Effects of birth cohort and age on body composition in a sample of community-based elderly[1–3]

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ABSTRACT

Background: The effect of the recent obesity epidemic on body composition remains unknown. Furthermore, age-related changes in body composition are still unclear.

Objective: The objective was to simultaneously examine the effects of birth cohort and age on body composition.

Design: A total of 1786 well-functioning, community-based whites and blacks (52% women and 35% blacks) aged 70–79 y from the Health, Aging, and Body Composition Study underwent dual-energy X-ray absorptiometry annually from 1997 to 2003.

Results: At baseline, mean ± SD percentage body fat, fat mass, and lean mass (bone-free) were 28 ± 5%, 24 ± 7 kg, and 56 ± 7 kg, respectively, for men and 39 ± 6%, 28 ± 9 kg, and 40 ± 6 kg for women. Mixed models were used to assess the effects of cohort and age-related changes on body composition. Later cohorts in men had a greater percentage body fat (0.32% per birth year, $P < 0.0001$) than did earlier cohorts. This cohort effect was due to a greater increase in fat mass than in lean mass (0.45 kg and 0.17 kg/birth year, respectively). With increasing age, percentage body fat in men initially increased and then leveled off. This age-related change was due to an accelerated decrease in lean mass and an initial increase and a later decrease in fat mass. Similar but less extreme effects of cohort and age were observed in women.

Conclusions: The combination of effects of both birth cohort and age leads to bigger body size and less lean mass in the elderly. *Am J Clin Nutr* 2007;85:405–10.

KEY WORDS Birth cohort, age, body composition, elderly, fat, lean

INTRODUCTION

Body composition plays an important role in health consequences in older adults. A greater fat mass is associated with a greater risk of disability (1, 2) and with the presence of metabolic abnormalities (3) such as hyperinsulinemia, dyslipidemia, and hypertension in older adults. Deficiency of skeletal muscle mass, which comprises approximately one-half of lean mass, may be associated with the presence of disability in old age (4). Furthermore, greater fat mass and lesser skeletal muscle mass may act synergistically to cause disability in older adults (5). A better understanding of changes in body composition is needed to develop preventive strategies for body composition–related diseases in old age.

The secular trend (or the birth cohort effect) may be a key determinant of body composition in older adults. A report from the National Health and Nutrition Examination Survey indicated that the prevalence of obesity, defined as body mass index (in kg/m^2) ≥ 30, doubled from 14% and 21% in 1976–1980 to 36% and 40% in 1999–2000 in older men and women, respectively (6). Therefore, at the same age, later birth cohorts had a greater body size than did earlier birth cohorts. However, it remains unknown how fat mass and lean mass were affected by this secular trend.

Increasing age is an important determinant of changes in body composition in older adults. To date, information on age-related changes in body composition was derived mainly from cross-sectional studies (7). One main limitation of such studies is that

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age-related changes in body composition, inferred from cross-sectional studies, represent mixed effects of both birth cohort and age on body composition (8). The growing obesity epidemic suggests that the effect of birth cohort may be too substantial to be ignored. Several longitudinal studies suggest that fat mass increases with age in older men but not in older women (7, 9) and that lean mass decreases with age in older adults (7, 10, 11). However, even in these longitudinal studies, the effect of birth cohort could not be fully accounted for because of small sample sizes and a lack of serial measures of body composition.

To further our understanding of changes in body composition, large community-based longitudinal studies are needed. The Health, Aging, and Body Composition (Health ABC) Study is a large, prospective, community-based study investigating the effect of body composition on morbidity, disability, and mortality in the elderly. One unique feature of the Health ABC Study is that body composition has been measured by dual-energy X-ray absorptiometry (DXA) annually during a 5-y follow-up. The Health ABC Study therefore provides a unique opportunity to simultaneously examine the effects of birth cohort and age on body composition in the elderly.

SUBJECTS AND METHODS

Study population

A total of 3075 participants of the Health ABC Study were recruited from a random sample of white and of all of the black Medicare beneficiaries residing within each ZIP code from the metropolitan areas surrounding Pittsburgh, PA, and Memphis, TN, from 1997 to 1998. Participants were eligible if they were aged 70–79 y; reported no difficulty walking one-quarter of a mile, climbing up 10 steps, and performing mobility-related activities of daily living; denied radiation treatment or chemotherapy for cancer in the past 3 y; were not enrolled in a trial of a lifestyle intervention; and had no plans to move out of the area in the next 3 y. Participants underwent an annual DXA examination of body composition during a 5-y follow-up. We excluded 135 participants because they were <70 y or >79 y old at the time of the body-composition assessment. In addition, a total of 358 participants who died during the follow-up were excluded because their age-related changes in body composition were complex and different from participants who remained alive. Of the remaining 2582 participants, 1786 (855 men and 931 women) completed all 6 DXA examinations.

All participants provided written informed consent. The study was approved by the institutional review boards of both the University of Pittsburgh and the University of Tennessee.

Body composition

Body composition was measured with the use of fan-beam DXA (Hologic QDR4500A, software version 8.21; Hologic, Waltham, MA) (12). A detailed operations manual was provided for DXA operators. All operators were trained and certified annually. DXA scans were performed and archived on optical disks in clinical centers. The scans from each clinical center were then sent to the Health ABC Study DXA Reading Center (University of California, San Francisco, CA) for incorporation into the studywide database. Scans of phantoms were performed daily for monitoring of machine performance and annually across clinical centers for cross-calibration purposes. In addition, a random sample of scans from each clinical center was also reviewed at the Health ABC Study DXA Reading Center. Fat mass, lean mass (bone-free), and total body mass (body weight) were measured. Percentage body fat (%BF) was calculated as fat mass divided by total body mass.

The validity and reproducibility of the QDR4500A scanner have been reported previously (13–16). The assessment of fat mass and lean mass is highly reproducible (14, 16). The QDR4500A scanner overestimates lean mass compared with the method of the four-compartment model (16). Therefore, a correction factor of 0.964 was applied to the measure of lean mass in the current study (14). More important, the QDR4500A scanner provides a reasonable assessment of longitudinal changes in fat mass and lean mass (15).

Other covariates

Age at baseline (from 70 to 79 y), sex, race, and clinic site were ascertained by interviewer-administered questionnaire. On the basis of age at baseline, 10 successive annual birth cohorts were defined for the years 1918 to 1927. Age at examination (from 70 to 84 y) was calculated on the basis of birth date and examination date. Standing and sitting heights at baseline were measured with a Harpenden stadiometer (Holtain, Crosswell, United Kingdom). Race was defined according to the participant's self-report. Sitting height is a measure of the upper segment of the body, including the trunk, neck, and head heights. Leg length was defined as the difference between standing height and sitting height. Weight at baseline was measured with the use of a standard balance-beam scale while the subjects was wearing light clothing but no shoes. Body mass index at baseline was calculated.

Statistical analysis

The baseline characteristics were compared between participants with all 6 DXA examinations and participants missing ≥1 DXA examination but remaining alive during the 5-y follow-up with the use of *t* tests and chi-square tests for continuous and categorical variables, respectively. To distinguish the cohort effect and age-related changes, means of %BF, fat mass, and lean mass against age at examination were plotted for each birth cohort. Mixed models (17) were used to assess the cohort effect and age-related changes in %BF, fat mass (in kg), and lean mass (in kg) with birth cohort; age at examination; square of age at examination; race; and clinic site in the models. Age-related changes were examined in the model as a random effect, assuming that age-related changes in body composition are person-specific with a normal distribution. A quadratic term for age was also used in the analysis because age-related changes in body composition were not linear. Because age-related changes in body composition were different by sex but not by race, all analyses were stratified by sex. Neither sex nor race modified the effect of birth cohort on body composition. We used SAS software (version 9.00; SAS Institute Inc, Cary, NC) for the analysis.

RESULTS

At baseline, compared with participants with all 6 DXA examinations, participants missing ≥1 DXA examination but remaining alive during the 5-y follow-up were significantly older, were significantly more likely to be black, and had significantly more fat mass (**Table 1**). Of the participants with all 6 DXA examinations, a larger proportion of men than of women were

TABLE 1
Baseline characteristics for 2582 Health, Aging, and Body Composition Study participants, including 1786 participating in all 6 dual-energy X-ray absorptiometry (DXA) examinations and 796 missing ≥1 DXA examination but remaining alive during the 5-y follow-up

	Participating in all 6 DXA examinations				Missing ≥1 DXA examination	
	All (n = 1786)	Men (n = 855)	Women (n = 931)	P^1	(n = 796)	P^2
Age at baseline (y)	73.5 ± 3[3]	73.7 ± 3	73.3 ± 3	0.001	74.0 ± 3	< 0.0001
Male (%)	47.9				43.9	0.052
White (%)	64.8	70.4	59.6	< 0.0001	47.8	< 0.0001
Memphis (%)	49.8	49.5	50.2	0.77	48.2	0.28
BMI (kg/m^2)	27.2 ± 5	27.2 ± 4	27.4 ± 5	0.23	27.8 ± 5	0.20
Percentage body fat (%)	34.1 ± 8	28.3 ± 5	39.4 ± 6	< 0.0001	34.8 ± 8	0.06
Fat mass (kg)	25.9 ± 8	23.6 ± 7	28.0 ± 9	< 0.0001	26.8 ± 9	0.02
Bone-free lean mass (kg)	47.3 ± 10	55.5 ± 7	39.8 ± 6	< 0.0001	47.0 ± 10	0.40

[1] Comparing men with women by using t test and chi-square test for continuous and categorical variables, respectively.
[2] Comparing those participating in all 6 DXA examinations with those missing ≥1 DXA examination by using t test and chi-square test for continuous and categorical variables, respectively.
[3] $\bar{x}$ ± SD (all such values).

white. Men had less fat mass and more lean mass; therefore, they had less %BF than did women.

Means of %BF, fat mass, and lean mass according to age at examination and birth cohort in participants with all 6 DXA examinations are shown in **Figure 1**. At the same age, later cohorts had a higher %BF than did earlier cohorts in both men and women (Figure 1A). Within each cohort, %BF initially increased with age and then leveled off in men after ≈80 y of age. The pattern was similar in women, but the initial increase was less rapid. Relying on cross-sectional data at baseline would make it appear that %BF decreased dramatically with age in both men ($\bar{x}$ ± SD: 28.67 ± 5%, 28.94 ± 5%, 28.16 ± 5%, 28.02 ± 5%, 27.98 ± 5%, 28.91 ± 5%, 27.84 ± 5%, 28.82 ± 4%, 28.69 ± 6%, and 26.67 ± 5%) and women (39.76 ± 6%, 39.80 ± 6%, 39.44 ± 6%, 39.88 ± 5%, 38.99 ± 5%, 39.74 ± 5%, 39.30 ± 5%, 39.25 ± 6%, 38.60 ± 6%, and 37.23 ± 5%) from age 70 y to age 79 y. The means of fat mass are shown in Figure 1B. At the same age, later cohorts of both men and women had a greater fat mass than did earlier cohorts. Within each cohort, the amount of fat mass increased with age initially and then decreased in men after ≈80 y of age. The pattern was similar in women, but fat mass decreased more rapidly after ≈80 y of age. The means of lean mass are shown in Figure 1C. At the same age, later cohorts of both men and women had more lean mass than did earlier cohorts. Within each cohort, lean mass decreased with age for both men and women, but the decrease was more rapid in men than in women. With inclusion of participants missing ≥1 DXA examination but remaining alive during the 5-y follow-up, the patterns for cohort and age-related changes in body composition were similar (data not shown).

In participants with all 6 DXA examinations, cohort effect and age-related changes in body composition were assessed in mixed models with birth cohort, age at examination, square of age at examination, race, and clinic site in the models (**Table 2**). Of men, each successive cohort had a 0.32% increase in %BF, when later cohorts were compared with earlier cohorts. The increase in %BF was due to a large increase in fat mass (0.45 kg/birth year) and a moderate increase in lean mass (0.17 kg/birth year). With increasing age, %BF in men increased at younger ages and then leveled off at older ages (the quadratic term of age at examination was significant, which indicated a curvilinear relation). Fat mass in men followed a pattern similar to that of %BF. Lean mass in men decreased with age, and the decrease accelerated at older ages. As in men, later cohorts in women had a greater %BF (0.16%/birth year) than did earlier cohorts. The increase in %BF was also due to a large increase in fat mass (0.34 kg/birth year) and a moderate increase in lean mass (0.18 kg/birth year). With increasing age, both %BF and fat mass in women increased initially and then leveled off. Lean mass in women decreased with age. With inclusion of participants missing ≥1 DXA examination but remaining alive during the 5-y follow-up in the analyses, the results were similar.

A secular trend of increasing height in the recent 2 decades has been described (18). The cohort-related changes in body composition could be partly due to the changes in height. Therefore, we repeated the analysis after adjustment for height at baseline. Because leg length may be less affected by increased age in the elderly (19), we entered leg length, instead of standing height, into the models. The results were virtually unchanged (data not shown).

DISCUSSION

This study, to our knowledge for the first time, simultaneously investigates the cohort effect and age-related changes in body composition in the elderly. These data show that, in older men and women, later cohorts had a greater %BF than did earlier cohorts. The increase in %BF was due to a larger increase in fat mass and a moderate increase in lean mass. Our data also show that lean mass declined with age and that fat mass initially increased and then decreased toward the end of the eighth decade of life. As a result, %BF initially increased with age and then leveled off in both older men and women.

The results from the current study are consistent with an increasing trend in obesity (6). Over the past 2 decades, the prevalence of obesity has increased dramatically (6). However, previous studies did not address the ways in which body composition changed with the increasing prevalence of obesity. For example, it is not clear whether the increases in fat mass and lean mass are proportional. The current study indicates that, even though the amount of fat mass was much less than that of lean mass, the increase in fat mass was greater than that in lean mass.

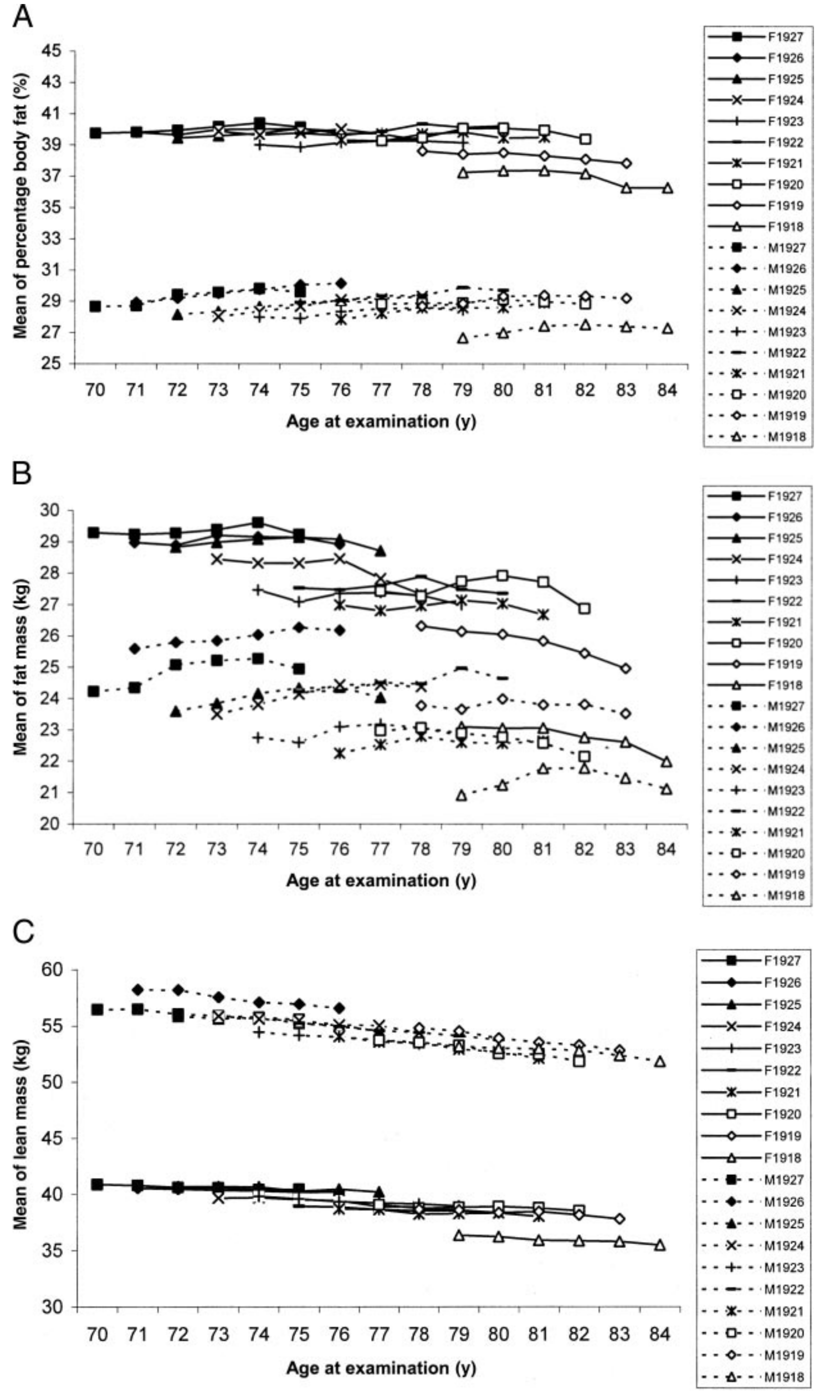

FIGURE 1. Evaluation of percentage body fat, fat mass, and lean mass in study subjects. A: Mean percentage body fat by age at examination (70–84 y) and birth cohorts (birth years 1918–1927) in 855 men (M) and 931 women (F) who participated in all 6 dual-energy X-ray absorptiometry (DXA) examinations during the 5-y follow-up in the Health, Aging, and Body Composition (Health ABC) Study. B: Mean fat mass by age at examination (70–84 y) and birth cohorts (birth years 1918–1927) in 855 M and 931 F who participated in all 6 DXA examinations during the 5-y follow-up in the Health ABC Study. C: Mean lean mass by age at examination (70–84 y) and birth cohorts (birth years 1918–1927) for 855 M and 931 F who participated in all 6 DXA examinations during the 5-y follow-up in the Health ABC Study.

Therefore, each successive cohort from birth year 1918 to 1927 had a greater increase in %BF in the elderly. The increase in %BF affected men more; the increase in men was double that in women (0.32% compared with 0.16%/birth year). These changes in body composition may be attributed to sedentary lifestyles and increased caloric intake (20). Excess fat mass may be a risk factor for disability in older adults (1, 2). Excess fat mass is also a risk factor for diabetes mellitus, cardiovascular disease, hypertension, dyslipidemia, certain cancers, and mortality in middle-aged adults (21). In older adults, the association of fat mass with mortality is controversial (22). However, excess fat mass is still associated in older adults with a greater burden of type 2 diabetes,

TABLE 2
Cohort effect and age-related changes in percentage body fat, fat mass, and lean mass in 2582 Health, Aging, and Body Composition Study participants, including 1786 participating in all 6 dual-energy X-ray absorptiometry (DXA) examinations and 796 missing ≥1 DXA examination but remaining alive during the 5-y follow-up[1]

	Birth cohort		Age at examination		Square of age at examination	
	β	P	β	P	β	P
Participating in all 6 DXA examinations (n = 1786)						
Men (n = 855)						
Percentage body fat (%)	0.32 (0.06)[2]	< 0.0001	0.40 (0.05)	< 0.0001	−0.01 (0.003)	< 0.0001
Fat mass (kg)	0.45 (0.09)	< 0.0001	0.40 (0.06)	< 0.0001	−0.02 (0.003)	< 0.0001
Lean mass (kg)	0.17 (0.09)	0.05	−0.18 (0.04)	< 0.0001	−0.008 (0.002)	0.005
Women (n = 931)						
Percentage body fat (%)	0.16 (0.07)	0.02	0.19 (0.05)	< 0.0001	−0.01 (0.003)	< 0.0001
Fat mass (kg)	0.34 (0.10)	0.001	0.20 (0.06)	0.0006	−0.02 (0.004)	< 0.0001
Lean mass (kg)	0.18 (0.07)	0.006	−0.09 (0.03)	0.005	−0.002 (0.002)	0.25
All participants (n = 2582)						
Men (n = 1206)						
Percentage body fat (%)	0.27 (0.05)	< 0.0001	0.35 (0.04)	< 0.0001	−0.01 (0.003)	< 0.0001
Fat mass (kg)	0.36 (0.07)	< 0.0001	0.32 (0.05)	< 0.0001	−0.02 (0.003)	< 0.0001
Lean mass (kg)	0.11 (0.07)	0.10	−0.24 (0.04)	< 0.0001	−0.007 (0.002)	0.007
Women (n = 1376)						
Percentage body fat (%)	0.20 (0.06)	0.0004	0.19 (0.04)	< 0.0001	−0.01 (0.003)	< 0.0001
Fat mass (kg)	0.34 (0.09)	< 0.0001	0.18 (0.05)	0.0008	−0.02 (0.004)	< 0.0001
Lean mass (kg)	0.17 (0.05)	0.001	−0.09 (0.03)	0.002	−0.003 (0.002)	0.08

[1] Analysis included birth cohort, age at examination, square of age at examination, race, and clinic site in mixed models.
[2] Regression coefficient; SE in parentheses (all such values).

cardiovascular disease, hypertension, and dyslipidemia (3, 23). Should body-composition trends continue, these data may portend a growing burden of body composition–related health conditions.

After adjustment for the cohort effect, the current study describes the pattern of age-related changes in body composition through the eighth decade of life. Cross-sectional studies suggest that fat mass may be relatively stable in older men but may decrease with age in older women (24) and that lean mass may decrease with age in older adults (24, 25). Data from cross-sectional studies may distort the age-related changes in body composition. Longitudinal studies, including a previous Health ABC Study report with a 2-y follow-up, further suggest that fat mass may increase with age in older men but not in older women (7, 9, 12). However, these longitudinal studies did not assess the effect of birth cohort, and age-related changes in body composition were potentially biased by the cohort effect. Our results showed a linear decline in lean mass with age in women and also showed an accelerated decline in men. Moreover, instead of increasing linearly with age, fat mass increased initially and then declined in both men and women. As a result, %BF initially increased from age 70 to 80 y and then leveled off from age 81 to 84 y. The underlying mechanisms of age-related changes in body composition are still unclear, although declines in basal metabolism (11) and an impairment in the ability to regulate energy balance (26) in older adults may be contributing factors. It is important that, from a clinical perspective, these age-related changes in body composition may underlie many age-related diseases, such as disability (27).

The current study, with 6 annual DXA measures in a large sample of elderly, provides data on the cohort effect and age-related changes in body composition. Nevertheless, the results from this study should be interpreted with caution. First, the study participants were 70–79 y old at baseline. Therefore, the results from this study may not be generalized to other age groups. However, this age range is the critical period for the development of disability (28), in which body composition may play an important role. Second, the current analysis was limited to participants who remained alive during the 5-y follow-up. Because various underlying causes of death are likely to alter age-related changes in body composition, the results from the current study may not also be found in persons approaching the end of their lives. Third, participants who missed 1–5 DXA measures but remained alive during the 5-y follow-up had slightly more fat mass at baseline than did participants with all 6 DXA measures. However, when the analyses included participants missing ≥1 DXA examination but remaining alive during the 5-y follow-up, the results were similar. Fourth, at baseline, only the well-functioning elderly were recruited to the current study. The older participants, who represented earlier cohorts, may be even more selective than the younger participants with regard to physical function. If better physical function is associated with lower %BF, the decreased %BF in earlier cohorts may be partly due to the selection bias. However, this should not affect the assessment of age-related changes in body composition.

In summary, our data show that, during the epidemic of obesity in the past 2 decades, the increase in body size in the elderly is mainly due to a large increase in fat mass and a moderate increase in lean mass. Therefore, %BF in the elderly has greatly increased in the past 2 decades. The current study also delineates the patterns of age-related loss of lean mass and age-related changes in fat mass and %BF in community-based elderly, which could serve as a reference for clinical practice and future studies. Finally, the confluence of the effects of birth cohort and age on body composition results in bigger body size and less lean mass among the elderly. The combination of both an increase in fat mass and a loss of skeletal muscle, termed sarcopenic obesity, may even be reinforcing and may lead to disability and other illnesses in the elderly (29). With the aging of the population (30), the effect of sarcopenic obesity may be dramatic in the coming years. As a result, the development of appropriate interventions that target fat loss while preserving skeletal muscle to prevent disability and other illnesses in the elderly is of great importance for public health.

JD and TBH were responsible for the conception and design of the study. All authors were responsible for the conduct of the study and data interpretation. JD was responsible for drafting the manuscript, and all authors participated in revising the manuscript. None of the authors had a personal or financial conflict of interest.

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