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Detecting overweight and obesity among young Syrian boys based on skinfold thickness

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ABSTRACT: There is no data on the prevalence of overweight and obesity in young Syrian boys. Therefore, the present study aimed to provide baseline and reference data on the prevalence of overweight and obesity among young Syrian boys using skin-fold thickness measurements and deuterium dilution (DD) as a reference method. The sample of 2470 healthy Syrian 18- to 19-year-old boys were enrolled in this study. SFTs were measured at the biceps (B), triceps (T), subscapular (SI) and suprailiac locations (SS) were done and validated using the DD technique as a reference method. Receiver operating characteristics (ROC) curve was drawn to determine appropriate cut-off points of the $\sum_2$ limb SFT (T+B), $\sum_2$ trunk SFT (SI+SS), $\sum_4$ SFT (T+B+SI+SS) and Log $\sum_4$ SFT for defining overweight and obesity. The overall prevalence of overweight and obesity in young Syrian boys, based on biceps SFT, triceps SFT, subscapular SFT, suprailiac SFT, $\sum_2$ limb SFT, $\sum_2$ trunk SFT, $\sum_4$ SFT, logarithm $\sum_4$ SFT, and DDT were 35.3%, 32%, 31.6%, 14.8%, 32.9%, 26.6%, 28.1%, 24.1%, 46.5%, respectively. Strongly positive correlation was found between SFT and total body fat in adolescents. For diagnosing overweight on the basis of $\sum_2$ limb SFT, $\sum_2$ trunk SFT, $\sum_4$ SFT and logarithm $\sum_4$ SFT, we propose the following cut-off points: 17.25 mm, 23.50 mm, 39.25 mm and 1.60, respectively. To predict obesity, $\sum_2$ limb SFT, $\sum_2$ trunk SFT, $\sum_4$ SFT and logarithm $\sum_4$ SFT threshold were increased to 23.25 mm, 32.50 mm, 55.25 and 1.75, respectively. Basing on SFT clearly leads to underestimates of the prevalence of weight problems among young boys. SFT measurement screen missed 11.2 to 31.7% of overall overweight and obesity cases.

KEY WORDS: body fat percentage, deuterium dilution, obesity, overweight, skinfold thickness, young boys

Introduction

Obesity in childhood and adolescence has increased at a dramatic pace over the last few years all over the world in industrialized, as well as many developing countries (Oken and Gillman 2003; Ahrens et al. 2006). More than 20% and an additional 30% of adults were defined as clinically obese and overweight, respectively, and the prevalence of overweight in adolescents has nearly tripled in the United

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States in 2000 compared to two decades before (LeBlanc et al. 2011). Obesity is mainly considered to be caused by overweight and lack of physical activity on a background of genetic predisposition (Xu et al. 2011). Ethnic and genetic factors also play an important role in the susceptibility to obesity (Bell et al. 2005; Li et al. 2010). Although the reason for the increase in obesity prevalence has been largely attributed to lifestyle changes there are many other determinants of elevated weight status (French et al. 2001).

The percent of body fat (PBF) could be used as an indicator to determine overweight and obesity. PBF of up to 20% may be considered normal in young healthy men, whereas, with increasing age, greater amounts of PBF may be considered "normal". However, a value of 20% BF for defining overweight and 25% BF for defining obese has been suggested by various workers (Okorodudu et al. 2010; McArdle et al. 1996).

Fat content estimation by skinfold thickness was a far better indicator of both overweight and obesity (Sushma et al. 2013; Mozaffer et al. 2009).

Hitherto, overweight and obesity in the Syrian population have not been monitored. As part of periodic health examination, service personnel are weighed and given advice. However, there is no routine information system to estimate obesity in the Syrian population. It is unclear how healthcare staff interprets height and weight measurements to advise and manage obesity. Therefore, the present study aimed to provide baseline and reference data on the prevalence of overweight and obesity among young Syrian males (18–19 years old) in the city of Damascus, and to investigate the agreement between the estimates obtained using skinfold thickness measurements and deuterium dilution as a reference method.

Materials and methods

Subjects

We recruited 2470 apparently healthy 18- to 19-year-old boys from Damascus city. Subjects were excluded if they were suffering from acute illness that would have produced abnormalities in body composition. Subjects were asked to abstain completely from consuming food and drink in the 12 hours before visiting the tasting field. All anthropometry measurements and sampling were completed during a single visit to the tasting area. The study protocol was approved by the scientific research and the ethical committee of the Atomic Energy Commission of Syria (AECS). Each participant provided their informed consent prior to participation after a detailed explanation of the study protocol. This study was performed in accordance with guidelines prescribed by Helsinki declaration of the world medical association.

Anthropometry

Skinfold thicknesses (SFTs) were measured at the biceps (B), triceps (T), subscapular (SI) and suprailiac locations (SS) (right sided) using a Lange skinfold caliper (Beta Technology Incorporated; Cambridge, Maryland). Lange skinfold caliper is factory calibrated to the accuracy of ±1 mm. Sum of all skinfolds was based on the sum of all four measurements of SFT ($\sum_4$ SFT), sum of trunk SFT on the sum of subscapular and suprailiac SFT ($\sum_2$ trunk SFT) and sum of limb

SFT on the sum of biceps and triceps SFT ($\sum_2$ limb SFT). In addition, logarithmic of sum of all SFTs were calculated. Body density was calculated using the formula of Durnin and Womersley (1974) and the percentage of body fat was then calculated by Siri's equation (Siri 1961).

Body composition by total body water

In this study, hydrometry was considered a reference method. Randomly selected 213 subjects of the participated group (2470 subjects, 18- to 19-year-old boys) were included in the deuterium dilution technique (DDT) study. Total body water (TBW) was determined by the isotope dilution technique using deuterium oxide according to the plateau method (Coward 1990). TBW was assessed by deuterium dilution measured with mass spectroscopy (IDECG 1990) with the use of dose equivalent to 0.05 g D_2O kg^{-1} body weight (99.8% atom present excess; Cambridge Isotope (D_2O) Laboratories, Inc, United Kingdom). Saliva samples were taken before the administration of the dose to each subject after a 6- to 12-hour fast and 3–4 hrs. after the dose was administered. Absorbent salivates (Sarstedt, Rommelsdorf, Germany) were used to collect the saliva. Saliva samples were analyzed by using Isoprime Ratio Mass Spectrometry (IRMS, GV Instrument). The values obtained were expressed relative to secondary standards (low-enrichment and high-enrichment standard water were similarly prepared to normalized data against V-SMOW-SLAP-GISP (Vienna Standard Mean Ocean Water/Standard Light Antarctic Precipitation,. Greenland Ice Sheet Perception). All samples were prepared and analyzed in triplicate. The mean SD deuterium analyzed was <2%. The equation used for the calculation of deuterium dilution space (N) was as follows (Halliday and Miler 1977):

$$N = (TA/a)\cdot((Ea - Et)/(Es - Ep)).$$

Where A is the amount of isotope given in grams, a is the portion of the dose in grams retained for mass spectrometer analysis, T is the amount of tap water in which the portion of a is diluted before analysis, and Ea, Et, Ep, and Es are the isotopic enrichments in delta units of the portion of dose, the tap water used, the pre-dose saliva sample, and the post-dose saliva sample, respectively. The deuterium dilution space was assumed to overestimate TBW by a factor of 1.04 (Forbes 1987). Fat free mass (FFM) was calculated from TBW, assuming that FFM has a hydration constant of 0.73 (Pace and Rathburn 1945). Fat mass was calculated as scale weight minus FFM.

Percent body fat measurement and diagnosis criteria

Body composition was predicted from skin-fold thickness by using a specific equation validated previously in this population. The following equations were used to estimate percent body fat PFB from body density and skinfold thickness:

$$\text{Body density X } 10^3 \text{ (kg/m}^3\text{)} = c - m \text{ X log skinfold}$$

(Durnin and Womersley 1974).

$$\text{Body fat\%} = 495 / D - 450$$

(Siri 1961).

$$\text{Body fat\% (men)} = [30.9 \text{ X log10 } \textstyle\sum_4 \text{ SFT } [0.271\text{X Age (years)}] - 39.9$$

(Han and Lean 2002).

Where c is slope, m is intercept, and D is body density that were calculated from skinfold thickness measurements with the prediction equation of Durnin and Womersley (1974). Fat mass (%FM) ≥20% was classified as overweight and ≥25% as obese (Okorodudu et al. 2010). A diagnostic performance meta analysis of BMI in relationship with percentage of body fat (Schwingel et al. 2007)

Statistical analysis

The data was managed in a Microsoft Excel worksheet. Mean and standard deviation (SD) of all anthropometric variables were calculated. Receiver operating characteristics (ROC) curve was drawn to determine appropriate cut-off points of skinfold thicknesses (SFTs) at different sites (biceps, triceps, subscapular, suprailiac, $\sum_2$ trunk SFT, $\sum_2$ limb SFT and $\sum_4$ SFT) in relation to the area under the curve (AUC), sensitivity and specificity in adolescents. The values of SFT indexes that resulted in maximizing the Youden index (sensitivity + specificity) were defined as optimal (Singh et al. 2008; Kesavachandran et al. 2012). Analyses were performed by using SPSS for windows (Version 17.0.1, 2001, SPss Inc., Chicago, USA). A p value of <0.05 was considered significant. Multiple regression analysis was performed to detect the relation between the variables; the coefficients of determination (R^2) for each regression model were calculated. Comparison between the different methods of body composition were done using the statistical analysis of Bland and Altman (Bland and Altman 1986).

Results

Anthropometry characteristics

Statistical analysis using SPSS to determine the normal distribution of $\sum_2$ limb SFT (biceps and triceps), $\sum_2$ trunk SFT (subscapular and supraailiac), and $\sum_4$ SFT for 2470 adolescents are presented in Table 1. The differences between the mean and median values of $\sum_2$ limb SFT, $\sum_2$ trunk SFT and $\sum_4$ SFT were small, suggesting a normal distribution. For the $\sum_2$ limb SFT, $\sum_2$ trunk SFT and $\sum_4$ SFT, the estimated 95% range was within or close to the minimum and maximum values. The descriptive table shows that the skewness and kurtosis values for $\sum_2$ limb SFT, $\sum_2$ trunk SFT and $\sum_4$ SFT, were between or close to the range of –3 and +3 suggesting that the distributions of these variables were within the limits of normal distribution.

Obesity and overweight based on skinfold thickness

The prevalence of overweight and obesity in our research objectives was measured by using the SFT at the biceps (B), triceps (T), subscapular (SI) suprailiac (SS), $\sum_2$ limb SFT, $\sum_2$ trunk SFT, and $\sum_4$ SFT locations, and DD references, which are shown in Table 2. If overweight is defined as > 20% body fat and obesity defined as > 25% for men (Okorodudu et al., 2010) then, based on the triceps SFT, 35.3% of adolescents were either overweight (20.0%) or obese (15.3%). Based on the biceps SFT, 32% of adolescents were either overweight (13.4%) or obese (18.6%). Based on the sub-scapular SFT, 31.6% of adolescents were either overweight (12.4%) or obese (19.2%). Based on the suprailiac SFT, 14.8% of adolescents were either overweight (12.1%) or obese (2.7%). Based on $\sum_2$ limb SFT, 32.9% of adolescents were either overweight (15.2%) or obese (17.7%). Based on $\sum_2$ trunk SFT, 26.6% of adolescents were either

Table 1. Statistical analysis using SPSS to determine the normal distribution of $\sum_2$ limb (Biceps+Triceps) SFT (mm), $\sum_2$ trunk (Biceps+Triceps) SFT (mm) and $\sum_4$ (Biceps+Triceps+Subscupular+Suprailiac) SFT (mm) for young Syrian boys

	$\sum_2$ limb SFT (mm) (biceps+triceps)	$\sum_2$ trunk SFT (mm) (subscapular+suprail-iac)	$\sum_4$ SFT (mm) (biceps+triceps+ sub-scapular+suprailiac)
Mean	19.45	27.88	46.82
Median	15.50	21.00	35.50
Std-deviation	11.30	18.25	28.93
Mean-median (mm)	3.95	6.88	11.32
Mean-median %	20.32	24.68	24.17
(Mean ±2SD)	19.45±(2 x 11.30)	27.88±(2 x 18.25)	46.82±(2 x 28.93)
Estimated 95% rang	19.01 to 19.90	27.07 to 28.69	45.53 to 48.10
Minimum and maximum Values	4.50 to 77.50	6.00 to 116.00	14.00 to 192.50
Skewness (SE)	1.582 (0.049)	1.685 (0.058)	1.629 (0.056)
Kurtosis (SE)	2.763 (0.098)	2.699 (0.111)	2.437 (0.111)

overweight (14.5%) or obese (12.1%). Based on $\sum_4$ SFT, 28.1% of adolescents were either overweight (14.6%) or obese (13.5%). Based on logarithm $\sum_4$ SFT, 24.1% of adolescents were either overweight (12.9%) or obese (11.2%). Finally, based on delirium dilution technique (DDT), 46.5% of adolescents were either overweight (19.5%) or obese (27.0%).

Skinfold thickness cut-off points for overweight and obesity

Curve was plotted based on receiver operating characteristics (ROC) analysis at different cut-off values of $\sum_2$ limb SFT, $\sum_2$ trunk SFT, $\sum_4$ SFT and logarithm $\sum_4$ SFT, while taking percentage of body fat as standard (Table 3). Results showed that $\sum_2$ limb SFT, $\sum_2$

Table 2. Prevalence obesity and overweight, using skinfold thickness and DDT in young Syrian boys

Criterion Skinfold thickness (mm)	Normal weight	Overweight	Obesity	Total
	< 20 % fat N (%)	20–24.9 % fat N (%)	>25 % Fat N (%)	N (%)
Triceps SFT	1597 (64.7)	494 (20.0)	379 (15.3)	2470 (100.0)
Biceps SFT	1681 (68.1)	330 (13.4)	459 (18.6)	2470 (100.0)
Sub-scapular SFT	1330 (68.5)	240 (12.4)	373 (19.2)	1943 (100.0)
Suprailiac SFT	1654 (85.1)	236 (12.1)	53 (2.7)	1943 (100.0)
$\sum_2$ (biceps+triceps) SFT	1583 (64.1)	450 (15.2)	437 (17.7)	2470 (100.0)
$\sum_2$ (subscapular+suprailiac) SFT	1426 (73.4)	281 (14.5)	236 (12.1)	1943 (100.0)
$\sum_4$ (biceps+triceps+ subscapular+suprailiac) SFT	1398 (72.0)	283 (14.6)	262 (13.5)	1943 (100.0)
Log $_{10}$ $\sum_4$ (biceps+triceps+ subscapular+suprailiac) SFT	1492 (76.8)	234 (12.9)	217 (11.2)	1943 (100.0)
DDT	114 (53.5)	42 (19.7)	57 (26.8)	213 (100.0)

Table 3. Receiver operating characteristics (ROC) analysis data suggested skin fold thickness cut-off points for young Syrian boys (18–19 years).

Anthropometric Index	Variables	Overweight (by 20% BF)	Obesity (by 25% BF)
$\sum_2$ limb (biceps+triceps) SFT (mm)	Suggested cut-off	17.25	23.25
	Sensitivity %	87.90	86.00
	Specificity %	82.50	92.90
	Positive predictive value	0.81	0.82
	Negative predictive value	0.89	0.95
	Area under the curve (AUC)	0.91	0.97
	p value	<0.0001	<0.0001
$\sum_2$ trunk (subscapular+suprailia) SFT (mm)	Suggested cut-off	23.50	32.50
	Sensitivity %	84.70	90. 0
	Specificity %	83.10	89. 0
	Positive predictive value	0.82	0.75
	Negative predictive value	0.85	0.96
	Area under the curve (AUC)	0.92	0.96
	p value	<0.0001	<0.0001
$\sum_4$ SFT (mm)	Suggested cut-off	39.25	55.25
	Sensitivity %	91.70	92.50
	Specificity %	84.40	91.70
	Positive predictive value	0.85	0.30
	Negative predictive value	0.92	1.00
	Area under the curve (AUC)	0.92	0.97
	p value	<0.0001	<0.0001
Log $_{10}$ $\sum_4$ SFT (mm)	Suggested cut-off	1.60	1.75
	Sensitivity %	91.70	92.50
	Specificity %	84.80	91.70
	Positive predictive value	0.85	0.80
	Negative predictive value	0.92	0.97
	Area under the curve (AUC)	0.92	0.97
	p value	<0.0001	<0.0001

In this particular case, the BF% has been determined on the basis of DDT.

trunk SFT, $\sum_4$ SFT and logarithm $\sum_4$ SFT provided high AUC values (more than 0.90) for Syrian adolescents. Data present in Table 3, demonstrates that, when defining the overweight adolescents by DDT as reference method, the proposed $\sum_2$ limb SFT, $\sum_2$ trunk SFT, $\sum_4$ SFT and logarithm $\sum_4$ SFT cut-offs were 17.25 mm, 23.50 mm, 39.25 mm and 1.60, respectively. To predict obesity, $\sum_2$ limb SFT, $\sum_2$ trunk SFT, $\sum_4$ SFT and logarithm $\sum_4$ SFT threshold increased to 23.25 mm, 32.50 mm, 55.25 and 1.75, respectively.

Body fat percentage of 10, 20, 30 and 40% for Syrian adolescents equates to $\sum_2$ limb SFT were 4.38, 18.65, 32.93 and 47.20 mm, $\sum_2$ trunk SFT were 2.49, 27.05, 51.61 and 76.17 mm, $\sum_4$ SFT were 4.25, 45.09, 84.92 and 124.76 mm, and logarithm $\sum_4$ SFT were 1.30, 1.60, 1.91 and 2.21, respectively (Table 4).

Table 4. Body fat percentage in different categories on ∑2 limb (biceps+triceps) SFT (mm), ∑2 trunk (subscapular+suprailiac) SFT (mm), ∑4 SFT (mm) and Log 10 ∑4 SFT (mm) in study subjects for young Syrian boys (18 – 19 years)

	Estimated Values by Correct Equation			
Fat %	$\sum_2$ limb SFT (mm)	$\sum_2$ trunk SFT) (mm)	$\sum_4$ SFT (mm)	Log 10 $\sum_4$ SFT (mm)
10	4.38	2.49	5.25	1.30
15	11.52	14.77	25.17	1.45
20	18.65	27.05	45.09	1.60
25	25.79	39.33	65.01	1.75
30	32.93	51.61	84.92	1.91
35	40.07	63.89	104.84	2.06
40	47.20	76.17	124.76	2.21
45	54.34	88.45	144.68	2.36

Data were obtained by means of a multiple regression analysis.

Discussion

Since there are no accepted cut-points for percentage body fat (PBF) (Flegal et al. 2009), we utilized the recommended body fat percentage (BFP) (BFP≥20 and ≥25) cut-points for overweight and obesity, respectively (Okorodudu et al. 2010). Percent body fat was calculated from body density that was calculated from skinfold thickness (SFT) measurements with the prediction equations of Siri (1961) and Durnin and Womersley (1974).

Body mass index (BMI) is an important indicator of obesity prevalence in a large population which generally reflects the degree of fatness among individuals (Sitek et al., 2014).

The present study is pioneering in identifying skinfold thickness cut-offs associated with overweight and obesity in young Syrian boys (18–19 years). There is no data on the prevalence of overweight and obesity in this age group neither in Damascus area nor in any other part of the country. In our study population, the overall prevalence of overweight and obesity, based on common international criterion (BFP≥20 as overweight and ≥25% as obese) (Okorodudu et al. 2010) estimated by biceps SFT, triceps SFT, subscapular SFT, suprailiac SFT, $\sum_2$ limb SFT (biceps and triceps), $\sum_2$ trunk SFT (subscapular and supraailiac), $\sum_4$ SFT, logarithm $\sum_4$ SFT, and deuterium dilution technique (DDT), were 35.3%, 32%, 31.6%, 14.8%, 32.9%, 26.6%, 28.1%, 24.1%, 46.5%, respectively. However, when the body fat estimated by SFT measurements is used for classification into body fat percentage categories (normal weight with body fat less than 20%, overweight with body fat between 20 and 25%, and obesity with body fat more than 25%), basing on SFT clearly leads to underestimates of the prevalence of weight problems. In our study, the skinfold thickness measurement screen missed about 11.2 to 31.7% of overall overweight and obesity cases, leading to an underestimation of overweight and obesity compared with that measured by the deuterium dilution technique (DDT). The present study demonstrated that quite large numbers of young boys were overweight and indicated that to some extent there was a high prevalence of overweight and obesity. The prevalence of both overweight and obesity still appears to be much lower in Syria than in the United State and Western Europe. In fact, the resent prevalence estimates of overweight and obesity in the US show that more than 60% of population are overweight or obese (Ogden et al. 2006). The present study provides the most recent prevalence estimates of overweight and obesity in Syria. This study shows that the prevalence of overweight and obesity in young Syrian boys is situated in the average range of that reported in other Mediterranean and Middle-East countries (Thibault et al. 2010; Micciolo et al. 2010; Cherkaoui Dekkaki et al. 2011).

Several reasons may explain differences in overweight and obesity outcome between Mediterranean countries and other European countries or United States (Micciolo et al. 2010). It is possible to speculate that the "Mediterranean dietary style" (Trichopoulou et al. 2005), together with the absence of systematic increase portion size (Silventooinen et al. 2004), may have been important factors that contributed to counteract epidemic of obesity in Syria. In fact, adherence to the Mediterranean diet is associated with lower prevalence of obesity (Buckland et al. 2008). Mediterranean diet adherence was not associated with overweight incidence in initially normal-weight subjects (Mendez et al. 2006). Therefore, overweight and obesity are common problems in Mediterranean countries, although they are likely to be related to limited physical activity in conjunction with excessive positive energy balance brought about by the westernization of the Mediterranean diet (Sanches-Villegas et al. 2006; Trichopoulou et al. 2005; Mendez et al. 2006). However, obesity is also affected by other factors. Changes in lifestyle, associated with the nutrition transition from traditional to modern habits, have led to the emergence and progression of overweight and obesity (Żądzińska et al. 2012). The dramatic changes in the lifestyle of Asian communities, including Syria, and the resultant changes in food and nutrition issues facing these countries, have been documented by some investigators (Tee 2002; Azizi et al. 2005). Overweighting and choosing high calorie foods, decreased physical activity and new sedentary lifestyle are an increasing concern (Tee 2002; Amani and Boustani 2008). As a result, the living conditions, dietary habits and lifestyle of the Syrian population improved continuously. Western-style food has become increasingly available in recent years. Western "quick service restaurants" (QSR), such as Kentuky Fried Chicken (KFC) and McDonalds, which are popular among children, have disproportionately increased dietary fat intake in children and adolescents. In developing countries and specially in lower socio-economic groups heaviness may be believed as an indicator of good health for children and adolescents (Jain et al. 2001).

In the published action plan of the Nutrition Task Force, it was stated that as the first step to combat obesity, attention should be directed towards prevention rather than its treatment (Clayton 1994). In principle, this is a sound recommendation given the appreciable increase in obesity documented in children and adults in Britain and elsewhere (Chinn and Rona 1994; Duran-Tauleria et al. 1995).

Limitations

Some limitations have to be taken into consideration. The study is cross-sectional and causation cannot be inferred. We only looked at a limited age group of 18–19-year old boys, so results cannot be expanded to other age groups. Therefore, our findings may not be necessarily applicable to the general population. The application of the reference method (DDT) based only on the sample (n=213 subjects) out of the total number of involved subjects (n=2470). No validation for the suggested cut off points for SFT, regarding their usefulness in overweight and obesity identification. A major strength of the present study is that this work is considered as documentation of prevalence of overweight and obesity in adolescents in addition to determining the cut-off points of SFT for defining overweight and obesity among Syrian adolescents.

Conclusion

Basing on SFT clearly leads to underestimates of the prevalence of weight problems among Syrian adolescents. SFT measurement screen missed 11.2 to 31.7% of overall overweight and obesity cases. The prevalence of both overweight and obesity still appears to be much lower in Syria than in the United State and Western Europe.

Abbreviations

BMI: Body mass index; FFM: free fat mass; FM: fat mass; BF: body fat; DDT: deuterium dilation technology; TBW: total body water; ROC: Receiver operating characteristics; EHN: European Heart Network; WHO: World Health Organization; CDCP: Centers of Disease Control Prevention; AUC: area under the curve; IDECG: International Dietary Energy Consultancy Group.

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Authors’ contributions

The authors have equal contributions in this paper.

Conflict of interest

The authors declare that there is no conflict of interests regarding publication of this paper.

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