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Research Article / Araştırma Makalesi

Trunk muscle endurance and upper extremity performance in healthy adults

Sağlıklı yetişkin bireylerde gövde kas endüransı ile üst ekstremite performansı ilişkisi

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ABSTRACT

Objective: The aim of this study was to examine the relationship between trunk muscle endurance and upper extremity performance in healthy adult individuals.

Materials and Methods: A total of 139 healthy individuals aged between 18-59 were recruited for the study. The McGill Trunk Muscle Endurance Tests, Upper Limb Rotation Test, Closed Kinetic Chain Upper Extremity Stability Test, and Upper Extremity Y-Balance Test were evaluated to investigate the correlation between trunk muscle endurance and upper extremity performance.

Results: A same-directional and low-level relationship was found between upper extremity rotation test scores and extensor endurance and flexor endurance test scores [r_s=0.382; r_s=0.329; r_s=0.244; r_s=0.243; (p<0.001)]. A same-directional and moderate relationship was found between upper extremity rotation test scores and flexor endurance, right and left lateral endurance scores [r_s=0.446; r_s=0.453; r_s=0.460; r_s=0.476; (p<0.001)]. A direct low level relationship was found between closed kinetic chain upper extremity stability test score and trunk endurance test scores [r_s=0.265; r_s=0.208; r_s=0.319; r_s=0.359; (p<0.001)]. Also, a same-directional and low-level relationship was found between upper extremity Y-balance test scores and extensor and flexor endurance test scores [r_s=0.275; r_s=0.232; r_s=0.274; r_s=0.361; (p<0.001)]. A same-directional and moderate relationship was found between upper extremity Y-balance test scores and right and left lateral endurance test scores [r_s=0.460; r_s=0.432; r_s=0.503; r_s=0.455; (p<0.001)].

Conclusions: The results indicate that as trunk muscle endurance improved in healthy adults, there is a linear increase in upper extremity performance. These findings underscore the multifaceted nature of the kinetic chain in movements and the significant relationship between upper extremity and trunk stability. Therefore, this study suggests that to enhance individuals' upper extremity performance, trunk muscle endurance exercises should take place in training programmes.

Keywords: *Muscle strength, trunk endurance, performance tests, upper extremity*

ÖZ

Amaç: Bu çalışmanın amacı sağlıklı yetişkin bireylerde gövde kas endüransı ile üst ekstremite performansı arasındaki ilişkinin incelenmesiydi.

Gereç ve Yöntem: Çalışmaya 18-59 yaş arası 139 sağlıklı birey alındı. Gövde kaslarının endüransını değerlendirmek için McGill Gövde Kas Endürans Testleri kullanıldı. Üst ekstremite performansını değerlendirmek için Üst Ekstremite Rotasyon Testi, Kapalı Kinetik Zincir Üst Ekstremite Stabilite Testi ve Üst Ekstremite Y-Denge Testi kullanıldı.

Bulgular: Üst ekstemite rotasyon test skorları ile ekstansör ve fleksör endürans test skorları arasında aynı yönlü ve düşük düzeyde ilişki olduğu belirlendi (r_s=0.382; r_s=0.329; r_s=0.244; r_s=0.243; (p<0.001)). Üst ekstremite rotasyon test skorları ile fleksör endürans, sağ ve sol lateral endürans skorları arasında aynı yönlü ve orta düzeyde ilişki olduğu belirlendi (r_s=0.446; r_s=0.453; r_s=0.460; r_s=0.476; (p<0.001)). Kapalı kinetik zincir üst ekstremite stabilite testi skoru ile gövde endürans test skorları arasında aynı yönlü ve düşük düzeyde ilişki olduğu belirlendi (r_s=0.265; r_s=0.208; r_s=0.319; r_s=0.359; (p<0.001)). Üst ekstremite Y-denge test skorları ile ekstansör ve fleksör endürans test skorları arasında aynı yönlü ve düşük düzeyde ilişki olduğu belirlendi (r_s=0.275; r_s=0.232; r_s=0.274; r_s=0.361; (p<0,001)). Üst ekstremite Y- denge test skorları ile sağ ve sol lateral endürans test skorları arasında aynı yönlü ve orta düzeyde ilişki olduğu belirlendi (r_s=0.460; r_s=0.432; r_s=0.503; r_s=0,455; (p<0.001)).

Sonuç: Sağlıklı yetişkin bireylerde gövde kas endüransı arttıkça üst ekstremite performansının arttığı belirlendi. Çalışmanın sonuçları hareketlerdeki kinetik zincirin çok yönlü doğasını ve üst ekstremite ile gövde stabilitesi arasındaki ilişkiyi vurgulamaktadır. Bu çalışma bireylerin üst ekstremite performansını geliştirmek için antrenman programlarına gövde kas endüransına yönelik egzersizlerin de konulması gerektiğini önermektedir.

Anahtar Sözcükler: *Kas gücü, gövde endüransı, performans testi, üst ekstremite*

INTRODUCTION

Movement patterns such as throwing (1), spike jump (2) and kicking (3) involving lower and upper extremities of healthy individuals are facilitated through the kinetic chain, in which many interconnected segments from the ankle joint

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to the glenohumeral joint work in synchronization and coordination with each other (4). To achieve optimum performance in the lower and upper extremities, muscle activation and force transmission throughout the entire kinetic chain is required (4), and this can be achieved by force transmission in the core musculature (5).

The core region, located at the center of the musculoskeletal kinetic chain, consists of the spine, pelvis, hip, proximal lower extremity and abdominal structures. It serves as an anatomical fulcrum for the movement of distal segments of the musculoskeletal system (6). This is known as proximal stability for distal mobility during throwing, running and hitting activities (7). Muscles such as latissimus dorsi, hamstring, quadriceps and iliopsoas, which are the primary mover muscles of distal joints, are located on the spine and pelvis. Similarly, the gluteals, hip rotators and trapezius muscles, which are the primary stabilizer muscles of the lower and upper extremities, are also located within the core area. As a result, core muscles are the structures responsible for the stabilization of the spine and pelvis, and the creation of movement and energy transfer from the larger joints of the body to the smaller ones through the kinetic chain (8).

Due to the kinetic chain mechanism, movements that require high explosive force, such as throwing and spiking, are generated mostly by the activation of core muscles through the extended range of shoulder internal rotation, combined with the forward movement of the trunk (1). Problems in core muscles' activation or mobility of the core region can lead to excessive load on the glenohumeral muscles, potentially resulting in injuries (5).

While there is consensus in the literature about the relationship between core muscles and lower extremity muscle strength and performance (4,6,9,10), the relationship between upper extremity muscle strength and performance continues to be investigated. A study reported that there was no statistical relationship between trunk muscle endurance and shoulder injury frequency in athletes (11). Similarly, Lin et al. (12) reported that there was no relationship between trunk muscle endurance and upper extremity performance in baseball athletes. On the other hand, it has been observed that there is positive relationship between trunk muscle endurance and throwing performance in handball athletes (13). However, there are also studies showing that throwing athletes with shoulder pain have lower core stability compared with healthy athletes (5), and that there is relationship between upper extremity Y-balance test and trunk muscle strength (14).

In studies conducted on athletes It is generally seen that there is no relationship between trunk muscle endurance and upper extremity performance in uninjured athletes (11,12), while in contrast relationship is found in injured athletes (5,13,14). We think that this may be due to the fact that athletes generally have higher muscle strength and that field test measurements may not distinguish small differences (15-17), thus possible relationships can be more easily revealed in healthy individuals. A limited number of studies have been found in the literature examining the relationship between trunk muscle endurance and upper extremity performances in healthy adults. Therefore, the aim of this study was to examine the relationship between trunk muscle endurance and upper extremity performance in healthy adults.

MATERIAL and METHODS

Study design

This is a cross-sectional study, that was approved by Ankara Yıldırım Beyazıt University Health Sciences Ethics Committee (Approval number: 14.06.2023/06-273). The study was conducted at the Faculty of Sports Sciences Laboratory of Ankara Yıldırım Beyazıt University in accordance with the Declaration of Helsinki.

Participants

Verbal and written announcements were made and snowball sampling method was used to reach out to individuals to be included in the study. Healthy individuals over the age of 18, who volunteered to participate in the study were selected. The exclusion criteria for the study were: having any neurological, musculoskeletal or cardiopulmonary disorder, having undergone any orthopedic and/or spinal surgery in the last six months, and having any pain complaints that would restrict one's movements. Informed written consent was obtained from individuals participating in the study.

Procedures

All evaluations were carried out by a physiotherapist with five years of experience through face-to-face meetings. The individuals' age (yrs), body weight (kg), height (m), gender and education profile (yrs) were recorded. Body mass index (BMI) values were calculated by dividing body weight by the square of height and expressed as kg/m^2 (9).

Trunk muscle endurance tests

Trunk muscle endurance was evaluated with McGill's trunk flexor, extensor and right/left lateral flexor muscle endurance tests.

Trunk flexor endurance test: It was performed while the individual positioned with the hands crossed on the shoulders, the hips and knees bent in 90° flexion, and the soles of the feet in a fixed hook position on the floor. The individual was asked to lean their shoulders on the 60° inclined wooden platform behind them and to maintain the position for as long as possible after the platform was pulled behind them. Timing was started after the platform was withdrawn, and during the test, the individual was asked to maintain the spine in a neutral position by using abdominal muscles. If there was a visually noticeable change in trunk position, the test was terminated and time was recorded in seconds.

Trunk extensor endurance test: It was performed while the individual was lying prone on a bed with the trunk exposed to the level of the anterior superior iliac spine. In order to stabilize the individual's lower extremity, abelt was passed over the ankle and another one was locked over the thigh. When individuals wereready, they were asked to cross their hands on their shoulders, extend their body until it was parallel to the ground, and keep their spine in a horizontal position by using the trunk extensor muscles. Timing started when individuals took their position, and if there is a visually noticeable change in trunk position, the test was terminated and time was recorded in seconds.

Trunk lateral flexor endurance tests: It was performed with the lower arm positioned under the body, the upper arm next to the body, and knees extended along the trunk side. When the individuals were ready, they were asked to lift their hips off the bed while maintaining the neutral position of the whole body on the forearm, as in the side-bridging exercise. Timing started when the individuals took their position, and if there was a visually noticeable change in trunk position, the test was terminated and time was recorded in seconds. The test was performed separately for both right and left trunk lateral muscle groups (18).

Upper extremity performance tests

Upper limb rotation test: It is a valid and reliable test (19) used for evaluating trunk and periscapular muscle strength. The starting position of the test is a modified push-up position with arms open at shoulder width, upper body supported with the forearm, elbow flexed at 90°, body and hip parallel to the ground. The individual takes the push-up position near the wall because the shoulder, lateral epicondyle, greater trochanter and lateral malleolus on the side closest to the wall are desired to be in contact with the wall. While the individual is in this position, the arm on the side closest to the wall was fixed to the ground. The body is externally rotated and shoulder in 90° abduction and 90° external rotation, and the person was asked to maintain this position for 15 s while the arm on the side of the rotation was in contact with the wall. The individual was allowed to try the test 1-2 times to become familiar with it. Afterwards, the test was repeated three times separately for the dominant and non-dominant sides, and the average of these values was used in the analysis.

Upper extremity closed kinetic chain stability test: It is a valid and reliable test (20) frequently used for assesment of periscapular muscle strength performance. For testing, two pieces of athletic tape were attached to the floor 0.9 m apart. The individual was asked to take a standard push-up position with hands open at the tape level. The individual was asked to move the hands from one tape line to the next as quickly as possible, touching each line by acting like a 'wiper'. Touches made were counted for 15 s with the help of a stopwatch, and the total number of touches was recorded as the final score and used in the analysis (20).

Upper extremity Y-balance test: It is a reliable and valid test (21) used for monitorising the neuromuscular control ability of the upper extremity. Starting position for the test was as such the individual's hands are in a stable balance in the push-up position (front position) at the center point of the Y-balance platform, feet are shoulder-width apart, legs and hips are in a fixed position parallel to the ground. The individual then maintains a fixed posture with the hand to be tested, reaches with only the upper extremity, without support from the lower extremity and hip center, and moves the hand in the medial (0°), inferolateral (45°) (from the inside under the other hand) and superolateral (45°) directions. They were asked to push the blocks with their fingertips. The individual carried out the test each time by bringing the hand back to a fixed stance without touching the ground. The test was repeated three times and the average of the three was recorded as the result of the test. Test normalization was achieved by proportioning the average score and upper extremity length (distance between the medial edge of the scapula and the tip of the 3rd finger).

Total Score = (Medial + Inferolateral + Superomedial) / (Extremity length x 3) x 100 is the formula used in calculation (21).

Sample size calculation

G*Power 3.1.9.7 program was used to calculate the smallest sample size required for analysis. Since the relationship between variables was to be examined, the correlation section of the G*Power program was used. In Cohen's study (22), Pearson correlation coefficient was defined as 0.10 (low), 0.30 (medium) and 0.50 (high). Considering the power of the test as 95%, the margin of error as 5%, and the effect size as 0.30 (medium), the total sample size was calculated to have 138 individuals.

Statistical Analysis

The data obtained from this study were evaluated with the SPSS (The Statistical Package for The Social Sciences) v23 program. Mean, standard deviation, median, minimum and maximum values were taken for quantitative variables, and frequency (n) and relative frequency (%) were taken for qualitative variables.

Shapiro-Wilks (n<50) and Kolmogorov-Smirnov (n≥50) tests were used to investigate whether the data revealed normal distribution. Equality of variances was investigated using Levene's test. Comparisons of variables in terms of gender were investigated using the independent samples t-test in groups with normal distribution, and using the Mann-Whitney U test in groups with non-normal distribution. For variables that did not show normal distribution, average rank numbers were also given as summary information. The relationshipsbetween trunk endurance tests and upper extremity rotation, closed kinetic chain upper extremity stability test and upper extremity Y-balance tests were examined using Spearman's rank number correlation coefficient. Correlation coefficient ranges between 0.90-1.00 indicate a very high correlation, between 0.70-0.89 indicate a high correlation, between 0.40-0.69 indicate a moderate correlation, and between 0.20-0.39 indicate a low correlation. The results were evaluated at the 0.05 significance level (22).

RESULTS

A total of 139 individuals were included in the study. The general characteristics of the individuals are summarized in Table 1. 72.7% of the individuals in the study were female and 27.3% were male. The dominant side of 95.7% of the individuals is right side (Table 1).

The individuals' age, weight, height, and UE length information are summarized in Table 2. The ages of the individuals ranged from 18 to 59.

Summary of the individuals' trunk endurance tests, upper extremity rotation, closed kinetic chain upper extremity stability test and upper extremity Y-balance tests are given in Table 3.

Table 1. General characteristics

Variables	Parameters	Frequency(%)
Gender	Female	101 (72.7)
	Male	38 (27.3)
UE Dominant side	Right	133 (95.7)
	Left	6 (4.3)

UE: upper extremity

Table 2. Participants' physical data

Variables	Mean±SD	Median	Range [min-max]
Age(year)	23.4±6.1	22.0	41 [18-59]
Weight (kg)	63.3±13.8	60.0	59 [43-102]
Height (cm)	166.7±8.3	165.0	46 [145-191]
UE length (cm)	83.8±4.9	83.0	27 [70-97]

UE: upper extremity

Table 3. Descriptive analysis of the results for upper limb rotation, upper extremity closed kinetic chain stability, upper extremity Y-balance, and trunk endurance tests.

Performance Tests	Mean±SD	Median	Range [min-max]
ULRT D (n)	8.12±2.91	8.00	15.0 [0.67-15.7]
ULRT ND (n)	7.80±2.86	8.00	16.3 [0.33-16.7]
UECKCST (n)	16.6±5.12	15.7	27.0 [5.33-32.3]
UEYBT D (cm)	69.9±11.5	68.9	77.3 [28.5-105.8]
UEYBT ND (cm)	71.2±11.6	71.1	70.4 [28.7-99.0]
Trunk muscle endurance (s)			
Extensor	74.0±40.0	65.0	173.0 [7.00-180.0]
Flexor	69.0±43.8	60.5	173.0 [7.00-180.0]
Lateral flexor-right	33.1±21.1	28.0	119.0 [3.00-122.0]
Lateral flexor -left	31.8±19.8	28.0	117.0 [4.00-121.0]

ULRT: upper limb rotation test; UECKCST: upper extremity closed kinetic chain stability test; UEYBT: upper extremity Y-balance test:, D: dominant, ND: nondominant.

The relationships between trunk endurance tests and upper extremity rotation, closed kinetic chain upper extremity stability, and upper extremity Y-balance tests were examined and the results are summarized in Table 4.

Table 4. Correlation coefficients (r), and difference (p values) between upper extremity performance tests and variables of trunk endurance tests

UE Performance tests		Trunk endurance tests			
		Extensor	Flexor	Lateral flexor-R	Lateral flexor-L
ULRT-D	r	0.382	0.244	0.446	0.460
	p	**<0.001**	**0.004**	**<0.001**	**<0.001**
ULRT ND	r	0.329	0.243	0.453	0.476
	p	**<0.001**	**0.004**	**<0.001**	**<0.001**
UECKCST	r	0.265	0.208	0.319	0.359
	p	**0.002**	**0.014**	**<0.001**	**<0.001**
UEYBT D	r	0.275	0.274	0.460	0.503
	p	**0.001**	**0.001**	**<0.001**	**<0.001**
UEYBT ND	r	0.232	0.361	0.432	0.455

*Spearman's rank correlation coefficient; UE: upper extremity; ULRT: upper limb rotation test; UECKCST: upper extremity closed kinetic chain stability test; UEYBT: upper extremity Y-balance test; D: dominant; ND: nondominant.

There was a significant linear low-level relationship between upper extremity rotation test scores, and extensor and flexor endurance test scores (r_S=0.382; r_S=0.329; r_S=0.244; r_S=0.243, respectively). There was a same-directional moderately significant relationship between upper extremity rotation test scores and flexor endurance, right and left lateral endurance scores (r_S=0.446; r_S=0.453; r_S=0.460; r_S=0.476, respectively) (Table 4).

A direct significantly low-level relationship was found between the upper extremity closed kinetic chain stability test score and the whole body endurance test scores (r_S=0.265; r_S=0.208; r_S=0.319; r_S=0.359, respectively). There was a direct significantly low-level relationship found between upper extremity Y-balance test scores and extensor and flexor endurance test scores (r_S=0.275; r_S=0.232; r_S=0.274; r_S=0.361, respectively). A same-directional moderately significant relationship was found between the right and left lateral endurance test scores (r_S=0.460; r_S=0.432; r_S=0.503; r_S=0.455, respectively) (Table 4).

DISCUSSION

The results of this study, which was conducted to examine the relationship between trunk muscle endurance and upper extremity performance in healthy adult individuals, indicated that as trunk muscle endurance increased, upper extremity performance also increased. Trunk muscles ensure the best production and transfer of energy during sporting activities. The trunk is responsible for maintaining the stability of the spine and pelvic floor muscles (23). We could not find any study in the literature conducted on healthy individuals examining the relationship between trunk, periscapular muscle strength and trunk endurance test scores. In our study, it was determined that as trunk extensor, flexor right and left lateral endurance test scores increased, upper extremity rotation test scores also increased.

The main purpose of functional performance tests is to evaluate an athlete's performance with tests that include the basic movement patterns of the sports branch being measured and also appropriate to the nature of the sport. The upper limb rotation test was developed by Decleve et al. (19) with consideration that other upper extremity performance tests did not include the trunk rotation and extension required to collect the potential energy at the beginning of a throwing pattern. The evaluated extremity ensures that the trunk remains balanced in the horizontal plane with fixed periscapular muscle contraction on the ground, while trunk rotation and extension movements are performed on the contralateral side. In context, the fact that the upper extremity rotation test results in our study revealed a positive correlation with trunk muscle endurance tests supports this. Similary Lin et al. (12) disclosed relationship of upper extremity performance with trunk muscle endurance. In contrast to our study they used bat velocity as upper extremity performance parameter. Although bat velocity demonstrates the main aspect of the sport, it only indicates velocity of the movement. Even though functional performance tests would not be as specific as sports movements, it shows wider aspects of sport such as strength, power, balance and agility.

Upper extremity closed kinetic chain testing evaluates glenohumeral joint kinetic chain stability, muscle endurance and coordination. This test involves bilateral upper extremity activation while an athlete is stable in the plank position. Movements in the upper extremities occur through the harmonic production of force by local muscles such as the glenohumeral and periscapular muscles, and global trunk muscles (24). The kinetic chain enables optimal performance by ensuring the effective transfer of force from the lower extremity and trunk muscles to the upper extremity muscles (23). The trunk enables dynamic activities of the upper extremities by providing proximal stability for distal mobility and acting as a kinetic link (25). In our study, it was determined that as trunk endurance test scores increased, the closed kinetic chain upper extremity stability test scores also increased. This supports the fact that trunk muscle endurance positively affects upper extremity performance. Similar to our results, in the literature a study conducted on university students revealed that trunk endurance had positive correlation with upper extremity performance in a closed kinetic chain (26).

During the upper extremity Y-balance test, both mobility and stability are challenged to the maximum. Neuromuscular control of the upper extremity is required to have adequate trunk stability to maintain body alignment within the narrow base of support. Thoracic rotation and trunk stability, as components of scapular mobility, are combined to prevent loss of balance. The trunk serves as a stable biomechanical platform for the work of peripheral muscles (21). Increased activation of trunk flexors and extensors during activities in which the arm is extended on the floor are reported (27,28). This activation is thought to result from increased muscle activity required to support the body on narrow support surface (28).

In this study, it was determined that as trunk extensor, flexor right and left lateral flexor muscle endurance test scores increased, upper extremity Y-balance test scores also increased. Similar to our study, Bauer et al. (13) conducted a study on adolescent athletes, and found positive correlati–

on betweeen trunk muscle endurance and upper extremity Y-balance test. But they used Bourban tests to meeasure trunk muscle endurance unlike to our study. Whereas Bourban tests measure dynamic muscle endurance, McGill tests measure static muscle endurance. Since both studies had positive correlation with upper extremity Y-balance test, it can be implied that either dynamic and static muscle endurance have positive impact on neuromuscular control of upper extremity. Moreover, superficial EMG studies in the literature examining the activation of trunk muscles during upper extremity movements indicate that distal extremity movements increase trunk muscle contraction (21,27-29). This may explain the positive correlation between trunk muscle endurance and upper extremity Y-balance test obtained in the current study.

Strengths and Limitations

This study is not without limitations, the fact that the physical activity levels of the individuals that participated in this study were not examined and reported in detail can be stated among the limitations of the study. Since this study was not conducted on athletes, it prevents our results from being transferred to athletes. Future studies conducted with larger sample sizes, particularly including athletes from various upper extremity-dominant sports, will provide more detailed information on the effects of trunk muscle endurance, especially on athletic performance.

However, the high validity and reliability of the evaluation methods used in the assessment of individuals made the study stronger. Also, another strength is that the similarity in education levels and the wide age range of the individuals that participated in the study (18-59) makes it easier to generalize the results to wider populations.

CONCLUSION

The study revealed significant correlations between trunk muscle endurance, and trunk and periscapular muscle strength and neuromuscular control ability of the upper extremity. This indicates a complex interaction of factors in trunk and upper extremity physical performance. According to results of the study, high upper extremity rotation test, upper extremity closed kinetic chain test and upper extremity Y-balance test performances were associated with high trunk extensor, flexor and lateral flexor muscle endurance scores. These findings have drawn the attention of clinicians and coaches who want to improve individuals' upper extremity performance to the importance of trunk muscle endurance. The positive linear correlation between upper extremity performance and trunk muscle endurance suggests that assessing trunk muscle endurance and incorporating exercises targeting trunk muscle development into the training and rehabilitation programs could be beneficial in enhancing upper extremity muscular performance.

Ethics Committee Approval / Etik Komite Onayı

The approval for this study was obtained from Ankara Yıldırım Beyazıt University Health Sciences Ethics Committee (Decision no: 06-273, Date: 14.06.2023).

Conflict of Interest / Çıkar Çatışması

The authors declared no conflicts of interest with respect to authorship and/or publication of the article.

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Author Contributions / Yazar Katkıları

Concept – BB; Design – BB; Supervision – BA, ŞTÇ; Materials: AA; Data Collect on and/or Processing – BB; Analysis and İnterpretation –AEY ; Literature Review – BB, BA; Writing manuscript – BB, BA, SS; Critical Reviews – BA, ŞTÇ, AA, BB. All authors contributed to the final version of the manuscript and discussed the results and contributed to the final manuscript.

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