Original article

Validity of the estimated body fat percentage by bioimpedance and skinfolds in middle-aged and elderly women

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Summary

Objectives: Verify the validity of electrical bioimpedance (BIA) and the skinfold method in estimating the percentage of body fat (% BF) in middle-aged and elderly women, using dual emission X-ray absorptiometry (DXA) as a reference method.
Material and methods: The sample consisted of 106 volunteers (middle age, n = 58 [51.3 ± 4.9 years] and elderly, n = 48 [67.2 ± 5.8 years]). The volunteers were submitted to anthropometric assessments and the % BF was subsequently calculated using the Jackson and Pollock 7 skinfold protocol (7SF). The % BF was also measured using BIA and DXA. Pearson's correlation, Bland and Altman method, effect size and repeated-measure t-test were used to test the hypotheses.
Results: Although there is a moderate positive relationship between the methods evaluated for middle-aged women (DXA vs 7SF, r = 0.67; DXA vs BIA, r = 0.62) and moderate to strong for the elderly (DXA vs 7SF, r = 0.57; DXA vs BIA, r = 0.75) (p ≤ 0.05 in all analyzes), the agreement between the methods was weak (limits of agreement > ± 3.5%). Additionally, when assessing the % BF mean using each method within the groups, it was observed that there was no significant difference between the estimates only between DXA and Pollock 7SF in the elderly group.
Conclusion: Therefore, both the 7SF method and the BIA are not valid for estimating body fat in the sample evaluated. It is necessary to develop equations for specific skinfolds to estimate the % BF of middle-aged and elderly women and review the equations used by the BIA.

Key words:
Body composition. Anthropometry. DXA

Validez del porcentaje de grasa corporal estimado por bioimpedancia y pliegues cutáneos en mujeres de mediana edad y ancianas

Resumen

Objetivo: Verificar la validez de la bioimpedancia eléctrica (BIA) y el método del pliegue cutáneo en la estimación del porcentaje de grasa corporal (% GC) en mujeres de mediana edad y ancianas, mediante la doble emisión de rayos X (DXA) como método de referencia.
Material y método: La muestra estuvo formada por 106 voluntarias (mediana edad, n = 58 [51,3 ± 4,9 años] y ancianas, n = 48 [67,2 ± 5,8 años]). Las voluntarias fueron sometidas a evaluaciones antropométricas y, posteriormente, se calculó el % GC utilizando el protocolo de pliegues cutáneos Jackson y Pollock 7 (7PC). El% de GC también se midió usando BIA y DXA. La correlación de Pearson, el método de Bland y Altman, el tamaño del efecto y la prueba t de medida repetida se utilizaron para probar las hipótesis.
Resultados: Aunque existe una relación positiva moderada entre los métodos evaluados para mujeres de mediana edad (DXA vs 7PC, r = 0,67; DXA vs BIA, r = 0,62) y moderada a fuerte para las ancianas (DXA vs 7PC, r = 0,57 ; DXA vs BIA, r = 0,75) (p ≤ 0,05 en todos los análisis), la concordancia entre los métodos fue débil (límites de acuerdo > ± 3,5%). Además, al evaluar la media de % GC usando cada método dentro de los grupos, se observó que no hubo diferencia significativa entre las estimaciones solo entre DXA y Pollock 7PC en el grupo de ancianas.
Conclusiones: Por tanto, tanto el método 7PC como el BIA no son válidos para estimar la grasa corporal en la muestra evaluada. Es necesario desarrollar ecuaciones para pliegues cutáneos específicos para estimar el % GC de mujeres de mediana edad y ancianas y revisar las ecuaciones utilizadas por el BIA.

Palabras clave:
Composición corporal. Antropometría. DXA.

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Introduction

Body composition has become increasingly relevant in assessing its impact on health and disease[1]. Several methods allow the quantification of the components of the human body, such as bones, musculature, and body fat[2,3]. These methods can be classified as direct, indirect, and doubly indirect, respectively, according to the technique adopted[2]. Among these, only the dissection of cadavers can be classified as a direct method, inasmuch as the separation of the structural components of the human body occurs, making this the most accurate of the methods for assessing body composition[4]. As for indirect methods, there is hydrostatic weighing and dual emission X-ray absorptiometry (DXA), which are able to quantify body components with a higher level of accuracy than doubly indirect methods, such as anthropometry and electrical bioimpedance (BIA), which use regression equations based on direct or indirect methods[2,4].

On the other hand, DXA is a more sophisticated procedure, has a higher level of precision, and is considered by many researchers as a "gold standard" for studies to validate methods and predictive equations of body composition[5,6], hence replacing hydrostatic weighing[7]. This method is considered non-invasive and can analyze fat mass, fat-free mass, and bone mineral content. Its limitations refer to the high cost of the equipment, the requirement of an adequate location, and the necessity of a technician to handle the equipment[6,8].

The doubly indirect methods can be considered easy to access and to operate, fast in data collection, and low cost[5,9,10]. Anthropometric measurements, especially skinfolds and circumferences, have a strong correlation with body fat, in order to enable the development of regression equations using anthropometric measurements to predict body fat, having a reference method to develop and validate the predictive equations. BIA consists of the passage of a low amplitude and high-frequency electric current through the body[6], which makes it possible to obtain parameters such as the percentage of body fat (% BF), fat mass in kg and % and total body water[11,12]. Although these methods are widely employed, there are controversies regarding precision and accuracy, considering that factors such as the technique, calibration, differentiation of equipment, and body hydration, can directly interfere in the results[3,6,12-16]. In addition, population characteristics such as ethnicity, age, sex, level of physical activity, diseases or disabilities that alter body composition should be analyzed for the development of specific equations both by anthropometric measurements and BIA, in order to check validity and precision.

It is known that there are characteristic changes in the body composition of women during the transition from middle to old age, like increases and redistribution of body fat, as well as a decrease in lean mass, which in turn can alter anthropometric measurements and the relationship of these measurements with body fat[17]. These changes are characteristic of this population group and are associated with factors such as menopause, sedentary lifestyle, inadequate nutrition and diseases[18]. Thus, taking into account these factors mentioned above and, as far as we know, there is no equation for estimating the % BF developed specifically for middle-aged and elderly women, and studies are needed to assess the agreement between doubly indirect methods and reference method in these age-groups. Since % BF has been employed in different situations, for example, monitoring the amount of body fat[1], determining training goals to be achieved[19], as well as identifying the risk of developing chronic diseases[20], the latter being fundamental for the control and maintenance of the health, the precision of the evaluated parameters is significant, which justify the necessity of assessing the agreement between doubly indirect methods widely used with a reference method.

In summary, it is paramount for health professionals to choose the method of assessment of body composition that is in agreement with those reference methods, in an attempt to have higher precision in the quantification of the parameters evaluated and minimize errors[21]. Thus, studies with different populations and techniques, to determine the accuracy of each method of assessing body composition, contribute to scientific knowledge and clinical practice.

Accordingly, the present study aimed to verify the agreement between the % BF estimative method (BIA and Jackson and Pollock 7 skinfold protocol [7SF]) with the reference DXA method in middle-aged and elderly women.

Materials and method

Participants

The study was accomplished with the participation of 106 volunteers, with 58 classified as middle age (45-59 years) and 48 classified as elderly (> 60 years)[22]. The volunteers were regular practitioners of physical activity (three sessions per week lasting 50 minutes each session) in the project "Health and life: gymnastics for middle-aged and elderly women" at the Federal University of Viçosa - MG, Brazil. All volunteers were informed about the objectives and methodological procedures of the study. Consent for participation in the study was obtained in writing from each volunteer after the necessary clarifications, being all aware that at any time they could, without embarrassment, stop participating in the inquiry. The Ethics Committee of the Federal University of Viçosa CAAE: 60303716.1.0000.5153 approved the present study, thus meeting the Brazilian legislation for studies with human beings, according to the law 466/12.

Anthropometric measurements

Body mass was measured on an electronic scale (TANITA® BF-680W DUO Plus, Arlington Heights, IL 60005 USA) 140 kg capacity and 100 g sensitivity. The volunteers were instructed to wear as little clothing as possible and to remain barefoot during the assessment. Height was measured with bare feet, keeping feet together and head positioned on the Frankfort plane. Subsequently, the body mass index (BMI) was calculated using the following equation: BMI = Weight (kg) / Height (m)^2.

The skinfolds (SF) were determined on the right side of the volunteers, in triplicate, recording the mean value of the measurements, using a plicometer (Cescorf) with a precision of 0.01 mm, totaling seven folds (tricipital, subscapular, bicipital, midaxillary, suprailiac, abdominal and thigh) as described by Jackson and Pollock (1985)[23]. Body density was calculated using the formula Jackson *et al.*, 1980[24]: DENS = 1.11200000 – [0.00043499 (Σ 7 SF] + 0.00000055 (Σ 7SF) 2 – [0.00028826 (age)].

Subsequently, % BF was obtained using the Siri formula, in which: % BF = [(4.95/Dens.) – 4.50] x 100.

The measurements were performed by a single professional with a degree in Physical Education adequately trained for this function. The evaluations occurred in a physical evaluation room of the Physical Education Department of the Federal University of Viçosa, Viçosa, Brazil. All recommendations of The International Society for Advancement of Kineanthropometry (ISAK) were followed[25] for the collection of anthropometric data, and all procedures were fulfilled in the morning.

Bioimpedance

Body resistance and reactance were measured utilizing a body composition analyzer (Scale, TANITA Scale plus body fat monitor BF-680) employed in different populations and national and international experimental designs[26-30]. The measurement was determined as described by Lukaski *et al.* [31,32]. The % BF was recorded on the device's monitor after the evaluated subject remained on the equipment for a few seconds. To obtain this result, it was necessary to insert values related to the height and sex of each volunteer in the device through a specific location. These procedures were performed by the same assessor, at the same place and time as the anthropometric assessment. To standardize the BIA's registration conditions, those evaluated were previously advised to adopt a series of conducts to minimize possible interference in the result, as previously indicated[31,32].

DXA (dual emission X-ray absorptiometry)

DXA measurements were performed by a single qualified professional with previous experience, utilizing Lunar Prodigy Advance DXA System version 13.31 (GE Medical, model 8743, Madison,WI, USA) in the Health Division of the Federal University of Viçosa - MG. Summarily, DXA measurements were determined in full body scan. All scans were analyzed by this professional, employing the program for body composition analysis, LUNAR Radiation version 1.2i DPX-L.

Statistical analysis

To verify the data distribution, the Kolmogorov – Smirnov test was adopted. Since all variables had a normal distribution, the mean and standard deviation were used as descriptive statistics. Pearson's correlation was applied to relate the methods of estimating % BF through BIA and 7SF with DXA, and their magnitude determined as correlation (r): insignificant (0.0-0.3); small (0.3-0.5); moderate (0.5-0.7); strong (0.7-0.9) and very strong (> 0.9)[33]. The agreement between the different methods was tested using the Bland and Altman procedure[34], the limits of the agreement being defined as mean ± 1.96 standard deviations (SD) of the difference between the methods [95% confidence interval (95%CI)], adopting limits of ± 3.5% for validation[35]. The means of % BF of each method (BIA and 7DC) within the groups (middle age and elderly) were compared with the DXA, using the Student's t-test. Subsequently, the effect size (Cohen’s d) was calculated, its magnitude being classified as small (< 0.41), moderate (0.41-0.70), or large (> 0.70)[36]. For statistical data processing and analysis, the statistical software GraphPad Prism 3.0 was employed, applying a significance level of $p < 0.05$.

Results

Table 1 presents the general characteristics of the volunteers in the two groups (middle age and elderly). As displayed in the table, there was no significant difference only between the mean of the percentage of body fat of DXA vs. Pollock 7 skin folds for elderly women ($p = 0.461$ and effect size [Cohen's d] = 0.15).

Figure 1 depicts the results of the correlation tests between DXA and the estimation methods and reveals that both in middle-aged and elderly women, they have a moderate to strong relationship (r = 0.55 a 0.75) and significant ($p < 0.05$) in all analyzes.

Figure 2 portrays the graphs of agreement between the different methods proposed by Bland & Altman[37]. Similarly to the correlation assessment, we evaluated the agreement between the % BF estimates between the methods: DXA vs. BIA (panel, A and C) and DXA vs. % 7 Folds (panel, B, and D) for the experimental groups of middle age and elderly respectively. All analyzes have wide limits of agreement between the methods (limits of agreement > ± 3.5%).

Discussion

The main objective of the present work was to verify the agreement of two methods of estimating % BF (BIA and sum of SF) against a reference method (DXA). The findings, in general, demonstrate a significant difference and that the methods have low agreement to estimate BF in middle-aged and elderly women, which indicates that when used, the data need to be interpreted carefully. Thus, a critical analysis of the indiscriminate application of these techniques for the public evaluated here is necessary.

To compare the methods, different statistical analysis strategies were employed. We observed that there are positive correlations, ranging from moderate to strong, with an r-value ranging from 0.55 to 0.75 and statistically significant ($p < 0.05$) between the methods evaluated, both for middle age and elderly women. These values are below that recommended for studies of validation of body composition assessment methods, which should have a value of r > 0.79[38].

Table 1. General characteristics of the middle-aged and elderly group.

	Middle-age	Elderly
Sample size	58	48
Age (years)	51.25 ± 4.91	67.16 ± 5.84
Body Mass (Kg)	66.87 ± 10.15	66.52 ± 11.75
Stature (m)	1.58 ± 0.06	1.54 ± 0.05
BMI (Kg/m²)	26.69 ± 4.13	27.71 ± 4.32
% BF DXA	38.70 ± 6.45	40.22 ± 6.20
% BF BIA	34.61 ± 5.74**	36.84 ± 5.00**
% BF Folds	36.94 ± 6.03*	39.40 ± 4.48

Body mass index (BMI); Percentage of body fat estimated through dual emission X-ray absorptiometry (% BF DXA); Percentage of body fat estimated through electrical bioimpedance (% BF BIA); Percentage of body fat estimated using the Jackson and Pollock 7 skinfold protocol (% BF Folds). * = $p < 0.05$ vs. % BF DXA; ** = $p < 0.001$ vs. % BF DXA, within each age group.

Figure 1. Illustration of Pearson's correlation between the methods of estimating the percentage of body fat (% BF) for the middle age group (panels, A and B) and elderly (panels, C and D).

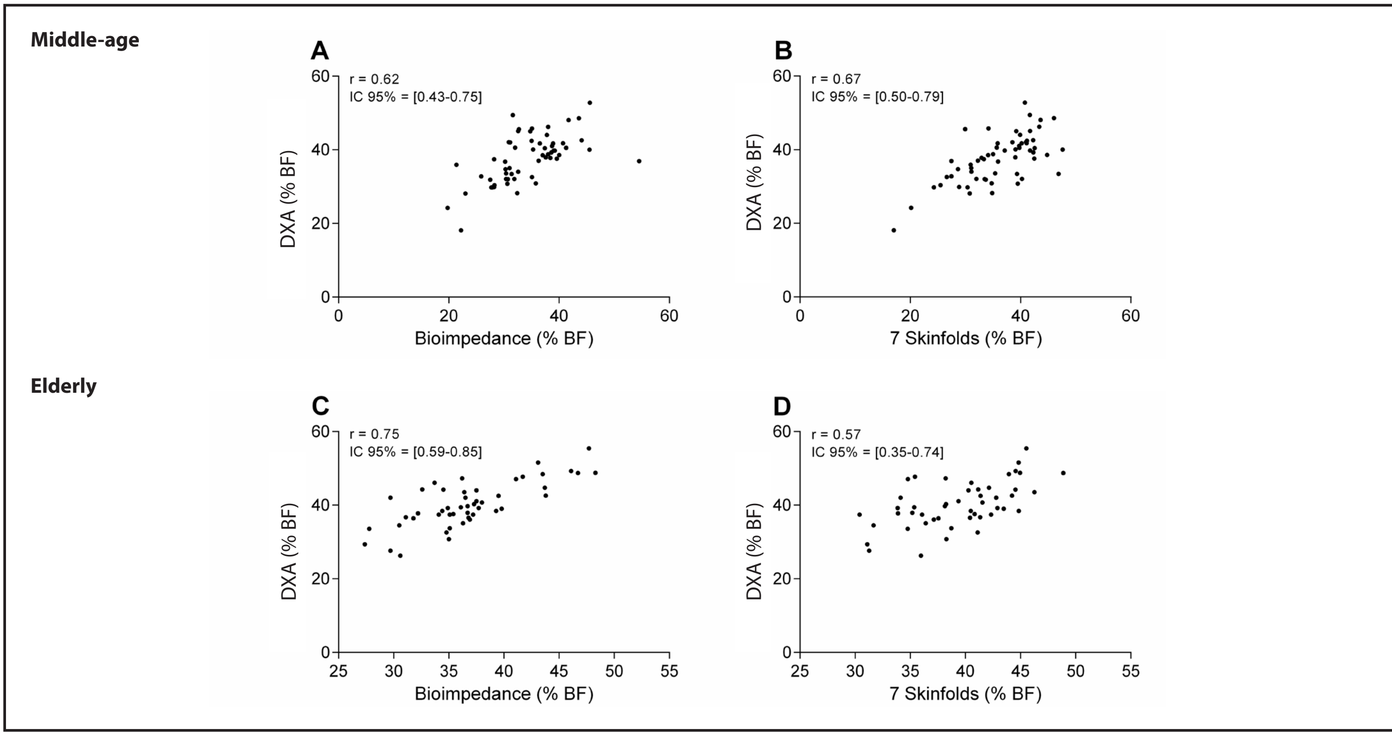
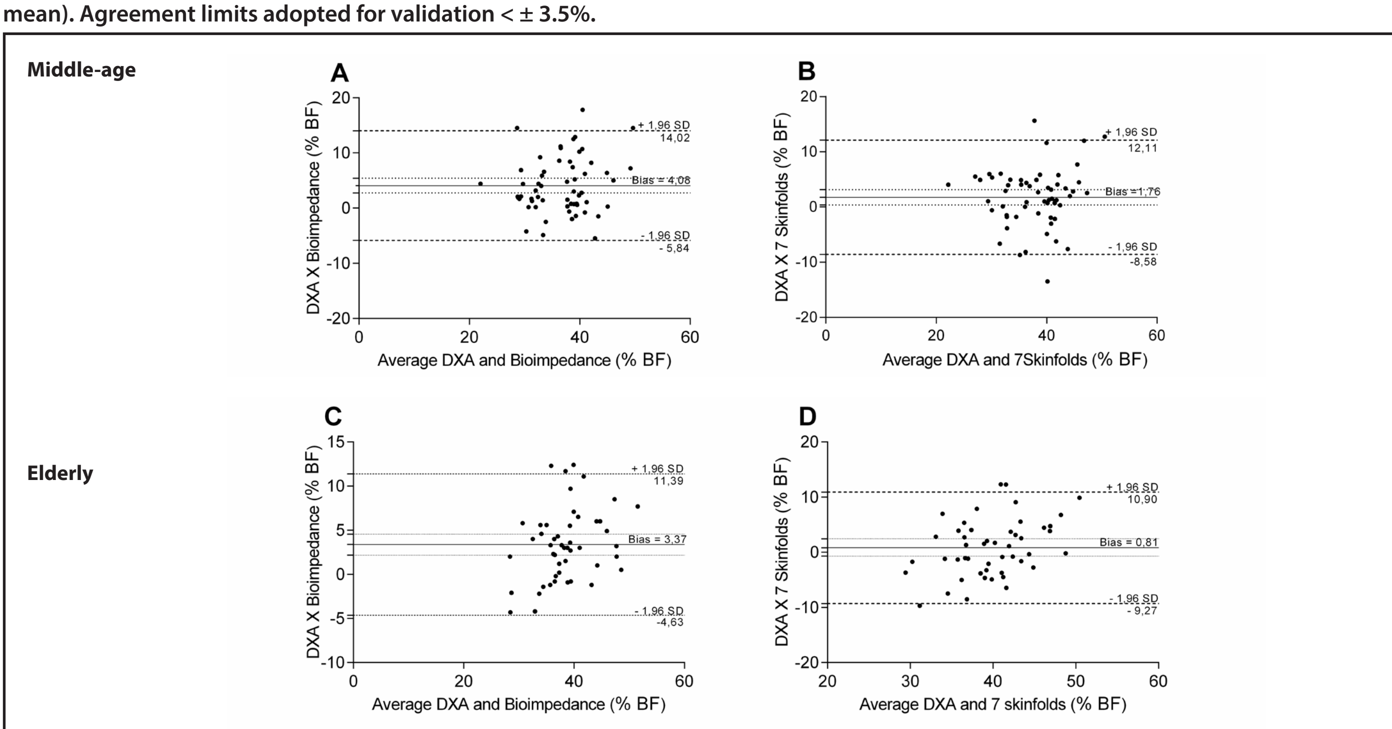


Figure 2. Graphic illustration of the Bland and Altman analysis to assess the agreement between methods of estimating the percentage of body fat (% BF) for the middle age (panels, A and B) and elderly (panels, C and D) groups. The intermediate continuous line represents the average difference between the methods (bias). The two external dashed lines immediately after the bias indicate the 95% confidence interval for the difference in means. The dashed lines at the upper and lower limits indicate the limits of agreement (± 1.96 SD of the mean). Agreement limits adopted for validation < ± 3.5%.



Our results are in accordance with previous studies that evaluated different methods for estimating body fat and observed relationships between the evaluation methods[39-42].

The results (table 1) revealed that there was a statistically significant difference between the % BF estimates in both groups, except between DXA and 7 folds in the elderly group, results that are similar to others found in the literature with elderly women[14], young patients with cystic fibrosis[43] and children[44], and different of others studies that evaluated adult patients with cystic fibrosis[43,45] and overweight and obese adults[46]. Although significant differences between means have been utilized as a factor that demonstrates a method's lack of validity, this approach does not inform us about the accuracy of the methods since the greater the measurement error, the less the chance of a significant difference[47,48]. In this case, Bland and Altman, a statistical procedure that assesses agreement between two methods, is more sensitive to differences than correlations and differences between means[49].

In the analysis of agreement between the methods performed with the Bland and Altman technique[34], the wide limits of agreement indicate that the methods are not interchangeable. There was substantial variation in the results, both for underestimation and for overestimation. In the analysis of the agreement between DXA and bioimpedance, the underestimation values are more prominent. To our knowledge, this is the first study to assess the agreement between these methods in middle-aged and elderly women who practice regular physical activity. Similar studies, however, with different samples showed agreement between the DXA and SF method (women with anorexia nervosa, obese and diabetics)[41,42,50]. In contrast, other studies have found low agreement between these methods (healthy young people and ballet dancers)[43,51] also observed that different anthropometric equations were not valid for estimating % BF in elderly women compared to DXA, corroborating the findings of the present study. This evidence makes clear the need to expand the base of studies on this topic.

Furthermore, it should be noted that the methods employed here have limitations for their usage. The greater the accuracy of the devices employed, the greater the accuracy of the measurement. Skinfold measurements are widely applied to estimate % BF, as they are relatively easy to obtain, low cost and applicable in field studies. In elderly individuals, these measures may have some limitations due to changes in the redistribution and internalization of subcutaneous fat, adipocyte atrophy, skin thickness and elasticity. Therefore, these changes in body composition can significantly affect the validity of BF estimates and contribute to explaining the differences between the methods[52].

It is also important to note that the methods adopted here have their predictive equations developed and validated in individuals from developed countries with different ages. Besides, it is essential to observe that differences in the pattern of fat distribution between different ethnicities can alter the relationship between the sum of the folds and the measurement of body composition, as well as body density values[53,54]. Some studies have shown that Asians, Blacks and Hispanics appear to have a higher fat deposit on the trunk than on the extremities, and also appear to have more subcutaneous fat on the upper body when compared to Caucasian individuals[53,55]. Consequently, we believe that these methodological limitations inherent to the methods used and the miscegenation of the studied population could be a possible and reasonable explanation for the differences between the methods.

As a practical implication of this investigation, it is necessary to implement population-based studies aimed at proposing equations through skinfolds that are validated for the population of active middle-aged and elderly women, as well as reviewing the proposed equations for BIA. Pending this and considering the difficulty of accessing DXA, BIA and the skinfold technique continue to be applied to predict the percentage of fat. However, the results of % BF estimates through these techniques should be considered with caution for these populations and may have limited use only for the purposes of monitoring intra-individual variations.

Conclusion

The methods of estimating BF by bioimpedance and SF are not valid for middle-aged and elderly women. These methods are not interchangeable and should not be applied as an alternative to DXA to estimate % BF. It is necessary to develop specific skinfold equations to estimate the % BF of middle-aged and elderly women, as well as to review the equations utilized by BIA.

Conflict of interest statement

The authors do not declare a conflict of interest.

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