HUMAN MOVEMENT
2018; 19(1): 26–33

SOMATIC AND FUNCTIONAL COMPENSATIONS IN JUNIOR BADMINTON PLAYERS

original paper
DOI: https://doi.org/10.5114/hm.2018.73609

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ABSTRACT
Purpose. The aim of the study was to examine mutual compensations of somatic and functional variables in a group of junior badminton players.
Methods. The material of the study represented the results of 24 elite Polish badminton players with average competitive experience of 8.2 year. Basic somatic characteristics, coordination motor abilities, and motor fitness in terms of speed abilities, maximum anaerobic power, muscle strength, and cardiorespiratory strength were examined.
Results. The morphofunctional profiles in 7 players with top skill level are not identical. The variables that form these profiles interact with and compensate for each other. Some elite players show dominance of physical abilities, while somatic or coordination motor abilities are more pronounced in others. Several athletes were also characterized by a balanced morphofunctional profile.
Conclusions. The phenomenon observed requires further examinations, especially those based on the data derived from the category of senior champions.
Key words: badminton, junior players, training, somatic features

Introduction

The problem of optimization of achievements in badminton has to be considered in the aspect of various feedbacks that are present in both practice and broadly understood sports science. Coaching and training in badminton in children and youth should be oriented at identification of cause-and-effect relationships between somatic, metabolic, coordination, and psychical aptitudes, and improvement in performance. Observation of the game of badminton shows that the exercises performed by badminton players are of speed and endurance character. Two types of load are observed during the game: anaerobic, which is manifested in dynamic motor activities such as starts, changes of direction, fast and strong striking the shuttlecock, jumps, etc.; and aerobic, which results from effective game time and the number of repeated movement sequences [1, 2]. In racquet sports, playing time varies substantially, ranging from 6 minutes in squash to even more than 5 hours in tennis [3, 4]. In general, matches take 20–90 minutes, with a mean time of a single action ranging from 3 to 10 seconds [2, 5, 6]. In badminton, an average match takes 40–60 minutes [7–9], whereas average individual duration of actions is 7 seconds with 15-second breaks between actions [10].

During a match, around 60–70% of energy is supplied from aerobic processes whereas the remaining 30% are anaerobic in nature [10]. Therefore, anaerobic exercise during the game of badminton is observed during individual actions, whereas aerobic exercise results from the duration of the game and the number

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Received: August 23, 2017
Accepted for publication: October 15, 2017

Citation: Jaworski J, Żak M, Lech G, Bujas P, Żak S, Tchórzewski D. Somatic and functional compensations in junior badminton players. Hum Mov. 2018;19(1):26–33; doi: https://doi.org/10.5114/hm.2018.73609.

of various repeated movement sequences. Mechanisms concerning physiological aspects of preparation of athletes at different age and at different sports skill levels have been well described in the literature [10–13]. Furthermore, it is important for the effectiveness of the game to determine optimal somatic parameters. The number of publications that have discussed these aspects of the game in different countries is also substantial. Few studies on the theory of badminton training have examined the development of coordination abilities and their importance to competitive performance. The studies that have analysed this problem were carried out by Yuan et al. [14], who conducted laboratory tests (using optical apparatus) to determine the level of visual-motor coordination and reaction time in badminton players. They examined 9 badminton players, 8 gymnasts, and 20 university students from New Zealand and demonstrated a substantial advantage of the badminton players compared with control groups. Other interesting investigations were presented by Poliszczuk and Mosakowska [15], who explored the efficiency of reception and visual information processing during movement and determined mutual relationships between these phenomena in high-level badminton players aged 19–26 years. The tests were applied in order to control the level of coordination abilities, including the scope of peripheral vision when using the right hand during the game. The authors found better angle of view for the left eye. Reaction time tests did not reveal such differences. Other analyses based on scientific experiments determined the relationships between reaction abilities in badminton players and their perception during tasks connected with motor activity. A significant correlation was found between the reaction time of hand and feet. However, the study had only one contributive character as it examined only 16 experienced players and 10 beginners [16]. These explorations were continued in another study by Wang et al. [17]. It focused on 18 professional players and 6 university students. The analyses demonstrated substantial contribution of perception to the effectiveness of motor training during the development of playing skills. The study reported improved abilities among elite players in speed and accuracy of movements.

There are also some studies concerning the level and effect of balance on the effectiveness of playing badminton. Very interesting findings were presented by Masu et al. [18], who compared changes in the centre of gravity (COG) in badminton players in two groups, depending on their sports level. The study was conducted for both dominant and non-dominant limbs, with eyes open and closed. The results pointed to the usefulness of standing on the non-dominant leg with eyes closed for assessment of balance in badminton players. The opportunities for effective balance training in young badminton players were also emphasized by Ozmen and Aydogmus [19]. The results obtained in their study showed that the 6-week training caused statistically significant improvements in dynamic balance. The possibilities for postural stability training through short-term and long-term vibration of the whole body were emphasized by Piecha et al. [20]. The 4-week vibration training significantly shortened the rambling and trembling paths in the frontal plane. The path lengths were significantly reduced in the frontal plane a week after the training end date.

The studies of children and youth are relatively scarce. The majority of them have been conducted among adult populations. Few studies have been devoted to the problems of motor coordination and its importance for athletic training. Almost no data have been provided in the literature on the determinants of sports skill level at individual stages in the training of young athletes. Therefore, it seems purposeful to shift more attention to the problems of correlations of different groups of aptitudes (physical and somatic) with sports skill level in athletes at different stages of coaching (children and youth), with particular emphasis on coordination aptitudes and the phenomenon of trait compensation. The present study represents a specific contribution to this domain of scientific research.

The main aim of the study was to find mutual compensations of somatic and functional variables that determine sports skill level in junior badminton players.

The following research questions were formulated:

– Do morphofunctional variables included in the models proposed in the study have different effect on the development of sports skill level?

– Does the phenomenon of compensation of somatic characteristics and motor abilities occur in terms of variables that determine sports skill level in badminton players?

Material and methods

Subjects

The material for the study consisted of results collected in a group of 96 badminton players aged 10–19 years. Owing to the specific problems discussed in the study, a group of 24 juniors (17–19 years) was chosen. Average competitive experience of the juniors was 8.2 years. The study analysed athletes from athletic coaching centres in 4 sites.

Sports skill level was evaluated indirectly, with the use of the ranking lists prepared by the Polish Badminton Association. The lists are updated after completion of annual tournament cycles. Players score points for accomplishments in individual tournaments and the total number of points scored places a player at a specific position. If the number of points is equal or other doubts are raised, the evaluation is supplemented with the expert method. It is remarkable that the study group was composed of players who were regularly qualified for the national team, including Polish champions, runners-up, and athletes who regularly participated in international tournaments.

Procedures

Somatic measurements

The standard Martin's method was used for measurements of morphological parameters such as body height, upper limb length, sitting body height, subischial leg length, length of an arm with a racquet for a forehand grip, shoulder and hip width, body mass and its components (lean body mass and fat mass were measured with the TANITA TBF-551 body composition analyser), flexibility [21], and wrist flexibility.

Measurements of physical abilities

The analysis also included selected physical abilities such as: standing long jump (maximum anaerobic power [MAP] of lower limbs), static force measured with handgrip tester, dynamic strength of the abdominal muscles, 10 × 5 metre shuttle run, endurance shuttle run (all the tests performed according to the methodology of the Eurofit [21] test battery), overhead 2-kg medicine ball throw with both hands from standing position (feet apart) facing and back to the throwing direction (MAP of lower limbs), running with changes in directions ('envelope-shaped' run, with the total time of 3 repetitions recorded), power tests: overhead 1-kg medicine ball throw from the kneeling position, 10 × 3 metre shuttle run, and tapping with a 2-kg medicine ball (10 cycles of tapping with the ball held with both hands over the head against the wall and against the ground between the lower limbs). All the data were collected by using standardized equipment and tests.

Measurements of coordination abilities

With regard to contemporary research tendencies in the field of measurement of coordination-related aptitudes, we used computer tests of coordination motor abilities [22] that evaluated kinaesthetic differentiation of temporal movement parameters, frequency of hand movements, visual-motor coordination (optional mode and forced mode), spatial orientation (optional mode and forced mode), auditory reaction time (minimal, mean, maximal), visual reaction time (minimal, mean, maximal), choice reaction time to visual and auditory stimuli (minimal, mean, maximal), rhythmization, coupled motions, kinaesthetic differentiation (spatial and dynamic parameters).

All the measurements of fitness abilities were preformed in a sports hall in the afternoon (between 3:00 and 6:00 p.m.), according to the recommended procedure [21].

Tests of coordination abilities were also performed in the same hours. Coordination tests were carried out each time before the measurements of physical abilities owing to the possible effect of fatigue on performance. The tests took place in a separate room, which ensured the necessary silence required for each person tested. In order to motivate the participants, each of them was informed about the aim of the study and testing procedure. Before the test was recorded, the subjects had performed a trial test. Coordination tests were always performed in the same order for each badminton player. The people waiting for the tests did not watch the tests performed by previous subjects in order to eliminate the likelihood of remembering the test settings and the fatigue caused by concentration on the previous tests. Therefore, the tests were carried out individually for each subject. All the tests were conducted by the second author of the study, using the same touch-panel tablet (Toshiba R15) and the author's software for testing coordination abilities. The reliability of coordination tests has been demonstrated in previous studies [22]. *Test-retest* intraclass correlation coefficient (ICC) ranged from 0.60 to 0.93, depending on the test.

Statistical analysis

In this study, the following statistical methods were applied:

1. Before the main statistical analysis, the conformity of distribution of variables with normal distribution was tested with the Shapiro-Wilk test.
2. On the basis of the factor analysis, the number of variables included in the analysis was reduced (to 26 variables). Calculations were performed with the values normalized for arithmetic means and standard deviations in the group of juniors. The variant of factor analysis was based on the Hotelling principal

component method modified by Tucker and supplemented with Varimax rotation.

3. In order to determine the combined effect of variables selected through factor analysis on sports skill level of juniors, we used a stepwise regression model. A model of multiple determinations, which estimates the combined effect of significant parameters, was selected among all the parameters adopted for the analysis. This operation yielded 12 variables, which determined the sports results in juniors the most substantially. Owing to the limited scope of this publication, the reports on the above two analyses were not presented. They were only used for further analyses.

4. The variables, which formed the structure of these models, were normalized in scale T. Since relationships of many characteristics and abilities with morphological age and substantially lower dispersion of the results were found, normalization in the sets of morphological age was performed.

5. A relatively high number of variables that formed the morphofunctional model of juniors and the usually balanced character of these variables point to the necessity of performing more detailed analyses, that is, interpretation of 'models of individual cases.' This problem was solved by using the results of 7 best players.

Statistica PL v. 10.0 software package was employed for the analysis of the results. Significance was set at $p < 0.05$.

Ethical approval

The research related to human use has been complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the authors' institutional review board or an equivalent committee.

Each participant (parents or legal guardians in the case of minor children) gave their written informed consent to participate in the study. The examinations were approved by the directors of the related sports clubs and by the Bioethical Committee at the Regional Medical Chamber in Cracow (approval No. 51/KBL/OIL/2010).

Informed consent

Informed consent has been obtained from all individuals included in this study.

Results

The morphofunctional profile prepared for older juniors in the previous studies [23] with respect to their morphological age was used as the basis for further detailed investigations. The results obtained suggest that the system of variables that determine success in the sport at the age of older juniors is formed by somatic and flexibility variables (wrist range of movement, body height, shoulder width, range of arm with the racquet), neurofunctional abilities (complex reaction time, spatial orientation, movement coupling, and kinaesthetic differentiation), and physical abilities (MAP of upper limbs, envelope run speed, MAP of lower limbs, and abdominal strength). Therefore, with the relatively high number of variables used in the analysed morphofunctional model and their generally balanced character, this phenomenon needs to be evaluated in the context of compensation of variables.

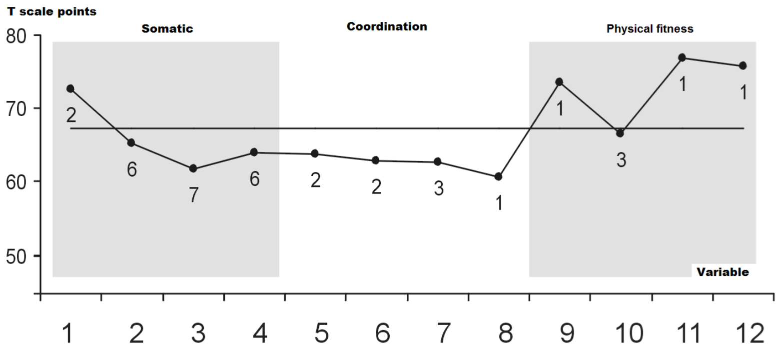
A detailed analysis of the structure of morphofunctional models of 7 best juniors leads to interesting conclusions, both in general terms and in the aspect of more complex interactions between individual variables (Figures 1–3, Table 1). A comprehensive analysis of the problems reveals that global contrasts between arithmetic means calculated for all the somatic traits and motor abilities studies cause interindividual variability with the range of only 0.65 of standard deviation. Interestingly, these values are almost identical in players with ranks 2 and 3 (Figures 2 and 3) and 5 and 6 (Table 1). This insignificant differentiation of the general modules, with substantial differentiation observed in the field of their internal structure, allows, to a certain degree, to analyse the phenomenon of compensation of variables that form a comprehensive character of specific dispositions. This reasoning is justified, on one hand, by their point scores calculated with respect to the whole population of badminton players – developmental aspect [23] and, on the other hand, by the ranking of individual parameters in the players categorized according to the sports skill level (level of development of the variables compared with the whole group of juniors). However, this specific accumulation of the phenomena does not necessarily mean a balanced influence. High rankings in the register of energy dispositions have slightly higher point scores compared with their counterparts in the area of the somatic traits, and substantially higher compared with coordination abilities.

Further investigations of this problem lead to determination of several specific morphofunctional types among 7 juniors. The player with the first place (Figure 1) in sports skill level exhibits a substantially varied profile, with the mean of 12 variables being 67.2 points (Figure 1). The predominant trait in this athlete is lower limb MAP. The parameters of abdominal strength, upper limb MAP, and wrist flexibility are also much

Table 1. Rankings and point scores for the variables from the morphofunctional profile of players with ranks 4–7

Player's rank	4		5		6		7	
Variable	R	P	R	P	R	P	R	P
Wrist flexibility	8	61.0	5	67.6	7	62.9	4	70.5
Body height	5	66.6	2	69.5	8	63.1	9	62.1
Shoulder width	6	62.8	3	65.5	9	60.9	10	60.4
Length of the arm with a racquet	5	64.4	2	66.8	4	64.9	8	63.0
Mean choice reaction time	7	58.2	6	59.2	5	60.3	11	55.5
Spatial orientation	6	58.2	5	59.7	3	62.1	12	51.9
Coupled motions	9	55.1	7	57.5	5	59.7	8	56.1
Kinaesthetic differentiation	10	53.9	3	58.4	4	57.8	9	54.5
Upper limb MAP	3	70.4	6	66.4	4	69.1	7	65.0
Running speed	1	70.0	7	62.0	6	62.9	5	63.8
Lower limb MAP	3	73.6	9	64.1	7	67.2	6	68.8
Abdominal muscle strength	2	70.9	9	56.5	5	61.3	8	56.5
	$\bar{x}$ = 63.7		$\bar{x}$ = 62.8		$\bar{x}$ = 62.7		$\bar{x}$ = 60.7	

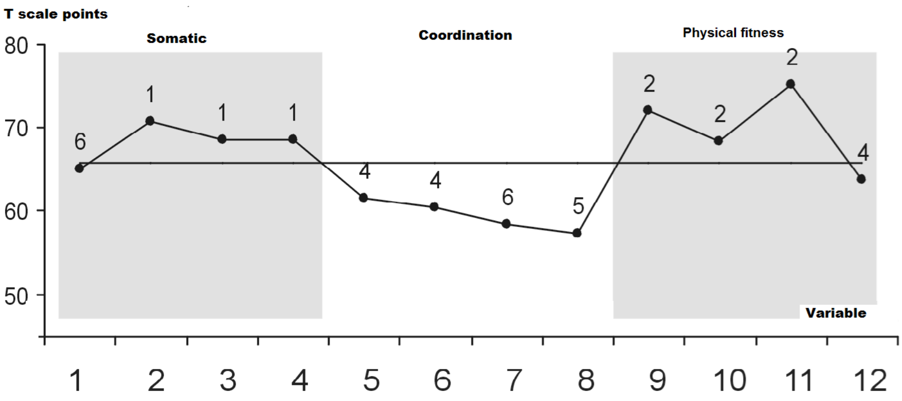
R – ranking, P – points in T scale, MAP – maximum anaerobic power, $\bar{x}$ = arithmetic mean



The horizontal line denotes $\bar{x}$ all the normalized variables (scale T) included in the profile.
Digits 1–7 indicate the ranking of variables.

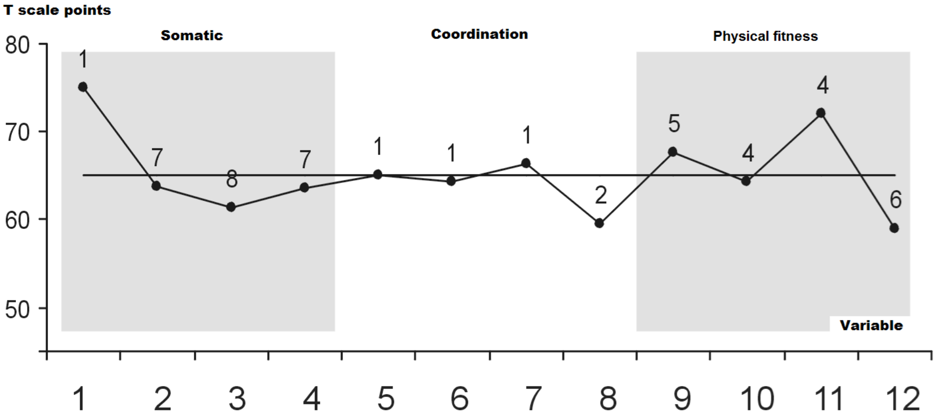
1 – wrist flexibility, 2 – body height, 3 – shoulder width, 4 – length of the arm with a racquet,
5 – mean choice reaction time, 6 – spatial orientation, 7 – coupled motions, 8 – kinaesthetic differentiation,
9 – upper limb maximum anaerobic power, 10 – running speed, 11 – lower limb maximum anaerobic power,
12 – abdominal muscle strength

Figure 1. Morphofunctional profile of the player with the first rank



Variables are represented as in Figure 1. The horizontal line denotes $\bar{x}$ all the normalized variables (scale T) included in the profile. Digits 1–6 indicate the ranking of variables.

Figure 2. Morphofunctional profile of the player with the second rank



Variables are represented as in Figure 1. The horizontal line denotes $\bar{x}$ all the normalized variables (scale T) i ncluded in the profile. Digits 1–8 indicate the ranking of variables.

Figure 3. Morphofunctional profile of the player with the third rank

higher than the mean. All the parameters of body size are below mean values, similar to coordination abilities, with the latter having, however, high ranks.

Entirely different distribution of variables was found in the player with the second place (Figure 2). The dominant trait in this badminton player is also lower limb MAP, whereas other distinguishing traits are upper limb MAP and body height. All the coordination abilities are much below the mean. They also show much lower ranking than in the player with the first rank. It is worth noting that, in general, the modules of two first badminton players differ from each other by only 1.4 points. The difference between the second and third player in these terms is much smaller and amounts only 0.7 points (Figures 2 and 3).

The predominant trait in the third player (Figure 3) is wrist flexibility, supported by a relatively high level of MAP parameters. However, all the coordination abilities had very high rankings, most of them being close to the mean. A relatively low ranking and level of development in this badminton player was observed for body size parameters.

The profiles of players with the rank from four to seven (Table 1) change in a similar manner, but their components obtain successively even lower places. However, it is worth emphasizing that the observed phenomenon of compensation concerns the relationships between energy-related dispositions, coordination abilities, and somatic traits. The abilities of energy origins are predominant in the player with the fourth rank; the fifth player exhibits a high level of body size, whereas the most harmonious distribution of variables is observed in the badminton player classified as sixth. The athlete with the seventh rank has a substantially differentiated profile of morphofunctional dispositions, whereas the variables that form this profile have substantially lower positions in the ranking. However, predominance in wrist flexibility and disposition connected with MAP in lower and upper limbs should be emphasized. Similar to the most of the players evaluated, the length of an arm with a racquet is also essential.

In conclusion of the results, one should emphasize that individual morphofunctional profiles are, however, identical in all the players. The variables that form these profiles interact to different degree and compensate for each other.

Discussion

Problems of talent identification in professional sport have been examined comprehensively [24, 25]. The correlation of body size with sports skill level points to a substantial role of the developmental age in early achievement of better sports results. This thesis is strongly reinforced by the fact of the view accentuated in the literature concerning the differentiation in the morphological age and its effect on the results in terms of achievement of motor tasks. Therefore, the factor of morphological age must be taken into account in coaching in the aspect of understanding the causes of delayed or accelerated development. Waddell [26] discussed this problem to a certain degree, and emphasized the need for adaptation of the drills to the developmental level of young badminton players and adequate development of the technique used during competitions adjusted to their physical abilities. According to this author, pressure to achieve the champion level too early is not recommended as it often limits the comprehensive development of the player.

For playing effectiveness, optimal somatic characteristics are also essential. With the standard classification of somatotypes proposed by Sheldon, badminton players are characterized by high indices of mesomorphy and ectomorphy [10]. In 13 studies, mean values were, respectively: 2.8 for endomorphy, 3.6 for mesomorphy, and 3.1 for ectomorphy. These studies have shown that optimal body build of a badminton player is characterized by substantial body height and low body mass.

In our study, variables connected with the length of the arm turned out to be important for juniors. It seems that this trait is important for all defensive actions in the game and might compensate for deficiencies, e.g. in moving speed on the field (based on the aptitudes in terms of lower limb MAP). This problem was also investigated by Amusa et al. [27], who analysed playing of the best juniors in Africa and made coaches aware of substantial importance of this somatic trait for the game. Furthermore, with respect to somatic development of badminton players in the aspect of recruitment and selection, many authors recommend selection of athletes with muscular bodies and average body height. However, they also note the problem of trait compensation. Their point of view to the problem connected with the developmental age in sport is also interesting. They argue that badminton players should be recruited from the individuals who develop less dynamically since they tend to show more adaptability in learning new movements. In the context of somatic conditions of sports skills level in authors' studies, these observations are apt and worth noting.

The morphofunctional model of juniors also included coordination abilities: mean choice reaction time, spatial orientation, coupled motions, and kinaesthetic differentiation of temporal movement parameters. The importance of visual-motor coordination and reaction time for the game was also confirmed in comparative studies [14, 16, 28–30]. Furthermore, their role in teaching technique has been discussed by Mooney and Mutrie [31], and Sakurai and Ohtsuki [32]. The results of our study point to the substantial role of spatial orientation at this stage of sports skill level. These regularities seem to be logical since the above ability is important to the evaluation of the trajectory of the shuttlecock and observation of the present situation on the field.

The morphofunctional model that determined the sports results also included the energy-related variables. The contribution of MAP of the lower and upper limbs and running speed is particularly noticeable. The regularities found in the study are consistent with numerous comparative studies that have categorized badminton as a strength-endurance sport, which resulted mainly from the specific character of the game [10, 11, 13].

Our study shows that an ideal profile of the athlete in this sport is represented by a subject with strong body build with the predominance of lean body mass, length of arms, above-average amplitude of movements (with the main focus on wrist flexibility), high anaerobic and aerobic capacity, and motor coordination with a high level of organization and specificity (spatial orientation, choice reaction time). The impossibility of meeting these criteria in practice is confirmed by observation of individual profiles of morphofunctional variables of the 7 best players, which points to the phenomenon of compensation of variables in individual 'champion models.' Some players exhibit a predominance of energy-related abilities, while others show better somatic traits or coordination abilities of higher order. There are also players at the champion level with balanced morphofunctional profiles.

Conclusions

1. Individual morphofunctional profiles of the 7 athletes with the highest ranking positions point unequivocally to the dynamic character of mutually compensating factors that determine the sports skill level of a player. However, the predominance of physical abilities in most of these models leads to the conclusion that badminton should be considered as a sport based on speed and endurance.

2. Although seemingly obvious and noticeable, the phenomenon of compensation requires further and more specific research since this problem is beyond the scope of a single study (necessity of examination of senior champions).

Disclosure statement

No author has any financial interest or received any financial benefit from this research.

Conflict of interest

The authors state no conflict of interest.

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