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Original Research

Dynamic balance in male youth soccer players: the role of anthropometric and physical fitness factors

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Abstract

Background: The purpose of this study was to analyze the factors needed to improve the dynamic balance of youth soccer players.

Methods: A total of 170 youth soccer players (84 U-15 and 86 U-18 players) participated in this study. Their anthropometric (height, weight, and body fat percentage) and physical fitness (dynamic balance, muscle strength, power, core strength, agility, reaction time, and flexibility) characteristics were evaluated. To investigate the effects of these factors on dynamic balance, a multiple regression analysis was conducted.

Results: The results showed that the weight (P = 0.008) and back muscle strength (P = 0.039); and actions, such as sit-up (P = 0.017), countermovement jump (P = 0.019), and trunk forward flexion (P = 0.009) were significant factors affecting balance in all the soccer players of this study (R^2 = 0.265). In the U-15 group, only the countermovement jump (P = 0.019) was found to significantly influence dynamic balance (R^2 = 0.275). In contrast, in the U-18 group, weight (P = 0.002), sit-up action ($P < 0.001$), countermovement jump (P = 0.019), and trunk forward flexion (P = 0.011) were found to affect dynamic balance (R^2 = 0.439).

Conclusion: Our study suggests that muscle strength, power, flexibility, and core strength are needed to improve the dynamic balance of youth soccer players.

Keywords

Youth soccer player; Dynamic balance; Muscle power; Core strength; Flexibility; Training

1. Introduction

Recent studies have reported that enhancing soccer players' balance ability can help improve their performance [1, 2]. Balance is the ability to maintain a state of physical equilibrium and position during any posture or activity and is classified into static and dynamic balance [3]. Static balance is an individual's ability to maintain the posture in a stable unmoving state. Dynamic balance is an individual's ability to maintain the posture while changing the body's center of gravity during a moving situation. It represents one of the key factors in ensuring optimal performance in soccer.

Most technical skills required for soccer, such as dribbling, kicking, and ball handling, require maintaining body balance and support [4]. Moreover, players should have the ability to regain proper body posture in order to reduce the risk of improper movement or injury when landing after a dynamic movement, such as sharp deceleration, cutting, or jumping [5].

Most studies on the fitness factors related to the performance of soccer players have reported the effects of aerobic capacity, anaerobic power, and agility [6–8]. However, some studies comparing static balance and dynamic balance according to the level of performance of soccer players showed no significant difference between the superior and inferior players in terms of static balance [9]. Furthermore, many studies have emphasized that dynamic balance plays a role as a co-factor in non-contact injuries, and thus is an important factor for injury prevention [10–12]. Therefore, dynamic balance, rather than static balance, maybe the key factor differentiating the skills and stamina of a soccer player.

Dynamic balance is an important factor for improving performance and preventing injury, as it is a fitness-related factor necessary for proper posture maintenance and transition in a soccer game that demands various movements. However, scientific evidence for effective training to improve the dynamic balance of soccer players is scarce. It is reported that the ability to balance plays an important role, especially among young athletes whose somatosensory and neuromuscular systems are still developing [13]. Therefore, the purpose of this study was to analyze the fitness factors needed to improve the dynamic balance of youth soccer players.

2. Methods

2.1 Participants

The subjects of this study were 170 male youth soccer players who visited the J Sports Science Center to assess their physical fitness between January 1 and December 31, 2019.

The measurements were conducted during the off-season within 2 to 4 weeks after the end of the season. The participants were divided into the U-15 (n = 84) and U-18 (n = 86) groups.

2.2 Measurements of anthropometric characteristics

The assessed anthropometric variables were height (cm), weight (kg), and body fat (%). Body fat was measured using a body composition analyzer (Inbody-720, Biospace, Korea) after their height and weight were measured.

2.3 Measurements of physical fitness

All participants had one day of rest to minimize any influences on their measurements. To minimize errors between measurements, we instructed the participants to refrain from excessive physical activity on the day before they visited the J Sports Science Center.

2.4 Muscle and core strength

Muscle strength was measured using a back muscle force system (TKK-5402, TAKEI, Japan). The participants stood in a normal position with their backs straight. Next, they were made to hold the knob on the equipment and pull it toward themselves while the machine moved forward and in the vertical direction. The maximum force in the vertical direction was then measured. Measurements were made in 0.1 kg units and measured twice. The highest value of the two was recorded as the final measurement. Core strength was measured using a sit-up test. The participants were made to lie down with the knees bent at right angles. They then performed sit-ups with both elbows touching the knees and then returning to their original position. The number of sit-ups each participant could perform in 1 min was recorded.

2.5 Muscle power and agility

Muscle power was measured using a countermovement jump (CMJ) tester (ST-150, Seed Tech, Korea) and a standing long jump meter (ST-130S, Seed Tech, Korea). The participants were asked to jump as high as possible at their place while standing. Two jumps were performed, and the maximum value was recorded as the final measurement. To maintain performance, 2 min breaks were provided between trials. Agility was measured using a side-step tester (ST-110, Seed Tech, Korea). The participants stepped to either side of the centerline when a signal was given. This was performed for 20 s, and the maximum number of steps that each participant took in both directions was measured.

2.6 Reaction time and flexibility

Reaction time was measured using a systemic reaction tester (ST-140, Seed Tech, Korea). Participants were asked to stand with their knees flexed lightly (120-160°) on the reaction plate. They were then asked to promptly step off the reaction plate when they recognized the visual stimulation, which was visible for 0.001 s. The fastest time was recorded. Flexibility was assessed by trunk forward flexion (TKK-5403, TAKEI, Japan) and trunk back extension (TKK-5404, TAKEI, Japan) testers. During trunk forward flexions, the point reached by the players when their arms were extended as far as possible while in a sitting position, was measured. During trunk back extensions, the linear distance from the floor to the tip of the chin when the participant was holding both hands behind their waist in the prone position and lifting the chin up, was measured. Each measurement was performed twice, and the highest value was recorded as the measured value.

2.7 Dynamic balance

Dynamic balance was measured using a dynamic balance analyzer (K-130, KL Sports Industry, Korea). The participant stood on a measuring plate that moved from side to side for 1 min. The time the participant either remained standing or used to tilt left and right out of the set angle were measured (Fig. 1).

2.8 Statistical analysis

All variables measured in this study were analyzed using SPSS version 23.0 for Windows (SPSS, Inc., Chicago, IL, USA). The mean and standard deviation (SD) of anthropometric and physical variables were calculated. An independent t-test was conducted to analyze differences in anthropometric and physical fitness variables between the U-15 and U-18 groups. The values of the effect size (Cohen's D) were also presented. The coefficient of variation for the measurements of each group is presented. To investigate the relative importance

TABLE 1. Anthropometric characteristics of the subjects (Mean ± SD)

Variables	Total (170) (CV)	U-15 (84) (CV)	U-18 (86) (CV)	Cohen's *d*
Age (years)	15.51 ± 1.71 (0.11)	14.01 ± 0.82 (0.06)	16.97 ± 0.87 (0.05)	3.501
Height (cm)	169.00 ± 8.05 (0.05)	164.92 ± 8.29 (0.05)	172.97 ± 5.42 ** (0.03)	1.149
Weight (kg)	60.89 ± 10.57 (0.17)	55.17 ± 9.43 (0.17)	66.49 ± 8.44 (0.13)	1.265
Body fat (%)	13.33 ± 4.29 (0.32)	13.39 ± 4.69 (0.35)	13.28 ± 3.90 (0.29)	0.026

CV, coefficient of variation; $^{**}P < 0.01$, Significant difference between U-15 and U-18.

TABLE 2. Results of physical fitness test in youth soccer players (Mean ± SD)

	Variables	Total (170) (CV)	U-15 (84) (CV)	U-18 (86) (CV)	Cohen's *d*
Balance	Central dynamic balance (sec/min)	22.07 ± 9.48 (0.43)	19.35 ± 7.32 (0.38)	24.72 ± 10.58** (0.43)	0.590
	Right dynamic balance (sec/min)	20.04 ± 7.24 (0.36)	19.86 ± 6.54 (0.33)	20.21 ± 7.89 (0.39)	0.048
	Left dynamic balance (sec/min)	17.89 ± 7.31 (0.41)	20.77 ± 6.68 (0.32)	15.07 ± 6.80 (0.45)	0.846
Muscle strength	Back muscle strength (kg)	102.51 ± 22.75 (0.22)	89.14 ± 20.99 (0.24)	115.58 ± 15.79 (0.14)	1.424
Core strength	Sit up (reps/min)	53.05 ± 7.58 (0.14)	52.17 ± 8.69 (0.17)	53.92 ± 6.24** (0.12)	0.231
Muscle power	Countermovement jump (cm)	57.72 ± 4.47 (0.08)	55.95 ± 4.61 (0.08)	59.45 ± 3.57* (0.06)	0.849
	Standing long jump (cm)	214.57 ± 20.70 (0.10)	203.18 ± 20.58 (0.10)	225.70 ± 13.58** (0.06)	1.292
Agility	Side-step (reps/20 sec)	44.01 ± 5.43 (0.12)	41.99 ± 5.37 (0.13)	45.98 ± 4.75 (0.10)	0.787
	Reaction time (light/sec)	0.257 ± 0.030 (0.12)	0.260 ± 0.031 (0.12)	0.254 ± 0.029 (0.11)	0.200
Flexibility	Trunk forward flexion (cm)	10.03 ± 7.91 (0.79)	7.18 ± 7.18 (1.00)	12.82 ± 7.62 (0.59)	0.762
	Trunk backward extension (cm)	44.91 ± 8.01 (0.18)	41.10 ± 7.80 (0.19)	48.62 ± 6.31 (0.13)	1.060

CV, coefficient of variation; $^{*}P < 0.05$, $^{**}P < 0.01$, Significant difference between U-15 and U-18.

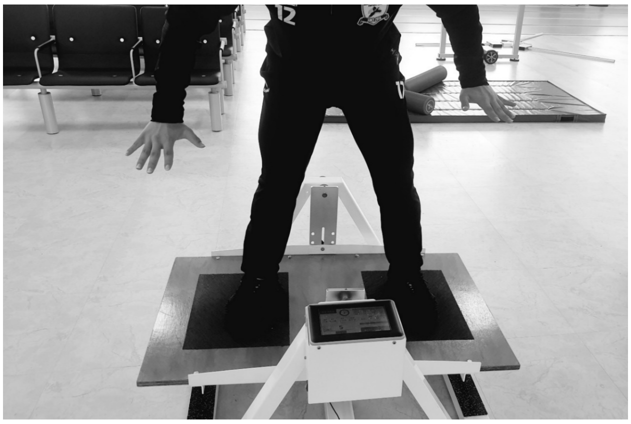

FIG. 1. Measuring device of dynamic balance.

of dynamic balance on anthropometric and physical fitness variables, Pearson's correlation analysis was performed. A multiple regression analysis was conducted after confirming that there were significant differences. The relative importance was analyzed using physical variables as predictors in order to identify the important physical factors for dynamic balance. The order of predictive variables was determined using the F-value and beta coefficients, and the level of statistical significance (α) was set to 0.05.

3. Results

3.1 Physical fitness test in youth soccer players

The anthropometric characteristics of the included participants are shown in Table 1. Table 2 shows the results for each physical fitness variable.

3.2 Correlation coefficients between central dynamic balance and assessed variables

Results of the Pearson's correlation analysis between dynamic balance and assessed variables are shown in Table 3. In the total group (n = 170), positive correlations were found between central dynamic balance and the following variables: back muscle strength (r = 0.152), sit-up action (r = 0.272), countermovement jump (r = 0.300), standing long jump (r = 0.161), side-step (r = 0.178), trunk forward flexion (r = 0.246), and trunk backward extension (r = 0.166). Concurrently, negative correlations were found between central dynamic balance and body fat (r = -0.171), right dynamic balance (r = -0.647), and left dynamic balance (r = -0.656). In the U-15 group (n = 84), negative correlations were found between central dynamic balance and height (r = -0.253), weight (r = -0.318), right dynamic balance (r = -0.540), left dynamic balance (r = -0.567), and reaction time (r = -0.272). In the U-18 group (n = 86), positive correlations were found for sit-up (r = 0.371), countermovement jump (r = 0.336), and trunk forward flexion (r = 0.238), and negative correlations were found for height (r = -0.278), weight (r = -0.362), body fat (r = -0.249), right dynamic balance (r = -0.766), and left dynamic balance (r = -0.667).

3.3 Multiple regression analysis of anthropometric and physical fitness factors affecting the dynamic balance

Results of the multiple regression analysis on the relationship of dynamic balance with selected variables are shown in Table 4, Table 5, and Table 6. In the total group (n = 170), the factors affecting dynamic balance were weight (*P* = 0.008), back muscle strength (*P* = 0.039), sit-up action (*P* = 0.017), countermovement jump (*P* = 0.019), and trunk

TABLE 3. Pearson's correlation coefficients between central dynamic balance and assessed variables

	Variables	U-15 (84)	U-18 (86)	Total (170)
Anthropometric	Height (cm)	-0.253*	-0.278**	-0.061
	Weight (kg)	-0.318**	-0.362**	-0.117
	Body fat (%)	-0.097	-0.249*	-0.171*
Balance	Right dynamic balance (sec/min)	-0.540**	-0.766**	-0.647**
	Left dynamic balance (sec/min)	-0.567**	-0.667**	-0.656**
Muscle strength	Back muscle strength (kg)	-0.104	0.059	0.152*
Core strength	Sit up (reps/min)	0.155	0.371**	0.272**
Muscle power	Countermovement jump (cm)	0.096	0.336**	0.300**
	Standing long jump (cm)	-0.066	0.084	0.161*
Agility	Side-step (reps/20 sec)	-0.016	0.162	0.178*
	Reaction time (light/sec)	-0.272*	0.023	-0.122
Flexibility	Trunk forward flexion (cm)	0.046	0.238*	0.246**
	Trunk backward extension (cm)	-0.127	0.179	0.166*

* $P < 0.05$, **$P < 0.01$.

TABLE 4. Multiple regression analysis of anthropometric and physical fitness factors affecting central dynamic balance in the total group

	Variables	B	S.E.	β	t	P	VIF
Total (170)	Constant	-10.129	27.142		-0.373	0.710	
	Height (cm)	-0.002	0.170	-0.001	-0.010	0.992	4.485
	Weight (kg)	-0.432	0.161	-0.482	-2.682	0.008**	6.949
	Body fat (%)	0.307	0.242	0.139	1.269	0.206	2.583
	Back muscle strength (kg)	0.101	0.049	0.243	2.079	0.039*	2.939
	Sit up (reps/min)	0.221	0.092	0.176	2.407	0.017*	0.865
	Countermovement jump (cm)	0.643	0.238	0.303	2.698	0.008**	0.369
	Standing long jump (cm)	-0.038	0.058	-0.084	-0.657	0.512	0.286
	Side-step (reps/20 sec)	0.094	0.141	0.054	0.668	0.505	0.707
	Reaction time (light/sec)	-15.407	22.231	-0.049	-0.693	0.489	0.939
	Trunk forward flexio (cm)	0.249	0.094	0.207	2.657	0.009**	0.764
	Trunk backward extension (cm)	0.024	0.098	0.020	0.245	0.807	0.681

* $P < 0.05$, **$P < 0.01$, F = 5.681 ($P < 0.001$), $R^2 = 0.265$, $_{adj}R^2 = 0.214$, Durbin-Watson = 1.845.

forward flexion (P = 0.009). These factors made up 26.5% of the explanatory power ($R^2 = 0.265$). In the U-15 group (n = 84), countermovement jump (P = 0.019) was a statistically significant predictor of dynamic balance and made up 27.5% of the explanatory power ($R^2 = 0.275$). In the U-18 group (n = 86), weight (P = 0.002), sit-up action ($P < 0.000$), countermovement jump (P = 0.019), and back muscle strength (P = 0.011) were significant predictors of dynamic balance, contributing 43.9% to the explanatory power ($R^2 = 0.439$).

4. Discussion

This study analyzed anthropometric and physical fitness factors related to dynamic balance to provide a scientific basis for effective training that can improve the dynamic balance required for proper posture maintenance and transition in soccer game, which requires various movements.

In our study, weight was the main factor that negatively affected dynamic balance in the total group. This was similar to the result of a previous study [14] which compared the dynamic balance of high-level athletes in gymnastics, soccer, and swimming events. This study showed a negative correlation between dynamic balance and weight [14]. According to previous studies, the accumulation of adipose tissue can reduce body balance and cause falls, and weight gain decreases the ability to respond to external factors and increases postural instability [15–17]. These results suggest that weight gain may affect dynamic balance in growing athletes, which can have a negative impact on their injury risk and performance. In view of these points, youth soccer players will need proper weight management through rational nutrition, in addition to training.

The second major factor influencing dynamic balance in the total group was the countermovement jump, which implies muscle power. This is similar to the result of a study that found that power was strongly related to dynamic balancing ability in male football players [18]. In addition, Erkmen *et al.* [19] reported a correlation (r = -0.59, $P < 0.05$) between balance ability and countermovement jump in male football players. To maintain balance during shooting or breakthrough in soccer, a certain amount of power is required to control the instantaneous torque generated as the players change their center of gravity [9]. In other words, power helps to maintain dynamic equilibrium by rapidly generating a greater opposing force to the force applied in one direction in a dynamic situation. Previous studies reported that players

TABLE 5. Multiple regression analysis of anthropometric and physical fitness factors affecting central dynamic balance in the U-15 group

	Variables	B	S.E.	β	t	P	VIF
U-15 (84)	Constant	39.413	30.001		1.314	0.193	
	Height (cm)	-0.084	0.186	-0.095	-0.453	0.652	4.388
	Weight (kg)	-0.292	0.210	-0.376	-1.390	0.169	7.255
	Body fat (%)	0.056	0.273	0.036	0.204	0.839	3.039
	Back muscle strength (kg)	0.060	0.066	0.174	0.918	0.362	3.544
	Sit up (reps/min)	0.123	0.093	0.146	1.319	0.191	1.216
	Countermovement jump (cm)	0.722	0.301	0.455	2.394	0.019*	3.585
	Standing long jump (cm)	-0.118	0.072	-0.332	-1.638	0.106	4.087
	Side-step (reps/20 sec)	-0.122	0.164	-0.090	-0.747	0.457	1.434
	Reaction time (light/sec)	-32.009	26.798	-0.136	-1.194	0.236	1.279
	Trunk forward flexion (cm)	0.112	0.122	0.110	0.922	0.359	1.412
	Trunk backward extension (cm)	-0.155	0.105	-0.165	-1.476	0.144	1.241

* $P < 0.05$, F = 2.478 ($P < 0.05$), R^2 = 0.275, $_{adj}R^2$ = 0.164, Durbin-Watson = 1.581.

TABLE 6. Multiple regression analysis of anthropometric and physical fitness factors affecting central dynamic balance in the U-18 group

	Variables	B	S.E.	β	t	P	VIF
U-18 (86)	Constant	-99.322	49.592		-2.003	0.049	
	Height (cm)	0.364	0.311	0.187	1.173	0.245	3.346
	Weight (kg)	-0.792	0.251	-0.632	-3.161	0.002**	5.272
	Body fat (%)	0.598	0.423	0.220	1.411	0.162	3.208
	Back muscle strength (kg)	0.065	0.067	0.097	0.964	0.338	1.328
	Sit up (reps/min)	0.621	0.164	0.366	3.792	0.000***	0.812
	Countermovement jump (cm)	0.793	0.330	0.268	2.403	0.019*	0.611
	Standing long jump (cm)	0.015	0.094	0.019	0.159	0.874	0.523
	Side-step (reps/20 sec)	0.206	0.219	0.093	0.941	0.35	0.781
	Reaction time (light/sec)	-18.709	34.424	-0.051	-0.544	0.588	0.857
	Trunk forward flexion (cm)	0.342	0.132	0.246	2.592	0.011*	0.839
	Trunk backward extension (cm)	0.107	0.171	0.064	0.626	0.534	0.729

* $P < 0.05$, **$P < 0.01$, ***$P < 0.001$, F = 5.268 ($P < 0.001$), R^2 = 0.439, $_{adj}R^2$ = 0.356, Durbin-Watson = 1.808.

who performed power training responded more quickly to perturbations than those who performed endurance training [20]. Therefore, it is clear that power-specific training can improve dynamic balance in youth soccer players. We believe that this factor must be added to their training program.

The third major factor influencing dynamic balance in the total group was the back muscle strength. Back muscle strength is one of the strength factors that represent the strength of the whole body [21]. Hammami *et al.* [13] reported a significant correlation (r = -0.486 to -0.791, $P < 0.001$) of muscle strength with all balance-related measurement variables while measuring balance and strength variables in young athletes. Moreover, Lockie *et al.* [22] reported that athletes with higher muscle strength showed significantly better dynamic balance. Thus, muscle strength may help soccer players maintain proper dynamic balance during their games. Increased muscle strength helps to maintain balance by absorbing, decelerating, and stabilizing the forces applied to the body center from various directions in dynamic situations [23, 24]. Therefore, to improve the dynamic balance of youth soccer players, it is necessary to improve muscle strength continuously. To this end, it is necessary to design a program to facilitate intensive training during the U-18 period, which is the best time for strength development [25].

The fourth major factor influencing dynamic balance in the total group was trunk forward flexion. This motion reflects the flexibility of the hamstring and erector spinae muscles [26]. Lack of flexibility between the lower extremities and the trunk affects the dynamics of various joints, which are required during soccer, such as breaking through the opponent's defense, landing after jumping or heading, and maintaining balance on one leg during shooting or passing after a sharp turn (a potential factor that disrupts the equilibrium situation) [27]. In particular, the growth phase is a period in which the extremities develop rapidly. During this time of growth, the muscles become shorter and tauter compared to the relatively long bones. Thus, flexibility between the lower extremities and the trunk may be reduced [25]. Therefore, to improve the dynamic balance of youth soccer players, flexibility reinforcement training that aims to enhance the flexibility between the lower limbs and the trunk is important.

The fifth major factor influencing dynamic balance in the total group was the number of sit-ups, which represents abdominal muscle strength [28]. Abdominal muscles, which represent core strength, play an important role in the stability and mechanical functions of the spine and pelvis of athletes. Strengthening the abdominal muscles helps to maintain dynamic balance by stabilizing the pelvis and the trunk during different situations in a soccer game. Therefore, it is necessary to perform abdominal strength training continually to improve the dynamic balance ability of youth soccer players.

In the U-18 group, weight, muscle strength, power, flexibility, and core strength affected the dynamic balance. In contrast, in the U-15 group, only the power factors significantly influenced the dynamic balance. This is thought to reflect the developmental characteristics of the growth period. In general, during the U-18 players age, individual muscle mass and weight reach levels similar to those in adults due to increased secretion of sex hormones, such as testosterone, during puberty [29]. In addition, the increase in strength and strength factors, such as power, anaerobic power, and aerobic power, develop rapidly [30, 31]. There is also a decrease in flexibility due to muscle tensions related to rapid skeletal growth [32]. This characteristic is relatively insignificant during the U-15 players age; we thought that the dynamic balance of the U-15 group would not be affected by other factors when compared to the U-18 group. However, muscle power is a factor that affects the way the nervous system works. Since the nervous system reaches 80% of the adult level of development at the age of 6 years and reaches the adulthood level of development at the age of 9 years, the development is completed early, and developmental characteristics are not significantly affected [33]. This is thought to be the only factor affecting dynamic balance in the U-15 group. These results suggest that discriminative training, such as power-specific training, should be applied during the development of dynamic equilibrium in the U-15 group.

Several limitations of this study should be acknowledged. First, the number of included subjects was relatively small. Second, as only U-15 and U-18 male soccer players were included, the results may not apply to female players, because growth patterns in women are different from those in men. Finally, it is necessary to examine how training affects the results of field fitness measurement (dribble, agility, and coordination) as related to dynamic balance and an athlete's performance, by conducting training that considers factors that potentially affect dynamic balance.

5. Conclusions

In our study, dynamic balance was related to muscle strength, power, flexibility, and core strength in young male soccer players. Future studies should analyze whether complex training that targets these factors improves dynamic balance.

Author contributions

All authors designed the data collection method, collected the data, analyzed the data and reviewed drafts of the paper. Buong-O Chun, Kyong-Tae Kim, and Kihyuk Lee analyzed the data, wrote the paper, prepared tables and reviewed drafts of the paper. Hong-Sun Song, Jooyoung Kim, and Kihyuk Lee analyzed the data, prepared tables and reviewed drafts of the paper. All authors read and approved the final manuscript.

Ethics approval and consent to participate

The participants were all elite soccer players registered with the Korean Sports & Olympic Committee. All participants who agreed to participate in our study received a detailed explanation of its purpose and methods, in accordance with the ethical principles of the Declaration of Helsinki. All participants signed an informed consent form before measurements.

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Conflict of interest

The authors declare that they have no competing interests.

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