

On the Analysis of Factors Affecting Static Balance Ability

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Abstract: This study investigates the correlation between static balance ability and various segmental fat-to-muscle ratios, waist-to-hip fat ratios, and body morphology, aiming to provide guidance for improving static balance, enhancing athletic training, and preventing injuries related to balance deficits. A total of 47 students from the Department of Physical Education at Jinzhong College, including 26 males and 21 females, were selected as subjects, and body composition, body morphology, and balance ability were measured using the Youjiu Health X-ONE PRO analyzer. Results showed a significant negative correlation between one-leg standing time with eyes closed and total body fat, left lower limb fat, and waist-to-hip fat ratio ($r < 0.05$), while no significant correlation was observed with total body muscle mass, segmental muscle mass, shoulder-to-waist difference, leg length, leg-to-body ratio, or body weight ($r > 0.05$). These findings indicate that balance ability is a complex function influenced not only by muscle strength but also by body fat distribution and neural regulation. Therefore, improving balance ability requires not only muscle-strengthening exercises but also body fat management and targeted balance training.

Keywords: static balance; body composition; body shape; college student

1. Introduction

Static balance ability is a fundamental component for maintaining posture, performing daily activities, participating in sports training, and preventing accidental events such as falls. In daily life, people constantly engage in activities such as standing, walking, sitting, or transitioning between postures, all of which rely on static balance to maintain stability and correct alignment. Efficient balance control allows the body to respond to internal and external perturbations, such as sudden shifts in body weight or uneven surfaces, and is therefore critical for both safety and functional independence. Moreover, static balance ability is crucial for sports performance. Athletes frequently need to maintain body stability in a static or quasi-static state to execute precise technical movements, adjust to opponents' actions, and implement tactical strategies effectively. In sports such as gymnastics, martial arts, shooting, and archery, even minor deficits in static balance can significantly compromise performance outcomes.

In addition to athletic applications, static balance plays a vital role in rehabilitation medicine. Patients recovering from musculoskeletal injuries, neurological disorders, or surgeries often exhibit impaired balance, which can hinder functional recovery and delay reintegration into daily life. Improving static balance can facilitate neuromuscular coordination, postural control, and proprioceptive function, thereby accelerating rehabilitation and reducing the likelihood of re-injury. A decline in static balance ability is also closely associated with an increased risk of falls, particularly in older adults or individuals with certain medical conditions. Falls can lead to fractures, traumatic injuries, or long-term disability, and interventions that enhance balance are known to reduce both injury incidence and associated healthcare costs.

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Since the mid-19th century, research on human balance has attracted considerable attention in sports medicine and kinesiology, focusing on factors such as vestibular function, somatosensory input, core strength, lower limb strength, and joint stability. Most studies indicate that static balance ability is positively correlated with muscle strength [1] and negatively correlated with body fat percentage [2]. While previous research has extensively examined the relationship between lower limb or core muscle strength and balance ability, relatively few studies have systematically investigated how segmental muscle mass or fat distribution influences balance. Segmental analysis, considering fat and muscle distribution in specific regions such as the lower limbs, trunk, and upper body, may provide more nuanced insights into how body composition affects postural stability [3,4].

Therefore, this study employs the Youjiu Health X-ONE PRO analyzer to measure body composition, body morphology, and balance ability. By examining the relationships between balance ability, segmental fat and muscle mass, waist-to-hip fat ratio, and body morphology, this research aims to provide a more detailed understanding of the physiological and morphological factors that contribute to static balance. The ultimate goal is to offer evidence-based guidance for improving static balance, optimizing athletic training programs, and developing interventions to prevent injuries associated with balance deficits, thereby supporting both health promotion and performance enhancement.

2. Research Objects and Methods

2.1. Research Objects

This study focused on factors influencing static balance ability. The experimental subjects consisted of 47 physical education majors, including 26 males and 21 females, with the gender distribution designed to facilitate analysis of potential differences between males and females. The participants had an average age of 21 years, an average height of 172 cm, and an average weight of 65 kg. The detailed basic information of the experimental subjects is presented in Table 1.

Table 1. Basic Information of Experimental Subjects (N=47).

Gender	Age (years)	Number	Height (cm)	Weight (kg)
Male	20.85 ± 1.46	26	178.77 ± 5.72	73.03 ± 7.73
Female	19.95 ± 0.92	21	163.76 ± 5.58	55.96 ± 6.65

Subjects were required to follow specific pre-experiment protocols to minimize confounding variables. They were instructed to ensure adequate sleep prior to testing, avoid any physical discomfort, refrain from consuming alcohol or undergoing medical treatments within 24 hours, maintain a normal diet while avoiding spicy or highly stimulating foods, and abstain from eating for at least two hours before testing. These measures were implemented to reduce the influence of temporary physiological or metabolic fluctuations on balance measurements.

During the experiment, participants were closely monitored for any signs of discomfort or adverse reactions. In such cases, testing was immediately terminated, and appropriate medical attention was provided to ensure participant safety. These stringent inclusion and monitoring criteria were adopted to enhance the reliability and validity of the data collected.

2.2. Research Methods

Body composition, body morphology, and balance ability were measured using the Youjiu Health X-ONE PRO analyzer, a device capable of providing precise and segmental assessments of muscular and adipose tissue distribution as well as postural stability. All testing was conducted in the physiology laboratory under controlled environmental conditions to minimize potential interference from external light, noise, or other distractions.

Prior to formal testing, participants were briefed on the procedures and safety precautions, and were allowed to practice each test once or twice to familiarize themselves with the equipment and reduce variability due to learning effects. Participants wore minimal clothing to ensure accurate recognition by the device and were instructed to sit quietly for one minute before testing to stabilize physiological conditions.

For body composition assessment, participants were initially weighed, then held the device handles with both hands while stepping on the electrode plates with both feet, maintaining an upright posture and keeping arms fully extended until the measurement was complete. This procedure enabled accurate recording of total and segmental muscle and fat mass. During body morphology measurements, participants followed device prompts, standing with arms naturally at their sides, feet together, and head facing forward, while adjusting body orientation as instructed to allow comprehensive assessment of morphological parameters such as limb length, shoulder-to-waist difference, and leg-to-body ratio.

For the single-leg closed-eye standing test, participants raised their arms to shoulder level, lifted the right foot so that the thigh was parallel to the ground, closed their eyes, and attempted to maintain balance until the pivot foot shifted or the body tilted. The test ended automatically at that point, with a maximum record of 25 seconds. Each participant performed the test three times, and the highest value was used for subsequent analysis. This testing protocol, combining advanced measurement instruments with standardized procedures and professional data processing techniques, was designed to provide a comprehensive analysis of the relationships between static and dynamic balance abilities and morphological indicators, offering empirical support for related research and a scientific basis for promoting the physical health of college students.

2.3. Statistical Processing

All collected data were organized using EXCEL and statistically analyzed using SPSS 27.0. Normality tests were conducted to verify the suitability of parametric analyses. In line with previously established statistical methods, Pearson correlation analysis was applied to evaluate relationships among single-leg closed-eye standing time, body composition, body morphology, and other relevant variables. Independent samples t-tests were performed to compare male and female participants; no significant differences in standing time were observed between genders. Consequently, subsequent analyses combined data from both males and females to increase statistical power and generalizability [5,6].

Overall, the study design emphasized methodological rigor and innovation, ensuring objectivity and reliability of the results. This approach provides a solid foundation for accurately identifying the factors associated with static balance ability and offers comprehensive theoretical and practical guidance for interventions aimed at improving postural stability and overall physical health among college students.

3. Research Results and Analysis

3.1. Correlation between Static Balance Ability and Segmental Muscle Mass

The correlation between total body muscle mass, segmental muscle mass, and single-leg closed-eye standing time is presented in Table 2. The results showed no significant t ($P < 0.05$). Previous studies have found that improving lower limb muscle strength positively impacts balance ability and that enhancing the strength of lower limb flexors and extensors can significantly improve both dynamic and static balance. However, muscle mass, as measured in this study, differs conceptually from muscle strength. Muscle mass refers to the amount of muscle in the body, whereas muscle strength reflects the force generated during muscle contraction, which depends not only on muscle mass but also on neuromuscular function. The current experimental results indicate that total and segmental muscle mass are not correlated with static balance ability.

Table 2. Correlation Analysis of Various Indicators with Single-Leg Closed-Eye Standing Time.

		Weigh ht (kg)	Fat Mass	Mus- cle Mass	Central Seg- ment Muscle	Left Lower Limb Muscle	Upper Limb Mus- cle	Central Fat Mass	Left Lower Limb Fat	Upper Limb Fat	Waist- to-Hip Fat Ratio	Leg- to- Body Ratio	Shoul- der-to- Waist Diff.	Leg Length
Single-Leg Closed-Eye Standing Time	Pear- son Cor- rela- tion	-.163	-.316*	-.036	-.070	-.037	-.073	-.302*	-.299*	-.170	-.328*	.073	.214	.015
		.273	.030	.810	.642	.802	.628	.039	.041	.252	.025	.624	.149	.921

3.2. Correlation between Static Balance Ability and Segmental Fat Mass

Table 2 shows that single-leg closed-eye standing time was significantly negatively correlated with total fat mass (* $r^* = .030$, $P = .030$), left lower limb fat mass (* $r^* = .041$, $P = .041$), and central fat mass (* $r^* = .039$, $P = .039$) ($P < 0.05$), but not with upper limb fat mass ($P > 0.05$). These findings suggest that body fat distribution and accumulation may affect balance ability. Central fat accumulation can shift the body's center of gravity, increase instability, and thus reduce balance. Excessive fat may also affect neural sensitivity and conduction velocity, further impairing balance ability [2]. However, this does not imply that simply reducing fat mass will necessarily improve balance.

3.3. Correlation between Static Balance Ability and Body Morphology Indicators

Single-leg closed-eye standing time was not significantly correlated with shoulder-to-waist difference, leg-to-body ratio, or leg length ($P > 0.05$), indicating that these morphological indicators may have limited influence on static balance ability. Due to limitations such as not accounting for the dominant limb and relying solely on the single-leg closed-eye standing test, these results may not fully represent overall static balance. Future research should control additional variables to improve validity.

3.4. Correlation between Static Balance Ability and Waist-to-Hip Fat Ratio

Single-leg closed-eye standing time was significantly negatively correlated with waist-to-hip fat ratio (* $r^* = .025$, $P = .025$). The waist-to-hip fat ratio reflects fat distribution, particularly central obesity. In Asia, the average waist-to-hip ratio is 0.81 for men and 0.73 for women, with central obesity defined as ≥ 0.9 for men and ≥ 0.85 for women [7,8]. A high ratio often indicates excessive abdominal and visceral fat, which can reduce balance ability and negatively affect overall health.

3.5. Relationship between Static Balance Ability and Body Weight

Single-leg closed-eye standing time was not significantly correlated with body weight ($P > 0.05$). Previous studies have reported a negative correlation between body weight and balance ability [6]. The lack of significance in this study may be due to the relatively small sample size.

In summary, these findings provide important insights into the physiological mechanisms underlying balance ability and have practical implications for sports training, rehabilitation, and public health. For athletes, controlling body fat, particularly central fat, may help improve balance and enhance performance. For the elderly or patients in rehabilitation, improving balance is critical for fall prevention and quality of life [9]. Interventions such as dietary management and appropriate exercise may effectively improve balance ability.

This study has several limitations. First, the sample size is relatively small and may not fully represent the population. Future research should expand the sample size. Second, only fat mass, muscle mass, body morphology, and their distribution were considered;

other factors such as age and exercise habits were not included. Third, the single-leg closed-eye standing test used a maximum limit of 25 seconds, while other studies consider 30-60 seconds as good and over 60 seconds as excellent [10]. Therefore, more diverse testing methods are recommended to better assess static balance ability and improve reliability.

4. Suggestions for Improving Balance Ability in the College Student Population

Balance ability is a complex function that not only relies on muscle strength but is also affected by multiple factors such as body fat distribution and neural regulation. Therefore, in practice, improving balance ability requires not only strengthening muscle exercise but also focusing on the management and control of body fat and carrying out targeted balance training to improve neuromuscular coordination.

When discussing measures to improve the balance ability of the college student population, it is necessary to analyze various influencing factors in depth. Based on this, a series of targeted improvement strategies are proposed, aiming to enhance physical stability, reduce the risk of injury, and improve sports performance and health.

4.1. Enhance Lower Limb Muscle Strength

An important strategy is to strengthen lower limb muscles. Research has shown that the strength of lower limb muscles is crucial for maintaining good balance. Therefore, college students are recommended to participate in regular strength training, especially exercises targeting the leg muscles. These exercises can include squats, heel raises, and leg exercises using resistance tools such as elastic bands. Gradually increasing training intensity and complexity can effectively enhance muscle strength and improve balance ability.

4.2. Enhance Core Strength

Core strength training should also not be overlooked. Earlier studies indicate that core strength is crucial for maintaining good posture and balance. Therefore, college students are recommended to perform exercises to enhance core strength, such as yoga, aerobics, or gymnastics. These activities not only improve the strength of core muscles but also enhance flexibility and coordination [11].

4.3. Perform Balance Training

Balance training should also be part of daily exercise. It has been suggested that unstable surface training can significantly improve balance ability. This training can include single-leg standing exercises or balance exercises on unstable surfaces, such as balance pads or wobble boards. Such exercises improve proprioception—the perception of body position and movement—which is crucial for maintaining balance [12].

4.4. Reasonable Diet

In addition to exercise and training, diet is essential. Adequate nutritional intake is important for maintaining muscle mass and bone health. College students are recommended to ensure sufficient protein intake, as well as foods rich in vitamin D and calcium, to support muscle and bone health.

4.5. Specific Environment Training

Environmental adaptability training is also important. Prior work shows that visual training is helpful for improving balance ability. This involves training students to maintain balance in different environments, such as under dim lighting. By simulating various situations that may occur in daily life, students can become more confident and stable when facing such conditions [13].

In summary, through the comprehensive application of core strength training, balance exercises, reasonable diet, and environmental adaptability training, students can effectively improve static balance ability. This provides a systematic plan to enhance balance, reduce injury risk, and improve overall quality of life, enabling more active participation in sports while maintaining health.

5. Conclusion

This study aimed to explore the relationship between single-leg closed-eye standing time and various body morphological indicators and body composition. Through empirical analysis, it was found that balance ability showed no significant correlation with physiological indicators such as body weight, total body muscle mass, and segmental muscle mass, nor with morphological indicators, but it had a significant negative correlation with total body fat mass and its distribution. This finding emphasizes the impact of body fat distribution, especially the accumulation of fat in the central region and legs, on balance ability.

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