World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(RESEARCH ARTICLE)

Check for updates

Correlation between dynamic balance ability and lower limb muscle strength of university students

Hongshuai Leng, Xingyu Shi *, Huihui Wang, Aochuan Xue, Longmin Meng, Zhaohong Zeng and Xianjun Zha

School of Physical Education and Health, Zunyi Medical University, Zunyi Guizhou, 563000.

World Journal of Advanced Research and Reviews, 2022, 14(03), 423–430

Publication history: Received on 06 May 2022; revised on 12 June 2022; accepted on 14 June 2022

Article DOI: https://doi.org/10.30574/wjarr.2022.14.3.0546

Abstract

Objective: To study the correlation between dynamic balance ability and lower limb muscle strength of university students.

Methods: 50 students of Zunyi Medical University (23 boys and 27 girls) were selected as the subjects. The dynamic balance ability of university students was tested by the YBT test system. Isokinetic muscle strength tester tests knee flexion and extension muscle strength under different angular velocity conditions.

Results: 1) At different angular velocities, there was a moderate positive correlation between knee flexion and extension muscle strength and YBT reaching all directions. Only when the angular velocity was set to 200° / s, there was a low positive correlation between knee flexion muscle strength and the front side of the YBT test. 2) There is a more significant correlation between the maximum distance of each direction of dynamic balance and the peak torque of knee extensor than that of flexor.

Research conclusions: For university students, there is a significant indigenous correlation between the directions of YBT arrival, and the correlation between the posterolateral and the posterolateral is stronger. The stronger the lower limb muscle strength is, the better the dynamic balance ability is, and the correlation between dynamic ability and knee extensor muscle strength is higher, which may be related to the fact that knee flexion control balance can more effectively activate knee extensor muscle group. University students generally have bilateral asymmetry of the lower limbs.

Keywords: University Students; Dynamic Balance; Isokinetic Muscle Strength; Knee Joint

1. Introduction

As the most important component of the human body for spatial mobility, the lower extremity is the basic condition for maintaining the body's standing and walking movements, and muscle strength is an important factor affecting balance. The lower extremity YBT (Y-balance test) is an injury risk screening tool that can be used to identify deficits in neuromuscular control and balance as well as core stability, and has a high reliability in assessing the dynamic balance of subjects [1].The YBT consists of 3 different distal reach directions (anterolateral, posteromedial and posterolateral) and is used to assess dynamic balance. In the YBT test, when the difference between the two sides of the forward reach distance is ≥ 4 cm, it indicates that the subject will be at a significantly increased risk of potential injury[2]. Isometric muscle strength tester (Iso Med 2000) has become an effective muscle training and testing instrument because of its safety and effectiveness, and its test index has high reliability and repeatability[3-4]. At present, the main research

* Corresponding author: Xingyu Shi
School of Physical Education and Health, Zunyi Medical University, Zunyi Guizhou, 563000.

direction for the relationship between muscle strength and balance mainly focuses on the relationship between the support side and the muscle strength of each lower limb joint in athletes, patients with injuries and ordinary people, and the most tested joint is the knee joint, and there is less research on the relationship between unilateral knee muscle strength and bilateral dynamic balance. In this experiment, the relationship between dynamic balance ability and knee flexion and extension muscle strength at different angular velocities was analyzed by conducting lower limb YBT and isometric muscle strength tests on 50 students in Zunyi Medical University to understand the relationship between dynamic balance ability and muscle strength of college students, and to provide scientific and reasonable theoretical basis for the development of sports training programs and prevention of sports injuries.

2. Research object and method

2.1. Object

Fifty students (23 male and 27 female) from Zunyi Medical University were selected as the experimental subjects. The average age of male students was 19.67±0.86 years old, and the average BMI was 22.4±3.56 kg/m2, while the average age of female students was 19.04±1.26 years old, and the average BMI was 21.66±2.95 kg/m2.

2.1.1. Inclusion criteria

- Age: 17-22 years old
- No serious muscle injury within six months (injury recovery time <10 days [5]); No history of genetic disease and good physical condition
- No strenuous exercise 24 hours before the test, no muscle fatigue or discomfort
- Active cooperation with the experiment and voluntary participation in the experiment

2.1.2. Exclusion criteria

- Serious muscle injury within six months (injury recovery time ≥ 10 days)
- History of genetic disease
- Irregularities in sleep, diet and other life
- Strenuous exercise 24 hours before the test, muscle fatigue and discomfort
- Not actively cooperate with the conduct of the experiment

2.2. Research Methodology

2.2.1. Data Acquisition

Dynamic balance ability related data collection

The YBT test system was used to test the anterolateral, medial posterior, and posterolateral reach distances of the subject's lower limbs. The lower extremity YBT test, as a valid method to assess the dynamic balance of the human body [6], mainly assesses the stability of the body posture of the contralateral limb when doing distal extension movements in different directions with unilateral support [7].Test procedure:

- Test lower limb length: lying on the back (feet shoulder-width apart), pelvis in neutral position, lower limbs straight, hip in neutral position, measure the distance from the anterior superior iliac spine to the lower edge of the medial ankle of the right lower limb;
- the subject stands with shoes off and the left thumb aligned directly in front behind the point of the center transverse line, hands cannot support objects;
- the right leg extends forward as far as it can 3 times to take the maximum value, then switch to the left leg and repeat 3 times;
- The right leg reached backward inward as far as it could 3 times, taking the maximum value, and then change to the left leg and repeat 3 times;
- The right leg reached backward outward as far as it could 3 times, taking the maximum value; then change to the left leg and repeat 3 times [8] . The indexes collected were: the maximum values of the anterior, medial and lateral posterior maxima of the left and right limbs, and the maximum difference between the left and right limbs in each direction. The whole test was supervised by two testers to complete the assessment recording.

Knee joint muscle strength acquisition

The Iso Med 2000 isokinetic test apparatus was used to test the subject's knee joint. The test procedure: (1) The subject sits on the test seat and holds the handle next to the seat, adjusting the seat backrest at 80°; (2) The pelvis and thigh of the tested leg are fixed with a fixation strap, the shoulder joint is fixed with a shoulder pad, and the axis of rotation of the instrument is aligned with the axis of rotation of the knee joint (lateral epicondyle of the femur). The arm of the instrument lever is fixed at the distal end of the tibia and the tibial pad is placed in the lower 1/3 of the calf; (3) Before measuring the right leg, the individual seat settings are stored in PC memory and the test is automatically activated during measurement of the left leg and subsequent tests[9]. In this experiment, static gravity correction was applied, and the range of motion was set to 10-90°of knee flexion (0°for full extension). 60°/s and 200°/s angular velocities were selected for the test, and flexion and extension movements at each angular velocity were tested five times with an interval of 30 s each, in the order of low to high speed, and all assessment tests were performed on the right lower extremity, using standardized indexes uniformly. The indexes collected were 60°/s and 200°/s peak flexion and extension moments (peak torque, PT) of the knee joint. The test was performed by two fixed individuals to ensure the accuracy of the test.

2.2.2. Mathematical and statistical methods

SPSS 26.0 software was used for statistical analysis, and the test data were tested for differences, and the results were expressed in the form of $\bar{x} \pm s$. One-way ANOVA was used for multiple group comparisons; Pearson correlation data were used to analyze the correlation between the test indicators, and correlation coefficients r in the range of 0.00 to 0.30 were low correlations, 0.31 to 0.49 were moderate correlations, 0.50 to 0.69 were high correlation, 0.70 to 0.89 very high correlation, and 0.90 to 1.00 approximate linear correlation [10], with a significance level of $P < 0.05$.

3. Study results

3.1. Dynamic balance ability test results

As shown in Table 1, the YBT test of the lower extremities of college students showed that the closest arrival distance of the left and right extremities was anterior, and the farthest arrival distance was posterior-lateral, and there were significant differences between the farthest arrival distances in each direction.

Table 1 Comparison of test results between the left and right lower limb YBT directions and the difference in maximum anterolateral reach distance

	Front side（cm）	**Rear inner side（cm）**	**Rear outer side（cm）**	**p**
Left lower extremity	60.12±7.57^{ab}	90.7±10.90^{c}	98.6±11.53	0.00
Right lower extremity	61.06±7.45^{ab}	91.6±10.80^{c}	99.7±10.04	0.00

Note: (a anterolateral-posterior medial p<0.05, b anterolateral-posterior lateral p<0.05, c posterior medial-posterior lateral p<0.05, p<0.05 with significant difference)

As can be seen from Table 2: when the left side was supported, the test side showed a very high positive correlation between posterior medial-posterior lateral (p<0.01), a moderate positive correlation between both anterior medial-posterior and anterior lateral-posterior lateral (p<0.01); when the right side was supported, the test side showed a very high positive correlation between posterior medial-posterior lateral (p<0.01), a high positive correlation between anterior medial-posterior lateral (p<0.01) and moderate positive correlation between anterolateral-posterior lateral (p<0.01).

Table 2 Relationship between the maximum arrival distances on the front side, inside and outside of the rear of the YBT

Support side	**Anterolateral - posterior medial**	**Anterolateral - Posterolateral**	**Posterior medial - posterior lateral**
Left side	0.49**	0.38**	0.86**
Right side	0.52**	0.37**	0.85**

Note: (* represents with significant difference ** represents with very significant difference Correlation coefficient r in 0.00 to 0.30 is low correlation, 0.31 to 0.49 is moderate correlation, 0.50 to 0.69 is high correlation, 0.70 to 0.89 is very high correlation, 0.59 to 1.00 is approximate linear correlation)

From Table 3, the number of subjects reaching out the maximum distance difference >4cm, it can be seen that the number of boys testing anterolateral difference >4cm was 7 and the number of girls testing anterolateral difference >4cm was 10.

Table 3 Number of men and women with the maximum distance difference between left and right lateral protrusion >4cm (number)

	men	**women**
Maximum distance of extension>4cm	7	10

Knee muscle strength test results

As can be seen from Table 4: the knee extensor muscle strength was significantly greater than the flexor muscle strength at different speeds ($p<0.05$)

Table 4 Comparison of peak moments of knee flexors and extensors tested at different angular velocities

Angular velocity（°/s）	**Flexor（Nm）**	**Extensor（Nm）**	**p**
60	98.87±30.09[a]	128.00±39.39	0.00
200	96.86±31.90[a]	104.80±41.36	0.02

Note:(a indicates $p<0.05$, significant difference between flexion and extension muscle strength)

3.2. Results between dynamic balance ability and isometric knee flexion and extension muscle strength

From Table 5, it can be seen that: when the isometric test apparatus was set at an angular speed of 60°/s and the YBT test was supported on the right side, the knee flexor and extensor muscle strength were moderately positively correlated with each index of the anterior, posterior medial and posterior lateral YBT test ($p<0.01$); when the angular speed was 200°/s, the knee flexor and extensor muscle strength were moderately positively correlated with each index of the anterior and posterior lateral YBT, and between the flexor and posterior medial YBT ($p<0.01$); when the angular speed was 200°/s, the knee flexor and extensor muscle strength were The positive correlation was moderate ($p<0.05$); the positive correlation between flexor muscle and YBT posterior medial test indexes was low ($p>0.05$), based on the above, it can be seen that there is a positive correlation between dynamic balance ability and lower limb muscle strength in college students, and there is a more significant correlation between YBT test anterior and posterior lateral and muscle strength than between posterior medial and muscle strength ($p<0.05$).

Table 5 Correlation between YBT right-sided support left lower limb test and muscle strength results

		Front side	**Rear inner side**	**Rear outer side**
60°/s	Flexor	0.27	0.38**	0.47**
	Extensor	0.43**	0.41**	0.49**
200°/s	Flexor	0.37**	0.24	0.33*
	Extensor	0.46**	0.34*	0.41**

Note: (* indicates a correlation between $p<0.05$ YBT and muscle strength test ** indicates a correlation between YBT test and muscle strength test at $p<0.01$ level)

As shown in Table 6, when the angular velocity was set at 60°/s and the YBT was supported on the left side, there was a moderate positive correlation ($p<0.01$) between the knee flexor and extensor muscle strength and the posterior medial and posterior lateral indices of the YBT, and between the extensor and anterior indices of the YBT, and a low positive correlation ($p>0.05$) between the flexor and anterior indices of the YBT; when the angular velocity was 200°/s, there was a moderate positive correlation ($p<0.05$) between the knee flexor and extensor muscle strength and the anterior and posterior medial indices of the YBT. Extensor muscle strength showed a moderate positive correlation ($p<0.05$) with each of the YBT anterolateral and posterior lateral indicators and between extensor and posterior medial indicators, and a low positive correlation ($p>0.05$) between flexor and YBT anterolateral indicators. As shown in Table 5 Table 6, there was a positive correlation between the YBT test indexes and the extensor muscle strength at each angular velocity ($p<0.05$).

Table 6 Correlation between YBT left-sided support right lower limb test and muscle strength results

		Front side	Rear inner side	Rear outer side
60°/s	Flexor	0.33*	0.33*	0.48**
	Extensor	0.48**	0.39**	0.48**
200°/s	Flexor	0.38**	0.23	0.31*
	Extensor	0.49**	0.33*	0.46**

Note: (* indicates a correlation between p<0.05 YBT and muscle strength test ** indicates a correlation between YBT test and muscle strength test at p<0.01 level)

4. Analysis and Discussion

4.1. Dynamic balance capability analysis

The YBT test has high requirements on the subject's lower limb balance, flexibility, movement stability and core stability, etc. The farther the tested side reaches, the better the subject's balance ability. It was also found that if the difference between the left and right side of the YBT test forward reach distance was greater than 4 cm, the risk of injury would increase to 2.5 times[8].The results of this test showed that the anterior reach distance was the closest, which may be related to the use of a greater degree of hip flexion, and some studies have shown that the anterior extension support side requires the most closed chain ankle dorsiflexion due to [11-12], which may also be related to the lack of quadriceps muscle strength, and the distance of anterior extension is also related to the strength of the hip abductors, with the gluteus medius playing a major role[13]; Knee extensors and hip abductors explained the anterior and posterior medial reach distances, while hip extensors explained the posterior medial and posterior lateral reach distances[14] , and the highest degree of correlation between posterior medial-posterior lateral in the YBT test can be seen from the experiment, which may be related to the similar degree of knee flexion angles of the mobilized hip and support leg; 17 of 50 subjects (7 males and 10 females) The asymmetry between the left and right limbs (the difference between the left and right limbs reaching the maximum value ≥ 4 cm) may be due to the unbalanced strength of the knee flexion and extension muscles, which cannot complete the whole process of knee flexion and extension better, or it may be related to the different utilization rates of the left and right limbs during daily production work and training, which in turn manifests as poor overall lower limb muscle strength and The lack of dynamic balance increases the risk of sports injuries. This reminds us of the importance of exercise to avoid changes in the body shape of university students and to reduce the occurrence of asymmetries [15]. When playing unilateral limb sports (e.g., badminton, tennis, etc.), the strengthening exercises for the non-dominant limb should be strengthened, so that the muscle strength difference between the dominant and non-dominant limbs can be stabilized within the normal range through the balanced development of both limbs to improve their sports performance and reduce the incidence of sports injury risk.

4.2. Analysis of isometric knee flexion and extension muscle strength in college students

The isokinetic tester can test the muscle strength of many kinds of joints. The main reason for choosing the knee joint as the strength test in this experiment is that the knee joint is the most complex of all joints in the human body, and the increase of muscle strength of its surrounding muscle groups can effectively reduce joint injury and prevent the occurrence of injury [16], and the knee joint is one of the main joints involved in the assessment of dynamic balance ability, while its surrounding The knee joint is one of the main joints involved in dynamic balance assessment, and its surrounding muscle groups are also an important guarantee to maintain the balance of the knee joint, so the knee joint was selected as the index of lower limb muscle function. By testing the knee flexor and extensor muscle strength in college students, it was found that knee extensor muscle strength was significantly greater than flexor muscle strength, which is consistent with previous studies [17]. Studies have shown that angular velocities higher than 120°/s may increase the error between tests [18], which suggests that human movement is more effective in recruiting muscles at low speeds; studies have confirmed that extensor muscle strength of the knee joint has a very significant role in stabilizing the athlete's landing and has the highest contribution to ensuring the stability of the center of gravity [19], so it is recommended that while focusing on the good development of extensor muscle strength of the lower limbs, it is also important to Therefore, it is recommended that the development of the knee flexor muscles should be strengthened along with the development of the lower extremity extensor muscles, so that they can better participate in sports through a comprehensive and balanced development, which will improve the performance and quality of sports, and thus prolong the "life span" of sports. In training, it is important not only to improve the centripetal force of the non-dominant anterior femoral group, but also to improve the centrifugal force of the non-dominant posterior femoral

group, so that the anterior quadriceps can give full play to its acceleration role, improve the quality of movement, and also prevent knee injuries [20].

4.3. Correlation analysis between dynamic balance ability and isometric knee flexion and extension muscle strength

The peak moment, as one of the most commonly used indexes in isometric muscle strength testing, can represent the maximum muscle force during joint flexion and extension muscle contraction, and also the different angles of joint movement are different for the degree of muscle recruitment, knee flexion and extension muscle contraction is mainly done by the quadriceps and posterior femoral group muscles, the main function of the extensor muscle is jumping movement, and the main function of the flexor muscle is the deceleration of the lower limb, as well as the domination of knee extension The main function of the flexors is the deceleration of the lower limb and the dominance of the knee extension to maintain its stability [21]. It has been suggested that there is a strong link between motor performance and muscle morphology [22], and when the right side is the supporting side, the anterior, posterior medial, and posterior lateral YBT movement tests are performed, the quadriceps muscle is mainly stimulated to fire to maintain body balance, while corresponding to the knee extensor muscle group in the isometric test. When the left side is the support side and the right side is forward, it also mainly stimulates the extensor muscle group of the right leg. From the results, it can be seen that there is a moderate positive correlation between the test index of each direction of YBT and the knee extensor muscle strength at different angular velocities. In addition, it is not only the motor system that works during exercise, but also the nervous system is one of the important "participants". The control of balance is a complex, multisystemic mechanism that requires the joint participation of the sensory and motor systems" [23]. Through the muscle system to maintain the basic form of the body and provide the power of movement, through the sensory system to control the balance of the body, and for proprioceptive training can effectively improve people's dynamic balance [24]. In our usual sports, dynamic balance ability and muscle strength are closely related, and good balance perception and muscle strength can enable people to have better performance and achieve better results in sports. This study confirms that there is a significant positive correlation between dynamic balance ability and lower limb muscle strength in college students, which indicates that the development of muscle strength should not be neglected while increasing the development of balance ability through the training of vestibular stability to adapt to the sports involved through coordinated development of each other, and the motor and nervous systems of the body should be fully activated before performing sports to reduce the risk of sports injury. At the same time, the coordinated development of balance and muscle strength training should be emphasized to enable better athletic performance in sports.

5. Conclusion

- There was a significant correlation between dynamic balance ability and lower extremity muscle strength in college students, with a low correlation between posterior medial and angular velocity of 200°/s flexor maximum muscle strength only when supported on the right side.
- There was a more significant correlation between the peak knee extensor muscle moment and the distance reached in each direction of dynamic balance than the peak flexor muscle moment, which may be related to the fact that knee flexor control balance activates the knee extensor muscle group more effectively.

Compliance with ethical standards

Acknowledgments

We thank the teachers of Zunyi Medical University for their great help and support for this experiment, and we thank the experimenters who participated in the experiment for their rigorous work attitude and the patients' active cooperation with the experiment without fear of hardship. We thank the Zunyi Medical University for supporting the project, and thank the Zunyi Medical University students entrepreneurship training project (ZYDC2020141) to provide funding.

Disclosure of conflict of interest

The authors have no conflflicts of interest to disclose. There is no conflict of interest in this experiment, and all issues of interest to the experiment were agreed upon by the authors, and the ranking of project authors was performed.

Statement of informed consent

Each participant signed a statement of informed consent obtained from all individual participants included in the study.

References

[1] Shaffer SW, Teyhen DS, Lorenson CL, et al. Y-balance test: a reliability study involving multiple raters [J].Mil Med. 2013; 178(11): 1264-1270.

[2] Smith CA, Chimera NJ, Warren M. Association of y balance test reach asymmetry and injury in division I athletes [J].Med Sci Sports Exerc. 2015; 47(1): 136-141.

[3] van Dyk N, Bahr R, Whiteley R, et al. Hamstring and Quadriceps Isokinetic Strength Deficits Are Weak Risk Factors for Hamstring Strain Injuries: A 4-Year Cohort Study[J].Am J Sports Med. 2016; 44(7): 1789-1795.

[4] Zhang JY, Wang YY, Wang CHF, et al, Age and gender characteristics of knee flexor-extensor muscle strength in healthy adults based on isokinetic technique [J], Chinese Journal of Rehabilitation Medicine. 2020; 35(01): 54-59.

[5] Bond CW, Dorman JC, Odney TO, et al, Evaluation of the Functional Movement Screen and a Novel Basketball Mobility Test as an Injury Prediction Tool for Collegiate Basketball Players[J], J Strength Cond Res. 2019; 33(6): 1589-1600.

[6] Tang Qiao, Zhang HZ, Correlation study of dynamic balance ability with bilateral knee muscle strength and lower limb explosive strength in athletes of integrated sports [J], China Sports Science and Technology. 2019; 55(05): 65-71+80.

[7] Gribble PA, Hertel J, Plisky P, Using the Star Excursion Balance Test to assess dynamic postural-control deficits and outcomes in lower extremity injury: a literature and systematic review [J], J Athl Train. 2012; 47(3): 339-357.

[8] Gao Xiaojiao, Xu Hui, Huang Peng, et al, Study on the assessment criteria of Y-balance test for rugby players in China [J], Chinese Journal of Sports Medicine. 2018; 37(03): 233-236+217.

[9] Lehnert Michal, Svoboda Zden☑k, Cuberek Roman, THE CORRELATION BETWEEN ISOKINETIC STRENGTH OF KNEE EXTENSORS AND VERTICAL JUMP PERFORMANCE IN ADOLESCENT SOCCER PLAYERS IN AN ANNUAL TRAINING CYCLE[J], Acta Universitatis Palackianae Olomucensis, Gymnica. 2013; 43(1).

[10] Lockie RG, Callaghan SJ, Jordan CA, et al, Certain Actions from the Functional Movement Screen Do Not Provide an Indication of Dynamic Stability [J], J Hum Kinet. 2015; 47: 19-29.

[11] Lisman P, Nadelen M, Hildebrand E, et al, Functional movement screen and Y-Balance test scores across levels of American football players [J], Biol Sport. 2018; 35(3): 253-260.

[12] Horn T, Brogden C, Greig M, Isokinetic profiling of elite youth footballers: informing selection of a practicable and efficacious isokinetic screening test [J], Res Sports Med. 2021; 1-12.

[13] Norris B, Trudelle-Jackson E. Hip- and thigh-muscle activation during the star excursion balance test. J Sport Rehabil. 2011. 20(4): 428-41.

[14] Nelson S, Wilson CS, Becker J, Kinematic and Kinetic Predictors of Y-Balance Test Performance [J], Int J Sports Phys Ther. 2021; 16(2): 371-380.

[15] Wang HH, , Xue A, Chuan Leng HS, et al, The effects of physical inactivity on college students' physical fitness in the context of physical health education [J], Contemporary Sports Technology. 2021; 11(35): 31-33.

[16] Wang Dong-need, the effect of functional training on the muscle balance of knee flexors and extensors in classical wrestlers [D]: Shandong Institute of Physical Education. 2020.

[17] Huang DAW, Liu L, Zhu X, et al, Isometric muscle strength characteristics of lower limb joints in female short distance speed skaters [J], Chinese Tissue Engineering Research. 2018; 22(36): 5803-5810.

[18] Delitto A, Rose SJ, Crandell CE, et al, Reliability of isokinetic measurements of trunk muscle performance [J], Spine (Phila Pa 1976). 1991; 16(7): 800-803.

[19] Dong JG, Liu JR, Cui JM, Research on isometric muscle strength characteristics of trunk, knee and ankle joints and static balance ability of excellent male trampoline players[J], Bulletin of Sports Science and Technology Literature. 2021; 29(04): 133-137.

[20] Liang YJ, Li ZY, Su LQ, et al, Bilateral isometric muscle strength characteristics of knee joints in high-level youth male badminton players [J], Journal of the Capital Institute of Physical Education. 2021; 33(06): 623-629+648.

[21] Wang Tao, Effects of soccer training on lower limb muscle strength in male college students [D]: Hangzhou Normal University. 2020.

[22] Özgünen K, Özdemir Ç, Adaş Ü, et al, Effect of repeated sprint training on isokinetic strength parameters in youth soccer players[J], Isokinetics and Exercise Science. 2021; 29(3): 343-351 [J],

[23] JI Zhongqiu, ZHANG Zihua, PANG Bo, et al, Exercise biomechanical study on the effect of exercise intervention on human postural control ability [A]. 2021.

[24] Shi Honggen, Yuan Wenxiao, Effects of proprioceptive exercises on balance ability of adolescent artistic gymnasts [J], Contemporary Sports Technology. 2019; 9(33): 24-26.