Exophthalmometry values of Turkish adult population and the effect of age, sex, refractive status, and Hertel base values on Hertel readings

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PURPOSE. *To establish normal exophthalmometry values in the adult Turkish population, and the impact of age, gender, interpupillary distance, Hertel base selection, and refractive status on globe position.*

METHODS. *Exophthalmometry measurements and refractive status of 2477 subjects were conducted in one tertiary and five primary health care centers. Change of globe position by age, intersex differences in terms of globe position, correlations of Hertel base with exophthalmometry results, and interpupillary distance (IPD) were evaluated. Multiple linear regression analysis was performed to test determination effect of each variable on final Hertel reading.*

RESULTS. *Median Hertel reading was 13 mm, and 95% of the population had an upper limit of 17 mm for both eyes. There was a negative correlation between spherical equivalent of refractive status and exophthalmometry results and a weak positive correlation between IPD and exophthalmometry result. Mean Hertel value was found to decrease significantly after the third decade. Hertel base value was found to have moderate linear correlation with Hertel results. A weak correlation was detected with Hertel base/IPD ratio with final Hertel results. Multiple linear regression analysis was performed and only 13% and 20% of change in Hertel values bilaterally were found to be determined by other variables (age, IPD, refractive status, and Hertel base value) for females and males.*

CONCLUSIONS. *Normative dataset for exophthalmometry results of the Turkish population is established to be used in clinical practice and research. Only 13% to 20% of change in Hertel values was detected to be determined by age, IPD and Hertel base values. (Eur J Ophthalmol 2008; 18: 165-71)*

KEY WORDS. *Age, Exophthalmometry, Hertel, Refractive status, Turkish population*

Accepted: September 24, 2007

INTRODUCTION

Despite advancing imaging technology, measurement of proptosis is still the mainstay in the diagnosis of most orbital diseases in daily clinical practice (1-7). Among several methods, Hertel's exophthalmometry is most widely used in the evaluation of globe position (i.e., exophthalmos and enophthalmos). Despite being criticized for its low reliability and reproducibility, and parallax error, it can be used for comparative, relative, and absolute exophthalmometry for comparison of results of the same Hertel type and manufacturers (1-3, 6, 8-11).

There are well established data in the literature in terms of upper and lower limits of proptosis for black, white, Asian, African, and American populations (1, 4, 5, 12-17). The upper limit is especially important clinically since most of the orbital diseases cause proptosis instead of enophthalmos. In most of these studies, upper limit of ocular protrusion is accepted to be 21 mm, however, this is not a clear-cut value because of racial anthropometric differ-

Presented in part at the 40th National Ophthalmology Meeting; Antalya, Turkey, 2006

1120-6721/165-07$25.00/0

ences in different geographic localizations, and upper limit for one race may not be the same for the others (5, 12-17). This kind of racial difference is important in certain clinical situations like Graves' ophthalmopathy, for which the amount of proptosis is required to determine the disease severity (12, 13, 16, 17). In this respect, the normal values are required to be established for each population in order to diagnose and grade the orbital disorders, especially when the disease is bilateral like Graves ophthalmopathy.

In this study we wanted to establish normal exophthalmometry values in the adult Caucasian Turkish population, and the impact of age, gender, interpupillary distance, and refractive status on globe position. Hertel base selection relative to the interpupillary distance (IPD) was additionally investigated in terms of correlation with consequent results in order to establish any possible effect of smaller or larger base selection on final Hertel measurement results.

MATERIALS AND METHODS

This study was conducted in a tertiary health care center at Ondokuz Mayis University, Ophthalmology Department, and five different primary health care centers between May 2006 and January 2007. A total of 2477 patients with no ophthalmic pathology except for a refractive disorder were included in the study. Subjects were excluded in presence of facial malformation, orbital deformity, Graves ophthalmopathy, orbital tumors, or inflammation. Subjects with extreme myopia and hyperopia were not excluded; however, Hertel measurement results of patients with high refractive errors were additionally assessed in order to assess the effect of all ranges of refractive status on globe position.

Exophthalmometry measurements were conducted by Hertel exophthalmometer (Oculus, Germany) with one mirror and curved footplates in a well-lit room. Measurements were performed bilaterally and simultaneously, while the patient was sitting upright and the eyes in the primary position. Left footplate, which is fixed, was rested on right lateral orbital rim, and the other footplate was moved to adjust that both footplates were at rest on orbital rims symmetrically. The instrument was held in frontal plane coinciding with the pupils sagittally. Several measurements to the nearest 1 mm were performed and the mode value was recorded with base selected. The same instrument was used for all the measurements by two ophthalmology residents (Y.O., H.E.O.) experienced in Hertel exophthalmometry measurements for at least 4 months in the oculoplastic department. Refractive status of the patients was determined by Nidek Speedy-1 autorefractometer (Nidek Corp., Japan) and converted to spherical equivalent by adding half of the cylindrical power to the spherical power. IPD of the patients were measured by a ruler.

After all the data were collected and transferred to PC, descriptive statistics (mean, median, minimum, maximum, standard deviation) were evaluated for all parameters. To determine the relationships between various characteristics, Pearson correlation coefficients (r) and determination coefficients (r^2) were calculated to estimate the strength of the correlations and the degree of variance in one measure determined by the other respectively.

Subjects were then further categorized according to age decades, and univariate analysis of variance was performed to test change of globe position by age by using post hoc Tukey HSD test. To examine for intersex differences in terms of globe position, Student *t*-test was used.

Correlations of Hertel base with exophthalmometry results and with IPD were assessed in order to test effect of base selection on Hertel results. Additionally, since lateral orbital rim to rim distance comprises most of Hertel base distance, and it is directly correlated with IPD (see below), we thought that Hertel base/IPD ratio should increase with larger base selection and decrease vice versa which should imply improper base selection. Hence, correlation of Hertel base selection/IPD ratio with Hertel results was additionally assessed to test effect of smaller and larger base selection on consequent results, and residents conducting measurements were not informed about this assessment so as to prevent any involuntary adjustment in base selection.

Multiple linear regression analysis was performed to test determination effect of each variable on final Hertel reading. Analyses were performed using the SPSS, Release 13.01, Statistical Package Program.

The study was conducted in adherence with the Declaration of Helsinki, and no ethics committee approval was deemed necessary.

RESULTS

A total of 2477 subjects (1507 female/970 male) with a mean age of 49.9±13.5 years were recruited in five primary health care centers and in our clinic. Descriptive statistics of Hertel results, refractive status, and IPD are given in Table I. Median Hertel readings were 13 mm bilaterally for men and women (Figs. 1 and 2), and 95% of the population had an upper limit of 17 mm for both eyes. Upper limits for Hertel readings were 18 mm and 17 mm for men in the right and the left eyes, respectively. For women the upper limit was 17 mm for both eyes.

According to Pearson correlation analysis there was a negative correlation between spherical equivalent of refractive status and exophthalmometry results (r –0.069, p 0.001, and r –0.057, p 0.004, for the right and the left eyes, respectively) and a weak positive correlation between IPD and exophthalmometry result (r 0.237, p<0.001, and r 0.232, p<0.001, for right and left sides, respectively). Hertel results of subjects with extreme values of refractive disorder were additionally evaluated (Tab. II). Subjects with extreme myopia do not necessarily have increased Hertel results, nor do subjects with hyperopia necessarily have decreased Hertel results.

Age was found to have a weak inverse correlation with Hertel results (r –0.151, p<0.001, and r –0.155, p<0.001, for right and left sides, respectively). According to univariate analysis of post hoc Tukey HSD test, there was a significant change in globe position between decades (Figs. 3 and 4). Mean Hertel value decreases significantly after the third decade (p 0.007 and 0.008 for right and left sides, respectively), which also continues to decline, albeit not to a statistically significant degree, with each consequent decade.

Student *t*-test showed a significant difference in globe position between male and female subjects (p 0.028 and 0.043 for right and left sides, respectively) (Tab. I). However, the difference was found to be only 0.2 mm (Tab. I).

When subjects in the first two decades (during which orbital development still continues) are excluded, median and upper limit (of 95% of population) of proptosis

TABLE I - DESCRIPTIVE STATISTICS OF HERTEL RESULTS, REFRACTIVE STATUS, AND INTERPUPILLARY DISTANCE (IPD)

		Mean ± SD (mm)	Median (mm)	Minimum (mm)	Maximum (mm)	95th percentile (mm)
Total	Hertel right	13.35±2.44	13	5	21	17
	Hertel left	13.26±2.44	13	5	21	17
Male	Hertel right	13.49±2.49	13	5	20	18
	Hertel left	13.38±2.48	13	5	20	17
Female	Hertel right	13.27±2.40	13	6	21	17
	Hertel left	13.18±2.42	13	6	21	17
Refractive status	Right eye	0.02±1.78D	0.00D	–16.25 D	+8.75 D	–
	Left eye	0.01±1.65D	0.00D	–17.50 D	+12.25 D	–
IPD		62.98±3.67	63	44	75	–

TABLE II - HERTEL RESULTS OF SUBJECTS WITH EXTREME VALUES OF REFRACTIVE DISORDER

Refractive disorder	Patient ID no. (side)	Refractive status	Hertel result	IPD
Extreme hyperopia	1172 (left)	12.25	15	65
	938 (left)	10.00	11	57
	938 (right)	8.75	12	57
	1990 (right)	7.50	15	62
	2277 (right)	7.25	14	63
	2012 (left)	7.00	15	65
Extreme myopia	877 (left)	–13.50	13	59
	1572 (right)	–15.00	17	66
	1665 (right)	–16.25	11	63
	371 (right)	–16.25	11	63
	1665 (left)	–17.50	11	63
	371 (left)	–17.50	11	63

IPD = Interpupillary distance

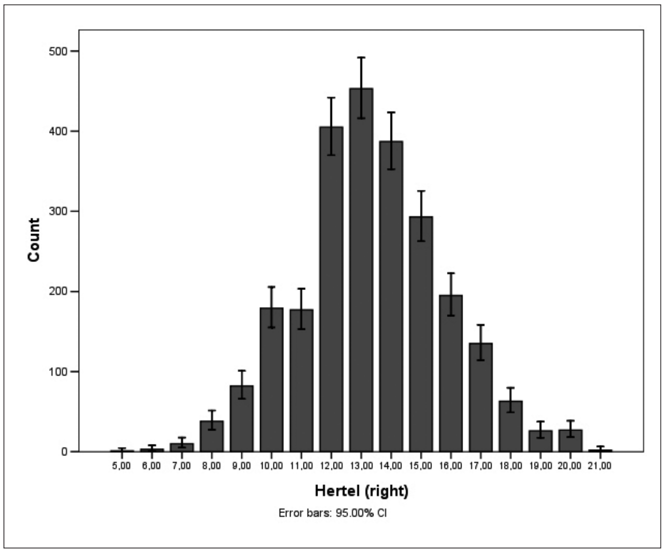

Fig. 1 - *Exophthalmometry distribution of right eyes.*

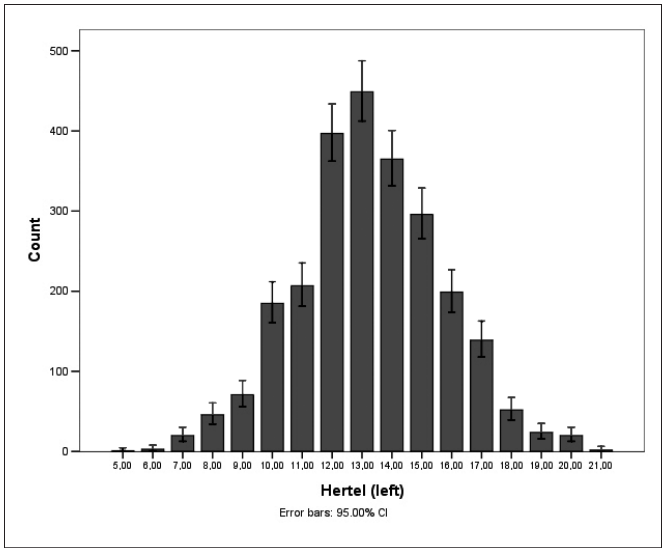

Fig. 2 - *Exophthalmometry distribution of left eyes.*

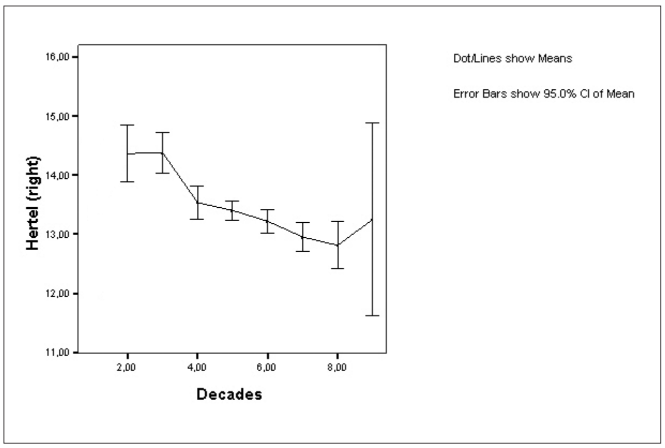

Fig. 3 - *Fiftieth percentile distribution curve of normal exophthalmometric values in the right eyes with error bars of fifth and 95th percentiles.*

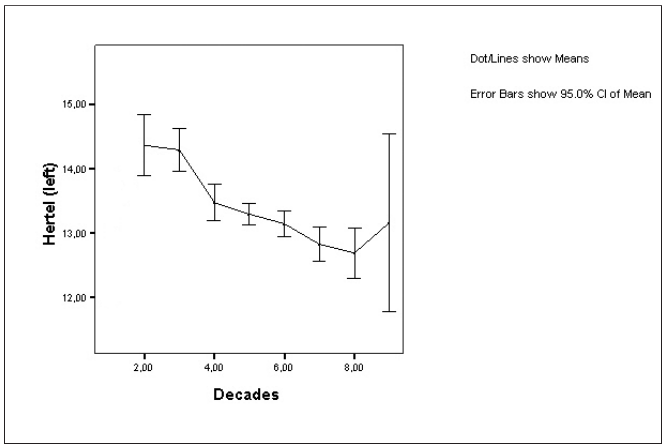

Fig. 4 - *Fiftieth percentile distribution curve of normal exophthalmometric values in the left eyes with error bars of fifth and 95th percentiles.*

(13 mm and 17 mm, respectively) were not found to be different from total population.

Hertel base value was found to have moderate linear correlation with Hertel results (r 0.365, p<0.01, and r 0.372, p<0.01, for right and left eyes, respectively), and strong linear correlation with IPD (r 0.618, p<0.01). Correlation of Hertel base selection/IPD ratio was additionally investigated in terms of correlation with consequent results, and a weak correlation was detected with Hertel base/IPD ratio with final Hertel results (r 0.063, p 0.02, and r 0.073, p<0.01, for right and left eyes, respectively) (Figs. 5 and 6).

Multiple linear regression analysis was performed and only 13% and 20% of change in Hertel values bilaterally were found to be determined by other variables (age, IPD, refractive status, and Hertel base value) for females and males, respectively. Additionally, refractive status and IPD were not found to be effective (p 0.1) in determining change in Hertel value, unlike age and Hertel base values (p<0.001).

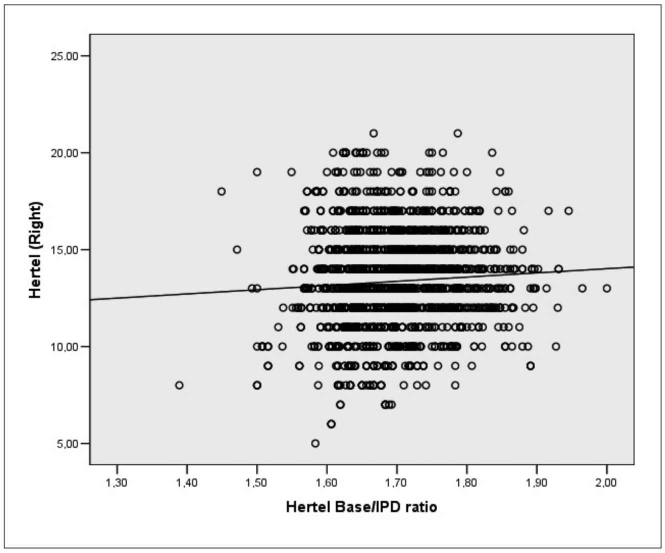

Fig. 5 - *Scatter plot of Hertel results according to Hertel base/interpupillary distance ratio, and regression line for the right eyes.*

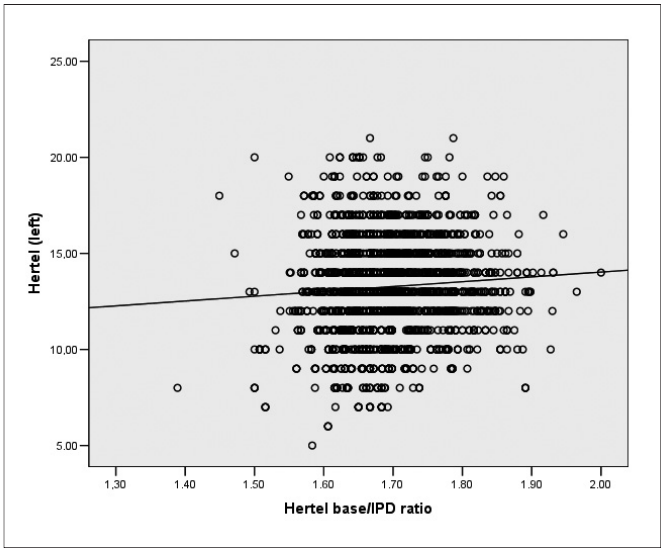

Fig. 6 - *Scatter plot of Hertel results according to Hertel base/interpupillary distance ratio, and regression line for the left eyes.*

DISCUSSION

Despite being criticized for its low reliability and reproducibility, Hertel exophthalmometry is still the most widely used instrument in evaluation of proptosis and enophthalmos (2-11, 14, 15, 18). Computerized tomography has been used to achieve more accurate measurements of proptosis (1, 5). However, mean results obtained by CT yield slightly different values than Hertel readings, and measurement of proptosis by CT scan was reported to be reproducible only if the patient's head was fixed with a mask, and the measurements were performed by the same technician (5). Moreover, considering the cost of the imaging methods, CT scan is not practical for screening and cannot substitute Hertel exophthalmometer in daily clinical practice, hence should better be reserved for research projects.

Hertel exophthalmometer is more reliably used for relative and comparative measurements (2, 3, 5, 6, 8). More than 2 mm difference between either eyes or change in globe position with sequential measurements over time is considered clinically significant. However, pathologic processes affecting both eyes simultaneously require absolute measurement as well as normative dataset of absolute values for the diagnosis to be established. There are well established data in the literature in terms of upper and lower limits of proptosis for many populations (1-3, 14, 15, 18-20). In most of these studies, upper limit of ocular protrusion is accepted to be 21 mm (12, 13, 15-17), however, this value might change with different races because of anthropometric differences in different geographic localizations. This kind of racial difference is quite important in certain clinical situations like Graves ophthalmopathy, since the amount of proptosis is required to determine disease severity (12, 13, 16, 17). Mourits et al (3), for example, reported that the adult Caucasian Dutch population has an upper limit of ocular protrusion to be 20 mm and 16 mm for males and females, respectively. In this respect, normal data should be established for each population. Our aim in this study was to establish normal exophthalmometric values for the adult Caucasian Turkish population.

In our study we detected the median exophthalmometric value to be 13 mm (5–21 mm) with a standard deviation of 2.44 mm. In our population, normal upper limit of exophthalmos (95th percentile) was detected to be approximately 17 mm (approximately the mean +2 SD for our Gaussian curve). This finding is important especially for patients with Graves ophthalmopathy where the disease is graded as moderate when more than 4 mm of exophthalmos presents (12, 13, 16, 17). For example, if we consider 21 mm of exophthalmos as an upper limit for the normal population (as stated in the literature) our patients with Graves ophthalmopathy are accepted to have mild disease as long as their Hertel readings were below 25 mm. However, with the normative data we present, we can consider the upper limit as 17 mm, and cutoff value of exophthalmos for moderate disease to be 21 mm for this kind of patients. In a recent report on 480 subjects by Bilen et al (21), mean Hertel value was reported to be 13.44 and 13.49 for males and females, respectively, in northeastern Turkey, with no significant gender effect. These results are consistent with the results of our study, indicating that Hertel measurements do not yield free-floating results, and these data can be used as normative values for the Caucasian Turkish adult population.

In previous studies subjects were excluded if they had myopia >6.00 D, so the impact of refractive status on Hertel readings was not evaluated (1-3, 14, 15, 18). Fledelius and Stubgaard (22), on the other hand, detected no significant correlation between the refractive status and the globe position in 554 subjects. In our study, we wanted to assess the effect of all ranges of refractive status on globe position, and we detected an inverse correlation between refractive status and exophthalmometry result (i.e., increasing proptosis with increasing myopia). However, only 0.5% of total change in Hertel result is directly attributable to the refractive change since the correlation was found to be quite weak (r –0.069 and –0.057 for the right and left side, respectively) in spite of being statistically significant. Additionally with multiple linear regression analysis, refractive status was not found to be a significant variable in determination of final Hertel value. Considering these results in addition to the fact that extreme values of refractive status are not necessarily accompanied by extreme values of Hertel results (Tab. II), one might think that refractive status does not affect Hertel results as much as thought before. However, since we did not classify the refractive status as axial or index (corneal, lenticular) these results should be better considered carefully and reassessed with further studies including measurement of axial length and position of the globe instead of including solely spherical equivalent of refractive status.

Incorrect measurements with Hertel's device might occur if footplates are not correctly positioned on the lateral orbital rim or the device is not aligned horizontally, and base measurement has great impact on final measurement yielded (1, 8, 15). Every 2 mm medial displacement of footplate was reported to result in 3.8 mm underreading of proptosis (8). In our study we detected that Hertel base value has moderate linear correlation with Hertel results (r 0.365 and 0.372 for right and left eyes, respectively), which implies that selection of larger base results in higher Hertel readings, which is consistent with previous reports. However, since both exophthalmometry results and base values are linearly correlated with IPD, we thought that Hertel base/IPD ratio should be clinically more important in terms of effect of improper base selection on consequent results. In this respect, a weak linear correlation is detected with Hertel base/IPD ratio with final Hertel results (r 0.063 and 0.073 for right and left eyes, respectively). Despite being significant, this correlation is weak, with a determination coefficient (r^2) of 0.004, implying that it is responsible for only 0.4% of change in final Hertel reading. We thought that should Hertel base/IPD ratio be strongly correlated with Hertel results, a standard ratio of Hertel base/IPD could be calculated which would be helpful in more standardized measurement of exophthalmos. However, we were unsuccessful in calculation of such a ratio since the correlation was found to be weak.

There are conflicting reports concerning gender effect on globe position. Kashkouli et al (2) reported no significant difference in males and females. Mourits et al (3), Dunsky (20), Baretto and Mathog (19), and Migliori and Gladstone (14), however, reported proptosis values to be greater in males, while Sodhi et al (15) and Kim and Choi (1) reported the opposite. This discrepancy might be related to racial differences or less probably to the sample size. In our study, the difference in globe position between males and females was found to be 0.2 mm. It can be considered clinically insignificant albeit being statistically significant since Hertel measurement is usually performed with 1 mm increments.

According to univariate analysis of post hoc Tukey HSD test, there was a significant change in globe position between decades (Figs. 3 and 4). Results of the first two decades are not included in statistical tests due to low number of subjects in these decades and globe position is known to be changing during this period (18). We detected a statistically significant decline in proptosis especially after the third decade. In spite of being progressive (Figs. 3 and 4) this decline did not reach statistical significance between each consequent decade. With the last decade (ninth) Hertel values reached the lowest values, probably due to loss of soft tissue around orbital rim, but due to low number of subjects in this decade (n = 12) mean Hertel value was not found to be statistically significant. Mourits et al (3) reported that age has no effect on proptosis and proposed that a larger sample size might reveal a small age effect. As stated above this small age effect is detected in our study and age with the Hertel base values was found to be an effective determinant of Hertel results among our variables. However, determination coefficient of 0.02 shows that the age effect is weak (2% of change in Hertel value), just as Mourits et al proposed (3).

In conclusion, we established a normative dataset for exophthalmometry results of the Caucasian Turkish population. Additionally, refractive status was not found to be as effective an determinant of Hertel values as considered before. Hertel values were also detected to decrease over each decade, as well as with increasing Hertel base selection. Finally, only 13% to 20% of change in Hertel values was detected to be determined by age, IPD and Hertel base values.

ACKNOWLEDGEMENTS

Statistical aid was supplied by Prof . Dr. Yüksel Bek, Department of Biostatistics, Medical Faculty, Ondokuz Mayıs University.

None of the authors has any financial interest in this article.

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