ScientificScholar®
Knowledge is power
Publisher of Scientific Journals

https://ijpp.com

Indian Journal of Physiology and Pharmacology

Original Article

Comparison between seated medicine ball throw test and Wingate test for assessing upper body peak power in elite power sports players

Anuj Kumar[1],Rupak Kumar Singh[2], Varad Vilas Apte[1], Amey Kolekar[1]

[1]Army Sports Institute, New Mundhwa Road, [2]Department of Physiology, Armed Forces Medical College, Pune, Wanowrie, Pune, Maharashtra, India.

***Corresponding author:**
Rupak Kumar Singh,
Department of Physiology,
Armed Forces Medical College,
Pune, Wanowrie, Pune - 411
040, Maharashtra, India.

rupaksingh83@gmail.com

Received : 26 August 2020
Accepted : 17 December 2020
Published : 27 February 2021

DOI
10.25259/IJPP_36_2021

Quick Response Code:

ABSTRACT

Objectives: Upper limb explosive power is an important motor quality for sporting performance and indicates use of anaerobic energy systems. The Wingate Anaerobic Test (WAnT) has been considered to be a valid and reliable tool for the assessment of anaerobic power and functional performance of elite athletes. However, it is expensive and a lab based test and requires skilled manpower. The seated medicine ball throw test (SMBT) is inexpensive, easy to assess and since equipment required is minimal, it can be easily used as a field test. Hence, the purpose of the study was to determine if the SMBT method could be used as an alternative for WAnT test so that a reliable and inexpensive test is available for athlete monitoring and talent identification screening.

Materials and Methods: Male elite athletes aged 18–30 years (n = 100), who were involved in national level competition of three sports discipline, namely, Boxing (n = 34), Wrestling Greco-Roman (GR) (n = 36), and Wrestling Freestyle (FS) (n = 30), were tested on crank-arm ergometer for WAnT and SMBT to measure an peak power or explosive power for the upper body.

Results: SMBT test results were significantly positively correlated with upper body peak power measured by WAnT in all sportsmen (r = 0.55, P = 0.0002). One sample t-test results showed that the mean difference between SMBT and peak power is close to zero among Boxers (P = 0.13) and FS wrestlers (P = 0.89) and GR Wrestlers (P = 0.49). Overall, 97% pairs of SMBT and peak power were within the limits of agreement among all sportsmen, showing that results using both the tests were agreeable.

Conclusion: This study suggests that SMBT tests could be used as an alternative field test to measure anaerobic power in Wrestlers, Boxers, and sports where the involvement of upper body muscles take place predominantly. In addition, the SMBT protocol used in this study provides an easy way for the coaches to assess the athletes on the field during talent identification and also to evaluate their training program.

Keywords: Boxers, Freestyle wrestlers, Greco-Roman wrestlers, Seated medicine ball throw test, Upper body anaerobic power, Wingate anaerobic test

INTRODUCTION

In sports, power has commonly been delineated as explosiveness, a combination of speed and strength.[1] Explosive power or alactic anaerobic power has been a game changing element in a wide range of sports mainly in power sports such as Boxing, Wrestling, Weightlifting, and Throwers, where a high amount of explosive power is required.[2,3] High-intensity activities in these sports need an immediate energy supply.[4] In many of these activities, explosive power

is generated by muscles of the lower extremities.[5] However, many athletic skills especially in the sports disciplines such as boxing and wrestling, presuppose explosive power of the upper body muscles vouched by lower body in the form of kinetic chain. In two type of wrestling style, that is, Greco-Roman (GR) and Freestyle (FS), superior upper body strength and anaerobic capacity in GR wrestling might be more beneficial for the initiation of moves and explosive execution of wrestling techniques because only upper body moves are allowed.[6] However, in freestyle wrestling as the move of both upper body and lower body is allowed. Hence, strength and power of both parts are required. Since there are two distinctive techniques involved, the physical fitness differences are also observed between freestyle and Greco-Roman Junior Wrestlers.[6] In amateur boxing, punching is an important component. To be productive, it requires a high level of both speed and power. In these circumstances, it has been suggested that the ability to produce high-level upper body muscular power is obligatory, in triumphant performance of elite amateur boxers.[7]

Although there are few tests to measure the explosive power of the lower extremities, there are very limited tests available to measure upper body explosive power. Some of the tests that have been used to assess the upper body explosive power include seated shot put (SSP),[8] Seated medicine ball throw (SMBT),[9] isokinetic testing instrument,[9] and upper body Wingate anaerobic test (WAnT).[10,11]

The WAnT has been shown to be a valid and reliable tool for the assessment of anaerobic power and functional performance of elite athletes[10,11] and clinical populations such as patients suffering from complete lower body paralysis.[12,13] The WAnT was majorly designed with intent to measure muscle performance through a simple, non-invasive, and safe method. It gives peak power, which is a reflection of the ability of the arms to produce a high amount of mechanical power. However, it is expensive and a lab based controlled method for the measurement of peak upper body power. Hence, it would not be wrong to say that most of the sports clubs or sports science facilities will not invest in the apparatus provided under extremely unavoidable circumstances.

The medicine ball throw (MBT) or SMBT has been used for more than thirty years and is still frequently used when assessing upper body power,[14-16] establishing baseline upper body power for pre/post-training studies[17] and as a criterion measure.[18] Despite use of SMBT for more than 30 years, there is a scarcity of literature with reference to test athletes of Indian origin and comparison of SMBT with gold standard methods such as WAnT. Compared to WAnT, this test is inexpensive, easy to assess and since equipment required is minimal, it can be easily used as a field test.

Assessment of anaerobic power of the upper body by various tests has been studied; however, no single test has been identified as an inexpensive and reliable indicator of anaerobic power. Although SSP is an acceptable field test of upper body power, none of the validity correlations seemed high enough to support that claim.[8] Despite being the gold standard test, due to above-mentioned reasons WAnT is not being used as a screening and monitoring tool on a large scale.

The SMBT also provides more close proximity of the movement which mimics the movement of the pushing mechanism which is similar to the nature of the games identified in this study. Hence, the kinetic chain of muscles involved is much similar to the coordinated movement of the SMBT.[19] This hypothetically gives us a better perspective of an athlete than the mechanized techniques of WAnT and other upper body isokinetic equipment used to validate the explosive power.

The main objective of the study was to determine if the SMBT method could be used as an alternative for WAnT test so that a reliable and inexpensive test is available for athlete monitoring and talent identification screening.

MATERIALS AND METHODS

A cross-sectional study was conducted in a national level sports training institute between August and November 2018. All male sportspersons of power sports, namely, Boxing, Wrestling Greco-Roman, and Wrestling Freestyle, were included in this study. All athletes (n = 100) were tested during the competitive phase of their training periodic cycle to ensure a high physical fitness especially in terms of muscle power. The study was approved by the Institute's Ethical Committee (Letter No: 301/Ethical Committee/SSF/ASI dt July 18, 2018). The consent forms were duly signed after mutual agreement between the researchers and the subjects. From total 100 sportsmen, 34 boxers, 36 GR wrestlers, and 30 FS wrestlers, voluntarily participated in the study.

The inclusion criteria for this study were as follows:[20]

1. Male sports person between ages of 18 and 30 years.
2. Involved in 6 months of regular training.
3. Minimum national level participation.

The exclusion criteria for this study were as follows:[20]

1. History of hospitalization for more than 2 weeks in past 3 months due to any reasons.
2. Any acute illness/injury during the time of study.
3. Those who did not participate in training in the preceding 3 weeks.

Body height and body mass

Stadiometer was used to measure the height of the subjects (Cardinal Detecto, US). The subjects were instructed to give the height, barefoot, and with their head held in the

Frankfort plane. Body weight was determined by a digital weighing scale (Omron digital weight scale, Kyoto, Japan) with subjects wearing only shorts.

Testing procedure

To make certain of the participant's complete recovery between the tests, they were tested over a period of 2 days.[20] All the subjects were given an in-depth explanation about the study encompassing all the tests and research. The subjects comprehensively demonstrated the testing procedure for familiarization of the crank ergometer and SMBT. Each subject was encouraged to clear their doubts if any. The subjects were also interviewed by an investigator regarding the testing protocols. Subjects were randomly picked and SMBT was performed on day 1. WAnT was conducted on day 2.[20]

Day 1: SMBT test[21,22]

SMBT was used as the field test for validation. Medicine ball (3 kg) measuring tape and chalk were used to measure the horizontal distance achieved.

Participants were advised to avoid intense exercise or any vigorous physical activity for 48 h before the testing. They were requested to continue their usual diet, remain euhydrated, and come for testing between 09:00 and 12:00, 2 h after light breakfast.[23] To warrant this, an extensive dietary recall history was taken. An euhydrated state of body was confirmed by <1% (or 0.4 kg) variation in baseline body mass recorded the previous day. All participants performed a standardized full body warm-up that included 5 min jogging and 5 min dynamic stretches of upper body such as neck flexions and rotations, arm rotation, and swing and thoracic spine rotations**,** on each testing day. For the SMBT, subjects were asked to sit on the floor with their back touching the wall for support and their feet stretched with minimal to no flexion at the knee joint while sitting on the ground. This was done to minimize the recruition of the posterior chain of muscles and core activation during the SMBT. A tape measure was placed on the ground at the front end of the subjects' hip joint and stretched out to a distance of 10 m. To account for different arm lengths of the subjects, they were asked to stand as close as possible to the wall with their head, thoracic spine, buttock and heel touching the wall and hold the ball in both hands with their arms extended away from their chests, that is, shoulder at 90° and elbow straight. They were then instructed to drop the ball straight on a tape measure. The tape was adjusted so that this point was the zero mark. Three attempts were then provided to every athlete to minimize the error with a 90-s rest between trials.[22]

They were instructed to push the ball away from the center of their chest as far as possible, using motion similar to a basketball chest pass. SMBT distance was recorded in meters (m). The best score among the three attempts was considered.

Day 2: WAnT test[23,24]

Modified electromagnetically braked crank-arm ergometer (Lode Excalibur Sport, Groningen, the Netherlands) was used to measure an absolute peak power for the upper body.

The standard warm-up was carried out as in the case of SMBT and followed similar movements for the same period of time followed by the similar dynamic stretching procedures as in the case of SMBT. Participants were asked to sit in a comfortable position so that both feet were flat on the floor and so the ergometer could be pedaled with no restrictions. Participants were allowed to maximize pedal speed approximately 3 s before test initiation to overcome the inertia of the flywheel. The test was initiated with the subject cranking at maximal cadence against no load. A command of "Go" provides the auditory cue to begin arm cranking. Once the subject is at maximal cadence (usually in first 5 s), a predetermined resistance of 0.055 kp.kg^{-1} body mass was used for the athletes for the 30 s all out test. The values chosen for this study were optimal loads for untrained adults as there is no normative data published on the gold standard for elite athletes. The test is terminated after 30 s of all-out work. Following the test, a 5 min cool down period was given. The subjects were verbally encouraged throughout the test to maintain as a high pedaling rate and encouragement for all the players was the same.

In WAnT, power was recorded in Watts every 5 s. Peak power (PP) output was calculated from the highest 5-s output metrics.[25]

Statistical analysis

All statistical analysis was performed in open source language R Studio Version 1.2.1335 (RStudio, Inc). Statistical significance was set at $P \leq 0.05$.

Descriptive statistics including mean and standard deviation (SD) were calculated for 3 kg SMBT and WAnT upper body PP.

Normality of the SMBT and PP was examined using Kolmogorov–Smirnov test and Shapiro–Wilk test. Shapiro–Wilk test is a highly recommended test as it has high power compared to other tests.[26] Data were normally distributed in Wrestling FS, Wrestling GR, and in overall Sportsmen data. Data were not normally distributed in boxing.

Pearson's correlation was used to check correlation between SMBT (m) and peak power (Watts) for all sportsmen and also for each discipline.

Correlation tells about linear relationships between variables but could not measure agreement between two variables. Therefore, Bland-Altman plot analysis was performed to measure agreement between two different measures, that is,

SMBT and peak power of sportsmen.[27] The z-scores were calculated for SMBT and PP as the difference between a value in the sample and the mean, and divided by the standard deviation. A variable, "diff" was calculated as the difference between the z-scores of the SMBT and peak power and another variable, "mean" was calculated as the mean of the z-scores of SMBT and peak power.

One sample *t*-test was applied to the variable "diff" to test if the mean of the difference of z-scores SMBT and peak power was zero. If this one sample *t*-test was not significant, it shows that the difference between the two measures SMBT and peak power is zero. The results were also verified using a non-parametric test, namely, one-sample Wilcoxon Signed-Rank Test. This non-parametric test was also examined as normality assumption was violated in boxing data.

Bland-Altman plots of agreement were plotted for each discipline and also for all sportsmen. In Bland-Altman plots of agreement, differences between the two measures SMBT and peak power (diff) were plotted on Y-axis against their mean values (mean) on X-axis. The limits of agreement were calculated as mean ± 1.96 * std. deviation of the difference between two measures SMBT and peak power and plotted on Y-axis. If 95% pair of difference and mean values is within confidence limits of agreement, then there is an agreement between two measures. [Figures 1-4] represents Bland-Altman plots.

Although Bland-Altman measures an agreement between two measures, it could not show the proportional bias between two measures. Hence, linear regression was applied on difference and mean of SMBT and peak power to test proportional bias or error is zero.

RESULTS

With an objective to evaluate agreement between SMBT and Upper Body Peak Power, overall 100 sportsperson (34 Boxers, 30 FS wrestlers, and 36 GR Wrestlers) were included in the study. Mean age of sportsmen was 22.9 (2.97) years [Table 1].

Data were normally distributed except boxing data. SMBT test results were significantly positively correlated with upper body peak power measured by WAnT in all sportsmen (r = 0.55, P = 0.0002).[28] Statistically positive correlation was observed between SMBT and Upper Body Peak Power among individual groups of Boxers (r = 0.5358, P = 0.0011), FS Wrestlers(r = 0.4244, P = 0.019), and GR Wrestlers (r = 0.6448, P = 0.012).

One sample t-test results showed that the mean difference between SMBT and peak power is close to zero among Boxers (P = 0.13) and FS wrestlers (P = 0.89) and GR Wrestlers (P = 0.49) [Table 2].

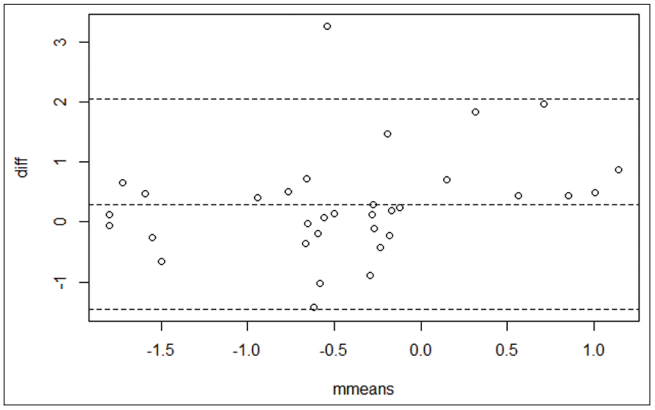

Figure 1: Bland-Altman agreement plot in boxing.

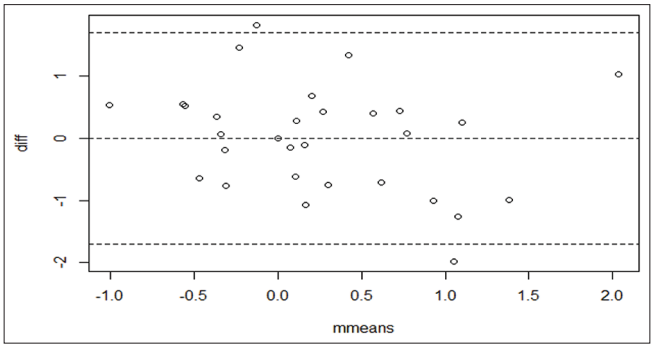

Figure 2: Bland-Altman agreement plot in freestyle Wrestling.

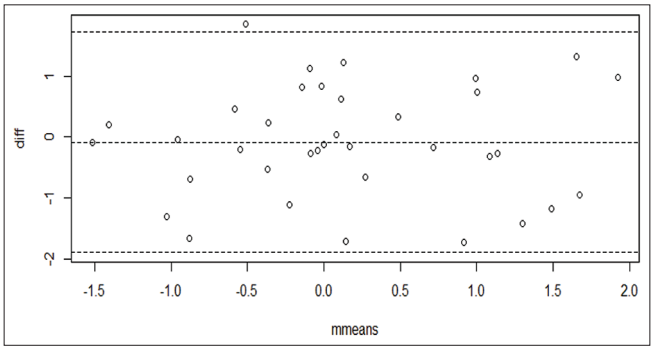

Figure 3: Bland-Altman agreement plot Greco-Roman Wrestling.f

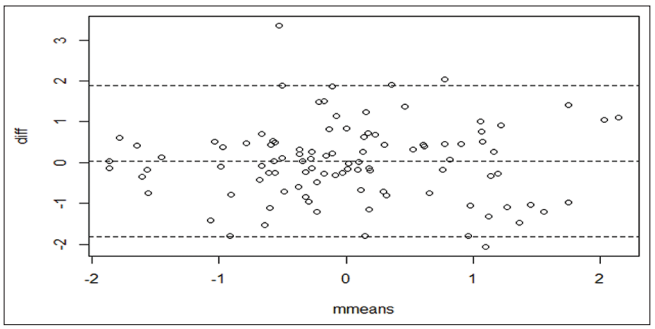

Figure 4: Bland-Altman agreement plot in all sportsmen.

Bland-Altman plots are shown in [Figures 1-4]. Among Boxers out of 34 pairs only one pair was not within the agreements, that is, 97% pairs were within the limits of agreement. Among FS Wrestlers out of 30 pairs 2 pairs were not within the agreements, that is, 93.4% pairs were within the limits of agreement whereas in GR Wrestlers out of 36 pairs only one pair were not within the agreements, that is, 97% pairs were within the limits of agreement. Overall, 97% pairs of SMBT and peak power were within the limits of agreement among all sportsmen, showing that results using both the tests were agreeable [Table 3].

To assess proportional bias linear regression was used. Difference between the two variables was used as dependent variable and mean of two measures as independent variable. It was observed that proportional bias or error term was close to zero in Boxers (P = 0.102), FS Wrestlers (P = 0.192), and GR Wrestlers (P = 0.83). Overall in all Sportsmen (P = 0.99) proportional bias was close to zero [Table 4].

DISCUSSION

Anaerobic energy level is expository for judging the concluding result in wrestling and boxing. This is due to the fact that the determinant moments of the match are mainly associated with the energy provided by the anaerobic energy systems.[3,29] An anaerobic activity or energy system is defined as energy expenditure that uses anaerobic metabolism (without the use of oxygen) which lasts less than 90 s, utilizing an exhaustive effort.[30] Two major energy sources are required during the WAnT. The first is the adenosine triphosphate-phosphocreatine (ATP-PCr) system, which lasts for 3–15 s during maximum effort.[30] The second system is anaerobic glycolysis system, which can be sustained for the remainder of the all-out effort during WAnT.[30] Therefore, the WAnT measures the muscles' ability to work using both the above-mentioned systems. PP, which we get during WAnT, is the highest power output, observed during the 1st 5-s exercise interval, indicates the energy-generating

Table 1: Discipline wise summary statistics of age, SMBT, and peak power.

Characteristics	Boxing (n=34)	Wrestling greco Roman (n=36)	Wrestling free style (n=30)	All Sportsmen (100)
Age (years)	22.4 (2.93)	23.7 (2.90)	22.8 (1.87)	22.98 (2.97)
Height (cm)	176.0 (8.00)	173.0 (8.00)	170.0 (7.00)	173.13 (7.67)
Weight (kg)	72.0 (13.00)	81.0 (19.00)	80.0 (17.00)	77.64 (16.91)
Upper body peak power (Watts)	747.11 (126.70)	860.37 (152.58)	860.2 (129.06)	818.5 (142.24)
3 kg medicine ball throw (m)	5.0 (0.68)	5.3 (0.77)	5.4 (0.48)	5.22 (0.64)

All the measures in above table are expressed as mean (standard deviation)

Table 2: One sample t-test results.

Discipline	Diff (ZMBT – Zpeak power)			
	One sample t-test			Wilcox Signed-rank test
	Mean (SD)	t-statistics value	P-value	P-value
Boxing (n=34)	−0.23 (0.95)	−1.9053	0.066	0.1348
Wrestling FS (n=30)	0.02 (00.89)	0.13107	0.8966	0.9354
Wrestling GR (n=36)	0.11 (0.96)	0.6924	0.4932	0.5089
All (n=100)	−0.03 (0.94)	−0.33	0.742	0.7925

Above test is used to test whether the mean difference between SMBT and PP is close to zero or not. Here, P-value > alpha in all disciplines so mean difference between these two variables is close to zero

Table 3: Bland-Altman 95% limits of agreement.

Discipline wise Bland-Altman plot values			
Discipline	Diff (ZSMBT–Zpeak power)		Data points within the limits (%)
	Mean (SD)	Agreement limits	
Boxing (n=34)	−0.228 (0.95)	−1.455, 2.048	97
Wrestling FS (n=30)	0.02 (00.89)	−1.694, 1.692	93.4
Wrestling GR (n=36)	0.11 (0.96)	−1.891, 1.723	97.3
All (n=100)	−0.03 (0.94)	−1.817, 1.879	97

Discipline wise Bland-Altman analysis values are tabulated in above table

Table 4: Proportional bias (error) between SMBT and peak power.

Discipline	Y = diff (ZSMBT – Zpeak power), X = (ZSMBT + Zpeak power)/2		
	Mean square error	F-statistics value	*P*-value
Boxing (*n*=34)	0.756	2.835	0.102
Wrestling FS (*n*=30)	0.7263	1.79	0.192
Wrestling GR(*n*=36)	0.8739	0.042	0.838
All (*n*=100)	0.8981	0.00	0.99

P-value tells whether proportional bias is close to zero or not. As all *P*-values> alpha in above table we may say that proportional bias is not present in the data

capacity of the immediate energy system (intramuscular high-energy phosphates, ATP, and PCr)[4] or in simple words is measurement of explosive power.

Power also incorporates both the force and velocity of contraction, and to be able to throw a medicine ball from a seated position, the physical traits needed to be successful include both muscular strength and power in the shoulder flexors and elbow extensors.[22]

The movements in the medicine ball throw and the muscle groups employed are similar to those incorporated in techniques of boxing and wrestling.

Since SMBT is a field test, equipment requirement is minimal and easily accessible, this study evaluates whether SMBT could be used as an alternative to assess upper body explosive power in comparison to the otherwise expensive and lab based testing procedure by upper body crank-arm ergometer. It also evaluates the correlation and agreement between the SMBT and WAnT for better utilization of the test procedures to evaluate upper body explosive power in wrestlers and boxers.

This study indicates a significant positive correlation between SMBT and PP as tested by WAnT in all sportspersons. The results of this study appear to be consistent with other studies which suggest that the SMBT could also be a valid and reliable test for assessing explosive power for an analogous total-body movement pattern and general athletic ability in field condition.[21,31] However, in both of these studies total number of subjects were less and neither of these studies compare the SMBT test with the gold standard test like the upper body Wingate test.[21,31]

There is good consonance between correlations of peak power as measured by Wingate test vis-à-vis the SMBT distance. Proportional bias was absent in the data which was assessed using linear regression. Mean difference between these two methods was statistically significantly close to zero. This finding was supported by Bland-Altman plots. Overall 97% data points were within the agreement limits of Bland-Altman plots [Table 3] which confirms the agreement between the methods as this percentage is above 95.

In comparison to other field tests to measure upper body power such as SSP, fails to establish strong correlation with upper body power.[8] Thus, we can assume that SMBT could be used as an alternative field test to measure upper body peak power in the athletes indulging in explosive sports and using more upper body muscles such as in Wrestling Greco-Roman style; Wrestling freestyle, and boxing.

In addition, the SMBT protocol used in this study provides an easy way for the coaches to assess the athletes on the field during talent identification and also to evaluate their training program. Because explosive power or PP is a combination of strength and speed and the source of energy of these explosive powers is the ATP-PCr and anaerobic glycolysis.[2,4] Hence, well developed these two energy systems in athletes are prerequisites of these sports.

CONCLUSION

This study suggests that SMBT method could be used as an alternative for WAnT test to measure anaerobic power in Wrestlers, Boxers, and sports where upper extremity kinetic chain of muscles is involved. It can be considered as a substitute to assess the power of upper limbs as screening tests in centers where Wingate testing ergometers are not available. The SMBT method is a simple method in understanding upper body explosive tests amongst the coaches. SMBT is also less expensive and very easy to use on the field.

However, further research is indicated on larger and more variable populations to corroborate and confirm our findings.

Practical application

A lot of coaches and athletes use medicine balls on a daily basis and it is a simple and less expensive tool. Hence, SMBT can be used to assess the power of upper limbs, monitoring power output gains after training, for early sports talent identification and as screening tests in centers where Wingate testing ergometers are not available.

Limitations of the study

However, the current study has limitations as the data collected are only of male athletes of Indian origin of age between 18 and 30 years and across the three disciplines, Boxing, Wrestling FS, and GR. This, thus, warrants further research on more variable disciplines of sport and populations of different origins.

Declaration of patient consent

Patient's consent not required as patients identity is not disclosed or compromised.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Yessis M. Training for power sports-Part 1. Strength Cond 1994;16:42-2.
2. Horswill CA. Applied physiology of amateur wrestling. Sports Med 1992;14:114-43.
3. Chaabène H, Tabben M, Mkaouer B, Franchini E, Negra Y, Hammami M, *et al*. Amateur boxing: Physical and physiological attributes. Sports Med 2015;45:337-52.
4. McArdle WD, Katch FI, Katch VL. Exercise Physiology: Nutrition, Energy, and Human Performance. Philadelphia, PA: Lippincott Williams & Wilkins; 2010.
5. Armstrong DF. Program design: Power training the key to athletic success. Strength Cond J 1993;15:7-11.
6. Demirkan E, Kutlu M, Koz M, Özal M, Favre M. Physical fitness differences between freestyle and Greco-Roman junior wrestlers. J Hum Kinet 2014;41:245-51.
7. Lenetsky S, Harris N, Brughelli M. Assessment and contributors of punching forces in combat sports athletes: Implications for strength and conditioning. Strength Cond J 2013;35:1-7.
8. Mayhew JL, Bemben MG, Rohrs DM. Seated shot put as a measure of upper body power in adolescent wrestlers. Pediatr Exerc Sci 1992;4:78-84.
9. Roetert EP, McCormick TJ, Brown SW, Ellenbecker TS. Relationship between isokinetic and functional trunk strength in elite junior tennis players. Isokinet Exerc Sci 1996;6:15-20.
10. Horswill CA, Scott JR, Galea P. Comparison of maximum aerobic power, maximum anaerobic power, and skinfold thickness of elite and nonelite junior wrestlers. Int J Sports Med 1989;10:165-8.
11. Kounalakis SN, Koskolou MD, Geladas ND. Oxygen saturation in the triceps brachii muscle during an arm Wingate test: The role of training and power output. Res Sports Med 2009;17:171-81.
12. Jacobs PL, Mahoney ET, Johnson B. Reliability of arm Wingate Anaerobic testing in persons with complete paraplegia. J Spinal Cord Med 2003;26:141-4.
13. Metter EJ, Talbot LA, Schrager M, Conwit RA. Arm-cranking muscle power and arm isometric muscle strength are independent predictors of all-cause mortality in men. J Appl Physiol 2004;96:814-21.
14. Adams KJ, Swank AM, Barnard KL, Berning JM, Sevene-Adams PG. Safety of maximal power, strength, and endurance testing in older African American women. J Strength Cond Res 2000;14:254-60.
15. Salonia MA, Chu DA, Cheifetz PM, Freidhoff GC. Upper-body power as measured by medicine-ball throw distance and its relationship to class level among 10-and 11-year-old female participants in club gymnastics. J Strength Cond Res 2004;18:695-702.
16. Schmidt WD, Piencikowski CL, Vandervest RE. Effects of a competitive wrestling season on body composition, strength, and power in national collegiate athletic association division III college wrestlers. J Strength Cond Res 2005;19:505-8.
17. Jones K, Hunter G, Fleisig G, Escamilla R, Lemak L. The effects of compensatory acceleration on upper-body strength and power in collegiate football players. J Strength Cond Res 1999;13:99-105.
18. Vossen JF, Kramer JE, Burke DG, Vossen DP. Comparison of dynamic push-up training and plyometric push-up training on upper-body power and strength. J Strength Cond Res 2000;14:248-53.
19. Cordasco FA, Wolfe IN, Wootten ME, Bigliani LU. An electromyographic analysis of the shoulder during a medicine ball rehabilitation program. Am J Sports Med 1996;24:386-92.
20. Krishnan A, Sharma D, Bhatt M, Dixit A, Pradeep P. Comparison between standing broad jump test and wingate test for assessing lower limb anaerobic power in elite sportsmen. Med J Armed Forces India 2017;73:140-5.
21. Stockbrugger BA, Haennel RG. Validity and reliability of a medicine ball explosive power test. J Strength Cond Res 2001;15:431-8.
22. Harris C, Wattles AP, DeBeliso M, Sevene-Adams PG, Berning JM, Adams KJ. The seated medicine ball throw as a test of upper body power in older adults. J Strength Cond Res 2011;25:2344-8.
23. Hübner-Wozniak E, Kosmol A, Lutoslawska G, Bem EZ. Anaerobic performance of arms and legs in male and female free style wrestlers. J Sci Med Sport 2004;7:473-80.
24. Lovell D, Kerr A, Wiegand A, Solomon C, Harvey L, McLellan C. The contribution of energy systems during the upper body Wingate anaerobic test. Appl Physiol Nutr Metab 2013;38:216-9.
25. Legaz-Arrese A, Munguía-Izquierdo D, Carranza-García LE, Torres-Dávila CG. Validity of the Wingate anaerobic test for the evaluation of elite runners. J Strength Cond Res 2011;25:819-24.
26. Ghasemi A, Zahediasl S. Normality tests for statistical analysis: A guide for non-statisticians. Int J Endocrinol Metab 2012;10:486-9.
27. Bland JM, Altman D. Statistical methods for assessing agreement between two methods of clinical measurement. Lancet 1986;327:307-10.
28. Mukaka MM. A guide to appropriate use of correlation coefficient in medical research. Malawi Med J 2012;24:69-71.
29. Said K. Physical and Physiological Profile of Wrestler Athletes: Short Review; 2016.
30. Kenney WL, Wilmore JH, Costill DL. Physiology of Sport and Exercise. United States: Human Kinetics; 2015.
31. Mayhew JL, Bemben MG, Rohrs DM, Piper FC, Willman MK. Comparison of upper body power in adolescent wrestlers and basketball players. Pediatr Exerc Sci 1995;7:422-31.

How to cite this article: Kumar A, Singh RK, Apte VV, Kolekar A. Comparison between seated medicine ball throw test and Wingate test for assessing upper body peak power in elite power sports players. Indian J Physiol Pharmacol 2020;64(4):286-92.