Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/mjafi

Original Article

Comparison between Standing Broad Jump test and Wingate test for assessing lower limb anaerobic power in elite sportsmen

Lt Col Anup Krishnan^{a,*}, Col Deep Sharma^b, Col Madhu Bhatt^c,
Col Apoorv Dixit^d, P. Pradeep^e

^a Medical Officer (Sports Medicine), Army Sports Institute, Pune 411036, India

^b Classified Specialist (Physiology), Command Hospital (Southern Command), Pune 411040, India

^c Senior Adviser (Physiology), Military Hospital Jhansi, UP, India

^d Col (Adm), Armed Forces Medical College, Pune 411040, India

^e Resident, Department of Sports Medicine, Armed Forces Medical College, Pune 411040, India

ARTICLE INFO

Article history:

Received 25 February 2016

Accepted 11 November 2016

Available online 23 December 2016

Keywords:

Wingate test

Standing Broad Jump

Elite sportsmen

Field test

ABSTRACT

Background: Lower limb explosive power is an important motor quality for sporting performance and indicates use of anaerobic energy systems like stored ATP and Creatine phosphate system. Weightlifting, Fencing and Wrestling use it for monitoring and identification of potential sportsmen. The Wingate test and Standing Broad Jump (SBJ) test are reliable and accurate tests for its assessment. This study conducted on elite Indian sportsmen tries to analyse feasibility of use of the SBJ test in sports and military medicine when Wingate test is impractical.

Methods: 95 elite sportsmen (51 Fencers, 17 Weight lifters and 27 Wrestlers) of a sports institute were administered Wingate cycle ergometer test and SBJ under standardised conditions. The results were analysed for mass and inter-discipline correlation.

Results: Analysis using Pearson's correlation showed significant positive correlation between Peak power ($r = 0.446$, $p < 0.0001$) and SBJ (distance) in all sportsmen. Inter-sport correlation showed positive correlation between SBJ and peak power ($r = 0.335$, $p < 0.016$) in Fencers and between SBJ, peak power ($r = 0.686$, $p < 0.002$) in Weightlifters. Bland–Altman plot analysis showed that about 94% pairs of peak power and SBJ were within limits of agreement for each discipline as well as among all sportsmen.

Conclusion: The test results show definite correlation and SBJ test can be used as a field test in performance monitoring, talent identification, military recruit screening and injury prevention.

© 2016 Published by Elsevier B.V. on behalf of Director General, Armed Forces Medical Services.

* Corresponding author:.

E-mail address: faujidoc@rediffmail.com (A. Krishnan).

<http://dx.doi.org/10.1016/j.mjafi.2016.11.003>

0377-1237/© 2016 Published by Elsevier B.V. on behalf of Director General, Armed Forces Medical Services.

Introduction

Anaerobic power is a critical component of success in sport and is important for performance in events where short-term explosive efforts are made. Alactic anaerobic power is vital in many sports like 100 m sprint, Weight lifting, Boxing, Wrestling, Fencing, etc. where highly explosive movements are required lasting up to approximately 8 s. High intensity exercise in short duration sports requires an immediate energy supply.¹ Energy is fuelled by immediate energy system (i.e. ATP and Creatine phosphate system) without significant contribution from the glycolytic pathway.¹

Anaerobic power tests are implemented in both clinical and field settings to assess an athlete's capability to produce both power and speed in a short period of time or over a relatively short distance.

The Wingate Cycle ergometry test and Standing Broad Jump (SBJ) tests are commonly used tests to assess lower limb power in sportsmen for the purpose of providing vital information regarding anaerobic performance of sportsmen in a given sports. Wingate test and SBJ test rely on the capabilities of ATP/PC energy system which contributes to maximum anaerobic power.

The Wingate anaerobic test is a valid and reliable test.^{2,3} The Wingate anaerobic test on a cycle ergometer has been used in laboratory settings for assessment of anaerobic performance.² The test was designed to be simple to administer, non-invasive, intended to measure muscle performance, safe to assume the peak power which is a reflection of the ability of the legs to produce high amounts of mechanical power. But it is an expensive method and requires equipment which is not feasible for administration to a wide variety of population.²

SBJ test is a commonly used field test to assess explosive leg power.⁴ Due to its simple and time-efficient implementation that does not require any equipment,⁵ it is routinely used by coaches of several sports for talent selection, measurement and prediction of anaerobic power. Wakai and Linthorne divided SBJ performance (distance) into three parts: (a) the take-off distance, which is defined as the horizontal distance between the take-off line and the jumper's centre of mass at the instant of take-off, (b) the flight distance, which is the horizontal distance travelled by the centre of mass while airborne and (c) the landing distance, which is defined as the distance between the centre of mass and the heels of the feet at the instant of landing.⁶

SBJ performance is highly correlated with physical characteristics, such as lean leg volume.⁷ The distance that is achieved has a direct correlation with the amount of force that is produced by muscle fibres. Compared to Wingate cycle ergometer test, this test is inexpensive, easy to assess and since equipment is minimal, it can be easily used as a field test.³

Assessment of anaerobic power by various tests has been studied; however, no single test has been identified as an inexpensive and reliable indicator of anaerobic power. Wingate cycle ergometers are expensive and require trained manpower. This prevents this test from being used as a screening and monitoring tool extensively.

The main objective of this study is to determine if the results of the SBJ test can be correlated with Wingate test so that a reliable and inexpensive test is available for athlete monitoring, talent identification and military recruit screening.

Materials and methods

An exploratory study was conducted in an elite sports training institute between February and August 2014. The study was approved by the Institute Ethics committee. Male sportsmen between the ages of 18–26 years, who were involved in 6 months of regular training and participated in national level competition of three sports discipline namely Fencing, Weightlifting and Wrestling, were included in the study. In all 95 sportsmen, which include 51 Fencers, 17 Weightlifters and 27 Wrestlers, were selected for the study. Sportsmen who had history of hospitalisation for more than 2 weeks in the last 3 months due to any reason, suffering from any acute illness or injury during the time of the study and those who did not participate in training in the preceding 2 weeks were excluded from the study.

Monark Cycle Ergometer with Wingate testing software (894 E) was used to measure an absolute and relative peak power by Wingate test. Measuring tape, weighing machine and chalk were used to measure length of leap by SBJ along with anthropometric measurements viz. height (cm), weight (kg) for each of these sportsmen.

Testing procedure

The participants were tested over 2 days to enable enough time for recovery between the tests. Each participant was interviewed by an investigator during which all risks, benefits and the necessity of conducting the study were explained in detail. Participants who fulfilled the inclusion and exclusion criteria were encouraged to ask questions and sign the consent forms. Random selection was done and SBJ was performed on day 1. Wingate cycle ergometer test was conducted on day 2.

Day 1: SBJ test

On the day prior to the performance tests, participants were advised to abstain from intense exercise. On each performance testing day, participants performed a standardised warm-up that included 5 min jogging and 5 min dynamic stretches. Each subject stood on the starting line with their legs parallel and feet shoulder-width apart. Participants were instructed to bend the knees (the depth of the flexion was self-selected) and bring the arms behind the body. Then, with a powerful drive they extended their legs, moved the arms forward and jumped as far as possible. The distance jumped was measured in centimeters.

Day 2: Wingate cycle ergometer test

Warm-up was given for 5 min in an intermittent manner (alternating 30 s exercise with 30 s rest). The warm-up was

done on a cycle ergometer to promote more specific physiological and motor adaptation.

On the command “Start”, the subject pedalled as fast as possible without any resistance. It takes 3–4 s to reach maximum speed. Once the maximum speed was achieved, a predetermined load, that is, 7.5% of body weight in kg was applied and the participant was coaxed to maintain the pedalling for 30 s. Verbal encouragement was given throughout the test. Any attempt to conserve energy during the last few seconds was discouraged.

Cooling down was done by 2–3 min of pedalling against a light resistance immediately following the test. The results were obtained in graphical form as in Photo 1 and in numerical values.

The data measured were absolute peak power expressed in Watts (W) and relative peak power expressed in W/kg as shown in Photo 2.

Statistical analysis

Summary statistics including mean and standard deviation were calculated. Pearson's correlation was used to assess correlation of SBJ (cm) with peak power (W/kg) for all sportsmen and also for each discipline. Bland–Altman plot analysis was used to measure agreement between two different measures SBJ and peak power as an anaerobic capacity of sportsmen. The z-scores were calculated for SBJ and peak power as the difference between a value in the sample and the mean, and divided by the standard deviation.

z-Scores of peak power were plotted on X axis against z-scores of SBJ on Y axis for perfect line of agreement plots. Difference between the z-values of two measures SBJ and peak power were plotted on Y axis against their mean values on X axis for Bland–Altman plots of agreement for sportsmen and each discipline. The limits of agreement were calculated as mean ± 1.96 std deviation of the difference between the z-scores of two measures SBJ and peak power and plotted on Y axis. 95% confidence interval (95%CI) for limits of agreement was also calculated for mean of the difference between z-scores of two measures.

One sample t-test was applied to test if mean of the difference of between the results of two methods SBJ and peak power is zero. Repeated measures ANOVA was used to test within sample variability in the results of two methods SBJ and peak power.

Table 1 – Discipline-wise summary statistics of age, SBJ and peak power.

Discipline	Age (years)	SBJ (cm)	Peak power (W/kg)
	Mean (SD)	Mean (SD)	Mean (SD)
Fencing (n = 51)	20.7 (5.32)	254.0 (19.30)	10.9 (1.48)
Weight lifting (n = 17)	17.9 (6.19)	253.4 (28.20)	12.0 (1.74)
Wrestling (n = 27)	21.0 (3.19)	241.2 (16.32)	10.2 (1.23)
All (n = 95)	20.3 (5.07)	250.3 (20.97)	10.9 (1.57)

All statistical analysis was done in SPSS version 20.0 for Windows (SPSS Inc, Chicago, IL, USA). Statistical significance was set at $p \leq 0.05$.

Results

Mean age of fencers was 20.7 years, weight-lifters was 17.9 years and wrestlers was 21.0 years. SBJ performance was 254 cm in fencers, a similar 253.4 cm in weight-lifters and 241 cm in wrestlers. Peak power was 10.9 W/kg among fencers, 12.0 W/kg among weight-lifters and 10.2 W/kg among wrestlers (Table 1).

SBJ was significantly positively correlated with peak power ($r = 0.446$, $p < 0.0001$) among all sportsmen. Discipline-wise, statistically positive correlation between SBJ and peak power was observed among fencers ($r = 0.335$, $p = 0.016$) and weight-lifters ($r = 0.686$, $p = 0.002$). Correlation was not significant ($r = 0.264$, $p = 0.183$) among wrestlers.

In Bland–Altman plot analysis, mean of the difference between results of two methods SBJ and peak power and 95% CI for fencers was 0.000 (95% CI: -0.3241 to 0.3241), weightlifters was -0.0015 (95% CI: -0.4085 to 0.4056) and wrestlers was 0.0035 (95% CI: -0.4771 to 0.4841). Mean difference was -0.003 (95% CI: -0.2146 to 0.2140) for all sportsmen. One sample t-test results showed that mean difference between SBJ and peak power was significantly close to zero among all disciplines and also all sportsmen (Table 2).

Bland–Altman plots are shown in Fig. 1. Among weightlifters, all points of SBJ and peak power were within limits of agreement. Four percentage points among wrestlers and 8% points among fencers were outside limits of agreement. Overall, 6% points of SBJ and peak power were outside the

Table 2 – Discipline-wise Bland–Altman plot values.

Bland–Altman plot values	Fencing	Weight-lifting	Wrestling	All
n	51	17	27	95
mean (diff)	0.0000	-0.0015	0.0035	-0.0003
SD (diff)	1.1523	0.7917	1.2149	1.0520
Mean (diff) – $1.96 \times \text{SD}$ (diff)	-2.2586	-1.5531	-2.3777	-2.0622
Mean (diff) + $1.96 \times \text{SD}$ (diff)	2.2586	1.5502	2.3847	2.0617
Test statistic for mean (diff) and p-value	$t_{50} = 0.000$, $p > 0.999$	$t_{16} = -0.008$, $p = 0.994$	$t_{26} = 0.015$, $p = 0.988$	$t_{94} = -0.002$, $p = 0.998$
95% CI for mean (diff)	-0.3241 to 0.3241	-0.4085 to 0.4056	-0.4771 to 0.4841	-0.2146 to 0.2140
95% CI for mean (diff) – $1.96 \times \text{SD}$ (diff)	-2.8161 to -1.7010	-2.2629 to -0.8433	-3.2094 to -1.5460	-2.4297 to -1.6947
95% CI for mean (diff) + $1.96 \times \text{SD}$ (diff)	1.7010 to 2.8161	0.8404 to 2.2600	1.5530 to 3.2163	1.6941 to 2.4292
% of points lie outside agreement lines	8%	0%	4%	6%

Fig. 1 – Discipline-wise Bland-Altman plots of agreement.

limits of agreement among all sportsmen, and showed that results by using both the tests were agreeable.

Repeated measures ANOVA results showed that within subject variation in the results of two methods SBJ and peak power was statistically not significant ($p = 0.288$). Mean square error (MSE) calculated through repeated measures ANOVA was 0.526 (95% CI: -0.896 to 1.948).

Discussion

In the present study, the subjects were Weightlifters, Wrestlers and Fencers. This study indicates moderate correlation between Peak power as tested by Wingate test and SBJ in all the sportsmen tested with certain inter sports discipline variations. The results of this study appear to be consistent with other studies examining power performance in both a Standing Broad Jump test and Wingate test⁸ and between the Wingate test and Vertical jump in Basketball players.^{9,10} In the present study, the subjects were elite sportsmen whereas previous studies were done on college students. Elite sportsmen by virtue of their training programme are likely to provide more reliable results.

There is good consonance between correlation of Peak power as measured by Wingate test vis-à-vis the SBJ distance. There is overall (all Sportsmen) positive correlation between the Peak power and SBJ distance. This finding was also supported by Bland–Altman plots, about 94% points of peak power and SBJ were within limits of agreement. There was no within subject variation between two measures SBJ and peak power among all sportsmen.

The present study finding shows that in Weightlifting, SBJ and Wingate test results are more correlated than in Wrestling and Fencing ($r = 0.6$). The results in Weightlifters although suggest that there is strong correlation and agreement between peak power as tested by Wingate test and SBJ test, the mean difference between these two methods was statistically significantly close to zero. In Fencers, there is weak correlation between peak power (W/kg) and SBJ (cm). This variation can be explained by the fact that Weightlifters totally depend upon anaerobic explosive power during competition and training session¹¹ while Wrestlers and Fencers are not totally dependent upon explosive power during their sporting activity. The explosive output of energy in a very short time as required in Weightlifting (power)¹² by the lower limb muscles is similar to the explosive power required during the act of SBJ. In case of Wrestling and Fencing, the energy output of muscular activity is more sustained as compared to Weightlifting and therefore the development of peak power is not to that extent. Our results also are in agreement to this fact.

Previous studies have demonstrated that there is significant correlation between Wingate and SBJ.⁸ The present results are also corroborative showing moderate correlation and strong agreement. Thus, SBJ is significantly in agreement with Wingate test in the estimation of lower limb peak power in trained elite sportsmen. However, in the absence of any Gold standard tests for anaerobic power, the application of the SBJ as a replacement to Wingate may require further studies.

Conclusion

The results suggest that SBJ tests can be accepted as valid field measures of anaerobic power in Wrestlers, Weightlifters and Fencers. It can be considered as a valid indicator to assess the power of lower limbs, monitoring power output gains after training, for early sports talent identification and as pre-recruitment tests in centres where Wingate testing ergometers are not available. Further research is indicated to further corroborate and confirm our findings and to develop correlation factors between the two tests.

Conflicts of interest

The authors have none to declare.

Acknowledgements

Col PS Cheema, VSM, Commandant and Mrs Uma Mahajan, Consultant Biostatistician, Army Sports Institute.

Supplementary data

Supplementary data (photos 1 and 2) associated with this article can be found, in the online version, at [doi:10.1016/j.mjafi.2016.11.003](https://doi.org/10.1016/j.mjafi.2016.11.003).

REFERENCES

1. Katch FI, Victor L. *Katch Exercise Physiology*. 7th ed. Wolters Kluwer; 2010.
2. Inbar O, Bar-Or O, Skinner JS. *The Wingate Anaerobic Test*. Champaign, IL: Human Kinetics; 1996.
3. Stauffer K, Nagle E, Goss F, Robertson R. Assessment of anaerobic power in female division I collegiate basketball players. *J Exerc Physiol*. 2010;13(1).
4. Moresi MP, Bradshaw EJ, Greene D, Naughton G. The assessment of adolescent female sportsmen using standing and reactive long jumps. *Sports Biomech*. 2011;10(2):73–84.
5. Burr JF, Jamnik RK, Baker J, Macpherson A, Gledhill N, McGuire EJ. Relationship of physical fitness test results and hockey playing potential in elite-level ice hockey players. *J Strength Cond Res*. 2008;22(5):1535–1543.
6. Pasand F, Keshavarz M, Mirzaei S, Zeinali Z. Evaluation of standing long jumping fundamental skill developmental sequence in children. *Int J Biol Pharm Allied Sci – IJBPA*. 2015;4(July (7)):4568–4578.
7. Davies BN. The relationship of lean limb volume to performance in the handgrip and standing long jump tests in boys and girls aged 11.6–13.2 years. *Eur J Appl Physiol*. 1990;60:139–143.
8. Almuzaini KS, Fleck SJ. Modification of the standing long jump test enhances ability to predict anaerobic performance. *J Strength Cond Res*. 2008;22(4):1265–1272.

9. Changela PK, Bhatt S. The correlational study of the Vertical Jump test and Wingate Cycle test as a method to assess Anaerobic Power in High School Basketball players. *Int J Sci Res Publ.* 2012;2(June (6)).
10. Hoffman JR, Epstein S, Merav E, Yitzhak W. A comparison between the Wingate anaerobic power test to both Vertical jump and Line drill tests in Basketball players. *J Strength Cond Res.* 2000;14(3):261-264.
11. Anton MM, Spirduso WW, Tanaka H. Age-related declines in anaerobic muscular performance weightlifting and powerlifting. *J Am Coll Sports Med.* 2004. 0195-9131/04: 3601-0143.
12. Otto III WH, Coburn JW, Brown LE, Spiering BA. Effects of weightlifting vs. kettlebell training on vertical jump, strength, and body composition. *J Strength Cond Res.* May 2012;26(6):1199-1202.

AWARDS FOR BEST PUBLISHED SCIENTIFIC PAPERS

1. The following awards will be presented during the 66th Armed Forces Medical Conference-2018 to be held at AFMC Pune in the month of Feb 2018:
 - (a) **Chief of the Army Staff Award** for best published article in the field of Pathology, Microbiology, Hematology & Biochemistry.
 - (b) **Chief of Naval Staff Award** for best published article in the field of **Medicine & allied specialities including Marine Medicine & Aviation Medicine.**
 - (c) **Chief of Air Staff Award** for published article in the field of **Surgery & allied specialities including Dental Surgery.**
 - (d) **DGAFMS & Sr Col Comdt Award** for best published article in the field of **Community Medicine including Epidemiology, Biostatistics, Health & Hospital Administration.**
2. Policy guidelines for the above awards have been issued vide O/o DGAFMS letter no. 17090/11/Policy/DGAFMS/DG-3B dated 01 Apr 2016.
3. Validity of paper: Article should have been published/accepted in the previous year i.e. Award being presented in Feb 2018 would be for the year 2017 and so the article should have been published/accepted in between 01 Jan 2016 and last date of submission (i.e. 31 Aug 2017). **The paper should have been approved by the office of DGAFMS before publication.**
4. The articles/papers should reach O/o DGAFMS through proper channel latest by 31 Aug 2017 accompanied by the following enclosures:
 - (a) One copy of the re-print of the published /accepted article along with abstracts.
 - (b) Name of the journal along with the impact factor (Thomson Reuters) in which the article has been published.
 - (c) No. of citations with proof thereof.
 - (d) Soft copy of the article.
 - (e) DGAFMS approval obtained for the article to be published in a journal other than MJAFI.