

Applicability of Tanaka–Johnston, Moyers, and Bernabé and Flores–Mir Mixed Dentition Analyses in School-going Children of Sri Ganganagar City, Rajasthan (India): A Cross-sectional Study

Abstract

Background: The orthodontic diagnosis and treatment planning are the fundamental goals during the mixed dentition period. Numerous methods have been proposed till date such as Nance method, Moyer's method, Staley–Kerber and Tanaka–Johnston's method, and Bernabé and Flores–Mir method. **Aim:** The aim of the study is to determine the mesiodistal widths of the lower permanent canines and premolars from Tanaka–Johnston, Moyers, and Bernabé E and Flores–Mir C mixed dentition analysis and to determine the correlation coefficients and the new prediction equation for Sri Ganganagar population. **Setting and Design:** A total of 3572 children were clinically examined from the contemporary population of Sri Ganganagar city and Outpatient Department of Pediatric and Preventive Dentistry in Sri Ganganagar, Rajasthan. A total of 150 individuals were randomly selected for the study based on the inclusion and exclusion criteria and were designated as “study samples. **Materials and Methods:** A total of 150 children aged 11–16 years of Sri Ganganagar city were randomly selected. The mesiodistal width of permanent incisors, canines, premolars, and molars was measured with the help of digital vernier caliper with an accuracy of ± 0.01 mm. The measurements of canines and premolars were summed up and compared with those derived from Tanaka and Johnston equations, Moyers probability tables, and Bernabé and Flores–Mir equations. **Statistical Analysis:** The data obtained were subjected to statistical analysis using IBM SPSS Statistics Windows version “20.0” using Student's *t*-test, Pearson correlation coefficient, and Kruskal–Wallis test. **Results:** All the three methods overestimated the actual sum of permanent canine and premolars in both the arches in our population. The correlation coefficients and the new regression equations were derived for both maxilla and mandible in males and females for Sri Ganganagar population. **Conclusion:** The predicted values obtained from all the three methods overestimated the actual values.

Keywords: Bernabé and Flores–Mir, mixed dentition analysis, Moyers', Tanaka and Johnston

Introduction

Pediatric dentistry is shifting from a conservative–restorative approach, toward a concept of total pediatric patient care, including early diagnosis and correction of developing malocclusion during the early or mixed dentition period. During this crucial period, the pediatric dentist is responsible to provide an opinion of the effect of this malocclusion on the ultimate occlusal status of the permanent dentition.

The orthodontic diagnosis and treatment planning are the fundamental goals during mixed dentition period to prevent future crowding or spacing in the teeth for the prediction of the space in the dental arch for accommodating unerupted permanent

teeth.^[1] Hence, an accurate space analysis is very important in this period for quantifying the degree of crowding and determining whether the treatment plan is going to involve guidance of eruption, serial extractions, space maintenance, space regaining, or just periodic observation of the patient.^[2]

Numerous methods have been proposed till date, but the basic approaches for doing this are (1) measurement of the teeth on radiographs such as Nance method, (2) estimation from prediction tables such as Moyer's method, (3) combination of radiographic and prediction table methods such as Staley–Kerber and Tanaka–Johnston's method, and (4)

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use of multiple regression schemes such as Bernabé and Flores-Mir method.^[3]

The various researchers have conducted numerous studies using different methods to derive regression equations, but still, the population of Sri Ganganagar (Rajasthan) has not been studied yet. As Sri Ganganagar is a major part of the Northern zone of Rajasthan state and is racially and geographically different, the aim of the present study was to evaluate the applicability of Moyers, Tanaka–Johnston, and Bernabé and Flores–Mir mixed dentition analyses in school-going children of age group (11–16) years in Sri Ganganagar city, Rajasthan (India).

Materials and Methods

The present study was done in the Department of Pediatric and Preventive Dentistry, Sri Ganganagar, Rajasthan. The ethical clearance was obtained for the study by the Institutional Ethical Committee (SDCRI/IEC/2013/017). The study was carried out from the time period September 18, 2013 to September 30, 2015.

A total of 3572 children were clinically examined from the contemporary population which included children studying in the different schools of Sri Ganganagar city and also patients seen in the Outpatient Department of Pediatric and Preventive Dentistry in Sri Ganganagar, Rajasthan. For the present study, using the sample size calculation method, considering $\alpha = 0.05$, $\beta = 0.1$, with power at 90%, confidence interval at 85% and Coefficient of variation at 17.5%; the sample size determined was $n = 142$. Considering the unknown error, the sample size for the present study was increased to 150.

Thus, a total of 150 individuals were randomly selected for the study based on the inclusion and exclusion criteria and were designated as “study samples.”

Inclusion criteria

- All the individuals should be the natives of Sri Ganganagar district, Rajasthan, 11–16 years old, with Angle’s Class I molar relation
- All the permanent teeth to be examined, i.e., maxillary and mandibular central incisors, lateral incisors, canines, and premolars; and maxillary first molars should be present and fully erupted, with no evidence of proximal dental caries, restorations, fractures, tooth wear, and dental anomalies.

Exclusion criteria

The individuals with moderate-to-severe malocclusion, those undergoing or had undergone an orthodontic treatment, and individuals with clinical abnormalities affecting the jaws, congenitally missing, or impacted permanent teeth were excluded from the study.

The impressions were taken for all the selected study samples using muscle molded Rim-Lock Trays no. U3–U5.

The trays were selected for each patient by checking the last molar coverage by tray and rims of the trays were 2 mm short of sulcus with the help of alginate impression material. The impressions were washed, disinfected by immersing in 2% glutaraldehyde solution for 10 min, and then poured immediately with a proper mix of dental stone. The study casts were checked for any distortions, disinfected, and trimmed. The standardized bases were made for all the 150 study casts, by keeping teeth in occlusion with the help of base formers.

The measurements of mesiodistal dimensions of the maxillary and mandibular teeth were made using a digital vernier caliper (calibrated to the nearest 0.01 mm), with a standard method by Moorrees and Reed^[4] [Figure 1]. To gain easier access to interdental spaces, the measuring tips of digital vernier caliper were narrowed. The eye, instrument, and light source lay approximately in a straight line, thus reducing errors of parallax to a minimum. To prevent eye fatigue, not more than 10 casts were measured at a time. The teeth measured were permanent maxillary and mandibular central incisors, lateral incisors, canines, premolars, and maxillary first molars. An average value for the canine and premolars was calculated from the values obtained individually for the right and left segments of the arch, for both maxillary and mandibular arch, respectively. This was done to attain one value for maxillary and mandibular canine and premolars, for each value of the mandibular incisors.

Three prediction methods were used in the study to analyze the applicability of mixed dentition analysis:

Tanaka and Johnston method

The mesiodistal dimensions of maxillary and mandibular canines and premolars were predicted using the following equation:

For each of the maxillary left and right permanent canines and premolars dimensions:

$$Y = 11 + 0.5 (X)$$

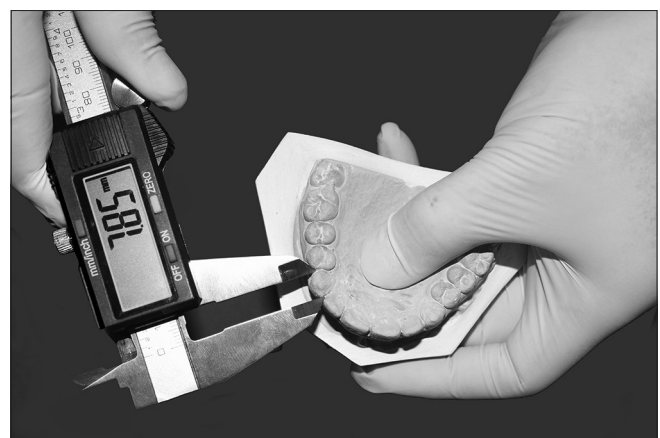


Figure 1: The measurements of mesiodistal dimensions of the maxillary and mandibular teeth using a digital vernier caliper

For each of the mandibular left and right permanent canines and premolars dimensions:

$$Y = 10.5 + 0.5 (X)$$

Y is the estimate of mesiodistal dimensions of unerupted permanent canine and premolars for each side; X is the sum of mesiodistal dimensions of four permanent mandibular incisors.^[5]

Moyers' method

The probability charts at 75th percentile levels were used to estimate the widths of permanent canines and premolars using sum of mandibular permanent incisors.^[6]

Bernabé E and Flores-Mir C method

The mesiodistal widths of the lower permanent canine and premolars were estimated by the following regression equation: $Y = 3.763 + 0.37 \times X_0 + 1.057 \times X_1 + 0.366 \times X_2$, where X_0 is the sum of the of the upper and lower permanent central incisors plus the widths of the upper permanent first molars, X_1 is 0 for the mandible and 1 for the maxilla, and X_2 is 0 for female and 1 for male.^[7]

The actual measurements taken from the dental study casts were then compared to those predicted using the Tanaka and Johnston method, and discrepancy between the two values was calculated. The new regression equations were determined using the lower four permanent incisors as predictors for the sum of the widths of lower permanent canine and premolars. The correlation and determination coefficients were also obtained.

To test the reliability of the measurements, all measurements were made by single observer and triple determination on a total of 20 randomly selected dental study casts was performed. The measurements were made for three times at an interval of 1 week to check the intraobserver bias. A total of 20 study models were analyzed for three times by the same observer and a mean value was obtained. The data thus obtained were subjected to statistical analysis using IBM SPSS Statistics Windows version "20.0" (IBM Corp., Armonk, New York, USA).

Results

The study sample consisted of 150 pairs of dental casts (both maxillary and mandibular) obtained from 73 males and 77 females with permanent dentition, having fully erupted teeth (maxillary and mandibular permanent teeth except third molars). The individuals included in the study were 11–16 years old with a mean age of 13.77 ± 1.27 years [Table 1].

In male participants, the mean mesiodistal dimension of the maxillary permanent canine was 7.71 ± 0.22 , maxillary first premolar was 6.87 ± 0.37 mm, and second premolar was 6.30 ± 0.43 mm. In the mandibular arch, the mean width

Table 1: Sociodemographic characteristics of the study sample

Gender	n	Age (mean±SD)
Male	73	13.85±1.24
Female	77	13.69±1.33
Total	150	13.77±1.28

SD: Standard deviation

was 6.49 ± 0.29 for canine, 6.80 ± 0.47 mm for the first premolar, and 6.92 ± 0.38 mm for the second premolar. In females, the mean mesiodistal measurement of the maxillary permanent canine was 7.24 ± 0.32 mm, maxillary first premolar was 6.13 ± 0.62 , and second premolar was 5.74 ± 0.61 mm, whereas the mandibular canine had mean mesiodistal dimension of 5.99 ± 0.47 ; for the first premolar, the values was 6.28 ± 0.41 mm; and for the second premolar, it was 5.91 ± 0.54 mm.

To check the intraobserver reliability, 20 pairs of the study casts were randomly selected from 150 samples and measured three times at an interval of 1 week. The intraobserver bias was calculated using Cohen's Kappa statistical analysis with statistical value 1.88 that represents very good agreement. The measurement obtained was then subjected to statistical analysis using Pearson correlation coefficient. Concordance between the three groups of measurements was high as the $P = 0.40$ in maxilla and 0.69 in the mandible, which was insignificant.

The mesiodistal measurements of canine and premolars between males and females for both maxilla and mandible were statistically analyzed by unpaired Student's *t*-test. The dimensions of both maxillary and mandibular canine and premolars were greater in males than in females. The statistical difference was found to be highly significant ($P < 0.01$) for both the genders in maxillary and mandibular arches. The degree of sexual dimorphism was observed to be highest in maxillary canine followed by mandibular canine.

In males, the correlation coefficient between the sum of mandibular incisors and the sum of canine and premolars were 0.42 and 0.53 for maxilla and mandible, respectively. This value in females was 0.51 for maxilla and 0.61 for the mandible. The correlation coefficients between the sum of maxillary and mandibular central incisors and maxillary first molars and the width of the canine–premolar segment in male participants were 0.352 and 0.417 for maxilla and mandible, respectively.

In the female participants, the correlation coefficient was 0.341 and 0.566 for the maxillary and mandibular arch, respectively [Table 2].

The two-tailed *t*-test was employed to compare the differences between the actual and predicted mesiodistal values of the sum of unerupted permanent canines, first and second premolars. All the three methods, Tanaka and

Johnston, Moyers, and Bernabé and Flores–Mir exhibited overestimation when the predicted values were compared with actual sum of permanent canine and premolars in males as well as females. The statistically difference was found to be highly significant ($P < 0.001$).

In males, Kruskal–Wallis test was applied between the mean difference values of the three different methods, which showed Tanaka–Johnston and Moyers’ methods were insignificant with each other ($P > 0.01$), while both the methods showed highly significant difference with Bernabé E and Flores–Mir C method for maxillary and mandibular permanent canines and premolars in both males [Table 3] and females [Table 4].

The simple linear regression employed by Tanaka and Johnston is defined by the formula $Y = a + b(X)$, where Y is the sum of mesiodistal widths of canine and premolars of a single quadrant, a and b are constants, and X is the sum of mandibular incisors. The parameter of interest is the slope of linear regression (b constant), a is the Y-intercept. This study found b coefficients of 0.38 and 0.33 for maxilla and mandible, respectively, in males, and

0.32 and 0.31 for maxilla and mandible, respectively, in females [Table 5]. The regression equations proposed for North Indian population are as follows:

- Males
 - Maxilla: $Y = 9.06 + 0.38(X)$
 - Mandible: $Y = 8.35 + 0.33(X)$
- Females
 - Maxilla: $Y = 9.79 + 0.32(X)$
 - Mandible: $Y = 7.98 + 0.31(X)$

Discussion

The most important factors in the reliability of a study based on odontometric data are the characteristics of the sample chosen. The study sample ($n = 150$) was considered acceptable according to Sri Ganganagar city population and uniform ethnic distribution (Rajasthan). The age range between 11 and 16 years was chosen, as these children have minimal dental attrition and the teeth to be measured would have been erupted into the oral cavity in both the dental arches. The study was cross-sectional study with random sampling, having 73 males and 77 females study participants.

Table 2: Determination of correlation coefficients for maxilla and mandible in both males and females

Statistical analysis	Maxilla		Mandible	
	Males	Females	Males	Females
Correlation coefficient (<i>r</i>) between sum of mandibular incisors with actual value of sum of canine and premolars	0.42	0.51	0.53	0.61
<i>P</i>	0.002*	0.003*	0.0002*	<0.0001*
Correlation coefficient (<i>r</i>) sum of maxillary and mandibular central incisors and sum of maxillary permanent first molars with width of canine-premolars segment	0.319	0.463	0.431	0.481
<i>P</i>	0.006*	<0.001*	0.0001*	<0.001*

* $P < 0.01$ is highly significant

Table 3: The comparison of predicted values based on methods of Tanaka and Johnston, Moyers, and Bernabé E and Flores-Mir C in male participants

Prediction Method	Tanaka and Johnston		Moyers’		BernabéE and Flores-Mir C		<i>P</i> [†]
	Maxilla	Mandible	Maxilla	Mandible	Maxilla	Mandible	
Predicted values of 345 (mm)	21.94±0.58 ^a	21.44±0.53 ^a	21.65±0.78 ^a	21.40±0.48 ^a	29.91±1.06 ^b	28.85±1.01 ^b	<0.01*
Actual values of 345 (mm)	20.12±1.23	19.29±1.24	20.12±1.23	19.29±1.24	20.12±1.23	19.29±1.24	
Difference (predicted-actual values)	1.82±0.92	2.15±0.81	1.53±0.97	2.11±0.79	9.79±1.13	9.56±1.09	
<i>P</i>	<0.01*	<0.01*	<0.01*	<0.01*	<0.01*	<0.01*	

[†]Kruskal-Wallis test; values in the column with different letters indicate significant differences at $P < 0.01$, whereas same letters denote insignificant difference, * P -Value= 0.01

Table 4: The comparison of predicted values based on methods of Tanaka and Johnston, Moyers, and Bernabé E and Flores-Mir C in female participants

Prediction method	Tanaka and Johnston		Moyers’		BernabéE and Flores-Mir C		<i>P</i> [†]
	Maxilla	Mandible	Maxilla	Mandible	Maxilla	Mandible	
Predicted values of 345 (mm)	21.69±0.64	21.19±0.63	20.88±0.50	20.51±0.55	29.46±1.51	28.41±1.48	<0.01*
Actual values of 345 (mm)	20.04±1.09 ^a	19.40±1.01 ^a	20.04±1.09 ^b	19.40±1.01 ^b	20.04±1.09 ^c	19.40±1.01 ^c	
Difference (predicted-actual values)	1.65±0.77	1.79±0.78	0.84±0.72	1.11±0.69	9.42±1.14	9.01±1.17	
<i>P</i>	<0.01*	<0.01*	<0.01*	<0.01*	<0.01*	<0.01*	

[†]Kruskal-Wallis test; values in the column with different letters indicate high significant differences at $P < 0.01$, *0.01

Table 5: Correlation coefficients of maxilla and mandible in males and females and corresponding regression equations derived from both male and female sexes

	Male		Female	
	Maxilla	Mandible	Maxilla	Mandible
Correlation coefficients	0.42	0.53	0.51	0.61
Correlation constants a	9.06	8.35	9.79	7.98
Correlation constants b	0.38	0.33	0.32	0.31
Regression equation Y=a + b (X)	Y=9.06 + 0.38 (X)	Y=8.35 + 0.33 (X)	Y=9.79 + 0.32 (X)	Y=7.98 + 0.31 (X)

Y represented the predicted combined mesiodistal widths of canines, and first and second premolars in one quadrant (dependent variable) and X represented the measured mesiodistal widths of the mandibular incisors. a and b were the regression constants statistically derived

Random but almost equal distribution of males and females has been taken as there is strong evidence that tooth sizes are expressed through X-linked inheritance. Garn *et al.*^[8] hypothesized that possession of two X chromosomes in females provided a higher measure of control which is lacked in males with only one X chromosome.

In the present study, Angle's Class I molar relation was used because this relation is a stable relation for all the teeth. The teeth that were to be measured should be fully erupted to measure any discrepancy between the predicted and actual value. Hence, for the finer measurements and results, fully erupted teeth were required.

The teeth to be measured were selected on the basis of exclusion and inclusion criteria so that there was no alteration in mesiodistal dimensions of the tooth.

The alginate material was chosen for taking impressions as it makes an accurate impression, allows for undercuts recording, and less time-consuming process. The impressions were washed and immersed in 2% glutaraldehyde solution for 10 min to maintain aseptic conditions. The standardized bases were prepared for all the 150 study casts that provided occlusal representation to identify Angle's classification of malocclusion, defining the relationship of the maxillary and mandibular teeth in the sagittal plane.

The measurement reliability is one of the most important aspects of odontometric studies; thus, the measurements were made from the dental casts rather than taking measurements intraorally, as they are more consistent and accurate than intraoral measurements, particularly in the posterior segments where measuring becomes unwieldy. The measurements were made using a digital sliding vernier caliper as suggested by Hunter and Priest,^[9] who found the sliding calipers to be accurate and precise. The greatest mesiodistal diameter was measured at the contact points parallel to the occlusal surface of the teeth and also parallel to the vestibular surface of the model, as suggested by Moorrees and Reed(1964).^[4] When a tooth was rotated or malposed in relation to the dental arch, the measurement was taken between the points on the approximate surface of the crown.

To diminish ocular fatigue, not more than 10 sets of casts were measured per day. To test the intraexaminer

variability, 20 study models were randomly selected and were measured three times at an interval of 1 week so that the first measurement did not prejudice the previous.

Keeping in view the racial and geographic differences, the present study attempted to establish the validity of Tanaka and Johnston equations, Moyers prediction tables, and Bernabé and Flores–Mir equations for mixed dentition analysis in a sample of Sri Ganganagar city (Rajasthan), occupying the major portion of Northwestern zone of India. Tanaka and Johnston method of mixed dentition analysis is one of the regression methods that vary considerably between different racial and ethnic groups.^[8] Moyers' method has minimal systematic error and does not require sophisticated clinical judgment and saves time. Bernabé E and Flores–Mir C (2005) developed regression equations for Peruvian adolescents to forecast the size of unerupted teeth. There have been several studies of mixed dentition space analysis in various population groups, disagreed with use of Moyers and Tanaka and Johnston methods. In addition, there is some evidence of secular trends of changing dimensions of the teeth, which may require progressive modifications of mixed dentition space analysis for different populations.

The present study showed consistently higher values of measurements of incisors, canines, and premolars in males than in females although the correlation observed was statistically insignificant. Studies conducted by Al-Khadra,^[10] Lee-Chan *et al.*,^[11] and Bhatnagar *et al.*^[12] found similar results between males and females while Moyers,^[6] Priya and Munshi,^[13] and Jaroontham and Godfrey^[14] found statistically significant differences between the two measurements.

In the present study, the *t*-tests were done to compare the mean values of tooth widths of males and females, revealed highly significant differences ($P < 0.01$), with males having the larger values for both maxilla and mandible arches. This is in accordance to the studies conducted by Yuen *et al.* (1997)^[15] Singh and Goyal,^[16] Arslan *et al.*,^[17] and Durgekar and Naik.^[18]

The correlation coefficients between the mesiodistal width of canine and premolars, and combinations of maxillary and mandibular central incisors and maxillary first molars in male and female participants were originally described by

Bernabé and Flores–Mir. The difference can be attributed to racial and ethnic variations. This indicates that overall, the sum of lower incisors is a better predictor of the size of permanent canine and premolars in the Northwestern zone of Indian population.

In the present study, Tanaka and Johnston method had overestimated the sum of mesiodistal width of canine and premolars in both sexes for both the arches. The results obtained were in accordance with the studies conducted by Diagne *et al.*^[19] and Arslan *et al.*,^[17] whereas under prediction has also been found with some studies Lee-Chan *et al.*,^[11] Yuen *et al.* (1998),^[15] and Abu Alhaija and Qudeimat.^[20]

The result of our study indicated that the frequently used Moyers analysis was not sufficiently accurate to predict the canine–premolar segment in the Northwestern zone of India. The 75th percentile value for girls and 50th percentile value for boys of Moyers probability tables gave closer values according to our study. Moyers' prediction tables tended to overestimate the mesiodistal dimensions of canine–premolar segments at the 75th percentile value. Studies in accordance to these results were Kaplan *et al.* (1977),^[21] Al-Khadra (1993),^[10] Durgekar and Naik.^[18] In another study conducted by Carrillo *et al.*, no statistically significant difference was observed when the extent of needed space was assessed in relation to different biotypes.^[22] About 50% probability level was more applicable in boys and 75% probability level in girls according to our study. The results obtained in our study were similar to the study conducted by Thimmegowda *et al.* in Bengaluru City of India to check the prediction of Moyers probability table.^[23] In another study conducted by Dhanu *et al.* in Northeastern Karnataka, overrated values were reported than the actual values obtained with Tanaka–Johnston analysis and Moyers 75th percentile prediction table, whereas underrated values were observed in both the arches with Moyers 50th percentile in both males and females.^[24] According to the study conducted by Kamatham *et al.*, Tanaka–Johnston and Moyers' method at 35% and 75% probability level could not be applied for the South Indian population.^[25]

In the present study, Bernabé E and Flores–Mir C regression equations were found to overestimate the size of canine and premolars in maxilla as well as mandible for both males and females. The mean difference between the actual values of canine and premolars in males and females was statistically significant and greatest among the three methods compared. Since the degree of associations between the sum of maxillary and mandibular central incisors and maxillary first molars and the actual size of permanent canine and premolars was low as compared to that observed for sum of lower incisors, this method of prediction was least accurate in use when applied to Northwestern zone population of

India. The result of the present study was in accordance with the study conducted by Juneja *et al.*^[26] also showed the same results.

Conclusion

1. The sum of lower incisors was a better predictor of size of permanent canine and premolars in this population as the correlation coefficients between the two variables were highly significant. This degree of association was higher than that obtained between sum of canine and premolars and the sum of maxillary and mandibular central incisors and maxillary first molars
2. All the three methods overestimated the actual sum of permanent canine and premolars in both the arches and genders. Moyers prediction method showed the least mean overprediction followed by Tanaka and Johnston and Bernabé E and Flores–Mir C which exhibited the maximum overestimation. Moyers probability tables at 75th percentile also overpredicted; however, the predicted values were closest to the actual widths of canine and premolars among the three methods
3. Tanaka and Johnston method of mixed dentition space analysis overpredicted the width of canine and premolars. Due to the discrepancy observed, new regression analyses were formulated similar to those proposed by Tanaka and Johnson originally but separately for males and females in an attempt to improve prediction accuracy.

Limitations of the present study

The accuracy and applicability of these methods should be further verified in various parts of the Northwestern zone of India. Further studies with large sample size are required to confirm these findings and to draw an appropriate regression equation for the study population.

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Conflicts of interest

There are no conflicts of interest.

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