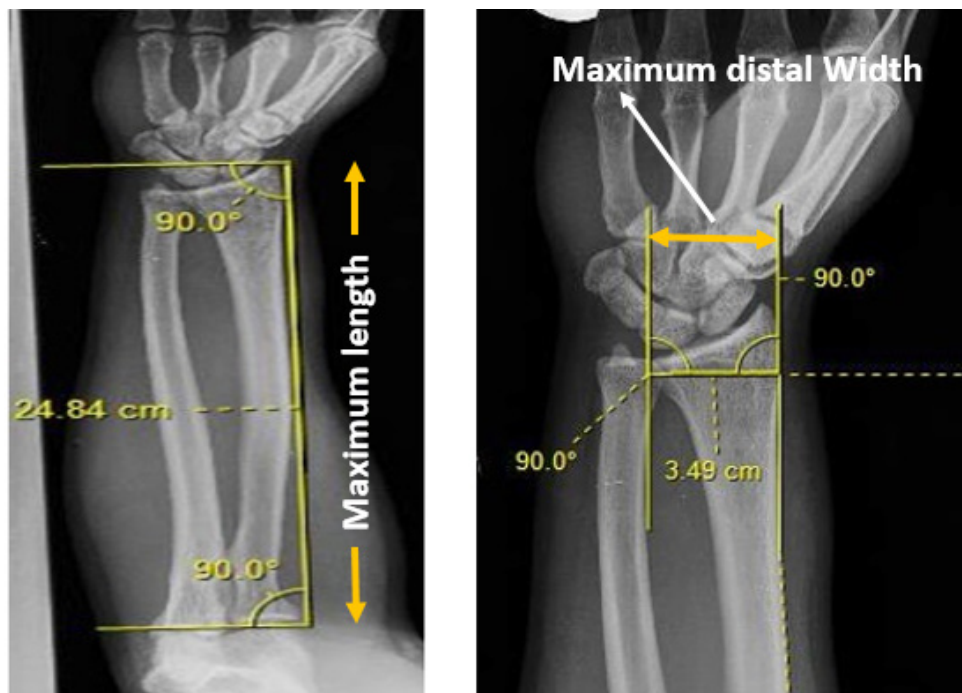
However, these values (23.17 cm) in German population were found using formalin fixed bone samples [16]. In Japanese population it was 21.96 cm using CT scan images [5]. In Akhlaghi et al. study that was performed on 10-80 years old Iranian population using fresh bone, it was 22.95(2.65) cm which was slightly different [3].

The MLR mean values in our study for men and women population were similar to studies by Barrier et al. [7], Petrovicki et al. [6], and relatively similar to Mall et al. [4], and Baumbach et al. [16] studies. However, it was different from Celbis et al. [2], Uzun et al. [8], Akhlaghi et al. [3], Je Hun Lee et al. [9], Chairiasi et al. [10], and Torimitsu et al. [5] studies. The differences could be due to various methodology, races, ages, and sample's types. The MLR accuracy for sex determination in our study was 83.3% which was similar to Je-Hun Lee et al. [9] study (82.2%). However, it had less accuracy than Celbis et al. [2], Mall et al. [4], and Barrier et al. [7] studies, with 96%, 89.13%, and 88%, respectively.

In the current study, the MWR measurement mean (SD) value, i.e. 3.3(0.3) cm in the total population was relatively similar to Baumbach et al. study [16]. Also, this value in men and women population was similar to Mall et al. [4], Barrier et al. [7], Uzun et al. [8], Chairiasi et al. [10], and Baumbach et al. [16] stud-

ies. The MWR accuracy (83.3%) in our study for sex determination was higher than that in Mall et al. study (78.26%) [4] and relatively similar to Barrier et al. study (81.5%) [7]. Race, population, and geographical situations, technique and methodology might be the reasons for obtaining such different figures and results. Based on the comparison of our results with other studies, it seems that maximum length of radius (compared to the maximum width) is more affected by race and geographical regions.

As the accuracy of the MLR and the MWR for sex determination were relatively high, we can determine gender of an incomplete body remains using radius bone. Also because the accuracy of length and width of radius is similar (83.3%), when only distal part of a radius bone is sent to the forensic department for identification, sex can be determined with relatively high accuracy. In our study, the comparison between three age groups showed that the mean value of MLR in old age group was shorter than young and middle age groups, in total, indicating that the MLR decreased with increasing age. However, MWR variations were not significant. We found that in young and middle aged adults, MLR accuracy for sex determination was significantly higher than MWR accuracy. That is probably due to bone degenerative changes and decreasing



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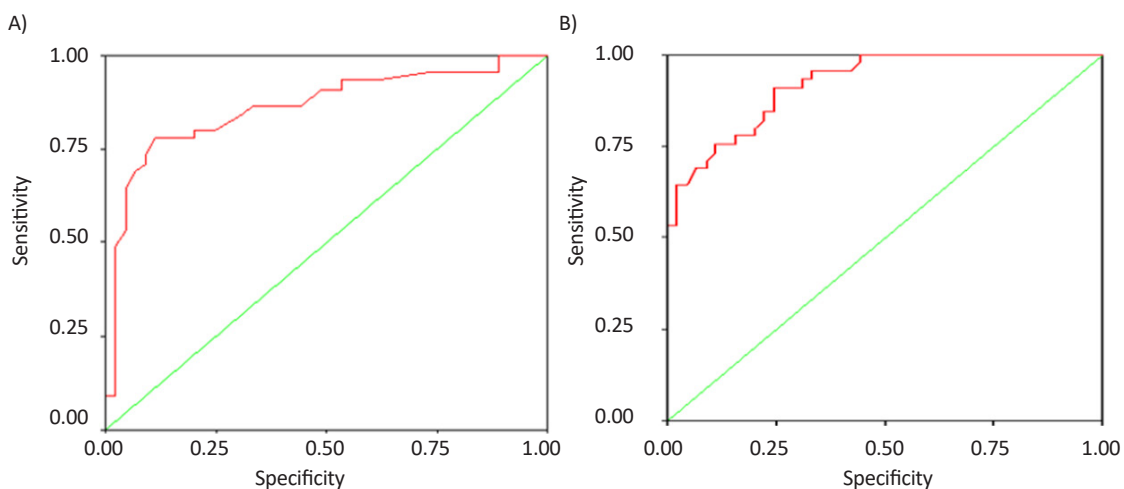
**Figure 1.** Measured parameters of the radius bone

A. Maximum Length of Radius (MLR): Vertical distance between higher points of radius head to the distal tip of radius styloid process; B. Maximum distal Width of Radius (MWR): Horizontal distance between the most lateral and medial points of the distal radius bone

bone length (especially in men) which will affect sex determination accuracy.

According to our study, the correlation between the MLR and MWR in the total population is 0.48, ( $P < 0.001$ ). The correlation between men and women were not statistically significant. Baumbach et al. [16] investigated the relationship between maximum radius

length and maximum distal width in two independent populations. One study was carried out in Germany on 135 formalin fixed radius (mean [SD] age: 79.12[9.95] years) using the osteometric board and caliper ruler to measure the MLR and MWR. Another study was carried out in Austria on 100 radius radiography of 20-70 years old patients (mean [SD] age: 37.88[13.82] years) that measuring was done digitally. The results showed a



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**Figure 2.** The ROC diagram for predictive value of maximum length (A), and maximum width (B) of radius in sex determination

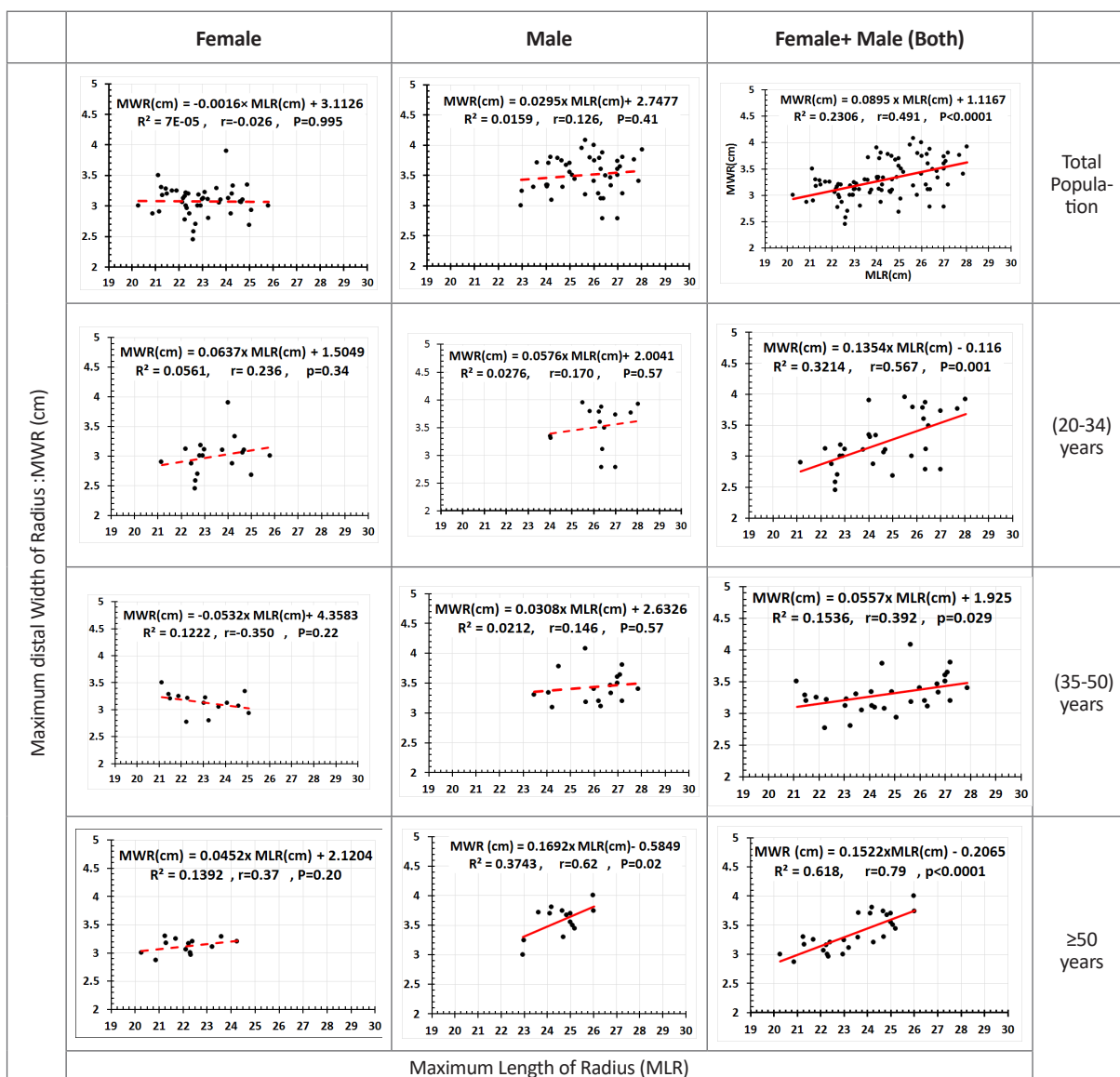


Figure 3. Correlations between maximum length and distal width of radius in total population and each age group

P≤0.05 is significant.

correlation of 0.621, (P<0.001) for German, and 0.753, (P<0.001) for Austrian population. Also, sex had significant effects on their results. The differences in the results might be related to the age and race of studied samples.

Our relationship investigation between MLR and MWR in each age group showed a strong correlation between the MLR and the MWR measurements in men (r=0.62) and total population (r=0.79) of age group C (≥50). Therefore, if only distal part of a radius is available and with using other documents and examinations, it was estimated that human remains belong to an over 50-year-old person, one can estimate the MLR and then body stature with higher accuracy.

### 5. Conclusion

The results of this study indicate that sex can be determined using radius bone dimensions (MLR or MWR) with relatively high accuracy if only radius bone is available. The predictive accuracies of these two measurements were similar (83.3%). Correlation of MLR and MWR were intermediate in total sample population and strong in the people ≥50 years. Therefore, for estimating the corresponding MLR from an MWR measurement, further studies with larger sample sizes are recommended. Since our study was carried out on an adult Iranian population using radiographic images, independent studies in other races are also suggested.

## Acknowledgments

This research was extracted from the MD thesis of So-mayeh Karimi Jeshni in Department of Forensic Medicine, Tehran University of Medical Sciences; and did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. The authors would like to thank radiology department staff of Sina Hospital in Tehran University of Medical Sciences. We wish to thank all our participants for their pivotal contribution to this study.

## Conflict of Interest

The authors declared no conflicts of interest.

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