

**ORIGINAL ARTICLE**

Physiological Approach on the Physical Fitness and Postural Balance Effects of a Whole-Body Vertical Vibration Intervention in Young Women

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ABSTRACT

With the advent of westernized diet and a lack of exercise, young female college students are paying more attention to their bodyweight and health. Whole-body vibration has been demonstrated to be a suitable training method for improving knee extension maximal strength in young female athletes, as well as the gait performance in elderly women. This study aimed to evaluate the effects of a vertical vibration intervention on the physical fitness and postural balance in young females. Fifty-four young women were recruited; all subjects were randomly assigned to the intervention group and control group. The intervention group underwent vertical vibration with a platform for 12 weeks. The results showed that body mass index and body fat percentage had decreased ($P < 0.05$). In addition, their muscle endurance as indicated by a sit-up test and their flexibility as indicated by a sit-and-reach test were both increased. With regard to postural balance, their 30-second sit-to-stand and timed up and go test results were improved. At the same time, their mean single-leg stance with eyes closed time increased ($P < 0.05$). However, there were no significant differences, meanwhile, for the control group. Overall, the results showed that the whole body vibration (WBV) intervention had some beneficial effects on physical fitness and postural balance in young women.

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INTRODUCTION

With dietary westernization in Taiwan, obesity of teenagers and college students has been severely increasing [1]. A statistical report on change in national nutrition and health status in Taiwan showed that the prevalence of overweight and obesity in young people over the age of 19 increased from 33% (1993~1996) to 38.3% (2013), and most of them were female (54.1%) [2].

Health Promotion Administration, Ministry of Health and Welfare also pointed out that obesity leads to the occurrence of many diseases, and overweight also leads to inconvenience in physical activities, lack of muscular strength and balance, and occurrence of shortness of breath during exercise. According to the suggestion from the U.S. Department of Health and Human Services, to maintain proper physical fitness, one should engage in aerobic exercise and muscular strengthening exercise to increase muscular endurance [3].

The Whole Body Vibration (WBV) protocols typically require the participant to stand or sit on a vibration platform while receiving a mechanical stimulus

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imparted by the device. According to the findings of recent studies, WBV can prevent osteoporosis, increase muscular strength and postural balance [4]. WBV training is helpful for patients with multiple sclerosis (MS) [5-8], chronic stroke patients [9, 10], even Parkinson's disease patients [11, 12], but WBV could be a risk factor for low back pain (LBP) based on the higher prevalence rates in the studied populations [13]. Most of the WBV related studies showed the benefit effects with gait function in the elderly [14-16], but less of the study focused on the young people and bodyweight loss or improve the health fitness.

WBV device is a professional device less accessible to general public. A Swedish doctor invented the vibration therapy device and used it for exercise therapy. Afterwards, in academic research, German sports developed a sports technique called "regular neuromuscular stimulation", which can reduce bone loss and increase muscular strength and balance to achieve the effects of rehabilitation and weight loss. In addition to being applied to medical treatment, WBV is also be used as a training device by athletes. WBV has been demonstrated as a suitable training method to improve knee extension maximal strength in young female athletes [17]. However, because the entire machine is larger it is more expensive. In addition, WBV device may easily be confused with non-vertical vibration or non-professional vibrator available in the market. Therefore, the general public do not fully understand the effectiveness of this training.

At present, many academic studies have begun to investigate the influence of WBV on teenagers, the elderly, athletes, and patients [18, 19]. However, the studies on teenagers have not discovered that WBV has a significant influence on their balance and muscular endurance. The reason may be that the physical status, muscular strength, and balance of teenagers are relatively better. Therefore, even the use of WBV cannot reflect an immediate effect of the young people [18]. Some studies on the elderly pointed out that WBV can improve the muscular strength and balance of the

elderly [3, 19]. Some research results also do not show a significant effectiveness. The studies on athletes found that WBV can strengthen athletes' muscular endurance [20]. In terms of patients, some studies found that WBV can achieve a better rehabilitation effect in patients with stroke [9, 17].

To date, even the study has found that the influence of WBV on teenagers or college students is not significant [18]. The research method was to enroll volunteers to receive the intervention training of WBV and observe the pre-and-post intervention changes. Most studies only found that there is a trend of increase in muscular endurance; however, the increase is not significant. The reason may be that the method of use and the length of time of intervention may affect the effect of WBV.

MATERIALS AND METHODS

1. Participants

This study used the vertical vibration device to investigate young college female students. It is a randomized controlled study, mainly enrolled college students of healthcare administration department of a technical college in Taiwan as the voluntary subjects using the intra-web announcements of various departments, written notifications of various departments, posters, and elevator propaganda, and excluded the male college students. This study used random sampling to enroll in the subjects. Analyses were limited to those randomized to the WBV intervention. The inclusion criteria included: (1) Voluntary participants over the age of 18 and under the age of 24. This study excluded voluntary participants with a BMI < 18.5 or BMI ≥ 27. (2) Voluntary participants had to undergo the assessment performed by the medical team at Department of Rehabilitation, Far Eastern Memorial Hospital to exclude those who were not suitable for participating in WBV movement or were complicated with other chronic illness. (3) Voluntary participants who agreed to participate in 12-week training and signed informed

consent form, owing to the usage of the data therein, entailing various ethical issues, the protocol of this study was evaluated and approved by the Research Ethics Committee, Far Eastern Memorial Hospital (FEMH-IRB-103021-F,v.03) and Oriental Institute of Technology and all participants signed IRB agreements before participation.

2. Study design

Fifty-four participants finished the study aged from 18 to 24 years (21.12 ± 0.85 in the intervention group; 21.14 ± 0.53 in the control group). The WBV device used in this study was vertical vibration platform, Brand: BODYBREEN (B.Green Technology Co., Ltd, model No.: # BW760), training intensity including Level: 1~7, frequency level: 5.6 Hz~13 Hz, and amplitude: 2 mm. The subjects received the training for 15 minutes every time, and the maximum weight bearing was: 120 kg. Different from complex training model used in other correlation studies, this study advised the subjects to receive two different WBV interventions (Figure 1). In addition, in order to avoid side effects or training-induced injuries, this study set up the medium and low intensity and frequency models that were more suitable for college students after the discussion with rehabilitation physicians and rehabilitation therapist at Division of Clinical Rehabilitation (recommended frequency protocol: 5.6 Hz→9 Hz), and selected the cycle of automatic mode 1 (Automatic cycle: →5.6 Hz: 30 seconds→7 Hz: 30 seconds→9 Hz: 30 seconds→5.6 Hz: 30 seconds→...; and repeat cycle) to receiving WBV

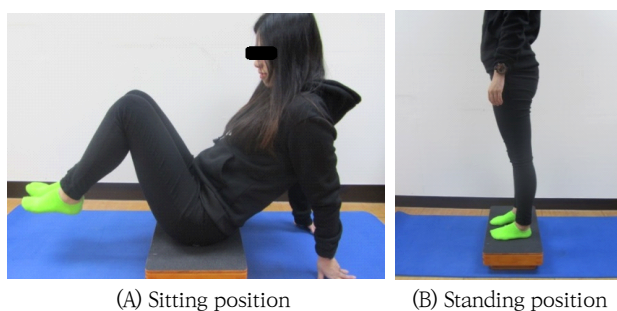


Figure 1. Simulations of postures of subjects receiving WBV intervention.

intervention, in order to investigate whether the training has a significant effect.

In this study, we are not using the “in side-alternating” rotational vibration (RV) (Figure 2A), we use the “vertical up-and-down” vertical vibration (VV) (Figure 2B). The subjects randomized to intervention experimental group received WBV training twice a day, 3 days a week. The training postures are shown in Figure 1. Each training session lasted for at least 15 minutes, and the training time every day had to exceed 30 minutes. The subjects randomized to the control group received the home exercise teaching CD provided by the research assistant. After the research assistant instructed them how to engage in voluntary home exercise, the subjects in the control group were advised to take exercise at home for at least three times per week, and each exercise session had to exceed 30 minutes. The training period for the two groups was 12 weeks.

3. Assessment indicators

The indicators used for assessing physical fitness in this study included: body mass index (BMI), body fat (BF), muscular endurance (sit-ups), flexibility (sit and reach), and cardiopulmonary endurance. The indices used for assessing postural balance included: 30-second chair stand test (CST), single-leg stance with eyes closed, and timed up-and-go test (TUG).

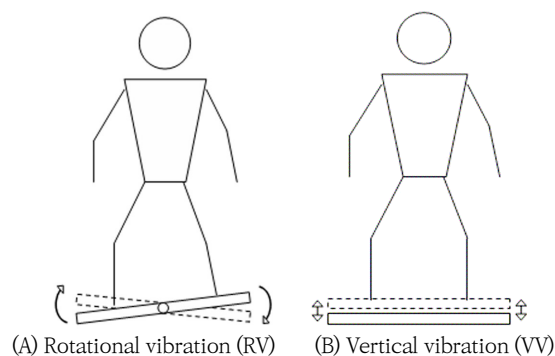


Figure 2. Comparison of rotational vibration (RV, left) and vertical vibration (VV, right). Platform displacements are exaggerated for demonstrative purposes (Ref: [21]).

4. Statistical analysis

Statistical analysis was performed using the SPSS, PC, Version 21.0 (SPSS, Chicago, USA) program. A mean (M) and standard deviation (SD) were calculated for the physical features and physical fitness and postural balance characteristics of the subjects. An analysis of variance (ANOVA) test is a major method in this study to find out if survey or experiment results are significant.

RESULTS

The main subjects enrolled in this study were college female students. This study successfully enrolled 54 voluntary participants, including 23 subjects participating in the 12-week WBV “intervention experimental group” and 31 subjects participating in voluntary home exercise “control group”. The analysis of the research results is as follows.

As shown in Table 1, the average age of a total of 23 subjects in the intervention group was 21.12 ± 0.85 (mean \pm standard deviation) years old, and the average age of a total of 31 subjects in the control group was 21.14 ± 0.53 years old. For objectively compare the differences with two groups, we excluded the few males. There was no statistically significant difference in average age and gender between the two groups. This study measured various indices of physical fitness

and postural balance from the young females in the two groups before intervention (Pre-training), 6 weeks after training, and 12 weeks after training, and performed statistical analyses on the two groups.

The 23 subjects of the experimental group underwent 12 weeks of systematic vertical-rhythm vibration intervention sessions, 15~30 minutes each time, 3 times a week. The 31 subjects of the control group advised to take exercise at home for at least three times per week, and we asked each exercise session had to exceed 30 minutes. In pre-training, 6-weeks, and 12-weeks of the study, physical fitness indicators and postural balance indices were measured.

Referring to Table 1, after completion of the 12-weeks training course, the mean of BMI results in the experimental group decreased from 23.58 ± 3.37 to 23.39 ± 3.59 , the BF also decreased from $30.57 \pm 6.04\%$ to $28.67 \pm 7.4\%$ ($P < 0.05$), the mean of Sit-Ups times increased from 28.71 to 29.30, and flexibility: Sit and Reach increased mean from 26.50 ± 10.34 to 27.00 ± 10.41 (cm). For postural balance indices, times of the 30-sec CST result increased 23.29 ± 3.81 to 25.33 ± 4.86 ; timed up-and-go test result decreased mean from 9.76 ± 13.65 to 7.66 ± 1.84 , at the same time, the single-leg stance with eyes closed increased from 18.56 ± 14.70 to 25.06 ± 32.43 sec ($P < 0.05$). Although there was not a very statistically significant difference in physical fitness or postural balance effect indicators between

Table 1. The statistical different and results with participants physical fitness and postural balance characteristics between the intervention and control group

	Intervention experimental group (N=23)			Control group (N=31)		
	Pre-training	6 weeks ^b	12 weeks ^c	Pre-training	6 weeks ^b	12 weeks ^c
Age (years)	21.12 ± 0.85^a			21.14 ± 0.53		
Body mass index	23.58 ± 3.37	23.25 ± 3.49	23.39 ± 3.59	21.39 ± 3.65	21.40 ± 3.78	21.50 ± 3.96
Body fat (%)	30.57 ± 6.04	27.62 ± 8.51	$28.67 \pm 7.4^*$	23.33 ± 11.46	23.41 ± 7.17	23.93 ± 7.37
Muscle endurance: Sit-ups (time)	28.71 ± 8.96	29.20 ± 9.12	29.30 ± 7.55	24.30 ± 12.82	25.00 ± 9.53	22.79 ± 9.36
Flexibility: Sit and reach (cm)	26.50 ± 10.34	27.02 ± 10.21	27.00 ± 10.41	26.73 ± 9.10	27.07 ± 7.12	25.67 ± 10.19
Cardiopulmonary endurance	59.85 ± 14.32	60.36 ± 12.48	55.29 ± 8.01	60.70 ± 12.34	57.96 ± 10.44	57.28 ± 8.54
Timed up-and-go test (sec)	9.76 ± 13.65	7.16 ± 1.44	7.66 ± 1.84	7.67 ± 1.20	7.20 ± 1.13	8.99 ± 1.10
Single-leg stance with eyes closed (sec)	18.56 ± 14.70	24.10 ± 26.71	$25.06 \pm 32.4^*$	25.68 ± 24.91	25.03 ± 43.49	26.16 ± 22.09
The 30-sec chair stand t (time)	23.29 ± 3.81	23.19 ± 6.74	25.33 ± 4.86	23.60 ± 5.36	22.31 ± 6.66	22.34 ± 6.61

^aMean \pm SD (standard deviation); *paired t-test*, ^bpost-training for 6 weeks vs. pre-training and ^c12 weeks vs. pre-training.

* $P < 0.05$.

difference intervention period. However, there are no significant differences in the control group, so we still found a good improvement trend in the experimental group.

For the 23 subjects of the experimental group, we further observe the two groups into normal bodyweight ($18.5 \leq \text{BMI} < 24$) and the overweight ($24 \leq \text{BMI} < 27$) groups, as shown in Table 2, we found the BMI results in the experimental normal bodyweight group decreased from 21.59 ± 1.39 to 20.74 ± 1.66 after completion of the 6-week training course ($P < 0.05$), and TUG had a statistically significant increased from 6.22 ± 1.47 to 7.51 ± 1.85 of 12-weeks ($P < 0.05$). In the overweight group, we also found that the WBV intervention had no obvious significant difference in physical fitness, but

the TUG had statistically significant increase from 6.14 ± 2.28 to 7.85 ± 1.91 of 12-weeks ($P < 0.05$), single-leg stance results increased from 20.31 ± 29.91 to 25.62 ± 24.41 (sec) after completion of the 12-week training course ($P < 0.01$). By the other way, 31 subjects of the control group (as Table 3), we did not find any statistically significant difference in physical fitness or gait function indicators between difference intervention period in normal bodyweight group and overweight group.

DISCUSSION

The past correlation studies on WBV training mainly enrolled athletes [4] and the elderly [14-16] and more

Table 2. The intervention group statistical different and results with participants physical fitness and postural balance characteristics between the into normal bodyweight and overweight groups

Intervention experimental group (N=23)	Normal body weight group (N=14) 18.5≤Body mass index<24			Overweight group (N=9) 24≤Body mass index<27		
	Pre-training	6 weeks ^b	12 weeks ^c	Pre-training	6 weeks ^b	12 weeks ^c
Body mass index	21.59±1.39 ^a	20.74±1.66*	20.95±1.67	27.16±2.86	26.59±2.16	26.65±2.73
Body fat (%)	17.89±3.44	17.62±8.51	18.67±5.26	35.4±7.02	33.12±7.56	34.00±0.67
Muscle endurance: Sit-ups (time)	29.22±9.15	29.27±11.46	33.00±6.50	27.80±9.58	25.11±5.75	28.78±6.40
Flexibility: Sit and reach (cm)	28.00±10.27	28.50±11.86	30.63±12.31	26.20±7.69	25.06±7.72	27.50±7.87
Cardiopulmonary endurance	55.73±6.93	54.16±12.56	56.35±8.79	66.44±21.04	67.87±12.76	65.23±7.52
Timed up-and-go test (sec)	6.22±1.47	6.87±1.79	7.51±1.85*	6.14±2.28	7.55±0.69	7.85±1.91*
Single-leg stance with eyes closed (sec)	17.59±11.40	19.65±31.31	18.65±24.91	20.31±29.91	21.70±18.13	25.62±24.41**
The 30-sec chair stand test (time)	24.33±4.12	23.25±6.68	24.92±5.26	21.40±2.51	20.11±7.21	19.56±4.45

^aMean±SD (standard deviation); *paired t-test*, ^bpost-training for 6 weeks vs. pre-training and ^c12 weeks vs. pre-training. * $P < 0.05$; ** $P < 0.01$.

Table 3. The control group statistical different and results with participants physical fitness and postural balance characteristics between the into normal bodyweight and overweight groups

Control group (N=31)	Normal body weight group (N=24) 18.5≤Body mass index<24			Overweight group (N=7) 24≤Body mass index<27		
	Pre-training	6 weeks ^b	12 weeks ^c	Pre-training	6 weeks ^b	12 weeks ^c
Body mass index	19.8±2.11 ^a	19.86±2.05	19.77±1.85	26.64±2.51	27.35±2.82	27.82±3.06
Body fat (%)	17.90±10.95	18.17±7.30	19.80±2.11	29.76±3.87	28.17±4.36	30.64±2.50
Muscle endurance: Sit-ups (time)	34.00±12.76	34.70±9.61	30.43±8.59	35.29±14.01	36.17±9.98	41.83±6.55
Flexibility: Sit and reach (cm)	30.26±6.65	28.61±5.88	29.02±7.98	15.14±5.81	16.17±8.87	12.83±7.25
Cardiopulmonary endurance	52.94±7.05	54.81±7.45	52.44±4.15	62.25±12.70	58.87±11.14	58.60±9.01
Timed up-and-go test (sec)	6.62±1.26	7.13±1.19	6.79±0.90	6.82±1.05	7.44±0.94	7.77±15.04
Single-leg stance with eyes closed (sec)	28.72±25.00	26.66±35.98	28.06±48.73	25.69±23.56	25.76±29.56	26.21±38.17
The 30-sec chair stand test (time)	23.09±5.37	22.48±6.98	24.57±6.85	20.29±5.38	19.67±5.79	20.33±4.97

^aMean±SD (standard deviation); *paired t-test*, ^bpost-training for 6 weeks vs. pre-training and ^c12 weeks vs. pre-training.

research to patients with chronic diseases [5-12] as the subjects, and their main purpose was to investigate whether WBV can strengthen muscular endurance to further improve athletes' exercise effect or improve the postural balance of the elderly to prevent falls. Resistance training and vibration improve muscle strength and functional capacity in female [7]. These past studies empirically verified the effect of WBV, and the design principle of the adopted WBV training devices included in side-alternating rotational vibration (RV) training and vertical up-and-down vertical vibration (VV) intervention. The past studies showed that the effectiveness of vertical up-and-down training is higher [21, 22], and Torvinen et al. [23] found vertically vibrating platform in whole body vibration-intervention enhanced jumping power in young adults. Schuhfried et al. [24] first explored and evaluation of WBV as a potential therapeutic intervention for MS, and observed significant improvements in mobility (Timed-Up and Go [TUG] performance) and postural stability lasting 1 week after an acute exposure of WBV (5 bouts of vibration at 2.0~4.4 Hz frequency, 3 mm amplitude, with 1-minute rest periods between exposures). Freitas et al. [5] setting WBV was applied using a vibration platform (Power Plate; Next Generation, Northbrook, Illinois) at a frequency of 30 Hz and a fixed low amplitude set at 3 mm (approximately 2.2 g acceleration) for 5 weeks of MS had significant improvements ($P>0.05$) in balance, postural stability. In this study, the frequency of 5.6~9 Hz, 2 mm amplitude, with 30-seconds for each frequency, 4 frequency types as a cycle until to 15 minutes. The intensity is somewhere in between that were more suitable for college students after the discussion with rehabilitation specialist and rehabilitation therapist. The study intends to understand whether such passive exercise can help teenagers improve physical fitness or reduce BMI, as well as assess whether it can improve teenagers' postural balance as it can do to the elderly. But the research results are different with the other studies on the elderly. The improvement effectiveness on college students after WBV inter-

vention was not significant. Even as some references found WBV interventions have reported no changes of functional performance in MS patients [3, 25-27]. However, in this the post-intervention BMI, body fat, and some of the balance indices of the subjects in the WBV training group were superior to pre-intervention ones. Although the research process was rigorous, due to the limitation of research funding, this study enrolled a smaller sample size of subjects and implemented single training condition. However, subsequent studies may use different training conditions, including changing the training model from 3 times per week to once per day, selecting different training postures, or changing the training model to different intensity and frequency. If a larger sample size of subjects receive the training for a longer period of time (12 weeks, 24 weeks or 36 weeks), the training effectiveness may be more significant. However, the empirical verification of subsequent correlation studies is still required.

Although this study faced the said research limitations, the statistical data collected and analyzed from the research subjects still can provide certain important information and results to researchers engaging in studies of relevant themes or subsequent researchers interested in this theme. Therefore, the following important conclusions are summarized from this research report. The effectiveness of voluntary home exercise of subjects in the control group seemed and the WBV intervention training effectiveness in the experimental group did not have too many statistically significant differences in this study. This research result might be associated with the number of subjects in the exercise experimental group and level of participation. Although the main reason was associated with research limitation, it is still necessary to reflect on whether the conditions of the WBV training model selected in this study (including the setting of training postures, frequency, and intensity) are suitable for teenagers, which is left to be empirically verified by subsequent researchers. According to the research results, after the WBV intervention, there were statistically significant

differences in some physical fitness indices (BMI in normal bodyweight group) and postural balance indices (including TUG in normal bodyweight group; and TUG and single-leg stance in the overweight group). However, after the WBV intervention, the effect in overweight ($24 \leq \text{BMI} < 27$) group was not better than that of those with normal weight ($18.5 \leq \text{BMI} < 24$) group in this study. On the contrary, the subjects with normal weight group seem to get better results. Because this study did not request the subjects to implement dietary control or other cooperation and restrictions, the reason for this result might be that teenagers with normal weight could better control diet than those with overweight and they could better cooperate with the requirements of research assistant to receive WBV intervention training or engage in voluntary home exercise.

According to various research results mentioned above, this study proposed the following suggestions. Due to lack of exercise and over westernized and high-calorie diet, young females in Taiwan have experienced the trend of overweight and decreasing physical fitness. Therefore, this study intends to investigate whether the intervention of easier passive WBV training can improve teenagers' physical fitness or balance. However, due to the lack of subjects and many other reasons, the researching finding was not as expected. Therefore, subsequent studies are advised to seek for different intervention models or exercise models, or even implement dietary control to find out specific suggestions to enable teenagers to effectively control weight or improve physical fitness. Due to the limitation of research funding and the fact that the research subjects had to be reviewed by IRB, the sample size was smaller. Scholars interested in engaging in relevant studies in the future are advised to fight for more funds, analyze more research subjects, and further investigate the difference in subjects of different ages and gender. In addition, it is also advised to find the research subjects in the control group with equal ratio of gender and age to perform analyses and

investigations.

This study found that an intervention involving whole-body vertical vibration (WBV) intervention had no obvious significant difference in physical fitness between overweight participants and normal bodyweight participants. Overall, the results showed that the WBV intervention had some beneficial effects on physical fitness and postural balance in young female participants. In addition, maybe young women should be more attentive in controlling their diet and exercise to enhance their physical fitness and health.

The strength of the study is that subjects focused on the physical fitness and postural balance effects of female college students rather than elderly or patients, and the results showed that the WBV intervention had some beneficial effects on physical fitness and postural balance in young women.

Meanwhile, one limitation of this study is that, due to this being a hospital-based analysis, variations across different institutions needs to be considered, and the intervention of high frequency or high-intensity WBV training may allow participants to produce dizziness or other side effects, need to be careful.

Due to the limitations of research funding and time, this study could not obtain sufficient samples for analysis, and neither could this study enroll subjects in the experimental group and control group with the same sample size of samples, such as gender, age, and BMI. Therefore, in terms of clinical contributions, the research analysis results may not be extendable or representative. However, the research results still can represent the subjects in this study.

This study selected young female college students as the subjects, and the subjects' consent had to be obtained. The subjects could not be enrolled in this study unless they completed the IRB-approved informed consent form (FEMH-IRB-103021-F,v.03). In addition, during this study, the exercise experimental group had to receive 12-week training. Therefore, this study could not enroll sufficient samples in this study. Therefore, subsequent studies may have to enroll more samples to

empirically verify the research results.

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Conflict of interest: None

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