Effect of Ascending an Inclined Surface versus Backward Walking on Flat Surface on Dynamic Balance in Healthy Older Adult Males

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Authors' contributions

This work was carried out in collaboration between all authors. Author MLH designed the study, wrote the protocol, participated in execution of the walk training program, collect the data and wrote the first draft of the manuscript. Author GSM managed the analyses and interpretation of data, managed the literature searches, performed the statistical analysis, revised the first draft critically for important intellectual content and wrote the final draft and is the corresponding author. Authors MHD and FMAN contributed to the conception of the work, participated in execution of the walk training program, helped the acquisition of data for the work. All authors read and approved the final manuscript.

Original Research Article

ABSTRACT

Aims: Falls among elderly are major health problem. Practice of physical activities such as walking on regular basis improves balance and reduces falls. The objective of this study was to determine whether ascending an inclined surface (ISU) and backward walking on a flat surface (FSB) regularly

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could improve dynamic balance in healthy older adults and check the interaction of body composition, leg muscle strength and vital capacity.

Study Design: Eight-week walk-training program with and without resistance.

Place and Duration of Study: Department of Field and Track Sciences, Faculty of Physical Education, Minia University, between July and September 2016.

Methodology: Sample: Twenty participants (males; 55-65 years old) and all of them practiced sports regularly. All participants continued with their regular exercise program, while adding walk training program either ISU or FSB for total of 24 training units and 1845 min. divided into three stages preparatory, foundation and development stages. Participants were tested pre-and post-training using - Body Composition Analyzer (Tanita SC240) and tests; Leg press test and dynamometer for muscle strength and Modified Bass test of dynamic balance.

Results: We found statistically significant intervention effects of the walking program on dynamic balance (P=0.0029 ISU and P=0.0054 FSB post vs pretest). Decrease in fat mass (P=0.0001) and increase in bone mass (P=0.001) in ISU group post vs pretest. An increase in dynamic balance (P=0.0215), leg muscles' strength (P=0.0121) and body muscle mass (P=0.0139) in the ISU group compared to FSB group on comparing the results of the posttest of both groups.

Conclusion: We suggest that physically active elderly who exercise regularly can benefit from the addition of walk training to their current exercise program. We recommend practicing ascending an inclined surface more than backward walking on a flat surface to improve dynamic balance, lean body mass, muscle strength and pulmonary function.

1. INTRODUCTION

Aging-induced decreased bone mass, muscle strength and balance with the resulting increased probability of falling and fractures are major health problem. American College of Sports Medicine and American Heart Association (ACSM/AHA) recommended physical activity for older adults to improve and maintain health. Previous study revealed that eight months of moderate intensity intermittent exercise training with weight bearing improved balance, bone mineral density, muscle strength and reduced fat mass in older women [1]. Another study showed improved muscle strength of legs and upper body parts, increased bone mass and reduced fat mass as well as falling fears among elderly women after three months walking program with ankle weights [2]. A meta-analysis including thirty studies with 2878 participants of both men and women with mean age ranging from 68 to 85 years reported that planned, repetitive and goal-directed physical activity reduced fear of falling to some extent just after the intervention, without increasing the incidence of falls [3]. Another meta-analysis included 94 studies and 9,917 participants mostly aged females concluded weak evidence that exercise training including balance, coordination and multiple exercise types are effective immediately after intervention, in improving clinical balance outcomes in older

people [4]. Both of the previous studies reported an insufficient evidence for the effects of walking, cycling or multicomponent exercise training on fear of fall and balance long after the period of intervention. Moreover, they recommended further studies using well-designed training methods to reduce fear of falling and improve dynamic balance in elderly people living in the community [3,4]. The previous preventive guidelines does not specify certain age, but they highlight data insufficiency concerning the effects of physical activity on falls in older adults less than age sixty five [5].

Balance exercises help to improve postural stability and improves the sensory-motor strategies used by the human body during different daily life activities [6]. Normal posture and locomotion including walking, running and hopping require both lower limbs in humans [7]. Since walking has low impact as opposed to running or jumping, it has been used as therapeutic and rehabilitation method for healthy young and old as well as patients suffering from obesity, diabetes or lung disease [8,9]. The goal of the current study was to determine whether walking up an inclined surface or backward walking on flat surface regularly for eight weeks with or without resistance could improve dynamic balance of healthy older adult males. Moreover, we examined the

interaction of body composition, leg muscles' strength and total vital capacity from the mechanistic point of view.

2. MATERIALS AND METHODS

2.1 Subjects

Participants consisted of twenty of older adults selected by stratified random sampling technique: age (55-65 years old), healthy, practice running or walking regularly. The goal of study explained to the participants before experiment and they agreed voluntarily on participation in the study.

2.2 Experimental Procedure

2.2.1 Methods

We used the pre-post two experimental groups' methodology.

2.2.2 Sampling equality

Researchers confirmed the uniform distribution of the two groups in the light of body composition, dynamic balance, legs muscles' strength and pulmonary function by calculating mean, median, standard deviation and variance for all participants before the start of the training program (Table 1). We found the mean almost equals the median for all parameters measured indicating that the distribution is symmetric. The variance of the sample population participating in this study ranges between (1.10 and -0.29) indicating that the sample lies within the normal distribution (-3 – +3) (Table 1).

2.2.3 Tools

Adequate floor space, sticky tape for marking floor, measuring tape, stopwatch for the Modified Bass Test. Takei 5402 Leg Muscle Digital Dynamometer for measuring leg and back muscle strength. Segmental Body Composition Analyzer (Tanita SC240 Bioimpedance operated, made in Japan). This equipment send out very weak electric current to measure impedance or electric resistance of the body. Therefore, users should be bare feet. Smart cell phone "electronic steps application". Spirometers T-20 Portable Spirometer SKU: SPMT20 used to measure total vital capacity (VC).

2.2.4 Test

Leg Press Test [10] as preliminary test to detect one repetition maximum (1RM) to plan for the walk exercise program with resistance. Leg Dynamometer to evaluate leg muscle strength in the pretest and posttest. We selected the modified bass test to measure balance because it represent postural steadiness, reach, and postural stability as well as it required minimal specialized equipment. It has excellent reliability and a large body of literature supporting them especially for healthy participants [11]. The course of the test is composed of ten squares. Subject stood on right leg at the start square. Then, jumped using the left leg to the first square keeping instep stationary for 5 seconds (s.), then jumped using the right foot to the second square keeping instep stationary for 5 s., so the performance continues with exchanging feet and keeping a stationary position until reaching the square number 10. The total mark given in the balance test is 100; 10 marks calculated for each square, five of them for correct landing on the foot instep, and covering the sign at the ground completely, while the other five marks are given for correct balancing for 5 s.

2.3 Inclusion Criteria

- Age: between 55 – 65 years old.
- Sex: males.
- Exercise: all practice exercise regularly (walking or running).

2.4 Exclusion Criteria

History of diabetes, hypertension, disability due to neurological disorder, joint disease, muscle disease or injury.

2.5 The Walking Program Details

The training program include two groups; either walking up an inclined surface or backward walking on a flat surface three times per week for eight weeks with resistance, without resistance and with ensuring the movement coordination of both the upper and lower limbs, muscle tone and improving the breathing ability, through considering the following criteria;

- Step frequency = number of steps divided by the total time.

3

- Step duration = total time divided by the number of steps.
- Step velocity = step length multiplied by step frequency.

Table 1. Means, median, standard deviation and variance of the body composition, dynamic balance, leg muscles' strength and vital capacity of the sample population included in the study

Variables		μ	m	σ	σ²
Body components	Water mass	45.35	45.00	1.57	0.67
	Fat mass	34.30	34.00	2.70	0.33
	Bone mass	3.95	4.00	0.89	-0.17
	Muscles mass	71.90	72.00	5.31	-0.06
Physical element	Dynamic balance	43.00	40.00	11.29	0.80
	Leg muscle strength	53.85	52.50	3.69	1.10
Functional	Vital capacity	2.97	3.00	0.31	-0.29

Body Composition Analyzer, Tanita SC-240, Bioimpedance operated; Spirometers T-20 Portable Spirometer SKU; (μ) mean; (σ) standard deviation; (σ2) variance; (n = 20)

Table 2. Walking plan of the two walk groups on inclined surface "upward" and on a flat surface "backward"

Training stages	No. of Training weeks	No. of training units/ week	Training unit duration in min	Total training units/ period	Total time in minutes	%	Free walking %	Free walking Min	Walking with resistance %	Walking with resistance Min	Walking with movement coordination %	Walking with movement coordination Min	Training functions
Preparatory	2	3	60	6	360	20	70	252	10	36	20	72	Increasing the movement transferring effectiveness Increasing flexibility of muscles and ankles
Foundation	3	3	75	9	675	37	20	135	70	473	10	67	Developing arms muscle strength Leg muscles ability to fast contracting
Developmental	3	3	90	9	810	43	10	81	20	162	70	567	Improving the breathing ability Increased movement coordination and muscle tone
SUM	8		675	24	1845	100	100	468	100	671	100	706	

*ISU: inclined surface "upward"; FSB: flat surface "backward". % = time (min) of the stage/ total time (min)*100, Min: minimum walking distance*

Table 3. Distributing loads and durations of "walking up an inclined surface and backward on a flat surface according to the three training stages

Walking style			Preparatory stage	Foundation stage	Developmental stage
Without resistance			12600 ST 15120 s.	5216 ST 8100 s.	3402 ST 4860 s.
With resistance			1800 ST 2160 s.	18256 ST 28620 s.	6804 ST 9720 s.
With coordination			3600 ST 4320 s.	2608 ST 3780 s.	23814 ST 34020 s.
Performance method	Size	Group type	One training group with ensuring dynamic transfer and extent	Two training groups with legs and arms resistance	Three training groups with ensuring muscle tone and movement coordination
		Frequency	6 times X 6 days = 36 times	4 times X 9 days = 36 times	4 times X 9 days = 36 times
	Strength	%	25	30	45
		Distance (m)	300	275	250
		ST length (cm)	60	75	80
		Total No. 78100 ST	500 ST * 36 times = 18000 ST * 1 groups = 18000 ST	365 ST * 36 times = 13140 ST * 2 groups = 26080 ST	315 ST * 36 times = 11340 ST * 3 groups = 34020 ST
	Condensation	Training units/ week	3	3	3
ST frequency			0.83	0.64	0.70
ST duration			1.2	1.6	1.4
ST velocity			42	52	56
Total			ST frequency = 78100 steps ÷ 110700 second = 0.70 ST duration = 110700 ÷ 78100 = 1.4		

ST: step; m: meter; cm: centimeter; s.: second; Step frequency: number of steps divided by total time; Step duration: total time divided by number of steps; Step velocity: step length multiplied by step frequency

2.5.1 Design

2.5.1.1 Principles of planning

Starting with warm-up and finishing with relaxation, no walking directly after meals and keeping breathing continuously and smoothly. Regular and active step, when one of the two feet touches the ground at walking. Using resistance with gradual weights from 30% to 50% of the maximum. Descending a slope surface after ascending and forward walking on a flat surface after backward walking, was a positive "active" rest period between ascending and descending. At backward walking, the person allowed to look backward once each training session. The walking distance on the inclined or flat surface was between 250-300 meters. The height of the inclined surface was 13 meter for every 100 meter.

2.5.1.2 Objective

Using the positive influence of ground during walking whether on inclined or flat surface to improve the dynamic balance of the two research groups.

2.5.1.3 Duration

Eight weeks total duration (three sessions/ week) starting at mid of July 2016 and ending at mid of September 2016. Six training units in the preparatory stage 60 minutes each, nine training units in the foundation stage 75 minutes each and nine units in the development stage 90 minutes each. Total training units twenty-four and total time of 1845 minutes or 110700 seconds (Table 2, 3).

3. RESULTS

3.1 Effect of Upward Walking on Inclined Surface and Backward Walking on a Flat Surface on Body Water Mass

We found statistically significant decrease in the body water mass in both groups ISU (P= 0.0001) and FSB (P= 0.0001) upon comparing the results of posttest with pretest (Fig. 1).
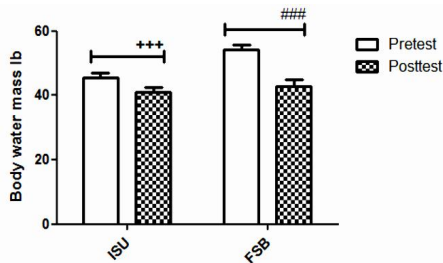

Fig. 1. Changes in the body water mass in the two walk groups (ISU) upward walking on inclined surface and (FSB) backward walking on a flat surface
Body Composition Analyzer; Tanita SC-240; data represent mean ± standard deviation; difference was detected using Student's two tailed t-test (⁺⁺⁺P = 0.0001 ISU post vs pretest; ###P = 0.0001 FSB post vs pretest; N = 10 in each group)

3.2 Effect of Upward Walking on Inclined Surface and Backward Walking on a Flat Surface on Body Fat Mass

We found statistically significant decrease in the body fat mass in ISU group ($P = 0.0001$). Statistically insignificant difference in the body fat mass in FSB group found in the posttest compared with the pretest ($P = 0.071$). No statistically significant difference in the body fat mass between the two groups in the pretest was found ($P = 0.156$) (Fig. 2).

3.3 Effect of Upward Walking on Inclined Surface and Backward Walking on a Flat Surface on Body Bone Mass

We found statistically significant increase in the body bone mass in ISU group in the posttest compared with the pretest ($P = 0.0011$). Statistically insignificant difference in the body bone mass in FSB group found in the posttest compared with the pretest ($P = 0.052$). No statistically significant difference in the body bone mass between the two groups in the pretest was found ($P = 0.808$) (Fig. 3).
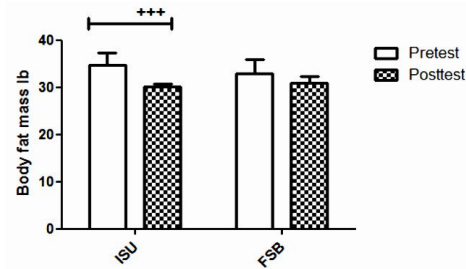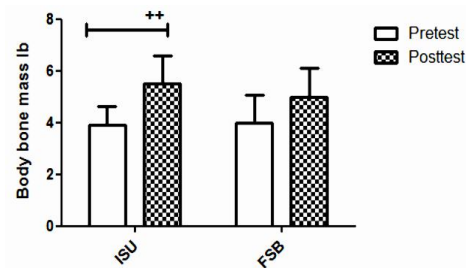

Fig. 2. Changes in the body fat mass in the two walk groups (ISU) upward walking on inclined surface and (FSB) backward walking on a flat surface
Body Composition Analyzer; Tanita SC-240; data represent mean ± standard deviation; difference was detected using Student's two tailed t-test (P value = 0.156 ISU vs FSB pretest; P = 0.123 ISU vs FSB posttest; ⁺⁺⁺P = 0.0001 ISU post vs pretest; P = 0.071 FSB post vs pretest; N = 10 in each group)

Fig. 3. Changes in the body bone mass in the two walk groups (ISU) upward walking on inclined surface and (FSB) backward walking on a flat surface
Body Composition Analyzer; Tanita SC-240; data represent mean ± standard deviation; difference was detected using Student's two tailed t-test (P value = 0.808 ISU vs FSB pretest; P = 0.319 ISU vs FSB posttest; ⁺⁺P = 0.0011 ISU post vs pretest; P = 0.052 FSB post vs pretest; N = 10 in each group)

3.4 Effect of Upward Walking on Inclined Surface and Backward Walking on a Flat Surface on Body Muscle Mass

We found statistically significant increase in the body muscle mass in ISU group ($P = 0.0139$) compared to FSB group on comparing the posttest results. Statistically insignificant difference in the body muscle mass in both the ISU ($P= 0.131$) and FSB ($P= 0.636$) groups was obtained in the posttest compared with the pretest. No statistically significant difference between the two groups in the pretest in the body muscle was found ($P= 0.489$) (Fig. 4).
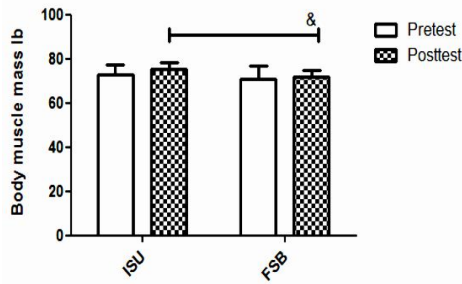
Fig. 4. Changes in the body muscle mass in the two walk groups (ISU) upward walking on inclined surface and (FSB) backward walking on a flat surface

Data represent mean ± standard deviation; Body Composition Analyzer; Tanita SC-240; difference was detected using Student's two tailed t-test (P value = 0.489 ISU vs FSB pretest; $^{\&}$P = 0.0139 ISU vs FSB posttest; P = 0.131 ISU post vs pretest; P = 0.636 FSB post vs pretest; N = 10 in each group)

3.5 Effect of Upward Walking on Inclined Surface and Backward Walking on a Flat Surface on Leg Muscles' Strength

We found statistically significant increase in the leg muscle strength in both ISU group (P = 0.0002) and FSB group (P= 0.0224) in the posttest compared with the pretest. Statistically significant increase in the leg muscle strength in ISU group (P = 0.0121) compared to FSB group on comparing the posttest was shown. No statistically significant difference (P = 0.725) in the leg muscle strength between the two groups in the pretest was found (Fig. 5).

3.6 Effect of Upward Walking on Inclined Surface and Backward Walking on a Flat Surface on Body Dynamic Balance

We found statistically significant increase in the dynamic balance in both the ISU group (P = 0.0029) and the FSB group (P = 0.0054) in the posttest compared with the pretest. Statistically significant increase in the dynamic balance in ISU group (P = 0.0215) compared to FSB group on comparing the posttest was shown. No statistically significant difference (P = 0.443) in the dynamic balance between the two groups in the pretest was found (Fig. 6).
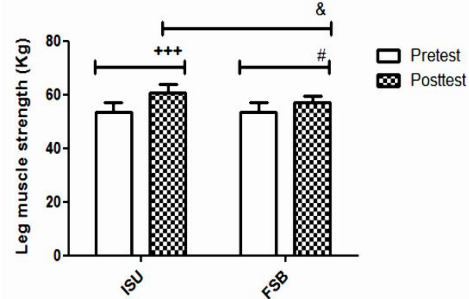

Fig. 5. Changes in the leg muscle strength in the two walk groups (ISU) upward walking on inclined surface and (FSB) backward walking on a flat surface

Data represent mean ± standard deviation; Leg dynamometer was used to detect muscle strength; Kg: kilograms; difference was detected using Student's two tailed t-test (P value = 0.725 ISU vs FSB pretest; $^{\&}$P = 0.0121 ISU vs FSB posttest; $^{+++}$P = 0.0002 ISU post vs pretest; $^{\#}$P = 0.0224 FSB post vs pretest; N = 10 in each group)

3.7 Effect of Upward Walking on Inclined Surface and Backward Walking on a Flat Surface on Total Vital Capacity

We found statistically significant increase in the total vital capacity in both the ISU group (P = 0.0009) and the FSB group (P = 0.0001) in the posttest compared with the pretest (Fig. 7).
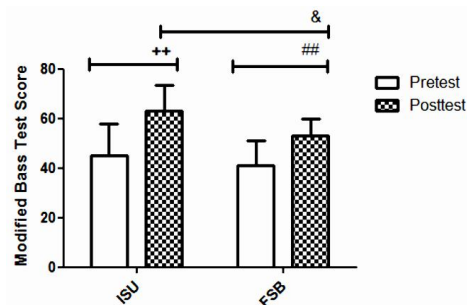

Fig. 6. Changes in the dynamic balance in the two walk groups (ISU) upward walking on inclined surface and (FSB) backward walking on a flat surface

Modified Bass test was used to detect dynamic balance; data represent mean ± standard deviation; difference was detected using Student's two tailed t-test (P value = 0.443 ISU vs FSB pretest; $^{\&}$P = 0.0215 ISU vs FSB posttest; $^{++}$P = 0.0029 ISU post vs pretest; $^{\#\#}$P = 0.0054 FSB post vs pretest; N = 10 in each group)
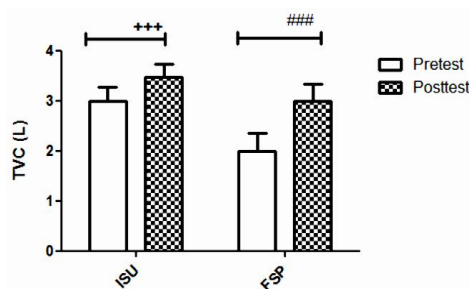
Fig. 7. Changes in total vital capacity in the in the two walk groups (ISU) upward walking on inclined surface and (FSB) backward walking on a flat surface

TVC: total vital capacity; L: liters; Spirometers T-20 Portable Spirometer SKU: SPMT20 used to measure TVC; data represent mean ± standard deviation; difference was detected using Student's two tailed t-test ([+++]P = 0.0009 ISU post vs pretest; [###]P = 0.0001 FSB posttest vs pretest; N= 10 in each group)

4. DISCUSSION

Physical exercise has preventive and therapeutic benefits against decreased muscle mass, bone mass and increased fat mass induced by aging. The results of the current training program showed statistically significant decrease in body water mass and statistically significant increase in leg muscles' strength, dynamic balance and vital capacity in both walk groups on doing the posttest compared to the pretest. In line with our results, Yoo et al found that walking program for three months with ankle weights improved aerobic endurance and body composition, increased strength of upper body and legs, reduced trunk fat and fear of falling [2]. Recent study showed that resistance and balance training for three months decreased fat mass and improved walking ability as well as insulin sensitivity in older adults one year after recovery from stroke [12]. Regular physical activity and balance exercise three times weekly are effective in reducing falls and fall related injuries by about (35–45%) in older adults at risk for falls [13]. Meta-analysis including 28 randomized controlled trials and 2646 participants of postmenopausal women showed that half an hour of daily moderate walking combined with a resistance training twice weekly decreased body weight, fat % and improved bone mineral density, muscular strength, flexibility, balance or coordination, maximal aerobic power, blood pressure, lipid profile and glucose homeostasis [14]. Exercise training twice weekly for eight months designed to load bones with intermittent

and multi directional compressive forces and to improve physical function reduced fat mass, waist circumference, improved handgrip strength, dynamic balance, and increased bone mass density at the femoral neck [1].

The results of the current study showed statistically significant decrease in fat mass and statistically significant increase in bone mass in the ISU group only in the posttest compared to pretest. Moreover, we found statistically significant increase in dynamic balance, leg muscles' strength and body muscle mass in the ISU group compared to FSB group on comparing the results of the posttest. Unfortunately, no previous studies compared the effects of walking on inclined surface and backward walking on flat surface on dynamic balance or body composition. One study done by Cromwell studied the effects of walking on an inclined surface on head stability [15]. They showed statistically significant improvement of dynamic stability in the frontal, sagittal and horizontal directions after Oreum trekking exercise program. They concluded that to keep balance of head over trunk and accommodate gravito-inertial changes during walking on the inclined surface, movement strategies adjustment of head-neck and neck-trunk patterns should develop by regular training. Two previous studies reported that control of the center of mass while walking on inclined or irregular surface needs efficient reactive and proactive response strategies to keep balance [16,17]. A recent study investigated the relation between core body stability and body mass index (BMI) in healthy adults [18]. They found that decreased BMI improved balance and core stability through better foot posture alignment. Taken together, we may speculate that ascending an inclined surface gave better results concerning dynamic balance compared to backward walking on flat surface because it developed better reactive and proactive response strategies and better foot posture alignment through decreasing fat mass, increasing bone mass , muscle mass and muscle strength.

5. CONCLUSION

The main goal of the current study was to investigate the effect of walk training program on dynamic balance and examine the interaction of different factors as body composition, leg muscles' strength and total vital capacity (VC) in older adult males at the age range between 55 to

65 years. The training program include two groups; either walking up an inclined surface or backward walking on a flat surface three times per week for eight weeks with resistance, without resistance and with ensuring coordination. We found statistically significant increase in muscle mass, leg muscles' strength and vital capacity in both walk groups upon comparing the results of posttest to the pretest. The present study showed statistically significant decrease in fat mass and statistically significant increase in bone mass in the ISU group only in the posttest compared to pretest. Moreover, we found statistically significant increase in dynamic balance, leg muscles' strength and body muscle mass in the ISU group compared to FSB group on comparing the results of the posttest of both groups. Finally, we recommend ascending inclined surfaces such as walking uphill, ascending mountains or ascending stairs more than backward walking on a flat surface to improve dynamic balance, lean body mass, muscle strength and pulmonary function in healthy older adults.

CONSENT

All authors declare that written informed consent was obtained from all participants of the current study for publication of this study.

ETHICAL APPROVAL

All authors hereby declare that all experiments have been examined and approved by the appropriate ethics committee and have been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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