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Comparison of Anaerobic Performance with Laboratory and Field Tests in Trained Children

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Abstract: Anaerobic performance is considered an indicator of performance for short-term muscle activities of high intensity. It is important to determine whether different anaerobic field tests performed to measure anaerobic performance can be used as an alternative to WAnT performed in the laboratory. The study aimed to compare the anaerobic performance with laboratory and field tests in trained children. One-hundred four athletes between the ages of 10 and 16, minimum age of training of one year in different sports voluntarily participated in the study. Wingate Anaerobic Test (WAnT) was performed as the reference test. Besides, Running-based Anaerobic Sprint Test (RAST) and Pediatric RAST (PRAST) were performed to determine anaerobic performance. Peak power (PP), average power (AP), minimum power (MP), fatigue index (FI) and total exercise time (TED) were determined for each test. All variables of WAnT, RAST, and PRAST were significantly different ($p<0.01$). According to test-retest results of all tests, ICC [95% CI] values have a high-reliability coefficient for all variables. It was found there is a high correlation significantly between WAnT and RAST for all variables ($p<0.01$). Besides, there were also high correlations significantly between WAnT-PRAST and RAST-PRAST excluding fatigue index ($p<0.01$). As a result of this study, it was determined all tests have high reliability. Considering that WAnT requires complex, expensive device and tools, trained staff and is performed in the form of cycling in the laboratory, RAST and PRAST performed with body weight in field conditions can be used to determine anaerobic performance in trained children. High correlations between tests support this determination.

Keywords: Anaerobic power, anaerobic capacity, WAnT, RAST

1. Introduction

It is known that children and young people have short-term, high-intensity, intermittent, or interrupted physical activity patterns rather than long-term, uninterrupted physical activity patterns compared to adult individuals in daily life and various sports activities. It is important to determine the anaerobic performance accurately, reliably, and practically in children and adolescents in terms of evaluating the capacity of functional loading in large populations (Jaafar et. al., 2014). It is also important to obtain normative values regularly with practical methods in large populations involving children and young people in terms of training guidance, monitoring of development, prediction and evaluation of performance and talent selection (Güvenç et. al., 2011; Güvenç, Aslan, & Açıkada, 2013).

Tests evaluating anaerobic performance include high-intensity exercises performed for a few seconds or minutes (Reaburn & Dascombe, 2009). To determine anaerobic performance, there are different laboratory and field test protocols that can be considered in two groups short-term and very short-term anaerobic tests generally. While short-term test protocols may reflect the performance of the lactic acid system, very short-term test protocols provide information on the alactic anaerobic component (Güvenç A., 2003; Sands et. al., 2004). Despite many different loading protocols, WAnT performed with cycling or arm ergometry on the lower or upper body in the laboratory is considered the gold standard by some investigators to evaluate anaerobic performance (Bongers et. al., 2014; Carvalho et. al., 2011). It is stated WAnT has high validity and reliability in evaluating anaerobic performance (Douma-van Riet et. al., 2012; Stickley, Hetzler, & Kimura, 2008; Zagatto, Beck, & Gobatto, 2009). WAnT is the most used test protocol in sports science laboratories (Inbar, Bar-Or, & Skinner, 1996; Reza & Rastegar, 2012; Queiroga et. al., 2013; Verschuren et. al., 2013; Zupan et. al., 2009), but it requires complex and expensive devices and materials. Furthermore, it may be needed to trained staff to implement the test protocol properly (Bongers et. al., 2014; Cooper et. al., 2004). The WAnT protocol is not a form of loading in which the whole-body weight is actively moved from one place to another, and which contains movement patterns that differ when carrying the whole-body weight. However, in many team sports movement patterns such as very short distance, high intensity, intermittent, acceleration, and deceleration are widely used in both training and competitions (Keir et. al., 2013; Zagatto et. al., 2009). It is controversial to what extent the results obtained from laboratory tests such as WAnT performed in a closed area and constant environmental conditions may reflect the situation in field conditions where training and competitions are performed (Aslan et. al., 2011; Kalva-Filho et. al., 2013).

RAST was developed at Wolverhampton University in England, adapted from the original WAnT test to evaluate anaerobic performance in field conditions. The RAST protocol includes six 35-meter repetitive sprints, with a 10-second rest between sprints. In the test results, anaerobic power (peak power (PP)), anaerobic capacity (average power (AP)), minimum power (MP) and fatigue index (FI) can be calculated similarly to WAnT (Beneke et. al., 2002; Zagatto et. al., 2009). The RAST results can reflect performance results both in relation to the alactacid component (anaerobic power) and lactacid component (anaerobic capacity) of anaerobic performance like in WAnT (Balčiūnas et. al., 2006). In the RAST, considering the participant's body weight, power output can be calculated separately from the running time for each sprint (Bongers et. al., 2014; Paradisis et. al., 2005). It is considered that it can be more appropriate to evaluate anaerobic performance with RAST especially in team sports such as athletics, soccer, basketball, and handball containing movement patterns in running form (Balčiūnas et. al., 2006). RAST does not require complicated and expensive devices and materials, unlike WAnT. It can be performed using a suitable running track, stopwatch, or photocell. Therefore, RAST is an attractive test protocol for individuals of all ages, athletes, and non-athletes, as it can be easily implemented by coaches in field conditions and allows for more practical and easy evaluation of anaerobic performance in large populations (Burgess et. al., 2016; Keir et. al., 2013; Verschuren, et. al., 2013).

PRAST was developed to evaluate the anaerobic performance of children with cerebral palsy, which can be performed more easily and at lower cost in the field conditions. It is generally performed to children and adolescents. The PRAST protocol includes six 15-meter repetitive sprints, with a 10-second rest between sprints. In the test results, all variables can be calculated similarly to RAST (Bongers et. al., 2014; Verschuren, et. al., 2013; Verschuren, et. al., 2007).

There are some studies on whether RAST can be an alternative method to WAnT in evaluating anaerobic performance in children, adolescents and athletic adults (Keir et. al., 2013; Queiroga et. al., 2013; Zagatto et. al., 2009). However, there are limited number of studies and more detailed studies are needed on this subject. In addition, there is a study on whether PRAST can be an alternative method to WAnt in healthy children (Bongers et. al., 2014). As an alternative method to WAnT, there is no study performed with different aspects and applications of RAST and PRAST in trained children in the literature. The aim of the present study was the comparison of the anaerobic performance with laboratory and field tests in trained children.

2. Materials and Methods

A total of 104 child and youth male and female athletes between the ages of 10-16 who regularly train in soccer (n=29), basketball (n=28), athletics (n=23), and swimming (n=24) and have a minimum training age of one year voluntarily participated in the study. The study started with 115 athletes, but 11 athletes were excluded from the study for various reasons (measurement deficiency, injury etc.). Participants were asked not to do any physical exercise 24 hours before the tests. They wore standard t-shirts, shorts and sneakers during all measurements and tests. All the participants and parents signed a consent form to participate in the research. The research procedures were explained to participating subjects.

The study has a cross-sectional design in which participants performed three test protocols. WAnT, RAST, and PRAST were performed to evaluate anaerobic performance. The completed randomization method was applied using the random numbers table (one number per participant) in the study. The groups were formed with number ranges. Repeated test results should not be affected by the test protocol performed. Therefore, three randomly selected groups performed the tests in three different test orders in each test session. The protocols were randomized for a group of participants. The tests were performed at intervals of at least 48 hours. Tests and measurements were performed at similar times (14:00 pm) of the day and at least two hours after the last meal of the participants. A total of 10 laboratory sessions were made for body composition (1 session) and WAnT (9 sessions) measurements. The interventions were performed in accordance with the ethical standards of the Declaration of Helsinki. The study received ethical approval from the human ethics committee of the local university (70904504/63).

Body weight (BW), body fat percentage, and lean body mass of participants were measured by using Tanita Body Composition Analyzer Type SC-330 on an empty stomach at 8:00 am on the first test day. Before the measurement, the electrodes were cleaned and dried with diluted alcohol and the participant's foot skin was cleaned.

The information (age, height, gender and body type) of the participant on the Tanita device was carefully entered for each participant. Height was measured by using a stadiometer (Holtain Ltd., UK). BMI was obtained by using an equation (Mitchell et. al., 2006).

WAnT was used to determine anaerobic power and capacity. Monark 894E bicycle ergometer (Monark-Crescent Sweden), computer, appropriate software, and weights were used. Participants were instructed about test protocol. Before each test, the seat height and handlebars of the cycle ergometer were adjusted, and then the participants were familiarized. Then, the warm-up was implemented for five minutes at a pedal speed of approximately 50-60 rpm/min without any resistance. Following five minutes of rest, the constant load was adjusted to 75 gr/kg of BW. Participants performed pedaling for 30 seconds at maximal speed and against the constant load. Participants were verbally encouraged by the researchers during the tests. Following 30 seconds, they were performed pedaling for five minutes without any resistance to recovery (Bar-Or, 1987). For the reliability of WAnT, the test were repeated on different days as described in a sub-sample group of 20 randomly selected participants.

The RAST protocol includes six 35-m repetitive maximal sprints with 10-second rests between each sprint. Primarily, the body masses of participants were measured with clothes. Two photocell gates (Newtest 2000, Oulu, Finland) were installed at both ends of a 35-m distance. The test protocol was explained in detail and the participants were familiarized. Following warm-up and five minutes passive rest period, when the participant was ready, the first sprint started with the administrator's instruction. Following the first sprint, the participant performed a 10-second rest. Then, the second sprint was performed by the participant. This procedure was repeated six sprints in total. Participants performed each sprint as fast as possible. For each sprint, time was measured. During each sprint, participants were verbally encouraged by the researchers. Finally, fifteen minutes of jogging was performed for recovery (Keir et. al., 2013). For reliability of RAST, the tests were repeated on different days as described in a sub-sample group of 20 randomly selected participants.

The PRAST protocol includes six 15-m repetitive maximal sprints with 10-second rests between each sprint. Initially, the body masses of participants were measured with their clothes. Two photocell gates (Newtest 2000, Oulu, Finland) were installed at both ends of a 15-meter distance. The test protocol was the same as the RAST protocol (Bongers et. al., 2014). For reliability of PRAST, the test were repeated on different days as described in a sub-sample group of 20 randomly selected participants. For RAST and PRAST, the power output (in watts) of each sprint was calculated from the following equation:

Power (W) = Body weight (kg) * Sprint distance^2 (m) / Sprint time^3 (sec)

PP was defined as the highest power output of six sprints, MP was the lowest power output and AP was the average of all six sprints. All power outputs were calculated as absolute (watt) and relative (watt.kg^{-1}) values. In addition, the FI was calculated from the following equation:

$$\text{FI } (\%) = \frac{PP - MP}{PP} * 100$$

All statistical analyzes were performed in the SPSS (version 22.0; Chicago, IL, USA) program. For descriptive statistical values, arithmetic mean, and standard deviation ($\bar{X}$±SD) were calculated for all variables. The assumption of normality was performed using The Shapiro-Wilk test. Pairwise comparisons were performed by Wilcoxon

Test for non-parametric values and triple comparisons were performed by One-Way Variance Analysis with Bonferroni correction in repeated measurements for parametric values. The correlations between the variables were examined by Pearson's Correlation Coefficient (r). The correlations were classified as follows: ,0-,30 (negligible); ,30-,50 (low); ,50-,70 (moderate); ,70-,90 (high) and ,90-1,00 (very high), as described by Mukaka (2012). Test-retest were analyzed for all tests. The significance level was set at $p<0.01$ and $p<0.05$.

3. Results

The demographics of the participants are shown in Table 1. Moreover; Table 2 shows that all variables shown in WAnT, RAST and PRAST are significantly different ($p<0.05$), but it is not clear that there is a difference between WAnT and RAST. All variables in PRAST were significantly higher than those in WAnT and RAST ($p<0.05$). According to test-retest analysis results performed for the reliability of all tests, there was no significant difference between first and second measurements of all power variables. Also, there was no significant difference between the first and second measurements of FI and TED variables. In other words, ICC [95% CI] values demonstrate the test-retest reliability coefficient is quite high (Table 3).

There were significantly high positive correlations between WAnT and RAST in relative PP and AP values (r=0,745; r=0,746, respectively). In addition, there was a moderate positive correlation between the tests in FI values (r=0,517) (Figure 1). There were significantly moderate and high positive correlations between WAnT and PRAST in relative PP and AP values (r=0,672; r=0,744, respectively). However, there was no significant correlation between the tests in FI values (r=0,114; $p>0.05$) (Figure 2). There were significantly high positive correlations between RAST and PRAST in relative PP and AP values (r=0,755; 0,808, respectively). However, there was no significant correlation between the tests in FI values (r=0,175; $p>0,05$). There was a significantly high positive correlation between the tests in TED values (r=0,787) (Figure 3).

Table 1. Demographic data of the participants

	Male $\bar{X}$±SD	Female $\bar{X}$±SD	Total $\bar{X}$±SD
Age (year)	14.03 ± 1.91	11.47 ± 1.26	13.22 ± 2.10
Training age (year)	3.90 ± 2.64	1.67 ± 0.74	3.19 ± 2.45
Height (cm)	166.89 ± 13.35	150.51 ± 7.75	161.69 ± 14.09
Body Weight (kg)	59.85 ± 17.78	39.21 ± 7.74	53.30 ± 18.07
BMI (kg/m^2)	21.09 ± 3.92	17.24 ± 2.84	19.86 ± 4.03
Body fat (%)	13.71 ± 6.50	16.10 ± 7.53	14.47 ± 6.90
LBM (kg)	51.07 ± 13.10	32.67 ± 4.83	45.24 ± 14.07

BMI: body mass index, LBM: lean body mass, $\bar{X}$: mean, SD: standard deviation

Table 2. Descriptive results of the tests

	WAnT $\bar{X}$±SD	RAST $\bar{X}$±SD	PRAST $\bar{X}$±SD
PP (W)	382.59 ± 198.32	377.54 ± 179.62	562.60 ± 321.16[a.b]
AP (W)	308.63 ± 155.43	307.02 ± 150.48	480.26 ± 275.93[a.b]
MP (W)	223.26 ± 113.58	244.89 ± 127.27[a]	405.97 ± 243.82[a.b]
PP (W.kg^{-1})	6.84 ± 1.66	6.83 ± 1.90	9.92 ± 3.68[a.b]
AP (W.kg^{-1})	5.53 ± 1.33	5.55 ± 1.66	8.45 ± 3.24[a.b]
MP (W.kg^{-1})	4.03 ± 1.13	4.42 ± 1.47[a]	7.12 ± 2.96[a.b]
FI (%)	40.08 ± 13.22	35.21 ± 10.53[a]	29.12 ± 10.71[a.b]
TED (sec)	30.00 ± 0.00	37.19 ± 3.59[a]	18.66 ± 2.69[a.b]

PP: Peak power; AP: Average power; MP: Minimum power; W: Watt, FI: Fatigue index, TED: Total exercise duration; Significantly difference ($p<0.05$) than [a]: WAnT; [b]: RAST; [c]: PRAST

Table 3. Results of Intra-class correlation coefficient (ICC) for all tests

	WAnT (ICC)	RAST (ICC)	PRAST (ICC)
Absolute PP (W)	0.967*	0,986*	0.964*
Absolute AP (W)	0.957*	0.997*	0.970*
Relative PP (W.kg^{-1})	0.907*	0.975*	0.948*
Relative AP (W.kg^{-1})	0.880*	0.995*	0.960*
FI (%)	0.966*	0.974*	0.884*
TED (sec)	-	0.996*	0.972*

PP: Peak power; AP: Average power; W: Watt; FI: Fatigue index, TED: Total exercise duration; ICC: Intra-class correlation coefficient, *$p<0.05$

Figure 1. Correlations Between Relative Power Variables and FI in WAnT and RAST

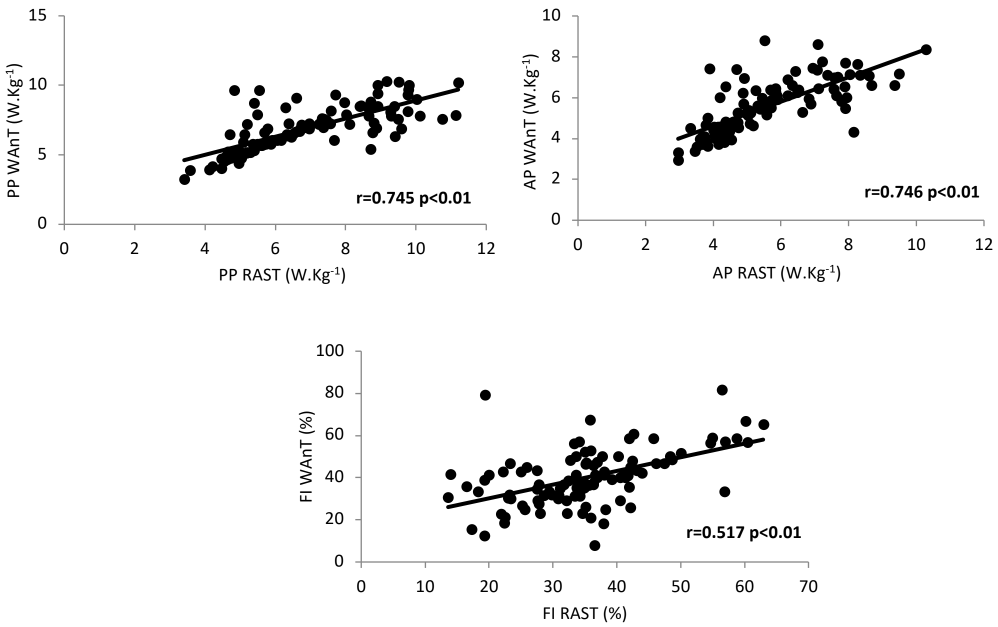


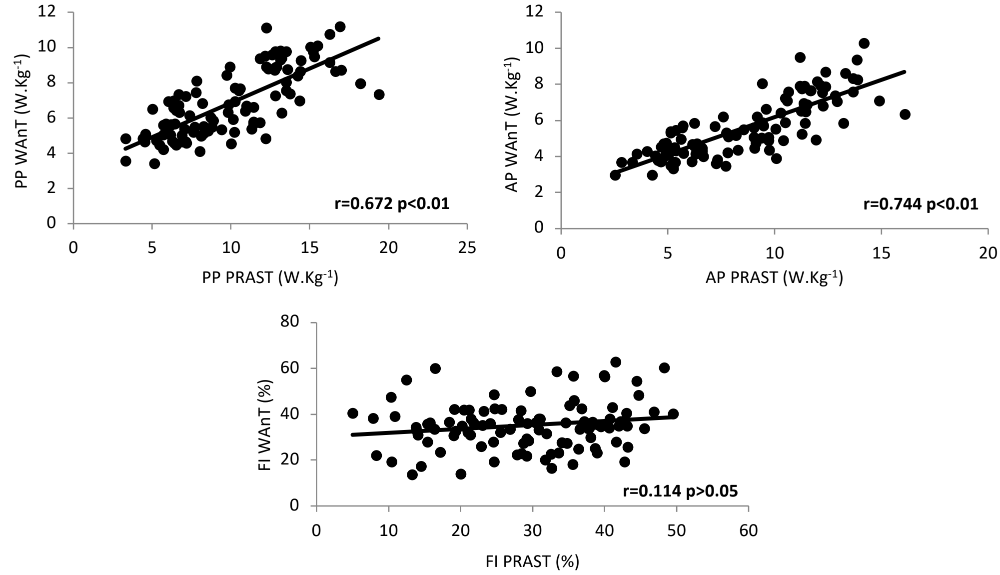
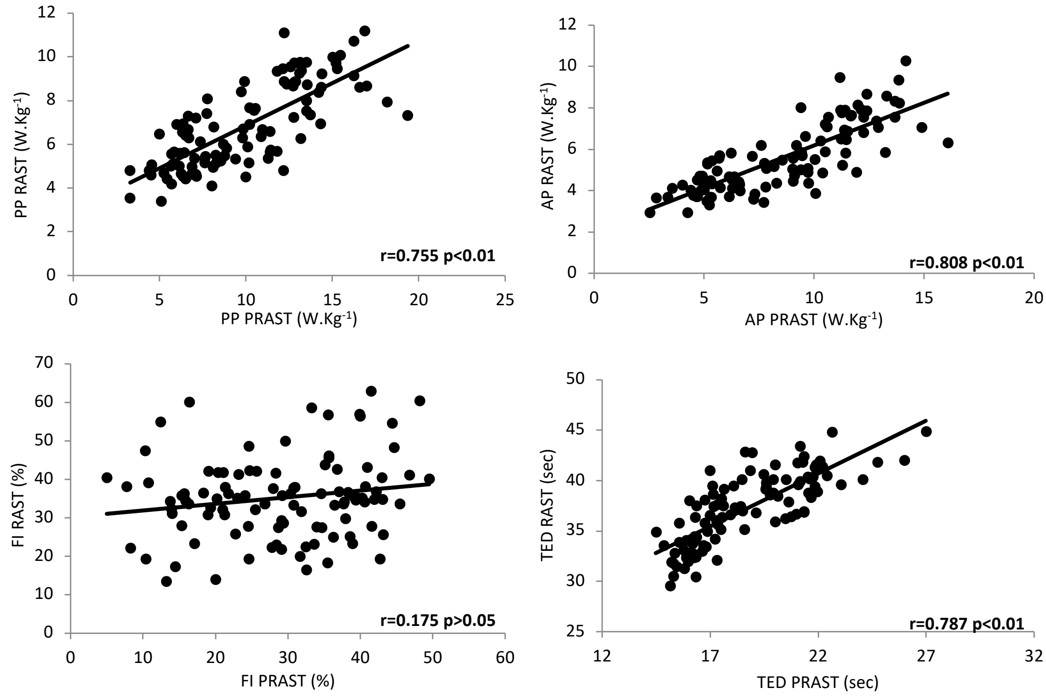
Figure 2. Correlations Between Relative Power Variables and FI in WAnT and PRAST


Figure 3. Correlations Between Relative Power Variables, FI and TED in RAST and PRAST


4. Discussion

This study aimed to compare the anaerobic performance with laboratory and field tests in trained children. The main finding of the study is that all tests showed statistically significant positive correlations for all variables except FI. The ICC values for all variables showed no statistically significant differences between the first and second measurements of the tests. Andrade et al. (2014) reported that RAST had moderate and high reliability by determining ICC values of all variables (excluding FI) in their study on child soccer players (ICCs between 0,60 and 0,96). Chatterjee et al. (2022) indicated that RAST showed good and moderate reliability for AP and MP on youth sprinters (ICCs: 0,628 and 0,471 respectively). Douma-van Riet et al. (2012) stated that ICC values for PRAST PP and

AP showed high reliability in their study on healthy children (ICCs: 0,98). Zagatto et al. (2009) also reported that RAST had high reliability according to ICC results in their study on recreationally active youth people (ICCs between 0,70 and 0,92). In this regard, the findings in these studies are like the findings in our study.

Many studies in the literature show there is a statistically significant correlation between the values in WAnT and RAST. Abbasian et al. (2011) reported there were significant correlations between WAnT and RAST in terms of PP and AP variables in young basketball players (r=0,901; r=0,975, respectively). Burgess et al. (2016) found statistically high positive correlations between the tests for PP and AP in young soccer players (r=0,70; r=0,60, respectively). Chatterjee et al. (2022) also indicated strong positive correlation for PP (r=0,644) and moderate positive correlations for AP and MP in male sprinters (r=0,424; r=0,477, respectively). However, since this study only included male athletes, it may affect consistency with the results of our study. Hazir et al. (2018) found high correlations between the tests in terms of PP, AP and MP despite the significant difference in values in young soccer players (r=0,806; r=887; r=0,826 respectively). Reza & Rastegar (2012) stated there were moderate correlations between PP, AP and MP variables in soccer players (r=0,59; r=0,64; r=0,45, respectively). Queiroga et al. (2013) also found significant correlations between PP and AP in cycling athletes (r=0,831; r=0,714, respectively). Zacharogiannis et al. (2014) stated there were significant high correlations between the tests in terms of absolute PP and AP variables in active youth (r=0,82; r=0,75, respectively). In some studies, the correlation between FI values was evaluated as well as power values. Despite significant differences being found between the result of tests, Zagatto et al. (2009) indicated there were moderate correlations between the tests in terms of absolute PP, AP and FI variables in moderately active youth (r=0,46; r=0,56; r=0,63, respectively). Although there were significant differences between the results of the tests in our study, statistically positive correlations were found between WAnT and RAST for relative PP, AP (high) and FI (moderate) (Figure 1). It can be said that the findings of our study and the above-mentioned studies indicate coherent results.

There are few studies in the literature investigating the correlations between WAnT and PRAST. However, most of these studies have been performed in children with cerebral palsy. There are only two studies performed in healthy or athletic children. Ağır and Özer (2019) indicated there were significantly high correlation between the tests for absolute AP in soccer boys (r=0,850). However, it is not clear whether there is consistency between this and our study due to including only boys to the study. Bongers et al. (2014) stated there were significantly high correlations between WAnT and PRAST for absolute PP and AP in healthy children (r= 0,86; r=0,91, respectively). In addition, there were moderate and high correlations for relative PP and AP in the same study (r=0,55; r=0,81, respectively). In our study, although there were significant differences between the results of the tests, statistically positive correlations were determined between WAnT and PRAST for relative PP (moderate) and AP (high). However, no correlation was found for FI values between the tests (Figure 2). Although the findings of our study and above-mentioned studies are partially consistent, further studies are needed for the WAnT and PRAST correlations.

There is no study investigating the correlations between RAST and PRAST in the literature. In our study, although there were significant differences between the results of the tests, statistically high positive correlations were determined between RAST and PRAST for relative PP, AP and TED. However, no correlation was found between the tests for FI values (Figure 3). In this regard, our study investigating also the correlations between RAST and PRAST is unprecedented.

5. Practical Applications

In conclusion, the high test-retest coefficients of the tests demonstrate they are reliable. Except for PP and AP (between WANT and RAST), the results of all variables showed significant differences. Therefore, it should be considered that especially PRAST may give higher values compared to the other two tests, depending on the short running distance. Although the values obtained from the tests were different, high positive correlations were found for all variables (except for FI) among the tests. The results show that RAST which is more economical and easier to perform can be used to evaluate anaerobic performance instead of WAnT which requires complex, expensive devices, and trained staff. Also, since RAST contains movement patterns suitable for many sports except cycling, it can be used easily for athletes in this population. In our study, physiological variables could not be measured due to a lack of opportunity and a large sample size. Future research can be measured and evaluated in different physiological and metabolic variables such as heart rate, blood lactate, and ratings of perceived exertion.

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References

Abbasian, S., Gholamian, S., Attarzadeh, S. R., Khabazan, M. A., & Khodadadi, H. (2011). The validity of between Wingate test and Running-based Anaerobic Sprint Test (RAST) in young elite basketball players. Int J Health Phys Educ Com Sci Sports, 4(1), 68-70.

Andrade, V. L., Santiago, P. R., Kalva Filho, C. A., Campos, E. Z., & Papoti, M. (2014). Reproducibility of Running Anaerobic Sprint Test (RAST) For Soccer Players. J Sports Med Phys Fitness, 56(1), 34-8.

Aslan, A., Güvenç, A., Hazır, T., Aşçı, A., & Açıkada, C. (2011). Çeşitli dayanıklılık protokollerine verilen metabolik cevapların karşılaştırılması. Hacettepe Üniversitesi Spor Bilimleri Dergisi, 22(3), 124-38.

Balčiūnas, M., Stonkus, S., Abrantes, C., & Sampaio, J. (2006). Long term effects of different training modalities on power, speed, skill and anaerobic capacity in young male basketball players. J Sport Sci Med(5), 163-70.

Bar-Or, O. (1987). The wingate anaerobic test: an update on methodology reliability and validity. Sports Med,4,381-94. https://doi.org/10.2165/00007256-198704060-00001

Beneke, R., Pollmann, C. H., Bleif, I., Leithauser, R., & Hütler, M. (2002). How anaerobic is the Wingate Anaerobic Test for humans? Eur J Appl Physiol, 87, 399-92.

Bongers, B. C., Werkman, M. S., Blokland, D., Eijsermans, M. J., Van der Torre, P., & Bartels, B. (2014). Validity of the Pediatric Running-Based Anaerobic Sprint Test to Determine Anaerobic Performance in Healthy Children. Pediatr Exerc Sci, 27(2), 268-76. https://doi.org/10.1123/pes.2014-0078

Burgess, K., Holt, T., Munro, S., & Swinton, P. (2016). Reliability and validity of the running anaerobic sprint test (RAST) in soccer players. J Trainol, 5, 24-9. https://doi.org/10.17338/trainology.5.2_24

Carvalho, H. M., E-Silva, M. J., Figueiredo, A. J., Gonçalves, C. E., Castagna, C., & Philippaerts, R. M. (2011). Cross-validation and reliability of the Line-Drill Test of anaerobic performance in basketball players 14-16 years. J Str Cond Res, 25(4), 1113-9. https://doi.org/10.1519/JSC.0b013e3181d09e38

Cooper, S. M., Baker, J., Eaton, Z., & Matthews, N. (2004). A simple multistage field test for the prediction of anaerobic capacity in female games players. Brit J Sport Med, 38(6), 784-9. https://doi.org/10.1136/bjsm.2004.012229

Chatterjee, S., Chakraborty, S., & Chatterjee, S. (2022). Validity And Reliability Study of The Running-Based Anaerobic Sprint Test for Evaluating Anaerobic Power Performance as Compared to Wingate Test in Indian Male Track and Field Sprinters. Eur J Phys Educ Sport Sci, 8(4), 38-50. https://doi.org/10.46827/ejpe.v8i4.4327

Douma-van Riet, D., Verschuren, O., Jelsma, D., Kruitwagen, C., Smits-Engelsman, B., & Takken, T. (2012). Reference values for the muscle power sprint test in 6-to 12-year-old children. Pediatr Phys Ther, 24(4), 327-32. https://doi.org/10.1097/PEP.0b013e3182694a4c

Güvenç, A. (2003). Çocuk ve Ergen Sporcularda Anaerobik Güç ve Kapasite Değerleri (Wingate Anaerobik Güç Testi). Atletizm Bilim ve Teknoloji Dergisi, 49, 32-40.

Güvenç, A., Açıkada, C., Aslan, A., & Kamil, Ö. (2011). Daily physical activity and physical fitness in 11-to 15-year-old trained and untrained Turkish boys. J Sport Sci Med, 10(3), 502-14.

Güvenç, A., Aslan, A., & Açıkada, C. (2013). Objectively measured activity in 8-10-year-old Turkish children: Relationship to health-related fitness. Pediatr Int, 55, 629-36. https://doi.org/10.1111/ped.12119

Hazir, T., Kose, M. G., & Kin-İsler, A. (2018). The validity of Running Anaerobic Sprint Test to assess anaerobic power in young soccer players. *Isokinet Exerc Sci, 26*, 201-9.

Inbar, O., Bar-Or, O., & Skinner, J. S. (1996). The Wingate anaerobic test. Human Kinetics.

Jaafar, H., Rouis, M., Coudrat, L., Attiogbe, E., Vandewalle, H., & Driss, T. (2014). Effects of load on wingate test performances and reliability. J Strength Cond Res, 28(12),3462-8. https://doi.org/10.1519/JSC.0000000000000575

Kalva-Filho, C. A., Loures, J. P., Franco, V. H., Kaminagakura, E. I., Zagatto, A. M., & Papoti, M. (2013). Comparison of the anaerobic power measured by the RAST test at different footwear and surfaces conditions. Rev Bras Med Esporte, 19(2),139-42. https://doi.org/10.1590/S1517-86922013000200014

Keir, D. A., Thériault, F., & Serresse, Ö. (2013). Evaluation of the running-based anaerobic sprint test as a measure of repeated sprint ability in collegiate-level soccer players. J Str Cond Res, 27(6), 1671-8. https://doi.org/10.1519/JSC.0b013e31827367ba

Mitchell, H., Whaley, P., & Medicine, A. o. (2006). Acsm's guidelines for exercise testing and prescription. Philadelphia: Lippincott Williams & Wilkins.

Mukaka, M. M. (2012). Statistics Corner: A guide to appropriate use of Correlation coefficient in medical research. Malawi Med J, 24(3), 69-71.

Paradisis, G. P., Tziortzis, S., Zacharogiannis, E., Smirniotou, A., & Karatzanos, L. (2005). Correlation of the running-based anaerobic sprint test (RAST) and performance on the 100m, 200m and 400m distance tests. J Hum Movement Stud, 49, 77-92.

Queiroga, M. R., Cavazzotto, T. G., Katayama, K. Y., Portela, B. S., Tartaruga, M. P., & Ferreira, S. A. (2013). Validity of the RAST for evaluating anerobic power performance as compared to Wingate test in cycling athletes. Mot Rev Educ Física, 19(4), 696-702. https://doi.org/10.1590/S1980-65742013000400005

Reaburn, P., & Dascombe, B. (2009). Anaerobic performance in masters athletes. Eur Rev Aging Phys Act(6), 39-53. https://doi.org/10.1007/s11556-008-0041-6

Reza, A. B., & Rastegar, M. (2012). Correlation between Running-based Anaerobic Sprint Test (RAST) field tests, Sargent jump and 300 yard shuttle run tests with laboratory anaerobic Wingate test in evaluation of indoor soccer player's anaerobic readiness. Ann Biol Res, 3(1), 377-84.

Sands, W. A., McNeal, J. R., Ochi, M. T., Urbanek, T. L., Jemni, M., & Stone, M. H. (2004). Comparison of the Wingate and Bosco anaerobic tests. J Str Cond Res, 18(4),810-5. https://doi.org/10.1519/00124278-200411000-00022

Stickley, C. D., Hetzler, R. K., & Kimura, I. F. (2008). Prediction Of Anaerobic Power Values From an Abbreviated Want Protocol. J Strength Cond Res, 22(3), 958-65. https://doi.org/10.1519/JSC.0b013e31816a906e

Verschuren, O., Bongers, B. C., Obeid, J., Ruyten, T., & Takken, T. (2013). Validity of the muscle power sprint test in ambulatory youth with cerebral palsy. Ped Phys Ther, 25(1),25-8. https://doi.org/10.1097/PEP.0b013e3182791459

Verschuren, O., Takken, T., Katelaar, M., Gorter, J. W., & Helders P, J. M. (2007). Reliability for Running Tests for Measuring Agility and Anaerobic Muscle Power in Children and Adolescents with Cerebral Palsy. Pediatr Phys Ther, 19,108-15. https://doi.org/10.1097/pep.0b013e318036bfce

Zacharogiannis, E., Paradisis, G., & Tziortzis, S. (2004). An evaluation of tests of anaerobic power and capacity. Med Sci Sports Exerc, 36(5),116. https://doi.org/10.1249/00005768-200405001-00549

Zagatto, A. M., Beck, W. R., & Gobatto, C. A. (2009). Validity of the running anaerobic sprint test for assessing anaerobic power and predicting short-distance performances. J Str Cond Res, 23(6), 1820-7. https://doi.org/10.1519/JSC.0b013e3181b3df32

Zupan, M. F., Arata, A. W., Dawson, L. H., Wile, A. L., Payn, T. L., & Hannon, M. E. (2009). Wingate Anaerobic Test peak power and anaerobic capacity classifications for men and women intercollegiate athletes. J Strength Cond Res, 23(9), 2598-604. https://doi.org/10.1519/JSC.0b013e3181b1b21b