https://doi.org/10.7251/SSH2201058V
**UDC:** 797.253-053.4/.5
***Short notice***
***Kratko saopštenje***

# Construction and Validation of Arm Wingate Test for Determination of Anaerobic Abilities in Water Polo Juniors

# Konstrukcija i Validacija Ručnog Wingate Testa za Procjenu Anaerobnih Sposobnosti Vaterpolo Juniora

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***Abstract:*** *The Wingate test is a widely spread test of anaerobic endurance and power in most sports. However, the standard model of the test is based upon a bicycle ergometer for evaluation of lower extremities, therefore, is poorly used in sports that demand a high level of upper body power. This research aims to determine the metric characteristics of the newly constructed arm crank Wingate test. The sample of participants is junior water polo players of VK Mornar Brodospas from Split, Croatia. Mean chronological age is 17-19 years and all participants participated in the test voluntarily. Results are showing a satisfactory level of reliability, homogeneity, and sensibility of measuring instrument and good application in sports such as water polo. Further research should include a bigger sample of participants and athletes from different sports.*
***Keywords:*** *metric characteristics, Wingate test, measuring instrument, hand ergometer.*

***Sažetak:*** *Wingate test je široko rasprostranjeni test anaerobne izdržljivosti i snage u većini sportova. Međutim, standardni oblik testa se zasniva na bicikl ergometru za procjenu donjih ekstremiteta te je slabo primjenjiv u sportovima koji zahtijevaju visoku razinu snage gornjeg dijela tijela. Cilj rada je utvrditi metrijske karakteristike novo konstruiranog ručnog Wingate testa. Uzorak ispitanika predstavljaju juniorski vaterpolisti VK Mornar Brodospasa iz Splita, kronološke dobi 17-19 godina te su svi sudionici pristupili testiranju dobrovoljno. Rezultati prikazuju zadovoljavajuću razinu pouzdanosti, homogenosti i osjetljivosti mjernog instrumenta te dobru primjenu u sportovima kao što je vaterpolo. Daljnja istraživanja trebala bi uključivati veći broj sudionika te sportaša iz drugih sportova.*
***Ključne reči:*** *Metrijske karakteristike, Wingate test, ručni ergometar.*

## Introduction

Many sports are characterized as interval sports. Precisely, they possess multiple changes in maximal and submaximal intensity periods. Short periods of maximal intensity require a high level of anaerobic capacities from athletes. Anaerobic capacity is defined as the work of the body without oxygen and it depends on anaerobic systems of each athlete. Therefore, many studies suggest that qualitative evaluation of anaerobic endurance is necessary for success in stated sports (Al-Hazzaa, Almuzini, Al-Refaee, & et al., 2001; Hoffman & Maresh, 2000). Furthermore, the importance of evaluating anaerobic capacities in sport is noticed in the development of profile-specific physical profiles, evaluation of the training processes, and evaluation of physical demands in various sports (Kalinski, Norkowski, Kerner, & Tkaczuk, 2002).

## Uvod

Vaterpolo je timski sport koji kombinira plivanje, šutiranje i hrvanje. Spada pod polistrukturalne, acikličke, konvencionalne sportove kao što su košarka i rukomet. Moderni vaterpolo je jako zahtjevna aktivnost koja kombinira intenzivan rad kojeg slijedi period manjeg intenziteta (Lozovina i Pavičic, 2004). Pored brojnih izmjena u ritmu igre, igrači imaju intenzivne periode međusobne kontakt igre. Zbog svoje specifičnosti vaterpolo zahtjeva od igrača veliku snagu i anaerobnu izdržljivost gornjeg dijela tijela posebno mišića ruku i ramenog pojasa. Međutim, u praksi je jako mali broj testova kojima se procjenjuje snaga i anaerobna izdržljivosti mišića ruku i ramenog pojasa.

Standardni Wingate test se zasniva na 30 sekunda cikličnog ergometra za evaluaciju izlazne snage pojedinca (Beneke, Pollmann, Leithe i Hutler, 2002; Wilson, Snyder

Water polo is a team sport that combines swimming, shooting, and wrestling. It is described as polystructural, acyclic, conventional sports such as basketball and handball. Modern water polo is a highly demanding activity that combines intensive work which is followed by periods of lower intensity (Lozovina & Pavicic, 2004). In addition to numerous changes in game rhythms, players have intensive periods of mutual contact. A high level of strength and anaerobic endurance of the upper body is needed because of specific demands in water polo. However, there is a small number of tests that determine the strength and anaerobic endurance of arms and shoulder girdle muscles.

Wingate test is based on 30 seconds of maximal effort to evaluate the output power of an individual (Beneke, Pollmann, Leithe & Hutler, 2002; Wilson, Snyder & Dorman, 2009) and it is a proven method for evaluation and prediction of lower body muscle extremities performances. Many test variants had been used previously, however, standard tests using bicycle ergometers (Lee, Oh, Gil, & Kim, 2021; Perez-Gomez, Rodriguez, Olmedillas, et al., 2008) and arm ergometers (Forbes, Kennedy & Bell, 2014; Kumar, Singh, Apte, & Kolekar, 2021) are mostly used methods. Namely, in sports that demand upper body strength usage of a bicycle-ergometer for the lower body isn't an applicable test. Therefore, the arm ergometer presents a good method to evaluate listed parameters for some sports.

Following that, this study aimed to determine the reliability and validity of the newly constructed arm Wingate test (AWT) for usage in specific sports.

## Methods

### *Sample of participants*

This study was conducted on a sample of participants of 7 junior water polo players from VK Mornar Brodospas, Split, Croatia. The chronological age of participants was 17-19 years and all of them were in good psycho-physical health. Mean body height was 187,00±5,23 and body mass 86,29±7,99. All participants volunteered for testing.

### *Sample of variables*

A sample of variables was made of participants' anthropometric parameters: body mass (BM) and body height (BH). Furthermore, output parameters of AWT were used: Peak Power (PP), average power (AP), minimal power (MP,) and Power drop or, the difference between peak and minimal power (PD).

i Dorman, 2009). Test se izvodi 30 sekunda maksimalnog napora suprotstavljajući se konstantnom opterećenju. Opterećenje u testu iznosi 7,5% pojedinčeve tjelesne mase za muškarce (Bar-Or, 1987). Standardni test se izvodi na bicikl ergometru koristeći donje ekstremitete te je dokazana metoda za evaluaciju i predikciju performanse mišićnih skupina donjih ekstremiteta (Meckel, Atterborn, Grodjinovsky, Ben-Sira i Rotstein, 1995; Perez-Gomez, Rodriguez, Olmedillas et al., 2008). Većina istraživanja koja koriste Wingate test služe se standardnim modelom ergometra (Meckel, Atterborn, Grodjinovsky, Ben-Sira i Rotstein, 1995; Patton i Duggan, 1987; Legaz-Arrese, Munguia-Izguierdi, Carranza-Garcia i Torres-Davila, 2011) te je mali broj koji koristi ručni ergometar (Forbes, Kennedy i Bell, 2014; Guglielm i Denadai, 2000). Naime, u sportovima koji zahtijevaju snagu gornjih ekstremiteta korištenje bicikl-ergometra za donje ekstremitete nema korisnu primjenu. Stoga, ručni ergometar predstavlja dobru metodu kod evaluacije navedenih parametara za pojedine sportove. Prethodna istraživanja (Forbes, Kennedy i Bell, 2014), koriste ručni ergometar za procjenu opterećenja prema spolu. Najrasprostranjeniji model ručnog ergometra je sjedeća varijanta gdje ispitanik cikličkim pokretima izvodi test. Ovakav oblik testa može uključivati primjenu i drugih skupina mišića, od strane pojedinca, te ne izolira mišićne skupine ruku i ramenog pojasa. Ovaj problem nastaje primarno zbog položaja u kojem se ispitanik nalazi.

Slijedom navedenog, cilj ovog rada bio je utvrditi pouzdanost i valjanost novo konstruiranog Wingate ručnog testa za primjenu kod specifičnih sportova (u ovom slučaju, vaterpolo).

## Metode

### *Uzorak ispitanika*

Uzorak ispitanika sačinjava 7 juniorskih vaterpolista igrača VK Mornar Brodospasa, iz Splita. Kronološka dob ispitanika je 17-19 godina te su svi bili dobrog psiho-fizičkog zdravlja. Ispitanici su bili prosječne tjelesne visine 187,00±5,23 te prosječne tjelesne mase 86,29±7,99. Svi ispitanici su dobrovoljno sudjelovali u testiranju.

### *Procedura testiranja*

Ispitanicima je izmjerena tjelesna masa (BM) koristeći digitalnu vagu u svrhu postavljanja valjanog opterećenja te tjelesna visina (BH) koristeći antropometar. Nakon mjerenja BM s ispitanicima je provedeno 15 minutno standardizirano zagrijavanje prije provođenja Wingate testa. Tijekom mjerenja koristio se Monark 894e bi-

***Testing procedure***

Participants' BM was measured using a digital scale for setting valid load, and BH was measured using the anthropometer. Participants did 15 minutes of standardized warm-up routine before executing AWT. Testing was done on the Monark 894e bicycle ergometer repurposed for this study, Monark Anaerobic Test Software was also used. Pedals of the ergometer were changed for arm usage and the bench was placed so that test could be done in a lying position.

The participant was positioned in a lying manner on the bench in front of the ergometer in the way that center of the shoulder girdle is at the same level as the center of the pedal rotation. The participant was fixed on the bench with adjustable slings so that (as much as it could be) muscles of the arms and shoulder girdle could be isolated during the test. Difference in the procedure of executing the leg Wingate test and AWT is in load which for AWT amounts to 2%BM. The retest was done seven days after the first testing session.

***Statistical analysis***

Examined metric characteristics of measuring instrument for evaluation of anaerobic abilities of upper extremities were following parameters: PP, AP, MP, and PD. Values are calculated for: the reliability-correlation test, sensitivity-Kolmogorov-Smirnov test, and homogeneity-T-test. All of the data was processed in the computer program software Statistica ver 13.00.

## Results

***Table 1.*** *Correlation analysis for assessment of reliability*

| Variables | PP [W]1 | PP [W/kg]1 | AP [W]1 | MP [W]1 | MP [W/kg]1 | PD [W]1 |
|---|---|---|---|---|---|---|
| PP [W] | 0.76 | | | | | |
| PP [W/kg] | 0.86 | 0.87 | | | | |
| AP [W] | 0.33 | -0.10 | 0.89 | | | |
| MP [W] | 0.43 | 0.01 | 0.98 | 0.87 | | |
| MP [W/kg] | 0.57 | 0.31 | 0.82 | 0.72 | 0.82 | |
| PD [W] | 0.58 | 0.44 | 0.03 | -0.35 | -0.51 | 0.72 |

Table 1. shows correlation analysis for evaluation of the reliability of the measuring instrument.

Table 1. shows the results of correlation analysis between two trials, positive and significant correlations were obtained between variables.

Descriptive parameters of participants with the K-S test for determination of measuring instrument sensitivity are shown in table 2.

cikl ergometar prenamijenjen u svrhu istraživanja, kao i Monark Anaerobic Test Software. Pedale ergometra su zamijenjene za ručnu upotrebu te je postavljena klupica kako bi ispitanici mogli izvršiti testiranje u ležećem položaju.

Ispitanika se postavilo u ležeći položaj na prethodno namještenu klupicu na način da središte ramenog obruča bude u razini centra vrtnje pedala ergometra. Nakon što se ispitanik pravilno pozicionira podesivim trakama se stabilizira u navedeni položaj. Test započinje laganim kretanjem do postizanja 100 rpm (rpm – brzina obrtaja u minuti) nakon čega se ispitaniku daje znak za start te se otpušta opterećenje od 2% BM. Nakon otpuštanja opterećenja vrši se maksimalni napor suprotstavljanja opterećenju u trajanju od 30 sekunda. Ponovljeno testiranje ili retest se radio sedam dana nakon prvog testiranja.

***Obrada podataka***

U svrhu utvrđivanja metrijskih karakteristika mjernog instrumenta za procjenu anaerobnih sposobnosti gornjih ekstremiteta promatrani su parametri: Maksimalna snaga (PP), prosječna snaga (AP), Minimalna snaga (MP) i Power drop ili razlika između maksimalne snage i minimalne snage (PD). Izračunate su vrijednosti za: pouzdanost-test korelacije, osjetljivost-Kolmogorov-Smirnov test te homogenost-T-test.

Svi dobiveni podaci su obrađeni u kompjuterskom softwareu Statistica ver 13.00.

## Rezultati i Diskusija

***Tablica 1.*** *Korelacijska analiza za procjenu pouzdanosti*

Analizom dobivenih podataka vidljivo je da mjerni instrument ima zadovoljavajuću pouzdanost te se greška u mjerenju svela na minimum. Također, treba naglasiti kako su dobiveni rezultati izuzetno zadovoljavajući s obzirom na veličinu uzorka, jer je poznato kako se s povećanjem broja ispitanika povećava i pouzdanost testa.

Deskriptivni parametri ispitanika uz K-S test za procjenu osjetljivosti mjernog instrumenta prikazani su u tablici 2.

***Table 2.*** *Descriptive analysis and Kolmogorov-Smirnov test for sensitivity assessment*

| Variables | N | AS± SD | Min | Max | K-S/d |
|---|---|---|---|---|---|
| BH | 7 | 187.00±5.23 | 180 | 195 | 0.14 |
| BW | 7 | 86.29±7.99 | 77 | 96 | 0.21 |
| PP [W] | 7 | 288.86±35.68 | 250.53 | 339.71 | 0.24 |
| PP [W/kg] | 7 | 3.36±0.37 | 2.78 | 3.75 | 0.26 |
| AP [W] | 7 | 172.01±18.57 | 140.36 | 195.53 | 0.18 |
| MP [W] | 7 | 104.20±22.42 | 77.54 | 137.85 | 0.16 |
| MP [W/kg] | 7 | 1.21±0.20 | 0.91 | 1.5 | 0.23 |
| PD [W] | 7 | 184.66±29.65 | 147.06 | 224.16 | 0.15 |
| BH | 7 | 187.00±5.23 | 180 | 195 | 0.14 |

***Legend:*** *N-number of participants; AS±SD-arithmetic mean and standard deviation; Min-Minimum; Max-maximal; K-S/d-Kolmogorov-Smirnov test.*

Table 2. shows the results of descriptive statistics and values of the K-S test which indicate that tested sample has normal data distribution.

For homogeneity of the measuring instrument T-test analysis was used and is shown in table 3.

***Table 3.*** *T-test for homogeneity assessment*

| Variables | AS | SD | t | p |
|---|---|---|---|---|
| PP [W] | 288.86 | 35.68 | | |
| PP [W]1 | 282.86 | 42.72 | 0.56 | 0.59 |
| PP [W/kg] | 3.36 | 0.37 | | |
| PP [W/kg]1 | 3.29 | 0.59 | 0.57 | 0.59 |
| AP [W] | 172.01 | 18.57 | | |
| AP [W]1 | 168.90 | 21.53 | 0.83 | 0.44 |
| MP [W] | 104.20 | 22.42 | | |
| MP [W]1 | 98.86 | 27.96 | 1.00 | 0.35 |
| MP [W/kg] | 1.21 | 0.20 | | |
| MP [W/kg]1 | 1.15 | 0.25 | 1.00 | 0.36 |
| PD [W] | 184.66 | 29.65 | | |
| PD [W]1 | 184.01 | 47.91 | 0.05 | 0.96 |

***Legend:*** *AS- arithmetic mean; SD- standard deviation; t-T-test; p-level of statistically significant differences p<0,005.*

Analysis of Table 3. Indicate that significant differences were not found between variables of test and retest. Furthermore, by looking at the values of the test it can be said that the measuring instrument has good homogeneity.

***Tablica 2.*** *Deskriptivna analiza i Kolmogorov-Smirnov test za procjenu osjetljivosti*

***Legend:*** *N-broj ispitanika; AS±SD-aritmetička sredina i standrardna devijacija; Min-Minimalan rezulatat; Max-maksimalan rezultata; K-S/d-Kolmogorov-Smirnov test.*

Analizom dobivenih podataka vidljivo je kako mjerni instrument nema značajnih razlika te postoji normalna distribucija rezultata. Pretpostavlja se kako mjerni instrument posjeduje dobro razlikovanje ispitanika prema izlaznim parametrima testa zbog toga što niti jedna varijabla ne prelazi graničnu liniju upotrebom K-S testa (Max d za 0,05 iznosi 0,48).

T-testom procijenjena homogenost mjernog instrumenta vidljiva je u tablici 3.

***Tablica 3.*** *T-test za procjenu homogenosti*

***Legend:*** *Mean-srednja vrijednost; SD-standrardna devijacija; t-T-test; p-nivo statističke značajnosti razlika p<0,005.*

Analizom tablice 3 vidljivo je kako izračunati parametar značajnosti nema značajnu razliku u nijednom izlaznom parametru testa. Ovakvi podaci ukazuju kako primjena ovog mjernog instrumenta ima dobru homo-

## Discussion

Results of correlation analysis (0,72-0,89) point out that the AWT test has satisfactory reliability. This implies that results derived from the test and retest are similar, respectively with small deviations. Also, it should be emphasized that results are exceptionally satisfactory taking into count the number of participants because it is known that with an increase of participants, the reliability of the test also increases. Furthermore, the distribution of the results of AWT is within borders of normal distribution (Max d for 0,05 amounts to 0,48) which implies that this test has satisfactory sensibility. The anthropometric characteristics of participants in our study are similar to previous studies (Uljević, Esco & Sekulić, 2014). Although this data is not directly connected with the aim of this study, it could be concluded that, despite the small number of participants, they are a representative sample. Also, the results of the T-test are not showing significant differences in all variables which implies that the measuring instrument has satisfactory homogeneity because it doesn't differ same participants in two trials.

Some previous studies (Guglielmo & Denadai, 2000; Bampouras & Marrin, 2009) show a deficiency in standard Wingate test in comparison to some specific anaerobic tests in sport. Therefore, it is possible that lying AWT has better pragmatism than the Wingate test, for which is necessary to compare newly constructed AWT with specific tests.

## Conclusion

The aim of this study was the construction and validation of a lying version of the Wingate test for the evaluation of anaerobic endurance and upper extremities strength. Results are showing the three most important findings. First, the good reliability of the test is shown due to the small sample of participants. Second, tests have good sensitivity and normal result distribution. Third, between the two trials, there are no significant differences in results and confirm good homogeneity.

Also, this type of test could be applicable in sports similar to water polo, such as swimming, wrestling, or throwing athletic disciplines. The advantages of this test are noninvasive measurement of a great number of parameters for anaerobic endurance and strength analysis in athletes. Therefore, good isolation of the aforementioned muscle groups is possible. Future studies should include a larger sample of participants and athletes from other sports, as well as other metric characteristic dimensions such as pragmatic validity, etc.

genost te ne razlikuje ispitanike u mjerenjima na 1. i 2. provedenom testiranju.

## Zaključak

Anaerobna izdržljivost i snaga gornjih ekstremiteta je od krucijalne važnosti za određene sportove kao što je vaterpolo, primarno zbog intenziteta i kontakta između sportaša. Stoga, testovi koji mjere navedene parametre bi trebali imati valjane metrijske karakteristike.

Novo konstruirani Wingate test prikazuje zadovoljavajuće metrijske karakteristike u dimenzijama pouzdanosti, homogenosti i osjetljivosti te je moguće prikazati stvarne rezultate u prethodno navedenim parametrima sportaša. Pouzdanost testa se očituje u zadovoljavajućoj raspodjeli rezultata između odabranih varijabli u oba testiranja ispitanika. Nadalje, homogenost je vidljiva u ne postojanju značajnih razlika između testa i retesta, dok je osjetljivost dokazana ne odstupanjem K-S testa od graničnih rezultata u nijednoj promatranoj varijabli.

Također, ovakav oblik testa moguće je primjenjivati na sportove slične vaterpolu kao što su: plivanje, hrvanje ili bacačke atletske discipline. Prednosti ovog testa su neinvazivno mjerenja velikog broja parametara za analizu anaerobne izdržljivosti i snage kod sportaša. Stoga, moguća je dobra izolacija navedenih mišićnih skupina od ostataka tijela. Daljnja istraživanja trebala bi uključivati veći broj sudionika te sportaša iz drugih sportova, kao i ostale dimenzije metrijskih karakteristika primjerice kao pragmatična valjanost itd.

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*Primljen: 13. mart 2022. / Received: March 13, 2022*
*Prihvaćen: 07. april 2022. / Accepted: April 07, 2022*