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The Validity of Anaerobic Power Test for Explosive Power - A Case Study of Wingate Experiment

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Abstracts: Research objectives: the purpose of this paper is to verify the validity of Wingate anaerobic power bicycle test for measuring explosive force. Through the laboratory accurate test of the explosive force of lower limbs, the validity of the explosive force measurement method is provided. Research methods: This study carried out Wingate experiment and RM longitudinal jump experiment with different loads on 15 undergraduates in track and field selected from College of Physical Education and Health of Guangxi Normal University. For the longitudinal jump test data, the peak average power obtained by summarizing and calculating the peak power of the lower limb of the vertical jump was selected. For the Wingate test data, the average power of the 0-5s time interval was selected (the peak power appeared in the 0-5s time interval). the experimental data obtained from Wingate anaerobic power test and longitudinal jump test with different loads were processed, compared and analyzed, and the normality test and correlation analysis were carried out. the results showed that there was significant correlation between the data of Wingate anaerobic power test and the longitudinal jump test. the correlation analysis of the data of the two groups showed that the correlation coefficient was 0.774, P=0.001, a significant correlation at the 0.01 level, indicating a positive correlation between anaerobic power and lower limb power. Research conclusions: the Wingate anaerobic power test can be used as an effective method to measure explosive power, and the measured data is valid.

Keywords: Wingate Anaerobic Power; Power Bicycle; Explosive Power; Lower Limb Explosive Force

1. Introduction

1.1 Research Background

In all sports events, besides the related techniques and tactics, the most important thing is the athlete's physical quality, the athlete's athletic ability is the foundation of completing the difficult technical movement. In many competitive sports events, the lower limb explosive force of athletes is required extremely high [1]. For example: running, jumping, throwing and so on with the lower limbs as the dominant project. Explosive force is the basic physical quality of athletes to improve their competitive level and athletic ability. Explosive force is a kind of fast force, the human body muscles against certain load when producing muscle tension, the force produced makes the action object produce rapid displacement [2]. Therefore, explosive force plays a very important role in the sports events dominated by strength, so explosive force is the key quality for athletes to win in competitive events [3].

The training and the optimization of the training plan are helpful to improve the athletic ability and competitive level of the athletes. At present, there are few literatures about Wingate test in China, and there is a lack of research about using Wingate test to evaluate the explosive force of lower limbs. Therefore, the purpose of this paper is to use the Wingate test and the three-dimensional force measuring platform longitudinal jump test to test the subjects, to carry on the statistical analysis to the experimental data after the experiment, to carry on the correlation analysis to the two experimental data, and to explore the Wingate anaerobic power test to measure the validity of explosive force. It provides data reference for the measurement of explosive power. This paper summarizes the related literatures of explosive power and anaerobic metabolic capacity at home and abroad, which is helpful for the subsequent scholars to carry on the theoretical reference. This paper analyzes the commonly used test indexes for power evaluation, and makes the experiments of Wingate test and dynamometer test, and compares the correlation between the two-test data, which can provide data reference for related research on power measurement.

1.2 Study on the Evaluation Index of Lower Limb Explosive Force

For the definition of explosive force, experts and scholars believe that explosive force is the strength expressed by muscles against resistance and the relationship between speed, power and time. It can be considered that the explosive force is the human body muscle in a certain load and time, the fastest movement of the body muscle contraction fully to produce the maximum muscle strength capacity. Maximum power, maximum acceleration and rapid force are only the external expressions of explosive force acting on external objects. It is believed that explosive force is the ability to resist resistance by producing maximum strength through maximum effort in the process of completing a certain movement [4]. Muscle explosive force refers to the ability of the muscle to convert chemical energy into mechanical energy in a short time and output the maximum mechanical power under reasonable working conditions. Through biomechanics analysis of explosive force, it is pointed out that explosive force should not only emphasize the muscle contraction force and contraction time [5], but also compare the muscle force under the condition of certain load overcome by the muscle and certain muscle contraction speed. the greater the muscle strength, the greater the explosive force [6]. Some scholars used the 30-meter sprint, standing long jump, vertical jump, 5×15-meter turnback, 10-yard sprint and T test for comparative analysis. the three-dimensional dynamometer was used to measure the influence of double-legged vertical jump on the lower limbs after multiple training of youth football players [7]. Speed-based strength training can improve the explosive force of lower limbs of sprinters more effectively [8].

1.3 Current Status of Research On Anaerobic Metabolic Capacity Measurement

The Wingate test has high effectiveness in measuring anaerobic power, and is easy to operate, practical and non-injurious to the tester. Therefore, Wingate test has become the most used method in measuring anaerobic power at present [9]. However, the experimental site, temperature, subjects of different ages, different populations, the degree of seriousness of the subjects to the experiment, and the proportion of the anaerobic metabolic energy supply system will affect the experimental results. Therefore, the accuracy of the experimental data can be improved by dealing with the factors that may affect the experimental results. Anaerobic metabolic capacity is the ultimate capacity of anaerobic metabolic energy supply system to provide energy for the body during exercise. [10]. In the two measurement methods, the physiological detection is more accurate, but the detection instrument is expensive, the operation is complicated and easy to cause certain damage to the subjects. Compared with physiologic testing, kinetic testing is more practical, simple and non-invasive, so kinetic testing is popular in practice [11]. Some domestic scholars believe that muscle oxygen is highly correlated with anaerobic power, and the quiet value of muscle oxygen can reflect anaerobic power [12]. Foreign scholars from the upper limb 30s Wingate test. the analysis of the change of anaerobic power can provide data reference for targeted training and reasonable periodic training plan, and comprehensively improve the athletic ability and performance of remote mobilization [14]. In addition, the standing long jump test can also be used as a method to measure anaerobic power of lower limbs of athletes [15].

1.4 Summary

At present, most experts and scholars have adopted a simple measurement method for the measurement of explosive force of lower limbs, including: Standing long jump, vertical jump in place, run-up jump, short sprint run, etc. A small number of experts use more precise instruments to measure, such as using three-dimensional dynamometer to measure the explosive movements of the lower limbs such as squat jump and half squat jump, and analyze the movement data of the tester experiment by using system software. At present, most of the research on the measurement of anaerobic power used indirect measurement. the maximum anaerobic power of the subjects was measured by the Wingate anaerobic power bicycle. (generally, in the first 5s of a 30s test) the average power and fatigue index were used to assess the exercise capacity of the subjects. But at present, there is a lack of research on using anaerobic power test to evaluate explosive power. This study draws on the previous research results, designs an experimental plan, carries on Wingate anaerobic power test experiment and vertical jump experiment, and compares the two groups of experimental data to analyze their correlation.

2. Research Methodology

2.1 Documentation Method

In this study, we searched CNKI, web of science, pub med and other databases and searched the relevant keywords, and classified, summarized and selected the retrieved articles. Most of them aim to study the effect of different training methods on the explosive force of lower limbs of athletes. After the experimental intervention, the explosive force data of subjects' lower limbs were obtained by simple testing methods such as squat, 30-meter sprint, standing long jump, vertical jump and more accurate three-dimensional dynamometer. Methods of anaerobic metabolism, anaerobic power, and power cycling were used to provide data and information related to this paper. Through the research of literature, journals and related data, we can understand the research status of this paper, and provide theoretical basis for the design and writing of this paper.

2.2 Experimental Method

2.2.1 Subject

In this experiment, 15 undergraduates of track and field majoring in physical education of School of Physical Education and Health of Guangxi Normal University were recruited as experimental subjects (the subjects were all male students). They were required to have certain strength training foundation, no serious injury or illness, and all of them volunteered to participate in this experiment. the following **Table 1** lists the basic information about the experimental objects.

Table 1. Subject Basic Information Table

Number of persons	sex	Age (year)	Height (cm)	Weight (kg)
15	male	21 ±1	1.74±0.05	68.53 ±6.49

2.2.2 Experimental instruments, software and equipment

The instruments used in the explosive force experiment include the infrared motion capture system of Qualisys Company, 8 high-speed infrared cameras, infrared reflective Marker ball and AMTI force measuring table. Two three-dimensional force-measuring tables produced by AMTI company are adopted. (L x W x H: 1800x400x82.55 mm, USA, model: 2 m) Monark 894E power bicycle, Monark power meter, notebook computer, made in Sweden.

The precision instruments and software such as QTM processing software and Visual3D analysis software are used to collect and analyze the data of vertical jump experiment. The Monark 894E power bike is equipped with anaerobic power test software for calculating anaerobic power.

The equipment required for the experiment is specially thickened and cushioned barbell bar and supporting barbell piece, elastic band, foam shaft, yoga mat, and test record form.

2.2.3 Lower extremity power test

(1) Test contents

The multi-joint longitudinal jump of the test table was performed with 20% 1RM, 30% 1RM, 40% 1RM, 45% 1RM, 50% 1RM, 55% 1RM, 60% 1RM, 65% 1RM.

(2) Preparations before the experiment

Before the experiment, the subjects were informed of the site and time of the experiment and informed of the formal experiment. Do not take part in vigorous exercise, drink alcohol and stay up late, and wear sports clothes with reflective logos. Upon arrival at the test site, the subject filled in his/her name, date of birth, height and weight and signed the informed consent form. After completing the basic information, the tester instructed the subjects to do pre-experimental warm-up activities, which included: Jogging, hands akimbo jump in place, barbell bar weight jump, leg lift, hip flexion and extension with elastic band. Warm-up is mainly aimed at lower limb muscle groups to avoid injury during the test. Formal experiments can be conducted after full warm-up.

(3) Acquisition of dynamic and static data signals

The first step is to collect the static data signal of the subject, and the static data signal needs to be measured before the acquisition

Calibration and parameter calibration of the force stations and the surrounding test sites that may be involved, with reference to the 3D force station system

Mark placement of the lower extremities was performed on the subjects. After the placement, check whether the placement of the placement points is correct and stable. After the completion of the inspection, the test personnel guide the subject to stand by the force measuring table and get ready. A total of 36-mark points needs to be attached. During static data signal acquisition, the subject heard the tester's "Ready" command, with his hands crossed over his shoulders, stood at the designated position of the dynamometer to get ready. At the hearing of the "Start" command, the subject was asked to face the HD camera and stand still in the designated position. When the subject hears the "End" command, it indicates that the static data information collection is complete and the subject walks out of the dynamometer. the second is the acquisition of dynamic data signals. After the acquisition of static model data, 8 reflective Mark points of the medial and lateral femoral condyles of both feet were removed.

(4) Test process

Before the test for each subject, the testers will guide the subject's movements and practice the passwords, and conduct a complete step simulation for the subject on the dynamometer according to the formal experimental procedure. After the subject finishes the learning of the experimental steps and masters the essentials, the formal test can be conducted. When the subject heard the tester give the "ready" command, the subject walked to the prepared barbell frame, held the barbell steadily, and then stood by the dynamometer. the subject entered the dynamometer and stood stably at the designated position, then the subject performed hip-knee-ankle flexion to the most suitable force-generating angle, and then performed explosive vertical jumps with the hip-knee-ankle extension with extreme strength until the toes just left the ground. Then naturally end the vertical jump and stand steady. Upon hearing the tester's "end" command, the subject stepped out of the force table and returned the barbell to its original position. During the entire vertical jump, the subject performed a coherent, rapid, explosive lower limb flexion to stretch to complete the vertical jump.

(5) Test requirements

During the whole process, two testers stand on both sides of the subject to protect the subject to avoid safety accidents during the experiment. the selection of barbell weights starts with the subject being able to complete three weights close to his/her maximum load, and increases until the subject can complete only one correct action, which is the subject's maximum load of 1RM. Finally, after the test is completed, the tester needs to observe the feed back experimental image record of the three-dimensional force measuring platform system, confirm that the subject completes the correct action, and record the experimental data in the corresponding record table for later data analysis and processing. At the same time, the subjects were instructed to use yoga mats and foam rollers to stretch and relax the lower limb muscles and relieve the muscle fatigue caused by the vertical jump test.

2.2.4 Wingate Anaerobic Power Bike Test

(1) Test contents

Subjects obey the test while conducting the formal test the person arranged and completed a full 30 s pedaling cycle, and when the maximum speed was reached, the subject was required to continue full pedaling for 30 s under a load of 0.075 kg/kg body weight [16].

(2) Test requirements

Before the test, the tester leads the subject to 10 to 15 minutes of preparation activities, including: Jogging, tucking between marching, high leg lift between marching, high leg lift joint acceleration run, back pedal run, small step run. After the warm-up, the lower extremity muscle groups were dynamically stretched for 1-2 minutes to fully activate the lower extremity muscle groups

Ride the bike under the guidance of the test person and adjust the height of the bike seat and handlebars according to your height

Fasten the buckle on the bicycle pedal when you get to the position you think is most comfortable. When the subject is ready, the tester

The participants were introduced to the use of the power bike, and the participants' hips were not allowed to leave the seat during the formal experiment.

(3) Test process

After the subjects fully understand the test methods and requirements, they are allowed to pedal for 3 to 5 minutes. After the subjects are fully adapted to the experimental instruments, they can conduct formal experiments. During the experiment, the subjects raised their hands to give their names, and the testers made records, and then the subjects got on their bikes and prepared for debugging. When hearing the tester's "start" command, the subjects immediately started pedaling their bikes without any negative. During the experiment, the testers clapped their hands and shouted to encourage the subjects to complete the anaerobic power test for 30s with the maximum ability. Finally, when the subject hears the "end" command, the subject is required to continue pedaling for 3 to 5 minutes, rather than braking immediately, to prevent injury and relieve fatigue in the lower limb muscle groups. After getting out of the car, the subjects used yoga mats and foam rollers to massage and relax the muscles of the lower limbs according to the tester's instructions to relieve muscle fatigue. the testers record the experimental data of the software system feed back of the anaerobic power bicycle in the corresponding table and wait for the later analysis and processing of the experimental data.

2.3 Mathematical Statistics

Input the basic information of the subjects and the corresponding experimental data into Excel form and save well, and sort out and calculate the peak average power of the lower limb explosive force test and Wingate test. the collated data were entered into SPSS 27. The mean, standard error and 95% confidence interval of the two experimental data were calculated by statistical analysis software, and the normal distribution test and correlation analysis were performed.

3. Research Results and Analysis

3.1 Analysis of Peak Average Power Data of Wingate Anaerobic Power and Vertical Jump Power

After SPSS26.0 and QTM processing software and Visual3D analysis software analyzed the measured data one by one, and obtained the results of vertical jump lower limb peak average power and Wingate power bicycle test, as shown in the following **Table 2**;

Table 2. Peak Average Power of Vertical Jump Test and Power Value of Wingate Test (unit: W)

Subject	Lower limb explosive force experiment	Wingate experiment	Subject	Lower limb explosive force experiment	Wingate experiment
ex-xx	1593.814(W)	599.44(W)	Zhao xx	2332.1558(W)	704.55(W)
Qin xx	1828.48(W)	579.53(W)	Kuang xx	2023.1513(W)	605.4(W)
Li xx	1751.858(W)	562.78(W)	Yang xx	1709.516(W)	536.22(W)
Chapter X	1540.799(W)	588.03(W)	King XX	1701.9978(W)	766.91(W)
Wei xx	1266.3473(W)	361.27(W	Sun xx	1367.5662(W)	491.92(W)
Ding xx	1364.9462(W)	304.58(W)	Tomaka xx	1261.6066(W)	468.5(W)
Hu xx	2059.5596(W)	783.73(W)	Zou xx	1759.3003(W)	627.55(W)
			He xx	1375.5981(W)	425.18(W)

In the data analysis, we first analyzed the characteristics of the data from Wingate experiment and vertical jump. Through SPSS27.0 software, we calculated the mean, standard error and 95% confidence intervals and performed the normal distribution test. the mean of Wingate experiment data is 560.3727 and the standard error is 136.17112, while the mean of vertical jump experiment data is 1662.446337 and the standard error is 313.9446965. Both groups of data were consistent with normal distribution, which provided a reliable basis for further correlation analysis. the inspection results are shown in **Table 3** below;

Table 3. Normality Test

Experiment Name	Average	standard error	95% confidence interval	Sample size	P value
Wingate experiment	560.3727	136.17112	(484.9636, 635.7817)	15	0.894
longitudinal jump test	1662.446337	313.9446965	(1488.5895591836.303115)	15	0.403

Note: indicates that $P > 0.05$ Data conform to normal distribution.

3.2 Correlation Analysis of Peak Average Power Data of Wingate Anaerobic Power and Longitudinal Jump Explosive Force Experiment

In the correlation analysis, we found a significant positive correlation between the peak average power of the Wingate test and the longitudinal jump test. This finding suggests that the Wingate anaerobic power test can be an effective method for measuring lower limb explosive force [17]. This result has important implications for practical applications in the field of sports science, as it provides a simple, practical, and non-injury testing method that can be used to assess lower limb explosive force of athletes. A correlation analysis result is shown in **Table 4** below.

Table 4. Correlation Analysis Results

Experiment Name	Sample size	correlation coefficient	P value
Longitudinal jump experiment/Wingate experiment	15	0.774	P=0.001

Table Note: " " was significantly associated at the 0.01 (two-sided) level. N is the experimental sample size.

To sum up, the measurement and evaluation of anaerobic metabolic capacity mainly include direct measurement and indirect measurement. Although the data of direct measurement is more accurate, the indirect measurement which is easy to operate, practical and non-damage is preferred because of its high cost and complicated operation. Among the relevant research on anaerobic power test, the data of anaerobic power measured by Wingate test have high validity and reliability. Wingate test is widely used in anaerobic power test of athletes in various events, and the data can accurately assess the athletic state and athletic performance of athletes [15]. Among the anaerobic power test methods, Wingate test is more popular in practice.

4. Conclusion

(1) Based on the above analysis, we conclude that: Wingate anaerobic power test is an effective method to measure explosive power, and its measurement data is valid. This finding provides a new tool for physical training and athlete assessment that can help coaches and athletes to more accurately assess and improve lower limb explosive strength.

(2) At the same time, there are limitations in this study, due to the limited sample size of this study, a more extensive comparison between samples was not possible. Therefore, we suggest that future studies should expand the sample size to include subjects of different genders, ages, and exercise levels to further validate the generality and applicability of the Wingate test. In addition, we recommend that special attention should be paid to the safety of the subjects when performing longitudinal jump experiments to ensure that adequate protection measures are in place to prevent injury during the experiment.

(3) This study provides a scientific basis for the application of Wingate anaerobic power test in measuring explosive power, and provides a valuable reference for future research and practice. From the experimental data, it can be concluded that: the Wingate anaerobic power test can be used as an effective index to measure explosive power, and the experimental data are valid.

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