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Obesity in Adolescents: Assessment by DXA Scan and Skinfold Thickness Equations

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Authors' contributions

This work was carried out in collaboration between all authors. Authors WLR, LMB and LU performed the statistical analysis, designed the study, wrote the first draft and managed the literature searches. Authors TB and PMG revised the manuscript and designed. All authors read and approved the final manuscript.

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ABSTRACT

Aim: This study aimed to compare obesity, estimated percentage of fat in adolescents in Brazil, using Dual-Energy X-Ray Absorptiometry (DXA) with skinfold data that were entered into mathematical models.
Study Design: This research is a cross-sectional, descriptive study.
Place and Duration of Study: Participants were randomly selected from a pool of 525 students. It was conducted employing a sample with students from elementary and high schools in Curitiba - Paraná – Brazil (December – 2013 to December 2014).
Methodology: Two hundred seventy two adolescents were evaluated (199 males and 73 females), ages 12 to 17.9 years. The percentage of body fat (%BF) has been calculated using five skinfold thickness equations: Slaughter; Boileau, Lohman and Slaughter; Durnin and Rahaman;

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Parizkova; Deurenberg, Weststrate and Seidell. They have been specifically applied to each gender, and compared to the reference method, DXA.

Results: The results show that despite all equations producing statistically significant correlations, none demonstrated agreement with DXA in a Bland-Altman plot. Sensitivity analyses showed a range of 37.3 to 77.7 for males and 21.2 to 69.2% for females, The Parizkova equation presented the best results in both genders.

Conclusion: It was concluded that mathematical modeling for skinfold-thickness among Brazilian adolescents for estimate %BF must be improved.

Keywords: Body composition; skinfold thickness; dual-energy X-ray absorptiometry; adolescents.

1. INTRODUCTION

Obesity has been shown to be one of the main risk factors for the manifestation of chronic diseases such as dyslipidemia, hypertension and diabetes [1]. This situation deserves greater attention among children and adolescents, because those who are obese, or present as overweight during childhood and adolescence, tend to become obese adults [2].

Different methods have been employed in the assessment of overweight and obesity [3]. In epidemiological research, for example, it is common to use methods such as Body Mass Index (BMI) which is simple and practical in its application, but is limited in its ability to determine fat mass, and fat-free mass [4].

The most accurate laboratory techniques for assessing body composition include: ultrasound [3], plethysmography [5], hydrostatic weighing [6] and dual-energy x-ray absorptiometry (DXA) [6,7]. The DXA technology is currently the most prominent because it is able to measure the density of muscle, fat mass and bone content with high accuracy. Because of this it is considered to be a reference methodology [6,8].

The fundamental principle of DXA is high energy photons attenuation by soft tissues and bones. An internal algorithm then calculates the amount of emitted and sensitized radiation by the detector after transposing the subject [6]. However, due to high cost, the method is still little used in the detection of obesity.

Considering the need for low cost and ease of use, skinfold measurements are often used, a method which is widely used for individuals and small groups to differentiate fat free mass and body fat mass [9,10]. The measurement of skinfold thickness involves the pinching of skin and measuring subcutaneous fat by use of a caliper. However, this technique has limitations because the mathematical models used to calculate body composition, especially among adolescents, frequently produce wide ranges of body fat percentage (%BF) for the same person [9].

The equations most commonly used for adolescents were developed over 20 years ago [11-13], which is a time period when there was a different obesity prevalence rate among children and adolescents [4]. Additionally there have been changes in physical activity behavior in this population since the formulation of these equations. These issues raise doubts about the accuracy of the results.

The purpose of this study was to compare different mathematical models that use skinfold thickness to assess body fatness among male and female adolescents with, DXA.

2. MATERIALS AND METHODS

2.1 Recruitment

This research is a cross-sectional, descriptive study. It was conducted employing a sample with students from elementary and high schools in Curitiba - Paraná – Brazil (December – 2013 to December 2014). Participants were randomly selected from a pool of 525 students. We accepted those students who did not use medicines containing calcium and had not been submitted to radiography / computed tomography in the seven days preceding the assessment. Overall, 272 students were assessed, all were of white.

2.2 Evaluated Protocol

The total body mass was measured using standard techniques through a Tanita electronic scale with a capacity of 150 kg and resolution of 0.1 kg. For height, a stadiometer with resolution of 0.1 cm was used (WCS, Curitiba, Brazil).

Body composition was assessed by DXA using Hologic QDR Discovery scanner fan-beam, scanning type (Hologic, Inc., Bedford, MA, USA). The DXA assessment is based on the emission of x-rays of low and high energy (40kV and 70kV, respectively). The total scan time was 5 minutes. The BF% was provided using specific software for adolescents presented in DXA equipment. All evaluations were performed in Biochemical and Densitometry Laboratory in Federal University of Technology–Paraná.

The measurements of skinfolds, triceps (T), subscapular (Sb), biceps (B), suprailiac (Sp), and medial calf (MC), were collected using a scientific caliper which has a resolution of 0.1 mm (Cescosrf, Brazil). Each fold was measured three times and the average of the values was used. The measures were taken by two researchers. The intra and inter-rater values of the measurements differed by 0.54% and 1.20%, respectively. Triceps measurement was obtained at the level of the mid-point between the acromiale and the radiale. The subscapular measure was taken at the lower angle of the scapula. The suprailiac measurement was obtained by measuring the lateral fold above the pelvic bone. Medial calf was measured at the point on the medial (inside) surface of the calf at the level of the largest circumference.

Initially, a literature review was conducted in the MEDLINE database (National Library of Medicine). To locate appropriate research papers the key words, “estimate the percentage of fat” (%BF) was entered. That procedure identified 68 research papers, but only six that had equations for both genders. The six papers were: Slaughter et al. [11], Boileau, Lohman and Slaughter [13], Durnin and Rahaman [12], Parizkova [14], Deurenberg, Weststrate and Seidell [15]. For the equation of Durnin and Rahaman and Parizkova it was necessary to use the equation of Siri [16] to convert body density in %BF. The equations used are shown in Table 1.

2.3 Data Analysis

Statistical analysis was made by descriptive presentation of the mean ± standard deviation values. Data normality was made using the Kolmogorov-Smirnov test. The validity of the proposed mathematical models was tested with the Pearson correlation. A paired t-test was used to estimate BF% measurements compared with DXA; total error (TE) and standard error of estimate (SEE) following the recommendations of Lohman [17] and agreement test between equations and DXA, was analyzed by the Bland-Altman test [18]. Cut points of SEE and TE < 3.5 [17] and statistical significance of $p < 0.05$ were used.

Sensitivity and specificity were estimated using %BF as reference of DXA. High % body fat was defined as ≥ 25% in adolescents males and ≥ 30% in females [19].

The Statistical Package for the Social Sciences (SPSS Inc. Released 2008. SPSS Statistics for Windows, Version 17.0. Chicago: SPSS Inc.), was used for all calculations.

Table 1. Generalized equations for body density and body fat percentage

Equation	Author	Gender	Equation
1	Slaughter et al. [11]	M	%BF = 0.735*(T+MC)+1
		F	%BF = 0.61*(T+MC)+5.1
2	Durnin and Rahaman [12]	M	D = 1.1533-0.0643*log(B+T+Sb+Sp)
		F	D = 1.1369-0.0598*log(B+T+Sb+Sp)
3	Boileau, Lohman and Slaughter [13]	M	%BF = 1.35*(T+Sb)-0.012*$(T+Sb)^2$-4.4
		F	%BF = 1.35*(T+Sb)-0.012*$(T+Sb)^2$-2.4
4	Parizkova [14]	M	D=1.130-0.055*log(T)-0.026*log(Sb)
		F	D=1.114-0.031*log(T)-0.041*log(Sb)
5	Deurenberg, Weststrate and Seidell [15]	M/F (a)	%BF=1.51*(BMI)-0.70*(Age)-3.6*(G)+1.4
		M/F (b)	%BF= 1.2*(BMI)+0.23*(Age)-10.8*(G)-5.4
6	Siri [16]	M/F	%BF=(495/D)-450

Where: M = Male; F = Female; %BF = Percentage Body Fat; D = Corporal Density; T = Triceps Fold; MC = Medial Calf Fold; B = Biceps Fold; Sb = Subscapular Fold; Sp = Suprailiac Fold; BMI = Body Mass Index; G = Gender, Male = 1, Female = 0; (a) age <15 (b) age >14.9

3. RESULTS

Table 2 describes the sample. It shows the means, standard deviations, minimum and maximum of age, body weight, height, and %BF as measured by the equations Slaughter et al. (Eq. 1), Durnin and Rahaman (Eq. 2), Boileau, Lohman and Slaughter (Eq. 3), Parizkova (Eq. 4), Deurenberg, Weststrate and Seidell (Eq. 5) and DXA. The sample was homogeneous for all variables.

The values for the validity of the equations to estimate body fat with reference to DXA are shown in Table 3. Significant correlations were observed for all equations, however, it was noted that the use of skinfold techniques tend to underestimate the value obtained in DXA in all situations, except for $\%BF_{Eq.\,4}$ - male.

Figs. 1, 2, 3, 4 and 5 illustrate the agreement analysis of Bland-Altman between the mathematical models and the DXA technique. Significant bias was found in all models ($p<0.05$).

Table 4 shows the values of sensitivity and specificity of the equations in the classification of normality and overweight in adolescents. Notice that the equations present a high degree of specificity in both genders and low values of sensitivity. All of the equations were effective at determining if a person was not obese, but all were poor at identifying if both males and females were obese.

4. DISCUSSION

Body composition reflects nutritional status and may assist patients in numerous clinical conditions [20]. Around 50% of body mass and 20%-25% of height are acquired during adolescence, therefore monitoring growth and development are important so that health professionals can guide people in health-related actions [21].

Table 2. Descriptive characteristics of the sample according to age, body weight, height and %BF

Variables	Male			Female		
	Mean	Minimum	Maximum	Mean	Minimum	Maximum
N		199			73	
Age (years)	15.1 ± 1.5	12	17	14.8 ± 1.7	12	17
Weight (kg)	61.8 ± 11.3	30.5	104.6	56.1 ± 11.0	33.0	83.5
Height (m)	1.70 ± 0.1	1.35	1.89	1.60 ± 0.1	1.43	1.75
$\%BF_{Eq.1}$	15.8 ± 7.7	7.1	58.6	25.8 ± 7.5	14.2	46.8
$\%BF_{Eq.2}$	19.2 ± 5.6	10.5	37.4	29.2 ± 4.8	20.2	39.5
$\%BF_{Eq.3}$	17.4 ± 6.4	8.0	33.5	27.0 ± 6.0	15.1	35.6
$\%BF_{Eq.4}$	21.1 ± 6.4	10.5	41.5	30.9 ± 5.5	20.4	42.1
$\%BF_{Eq.5}$	16.8 ± 4.9	6.4	32.8	24.7 ± 5.8	15.0	49.1
$\%BF_{DXA}$	20.3 ± 5.4	14.4	38.0	32.2 ± 5.1	19.1	44.4

Table 3. Validity of mathematical models for estimating body fat compared with DXA

Equation	Mean	r	t	CE	TE	SEE
			Male			
$\%BF_{Eq.1}$	15.8 ± 7.7	0.87*	15.72*	4.46	5.99	3.82
$\%BF_{Eq.2}$	19.2 ± 5.6	0.83*	4.72*	1.07	3.38	3.15
$\%BF_{Eq.3}$	17.4 ± 6.4	0.80*	10.65*	2.90	4.81	3.85
$\%BF_{Eq.4}$	21.1 ± 6.4	0.84*	-3.24*	-0.79	3.54	3.47
$\%BF_{Eq.5}$	16.8 ± 4.9	0.60*	10.65*	3.48	5.77	3.91
$\%BF_{DXA}$	20.3 ± 5.4					
			Female			
$\%BF_{Eq.1}$	25.8 ± 7.5	0.81*	12.10*	6.42	7.85	4.42
$\%BF_{Eq.2}$	29.2 ± 4.8	0.80*	8.07*	2.99	4.34	2.86
$\%BF_{Eq.3}$	27.0 ± 6.0	0.82*	12.95*	5.18	6.24	3.43
$\%BF_{Eq.4}$	30.9 ± 5.5	0.81*	3.43*	1.30	3.52	3.23
$\%BF_{Eq.5}$	24.7 ± 5.8	0.63*	13.60*	7.60	8.91	4.51
$\%BF_{DXA}$	32.2 ± 5.1					

*(r) Coefficient correlation; (t) t-test paired; (CE) Constant error; (TE) Total error; (SEE) Standard error of estimate; * p < 0.05*

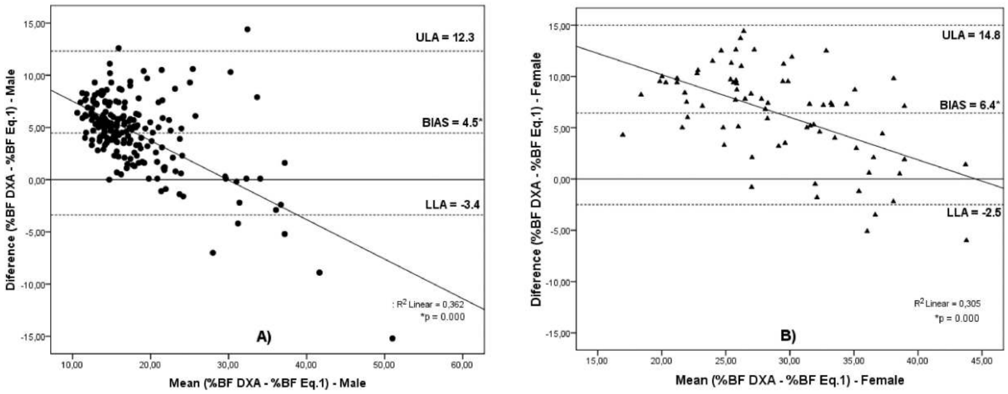

Fig. 1. A) Bland-Altman analysis of agreement %BF $_{DXA}$ - %BF $_{Eq.1}$ Male. B) Female. (ULA) Upper Limit of Agreement; (LLA) Lower Limit of Agreement;
**P < 0.05*

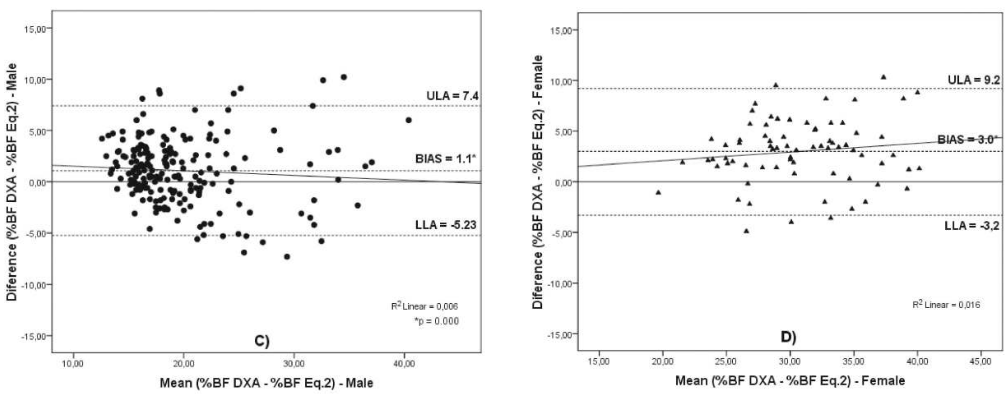

Fig. 2. C) Bland-Altman analysis of agreement %BF $_{DXA}$ - %BF $_{Eq.2}$ Male. D) Female. (ULA) Upper Limit of Agreement; (LLA) Lower Limit of Agreement
**P < 0.05*

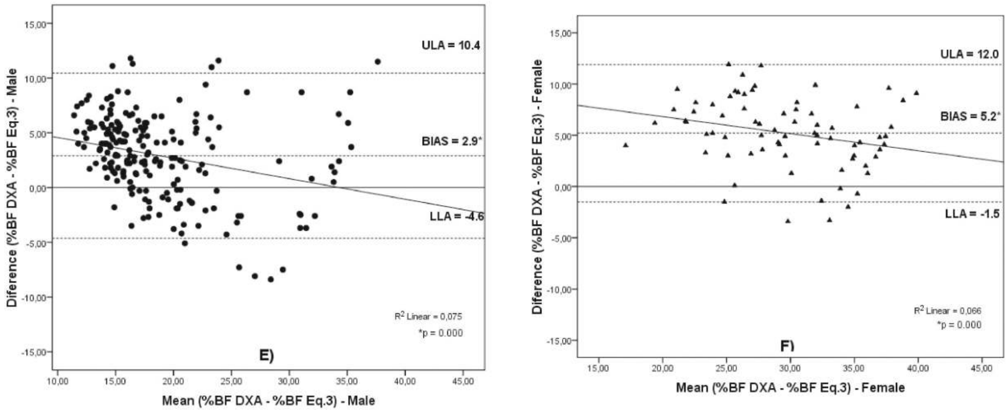

Fig. 3. E) Bland-Altman analysis of agreement %BF $_{DXA}$ - %BF $_{Eq.3}$ Male. F) Female. (ULA) Upper Limit of Agreement; (LLA) Lower Limit of Agreement
**P < 0.05*

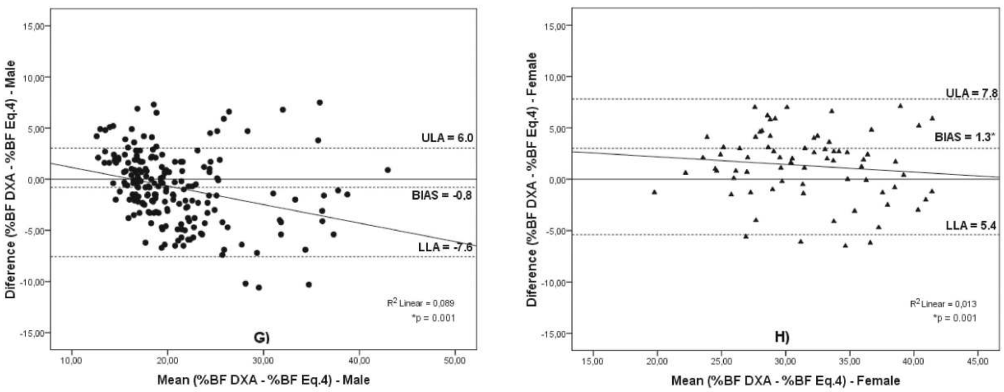

Fig. 4. G) Bland-Altman analysis of agreement %BF $_{DXA}$ - %BF $_{Eq.4}$ Male. H) Female. (ULA) Upper Limit of Agreement; (LLA) Lower Limit of Agreement

**P < 0.05*

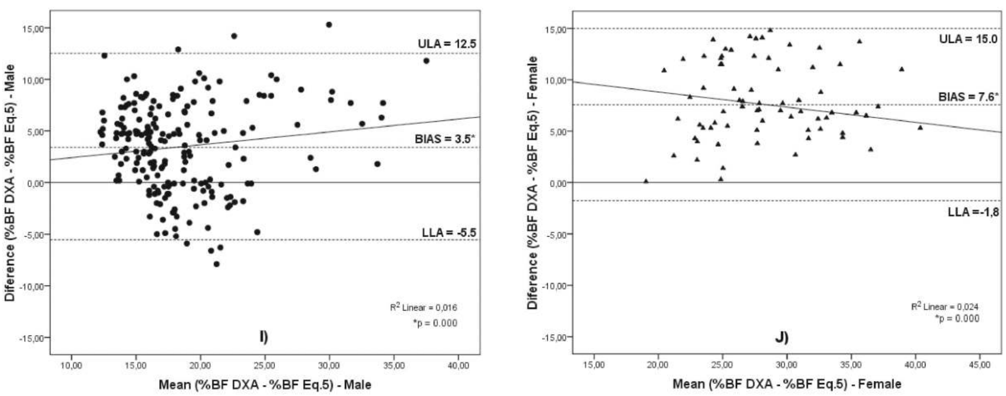

Fig. 5. I) Bland-Altman analysis of agreement %BF $_{DXA}$ - %BF $_{Eq.5}$ Male. J) Female. (ULA) Upper Limit of Agreement; (LLA) Lower Limit of Agreement

**P < 0.05*

Table 4. Sensibility and specificity for equations in male and female

Equation	Sensitivity /Specifity	
	Male	**Female**
Eq. 1	62.9% / 99.4%	38.5% / 100%
Eq. 2	70.4% / 95.9%	55.8% / 95.2%
Eq. 3	67.0% / 96.0%	48.1% / 95.2%
Eq. 4	77.7% / 88.9%	69.2% / 95.2%
Eq. 5	37.3% / 98.8%	21.2% / 100%

The results indicate that there are strong statistically significant correlations between the body fat equations and DXA for both genders, but when comparing the standard deviations and the averages, they show that these equations have a tendency to underestimate %BF related to those produced by DXA (Table 2), except for $\%BF_{Eq.4}$ male. These findings are similar results are reported in the literature [22-24].

As stated previously, the Slaughter et al. equation is most commonly used [22]. In the present study Slaughter et al. equation was also the one that showed the strongest correlation with DXA for males, however it presented lowest Bland-Altman agreement to this gender.

According to the literature, values below 3.5 for TE and SEE are acceptable. The only equation to reach this criteria was the $\%BF_{Eq.2}$ in males (Table 3). As for the SEE, $\%BF_{Eq.2}$ and $\%BF_{Eq.4}$ and was value above 3.5 in both genders and $\%BF_{Eq.3}$ for females. Cunha [25] found $\%BF_{Eq.1}$ of 3.2 and 2.7 for males and females respectively.

Disagreements in %BF have been investigated by Bland-Altman [8,22,26]. Among both genders, there is better agreement for estimation of body fat in male for $\%BF_{Eq.4}$ (0.8 / 1.3) and $\%BF_{Eq.2}$ (1.1 / 3.0). The results that are closer to those found using $\%BF_{DXA}$ can be explained by the lower %BF in males, who have smaller skinfold thickness that are more easily measured [27].

The skinfold technique is a low-cost, noninvasive, easy to use and affordable way to evaluate the body fat of large groups [28]. That method requires only limited training and can be used, for example, for the detection of cardiovascular risk [29], but the inappropriate choice of the equations for %BF prediction can result in unreliable conclusions [8,22,27,28].

However, it was noted that, despite being an appropriate choice for adolescents, the results do not meet scientific standards. Whether the morphological changes that have affected the global population of adolescents is the main factor for the test t failures of these equations is not known [30].

Sensitivity and specificity were calculated to assess the degree of efficiency of five equations. The sensitivity was best in $\%BF_{Eq.4}$ followed by $\%BF_{Eq.2}$ for males and females. However neither produced good or excellent discrimination.

The high specificity and low sensitivity shown in Table 4 indicate that the equations are weak instruments for evaluation of overweight and obesity in adolescents.

The strong points in our study include the representative adolescent sample and use of DXA as the reference method of body composition assessment. The limitations mainly refer the low number of specific equations for the age group from 12 to 17.9 years old (confirming the difficulty of assessing the percentage of fat in this age group) and not considering the sexual maturity of the adolescents.

5. CONCLUSION

In conclusion, none of predictive mathematical models of body composition available in the literature obtained satisfactory results when compared to DXA. The percentage of fat was underestimated in all cases except for males in Eq. 4.

It was noticed that, although presenting strong correlations, anthropometric equations have not achieved strong agreement with DXA methodology, as seen in the Bland-Altman analysis. These results point to the need to create new equations, corrections of existing ones, as well as more studies comparing doubly indirect methods with more efficient technologies such as DXA.

As can be seen in the sensitivity and sensibility analysis, the equations of Parizkova and Durnin and Rahaman present acceptable levels in the detection of overweight and obesity in adolescents. In Brazil, approximately 70% of the population use the public health system, therefore, equations available to healthcare professionals with results that are close to reality in terms of body fat are fundamental to early diagnose obesity. Thus, the results support the need to create new equations for estimating body composition in adolescents.

CONSENT

All authors declare that ‘written informed consent was obtained from the patient for publication of this paper and accompanying images’.

ETHICAL APPROVAL

All authors hereby declare that all experiments have been examined and approved by the appropriate ethics committee and have therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki. This research was submitted to the Ethics Committee of the Federal University of Technology - Paraná and has been approved under the number 11583113.7.0000.5547.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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