APPLICATION OF WINGATE TEST IN TAEKWON-DO ITF ATHLETES

Silvia ILIEVA-SINIGEROVA[1]*

[1] National Sports Academy "Vassil Levski", Faculty of Sport, Sofia, Bulgaria
*Corresponding author: nsastatics@gmail.com

DOI: https://doi.org/10.51267/icehhm2024bp14

Abstract. *The present study aimed to investigate the change in the anaerobic capacity of ITF competitors. Methodology: The study was conducted in the period 2015-2023 and a total of 142 athletes of both sexes participated, distributed as follows (men aged 20.14±3.2 years; weight 75.59±13.26 kg; height 179.93±7 cm and women aged 22.18±5.2 years; weight 60.68±8.69 kg; height 165.53±5.07 cm). Changes in metrics will be examined: peak power (w; w/kg), average power (w; w/kg), performance decline (%), maximum rpm, and heart rate of the athletes. Mathematical-statistical methods were applied: descriptive statistics, Pearson correlation, comparative analysis with Student's t-test for independent samples, and One-way ANOVA. Results: Statistically significant differences were observed in the indicators of peak power, average power, maximum revolutions, and pulse frequencies between the sexes. It was found that there were no statistically significant differences in the percentage level of decline in performance between athletes of both sexes. Differences in peak power, average power, and maximum revolutions were observed in the male competitors during the period under review. Female athletes show differences over the years in peak power and peak rpm. Conclusions: A large correlation between height and maximum and average power was found and a large correlation between weight and average power. An improvement in the level of anaerobic capacity was observed in ITF Taekwon-Do competitors of both sexes.*

Keywords: *anaerobic capacity; maximum anaerobic power; male; female.*

Introduction

Taekwon-do is a sport that uses both the anaerobic and aerobic systems to achieve the best results. In this way, fast and powerful movements can be performed over a long period (Hammad et al., 2019). Rocha et al., (2016) confirmed that the intense anaerobic nature of this combat sport and the ability of the lower limbs to generate high peak power may be essential during competition. Physiological and biomechanical differences between wheel pedaling and lower extremity stroke performance provoke the need for specificity in the testing protocol.

Sant'Ana et al., (2014) perform well in International Taekwon-do Federation - ITF-style Taekwon-do (ITF TKD) competitions require athletes to use complex coordinated movements that include maximum speed, high power, and absolute precision. This competitive model of TKD is characterized by phases of simultaneously repetitive low- and high-intensity physical activity. Factors that determine the nature of TKD during meetings include a high level of technical preparation of the athlete, sporting experience, good knowledge and adherence to the rules of competition, and level of physical fitness, all of which influence movement execution and therefore competition success. Tayech et al., (2020) conclude that Taekwon-do matches usually consist of three 2-minute rounds (when there is a tie, competitors play a third round), separated by a 1-minute rest. During rounds, competitors perform high-intensity actions (e.g. scoring or defensive techniques) followed by low-intensity periods (e.g. stepping actions or referee stoppages). Taekwon-do competitors require high anaerobic and aerobic power to effectively manage metabolic demands during bouts. According to Sant'Ana et al., (2014), significant anaerobic energy expenditure was observed, although sustained throughout by the aerobic energy pathway. Anaerobic muscle metabolism is critical during the impact phases. At the same time, the aerobic system is dominant during non-strike moments (active recovery) and plays an important role in the body's ability to regenerate energy. The ability to perform short maximal efforts is an appropriate characteristic in combat sports given the intermittent nature of the efforts required. The 30-sWanT is presented as the most common method for estimating peak and average scores (Taati et al., 2022).

According to Nabilpour et al., (2023), motor ability is used as a prerequisite for improving performance and sports success. The authors establish a strong relationship between psychological factors and the anaerobic and aerobic capabilities of the body.

The basics of the Wingate test show how important anaerobic capabilities are for Taekwon-do fighters. To properly manage the energy demands of competition, the ability of high anaerobic power, especially for the lower limbs, to produce high peak power is an important prerequisite (Khayyat et al., 2020). Athletes with improved anaerobic power can generate energy at a high rate, which delays the onset of muscle fatigue and allows the continuation of high-intensity exercise (Tayech et al., 2020).

The quality of athletes' biochemical indicators directly affects the quality of athletes' performance. Individual differences in training programs need to be considered, and the data obtained will vary depending on the athletes' achievements (Lin & Ding, 2023).

Hamdi et al., (2014) interest in the Wingate test is based on its simplicity as a testing protocol, peak power, little sophisticated equipment, and short duration.

The present study aimed to investigate the change in the anaerobic capacity of ITF competitors.

Methodology: The study was conducted in the period 2015-2023 and a total of 142 athletes of both sexes participated, distributed as follows (men aged 20.14±3.2 years; weight 75.59±13.26 kg; height 179.93±7 cm and women aged 22.18±5.2 years; weight 60.68±8.69 kg; height 165.53±5.07 cm).

The subjects were athletes from the Bulgarian ITF Taekwon-do national team in different age groups and weight categories of both sexes. Thanks to this, athletes with a high sports level from various cities in Bulgaria are covered. Competitors have passed the phase of specialized pre-selection for admission to participate with the national team. The tests are conducted in laboratory conditions during the preparatory camp meetings before the European Championship and the World Championship for the respective calendar year.

The test is carried out after a preliminary 10-minute warm-up, the athlete begins to pedal at maximum frequency without resistance. Within 3 seconds, the resistance is raised to a certain degree and the athlete continues to pedal at maximum frequency for 30 seconds. The load is adjusted to the body mass of the person examined. The standard formula is that 1 kilogram of body mass corresponds to 0.075 kg of resistance exerted by the pedals. An electric counter registers the number of revolutions in 5s intervals. The test is performed on a mechanical cycle ergometer Monark 894 E (Sweden).

The indicators are calculated:

- Peak power – the realized highest power in the first 5 s of the load reflects the capacity of the system for the immediate release of energy (the high-energy phosphate compounds ATP and CF).

- The relative peak power refers to 1 kg of body mass.

- Fatigue index – the indicator provides information on the percentage reduction of sustained fatigue.

- Anaerobic capacity – gives information about the total amount of work done in 30 s.

Changes in metrics will be examined: peak power (w; w/kg), average power (w; w/kg), performance decline (%), and maximum rpm of the athletes. To achieve a more complete analysis of the studied indicators, data on the height and weight of the studied persons are additionally presented.

Mathematical and statistical methods: descriptive statistics, Pearson correlation, comparative analysis with Student's t-test, and One-way ANOVA. Data were statistically analyzed with SPSS.v.25.

Results

The group of subjects was composed of heterogeneous competitors, representatives of different age and weight categories of both sexes.

Table 1. *Average values of indicators in men*

Indicator (n=74)	Min	Max	R	Mean±SD	V	Kur.	Skew.
Age	16	29	13	20.14±3.21	15.92	0.777	0.971
Height	160	190	30	179.93±7.01	3.89	0.899	-0.897
Weight	49.3	104.7	55.4	75.59±13.26	17.54	-0.402	-0.145
Peak power w	420.5	1393.0	972.5	912.66±209.80	22.99	-0.313	-0.011
Peak power w/kg	8.4	14.8	6.4	12.00±1.31	10.95	0.013	-0.191
Average power w	333.9	854.0	520.1	649.23±117.82	18.15	-0.032	-0.600
Average power w/kg	6.7	9.8	3.1	8.58±0.60	6.99	0.601	-0.442
Fatigue Index	29.2	71.8	42.6	53.34±8.76	16.42	0.076	-0.532
Maximum RPM	126.3	170.0	43.7	145.68±9.50	6.52	-0.263	0.355
Anaerobic capacity	9935.4	24188.1	14252.7	18525.7±3304.4	17.83	-0.244	-0.612

In table 1 we notice the greatest dispersion of values in the indicators of peak power and average power, which are mutually related. Given the fact that the load that was applied to the athletes was tailored to their weight, the large differences in the obtained values are due to other reasons. Among them can be:

Not the specificity of the test - the protocol for performing the Wingate test is very different from the motor activity in Taekwon-Do (general and specific). More experienced competitors who have already passed the Wingate test several times are familiar with the performance of the test itself.

Knowing the protocol and procedure of the test will help the contestants to better follow the instructions of the researchers, which will also have a positive effect on their results. The position to perform the test will be known and they will be able to choose between sitting and standing.

Diet and adherence to a diet - due to the need to reduce body weight and enter a certain category, adherence to a certain diet can negatively affect the results of the Wingate test.

- Adaptation changes and the need for them - preparation for a competition is aimed at a certain time range in which the specific competition will take place. This specificity of the training process can also hurt the results of athletes, especially those with less experience.

- Full recovery after the last training session - if the training process is planned incorrectly or it is difficult to book a time for conducting the Wingate test (a very common problem), likely, the athlete will likely not be fully recovered before the test, which will prevent him from developing his full potential.

- Existence of sports injuries – injuries accompany the daily life of athletes, but sometimes they are activated before or during the performance of this type of load, which will prevent the athlete from developing his full potential.

- Cumulative fatigue – testing is carried out during the preparatory camp meetings before European or world championships. Engaging in double or triple training loads has both positive and negative effects on athletes and fatigue builds up which can also have a negative effect on their performance.

Note that the average power achieved is above the 90% rank estimate for young physically active individuals (Mackenzi, 2005, p. 206). Measured mean values of relative peak power (w/kg) per kilogram of body weight are above the 90% rank estimate for young physically active individuals (Mackenzi, 2005, p. 206).

Table 2. *Average values of indicators in women*

Indicator (n=68)	Min	Max	R	Mean±SD	V	Kur.	Skew.
Age	*14*	*35*	*21*	*22.18±5.22*	*23.53*	*0.772*	*1.091*
Height	*150*	*175*	*25*	*165.53±5.07*	*3.07*	*1.191*	*-0.904*
Weight	*43.5*	*85.7*	*42.2*	*60.68±8.69*	*14.31*	*0.701*	*0.419*
Peak power w	*334.2*	*840.0*	*505.8*	*588.82±104.39*	*17.73*	*-0.137*	*0.055*
Peak power w/kg	*6.1*	*12.3*	*6.2*	*9.73±1.21*	*12.40*	*0.404*	*-0.329*
Average power w	*275.5*	*551.0*	*275.5*	*425.34±64.10*	*15.07*	*-0.363*	*-0.260*
Average power w/kg	*4.9*	*8.3*	*3.4*	*7.04±0.75*	*10.61*	*0.457*	*-0.746*
Fatigue Index	*32.1*	*89.3*	*57.2*	*53.15±9.15*	*17.21*	*4.302*	*1.229*
Maximum RPM	*104.6*	*151.0*	*46.4*	*127.77±9.51*	*7.44*	*0.608*	*-0.494*
Anaerobic capacity	*8174.2*	*15432.8*	*7258.6*	*12448.57±1865.5*	*14.98*	*-0.513*	*-0.229*

In table 2 we notice the greatest dispersion of values in the indicators of peak power and average power, which are interrelated. The reasons for the large dispersion of values are the same as for men, but there are also specific ones, such as:

- For women, results may vary depending on the different periods of the woman's monthly cycle.

Note that the average power achieved is above the 90% rank estimate for young physically active individuals (Mackenzi, 2005, p. 206). Measured mean values of relative maximal power (w/kg) per kilogram of body weight are above the 90% rank estimate for young physically active individuals (Mackenzi, 2005, p. 206).

Taekwon-do ITF does not use an electronic scoring system during competition. Therefore, the alternative specialized Taekwon-do tests that have been known in recent years will not be familiar to perform and sufficiently informative. There is a difference in the contact that must be applied between the two styles, the equipment, the rules, the nature of the applied techniques, the variety, and the intensity of the motor activity.

Table 3. *Comparative analysis*

№	Indicator	Male (n=74)	Female (n=68)	t-value	Sig. (2-tailed)
1	*Age*	20.14±3.201	22.18±5.22	-2.780	0.006
2	*Height*	179.93±7.01	165.53±5.07	14.111	0.000
3	*Weight*	75.59±13.26	60.68±8.69	7.985	0.000
4	*Peak power w*	912.67±209.80	588.82±104.39	11.786	0.000
5	*Peak power w/kg*	12.00±1.31	9.73±1.21	10.763	0.000
6	*Average power w*	649.23±117.82	425.34±64.10	14.217	0.000
7	*Average power w/kg*	8.58±0.60	7.04±0.75	13.495	0.000
8	*Fatigue Index*	53.33±8.76	53.15±9.15	0.120	0.905
9	*Maximum RPM*	145.68±9.50	127.77±9.51	11.218	0.000
10	*Anaerobic capacity*	18525.72±3304.4	12448.57±1865.5	13.336	0.000

The comparative analysis (table 3) between the data of male and female Taekwon-do athletes showed statistically significant differences in the indicators: height, weight, peak power (w; w/kg), average power (w; w/kg), and the maximum revolutions reached. The differences in the average values, as well as in the individual results, in the decline of working capacity in both sexes are minimal and not statistically significant. The average values of the measured pulse rate also did not show differences between the two sexes.

Riders for whom cycling is not a regular and intrinsic motor activity may experience difficulties during pedaling and reaching maximum revs.

Specific anatomical features of the body suggest differences in results between men and women in the levels of maximum and average power.

According to Mackenzi (2005, p. 206), the lowest ranking for men starts at 7.06 w/kg and reaches over 10.89 w/kg. For women, the lowest ranking starts at 5.98 w/kg and goes up to 9.02 w/kg. On the other hand, the peak power figures for men start at 570 w and reach over 822 w. While for women, the peak power starts from 353 w and goes up to 560 w.

Table 4. *PEARSON correlation*

	Age	Height	Weight	Peak power w	Peak power w/kg	Average power w	Average power w/kg	Fatigue Index	Maximum RPM	Anaerobic capacity
Age	1									
Height	-,021	1								
Weight	,088	,823**	1							
Peak power w	,028	,830**	,890**	1						
Peak power w/kg	-,068	,572**	,472**	,814**	1					
Average power w	-,008	,874**	,891**	,968**	,758**	1				

Average power w/kg	-,151	,578**	,352**	,661**	,858**	,733**	1			
Fatigue Index	-,011	,044	,311**	,370**	,348**	,225**	,004	1		
Maximum RPM	-,089	,659**	,570**	,811**	,840**	,776**	,735**	,262**	1	
Anaerobic capacity	-,054	,562**	,526**	,603**	,541**	,673**	,634**	,007	,524**	1

*Note: **p<0.001, *p<0.05*

Establish a large correlation dependence (table 4) between peak power and average power with the height and weight of the athletes studied. Anaerobic capacity of athletes has a significant influence on the maximum developed revolutions as well as on the peak and average power during the study. We can conclude that the height and weight of the subjects has a significant influence on their anaerobic capacity and maximally developed revolutions, but not on the fatigue index. The age of the athletes studied has no influence on any of the studied indicators.

Table 5. *One-way ANOVA (Male)*

ANOVA[a]		Sum of Squares	df	Mean Square	F	Sig.
Age	Between Groups	399.599	5	79.920	15.481	.000
	Within Groups	351.050	68	5.163		
	Total	750.649	73			
Height	Between Groups	1177.456	5	235.491	6.658	.000
	Within Groups	2405.206	68	35.371		
	Total	3582.662	73			
Weight	Between Groups	2943.437	5	588.687	4.045	.003
	Within Groups	9895.774	68	145.526		
	Total	12839.211	73			
Peak power w	Between Groups	885142.613	5	177028.523	5.171	.000
	Within Groups	2328002.125	68	34235.325		
	Total	3213144.739	73			
Peak power w/kg	Between Groups	15.613	5	3.123	1.922	.102
	Within Groups	110.487	68	1.625		
	Total	126.099	73			
Average power w	Between Groups	259542.357	5	51908.471	4.683	.001
	Within Groups	753796.945	68	11085.249		
	Total	1013339.302	73			
Average power w/kg	Between Groups	1.153	5	0.231	0.624	.682
	Within Groups	25.127	68	0.370		
	Total	26.281	73			
Fatigue Index	Between Groups	525.176	5	105.035	1.408	.232
	Within Groups	5072.453	68	74.595		
	Total	5597.629	73			
Maximum RPM	Between Groups	2024.314	5	404.863	6.032	.000
	Within Groups	4564.442	68	67.124		
	Total	6588.756	73			
Anaerobic capacity	Between Groups	140224127,583	5	28044825,517	2,903	,020
	Within Groups	656869894,471	68	9659851,389		
	Total	797094022,055	73			

a. Gender-male

The applied variance analysis One-way ANOVA (table 5) confirms the expected statistical differences between the competitors in the considered nine-year study period. From the specialized indicators studied, differences are found in the maximum developed power, average power, maximum revolutions, and anaerobic capacity.

Interestingly, the follow-up of the results of a longer period of application of the Wingate test gives differences between the groups in individual years in the indicators of peak power, average power, maximum revolutions, and anaerobic capacity. Differences between the measured results of the competitors from the same year are established for the same indicators.

Table 6. *One-way ANOVA (female)*

ANOVA[a]		Sum of Squares	df	Mean Square	F	Sig.
Age	Between Groups	301.944	6	50.324	2.017	.077
	Within Groups	1521.939	61	24.950		
	Total	1823.882	67			
Height	Between Groups	53.834	6	8.972	.328	.920
	Within Groups	1671.107	61	27.395		
	Total	1724.941	67			
Weight	Between Groups	556.309	6	92.718	1.257	.291
	Within Groups	4498.862	61	73.752		
	Total	5055.171	67			
Peak power w	Between Groups	215242.266	6	35873.711	4.250	.001
	Within Groups	514835.773	61	8439.931		
	Total	730078.039	67			
Peak power w/kg	Between Groups	27.878	6	4.646	4.075	.002
	Within Groups	69.554	61	1.140		
	Total	97.432	67			
Average power w	Between Groups	44678.933	6	7446.489	1.970	.084
	Within Groups	230628.788	61	3780.800		
	Total	275307.721	67			
Average power w/kg	Between Groups	3.098	6	.516	.919	.488
	Within Groups	34.267	61	.562		
	Total	37.365	67			
Fatigue Index	Between Groups	910.541	6	151.757	1.972	.084
	Within Groups	4694.988	61	76.967		
	Total	5605.529	67			
Maximum RPM	Between Groups	1623.889	6	270.648	3.725	.003
	Within Groups	4431.783	61	72.652		
	Total	6055.672	67			
Anaerobic capacity	Between Groups	34198313,677	6	5699718,946	1,747	,125
	Within Groups	198985747,300	61	3262061,431		
	Total	233184060,977	67			

a. Gender-female

In the female athletes, statistically significant differences (table 6) were found in the indicators related to the measurement of peak power (w; w/kg) and the maximum revolutions developed during the testing. For both male and female athletes, we find that the estimated between-group variance values are smaller than the within-group variance values.

We find an advantage in the application of the Wingate test in the exact dosing of the applied load about the body weight of the tested athletes. The specificity of the load allows us to compare the results of athletes from different weight categories.

Statistically significant differences were observed in the indicators of peak power, average power, maximum revolutions, and pulse frequencies between the sexes. It was found that there were no statistically significant differences in the percentage level of fatigue in performance between athletes of both sexes. Statistically significant correlations were found between anaerobic capacity and height, weight, peak power, average power, and maximum rpm. Differences in peak power, average power, maximum rpm, and anaerobic capacity were observed in the male competitors during the period under review. Female athletes show differences over the years in peak power and peak rpm.

Discussion and Conclusions

The authors Tayech et al., (2020) recall that the WanT is widely accepted as the "Gold Standard" for an anaerobic test and is much more widely used than any other anaerobic test. The assessment of anaerobic capacity can provide the coach with valuable information about the athlete's motor ability, as well as enable him to track its improvement through proper planning of the training process. Test scores can reliably determine peak power, anaerobic fatigue, and total anaerobic capacity (Mackenzie, 2005, p. 205). Rocha et al., (2016) Specific movements allow athletes to better synchronize different phases of performance, thereby conserving energy during the test.

Researchers Sant´Ana et al., (2014) presented the results of an analysis of respiratory and ventilatory variables following the Wingate test, which showed a slight increase in oxygen after exercise. Rocha et al., (2016) reported differences of 7% and 11% for the same variables, peak power, and average power, respectively, between study runs I and II for the TSAT protocol, both with ICCs greater than 0.83 and small to medium effect size, suggesting that these differences would not have a large effect in practice. The authors found results in some variables lower than those considered in the literature, such as peak power, relative peak power, and anaerobic capacity, which may explain the value presented in FI, i.e. the installed fatigue is also shorter, resulting in a lower FI. Sant´Ana et al., (2014) explained the lower values of the Taekwon-do anaerobic test in the FI variable, compared to WanT, because in WanT there is a constant load for the technical gesture (cycling), while in Taekwon-do-specific tests, there is a short pause between kicks, which somehow allows recovery, resulting in a lower performance drop.

Bonetti de Poli et al., (2021) shared the ability to assess phosphagen and glycolytic pathway capacity and therefore anaerobic capacity during 30sWanT during super maximal efforts that lead to exhaustion between the 2nd and 3rd minutes, regardless of the anaerobic training state, given that this pathway to exhaustion requires severe depletion of phosphocreatine and glycogen stores. Taekwon-do competitors elicit near-maximal heart rate (HR) responses (90% peak HR) and high lactate concentrations (7.0–12.2 mmol/l), suggesting high aerobic and anaerobic demands metabolism during matches. Anaerobic performance assessment can therefore provide the coach with valuable information about the motor ability of these athletes as well as allow them to monitor improvement through training (Tayech et al., 2020).

After conducting an expert analysis Liu & Jia (2023) found, that during training loads, attention should be paid to the combination of general and special physical training so that when coordination complex and difficult movements are shown during competitions, the movements can be completed and executed effectively. Boraczyński et al., (2017) studied men and youth showed differences during the individual stages of development, which is a consequence of longer training and competition experience and greater training loads in favor of men. Aerobic and anaerobic power are crucial determinants of success in this sport. Male Taekwon-do medallists were found to have higher anaerobic power scores on the Wingate test than their non-medal counterparts. In addition, there was a trend for male and junior medallists to show higher aerobic power on the multi-stage shuttle test compared to their non-medallist counterparts (Tayech et al., 2020). Alp & Gorur (2020) compared the explosive power and anaerobic capacity of Taekwon-Do and karate competitors, a difference was found that could be attributed to the duration of the competition, training programs, training methods, and physical demands of the two sports.

Ooi & Anowar (2018) found that Taekwon-do athletes showed higher aerobic capacity than Silat practitioners. Regarding the Wingate test anaerobic capacity, it was found that there were no statistically significant differences in average power, anaerobic power, peak power, anaerobic capacity, and fatigue index among the sedentary, Silat, and Taekwon-Do groups. The most notable finding in the study was that the Taekwon-Do group showed statistically significantly higher calculated aerobic capacity (VO2 max) compared to the sedentary control group and strength training groups. Tae Kwon Do training involves continuous jumping, lower limb kicks at high altitudes for a period, which requires aerobic fitness. Hammad et al. (2019) found no significant effect of listening to music on peak power ability, unlike slow music, which positively affects Taekwon-do athletes during their performance.

Chtourou et al., (2011) Investigated the time difference in the performance of the test and the results in short-term maximal performance. According to the authors, the lack of difference between morning and evening performance may be partly explained by the choice of step type of exercise in this study (i.e., a sudden, standardized decrease). The increase in short-term measures after a tapering phase was not affected by the time of day of the test. Thus, the study of strength and power indicators required for competition at a certain time of day (i.e., when the exact time of the competition is known) is recommended to coincide with the training ones. Lericollais et al., (2011) the authors confirmed diurnal variations in anaerobic power, i.e., PP and MP, during the 60s Wingate test. The results of this study show that FI is higher in the evening than in the morning. Fatigue change analysis performed during the study of power output every 2 s was higher in the evening than in the morning during the first 20 s of exercise, after which no difference was observed. These results indicate a greater progression of fatigue in the evening than in the morning. In this way, the intensity, recovery time, etc. should be determined. as a function of the time of day. Souissi et al., (2007) suggested that a strong level of motivation by subjects during the 30-second Wingate test was required to influence the results and minimize any existing time-of-day effect. Oral temperature is higher at 18:00 than at 06:00. Thus, the higher value of Ppeak and Pmean in the evening than in the morning may be related to changes in body temperature. The relative energy contribution of aerobic metabolism during the Wingate test is high. The power maintained during the 30-second Wingate test is related to the time of day. The data show that this difference is mainly due to a better aerobic contribution to energy production during the test in the afternoon than in the morning.

Performing the standing test among trained cyclists results in higher power output, therefore the most appropriate method to accurately test the peak anaerobic power output of a trained cyclist is 30 WAT completed in standing only or a combined stance protocol (Kadlec et al., 2022). Monteiro de Moura et al., (2017) the position adopted by cyclists during training or competition may not be ideal for maximal anaerobic performance. The results suggest that small adjustments in saddle height may affect the force-length relationship of lower limb muscles and therefore their recruitment pattern and ability to generate force.

Onuma et al., (2023) assumed that there may be a difference in the fatigue index, which is the rate of decline in power output within 30 s. The results obtained for athletes in the standing position in the WanT are better compared to the seated position. This result also helps in discussing the importance and inclusion of the relationship of body mass with anaerobic power production capacity in WanT, which should be considered in future studies.

Wilson et al., (2009) If the subject stands up from the seat during a sit test, this change should not affect his/her physiological changes. However, moving from one position to another during the test is not recommended due to the possibility of injury. Although the standard resistance for the Wingate test is 7.5% body weight, similar values of power decline have been achieved in trained athletes. Therefore, a resistance of 8.5% for well-trained athletes may be acceptable, while 7.5% may be best for health trainers or untrained individuals.

According to Akgul et al., (2023), lack of control over food intake as well as participants' diets may affect their aerobic capacity. Submaximal VO2, which allows efficient use of energy in training and competition, has been implicated as the reason for the differences in performance levels of athletes with an equivalent level of VO2 max. The authors note that a 2% improvement in submaximal VO2 provides a 2.5-minute advantage in marathon performance. Taati et al., (2022) Fluctuations in body mass can influence performance, but the magnitude of associations appears to vary with body composition ratio. A 1-kg decrease in body mass was associated with a decrease of 6.99 watts in WanT-PP and 4.62 watts in WanT-MP, while a 1-kg decrease in FFM was associated with a decrease of 14.73 watts and 4.62 watts in WanT-MP, respectively. 7.39 watts. Finally, a 1 kg reduction in LL-LST predicts a drop of 35.99 watts in peak and 21.62 watts in mean WanT outputs.

Coelho-e-Silva et al., (2020) The authors draw attention to the fact that combat sports athletes should monitor their body mass, which determines their competition categories, preferably combined with body composition assessment and reduced body fat. Weight loss through short-term restricted dieting can lead to a decrease in fat-free body mass, which in turn can lead to a deterioration in athletic performance. However, it was found that a ketogenic diet can be beneficial for athletes in weight classes (such as Taekwon-do competitors) to improve of aerobic capacity and fatigue resistance capacity (Rhyu & Cho, 2014).

Franchini (2019) found that athletes from consecutive weight classes did not differ in terms of PP or MP and could be grouped to perform training activities involving anaerobic power and capacity. It is also important to note that competitors in successive weight classes did not differ significantly in terms of skinfold thickness and limb circumferences. The observed anthropometric similarity may also be related to similarity in absolute PP and MP.

Taati et al., (2022) consider the relationship between specific body composition components and anaerobic performance, weight reduction should be managed critically, especially in avoiding excessive losses in FFM. According to the authors, the individual variability of impaired athlete performance associated with deliberate weight changes before competition also needs to be investigated.

In practice, several tests have been proposed in recent years designed specifically for Taekwon-Do athletes and assessing their anaerobic capacity. The TAIKT is a sport-specific kicking test that may be a specific and easy measure of anaerobic power assessment in Taekwon-Do athletes. It should not be overlooked that the TAIKT is a non-invasive, easy-to-perform, and affordable test that can be used regularly by coaches throughout the season to assess Taekwon-do sport-specific anaerobic performance of athletes. The TAIKT is a valid test characterized by good ability to distinguish between elite and sub-elite Taekwon-do athletes (Tayech et al., 2020). The test is designed to evaluate anaerobic power while determining absolute and relative peak power (Ppeak) and average power (Pmean), as well as fatigue index (FI). It has been reported that the advantage of using TAIKT to measure the anaerobic strength of Taekwon-do athletes will allow the execution of more Taekwon-do-specific movements, such as kicking, basic technique during attack and counterattack, and the execution of several punches in sequence. Boutios et al., (2022) A moderate correlation was observed between the WanT and the TAIKT in athletes with a medium-high technical level, indicating that the two tests are not interchangeable. For the assessment of anaerobic and physiological characteristics in Taekwon-do competitors, regardless of their technical level, the WanT test is suitable, not influenced by Taekwon-do-specific technical skills, but better assess functional performance and the specific demands of Taekwon-do, while the TAIKT is more indicative of mid-high-level athletes.

Sant'Ana et al., (2014) acknowledged the limitations of the WANT in terms of its ecological validity in Taekwon-Do. The authors propose a new anaerobic evaluation method that is specific to this sport, using the performance of the Bandal chagui kick. There is a suggestion that WanT underestimates the anaerobic performance of Taekwon-Do athletes. In fact, the results show the opposite, especially about the AC variable; due to a decrease in motor acuity when performing Bandal chagui with fatigue, techniques begin to be performed in areas further away from the center of the shield/sensor with lower impact values than the actual force applied. The results obtained show that TSAT has a level of agreement with WanT, especially in the variables PP, RPP, MAP, RMAP, and FI, therefore the protocol gives great specificity in the assessment of the anaerobic capacity of Taekwon-do athletes.

The TST test is a simple and practical tool for coaches and does not require invasive equipment. The specialized sidekicks with the left front leg (i.e. 'Yop-Chagi'), a kick with the right leg (in Taekwon-do terminology referred to as 'Bandal-Chagi'), and followed by a second back kick with the other leg (in Taekwon-do terminology called "Dwit-Chagi"). The total number of strokes to be scored during the TST is seven strokes (Aloui et al., 2022). The modified COD T-test is described as a measure of planned four-way agility and body control, which assesses the ability to rapidly change directions as well as maintain balance without loss of speed. Furthermore, the present test is suitable for examining performance differences according to expertise level (top elite vs. elite).

In addition to the above, the following conclusions can be drawn from the present study:

A large correlation between height and peak and average power was found and a large correlation between weight and average power. An improvement in the level of anaerobic capacity was observed in Taekwon-Do ITF competitors of both sexes.

Statistically significant differences were observed in the indicators of peak power, average power, maximum revolutions, and anaerobic capacity between the sexes.

It was found that there were no statistically significant differences in the percentage level of fatigue in performance between athletes of both sexes.

Statistically significant correlations were found between anaerobic capacity and height, weight, peak power, average power, and maximum rpm.

Differences in peak power, average power, maximum rpm, and anaerobic capacity were observed in the male competitors during the period under review.

Female athletes show differences over the years in peak power and maximum rpm.

References

Akgul, M. S., Karabiyik, H., & Akgul, M. N. (2023). A comparison of repeated Wingate based of high intensity interval training and moderate intensity continuous training on aerobic capacity under normobaric hypoxia. *Kinesiologia Slovenica, 29*(3), 49-61. https://doi.org/10.52165/kinsi.29.3.49-61

Aloui, A., Tayech, A., Mejri, M. A., Makhlouf, I., Clark, C. C. T., Granacher, U., Zouhal, H., & Adderrahman, A. B. (2022). Reliability and validity of a new taekwondo - specific change-of-direction speed test with striking techniques in elite taekwondo athletes: a pilot study. *Frontiers in Psychology, 13*, 1-15. https://doi.org/10.3389/fphys.2022.774546

Alp, M., & Gorur, B. (2020). Comparison of explosive strength and anaerobic power performance of taekwondo and karate athletes. *Journal of Education and Learning, 9*(1), 149-155. https://doi.org/10.5539/jel.v9n1p149

Bonetti de Poli, R. A., Miyagi, W. E., & Zagatto, A. M. (2021). Anaerobic capacity is associated with metabolic contribution and mechanical output measured during the Wingate test. *Journal of Human Kinetics, 79*, 65-75. https://doi.org/10.2478/hukin-2021-0063

Boraczyński, M., Boraczyński, T., Podstawski, R., Laskin, J., Choszcz, D., & Lipiński, A. (2017). Relationships between anthropometric features, body composition, and anaerobic alactic power in elite post-pubertal and mature male taekwondo athletes. *Human Movement, 18*(4), 30-40. https://doi.org/10.1515/humo-2017-0032

Boutios, S., Di Cagno, A., Buonsenso, A., Centorbi, M., Iuliano, E., Calcagno, G., & Fiorilli, G. (2022). Does the type of anaerobic test matter? A comparison between the anaerobic intermittent kick test and Wingate anaerobic test in taekwondo athletes. *Sports, 10*(10), 1-9. https://doi.org/10.3390/sports10100154

Chtourou, H., Zarrouk, N., Chaouachi, A., Dogui, M., Behm, D. G., Chamari, K., Hug, F., & Souissi, N. (2011). Diurnal variation in Wingate-test performance and associated electromyographic parameters. *Chronobiology International, 28*(8), 706-713. https://doi.org/10.3109/07420528.2011.596295

Coelho-e-Silva, M. J., Sousa-e-Silva, P., Morato, V. S., Costa, D. C., Martinho, D. V., Rama, L. M., Valente-dos-Santos, J., Werneck, A. O., Tavares, O. M., Conde, J., Castanheira, J. M., Soles-Goncalves, R., & Duarte, J. P. (2020). Allometric modeling of Wingate test among adult male athletes from combat sports. *Medicina, 56*(9), 1-14. https://doi.org/10.3390/medicina56090480

Franchini, E. (2019). Upper-body Wingate test classificatory table for adult judo athletes. *Journal of Exercise Rehabilitation, 15*(1), 55-59. https://doi.org/10.12965/jer.1836520.260

Hamdi, J., Majdi, R., Coudrat, L., Attiogbe, E., Vandewalle, H., & Driss, T. (2014). Effects of load on Wingate test performances and reliability. *Journal of Strength and Conditioning Research, 28*(12), 3462-3468. https://doi.org/10.1519/JSC.0000000000000575

Hammad, R., Baker, A. A., Schatte, J., Alqaraan, A., Almulla, A. & Hammad, S. (2019). The Effect of Different Musical Rhythms on Anaerobic Abilities in Taekwondo Athletes. *Journal of Educational and Developmental Psychology, 9*(2), 150-157. https://doi.org/10.5539/jedp.v9n2p150

Kadlec, J., Marko, D., Vondrasek, J. D., & Bahensky, P. (2022). Effect of body position during the Wingate test. *Journal of Physical Education and Sport, 22*(3), 690-695. https://doi.org/10.7752/jpes.2022.03086

Khayyat, H. N., Sagir, S. G., Hatas, O., Smolarczyk, M., & Akalan, C. (2020). Physical, physiological and psychological profiles of elite Turkish taekwondo athletes. *Biomedical Human Kinetics, 12*, 187-196. https://doi.org/10.2478/bhk-2020-0024

Lericollais, R., Gauthier, A., Bessot, N., & Davenne, D. (2011). Diurnal evolution of cycling biomechanical parameters during a 60-s Wingate test. *Scandinavian Journal of Medicine & Science in Sport, 21*(6), 106-114. https://doi.org/10.1111/j.1600-0838.2010.01172.x

Lin, H. F., & Ding, Z. L. (2023). Physical training intervention on the functional status of taekwondo athletes. *Revista Brasileira de Medicina do Esporte, 29*, 1-4. https://doi.org/10.1590/1517-8692202329012022_0293

Liu, F., & Jia, H. (2023). Influence of high-intensity training on the taekwondo athletes' performance. *Revista Brasilieira de Medicina do Esporte, 29*(1), 1-5. https://doi.org/10.1590/1517-8692202329012022_0395

Mackenzie, B. (2005). *101 Performance Evaluation Tests*. Electric Word plc.

Monteiro de Moura, B., Moro, V. L., Rossato, M., Dantas de Lucas, R., & Diefenthaeler, F. (2017). Effects of saddle height on performance and muscular activity during the Wingate test. *Journal of Physical Education, 28*(1), 1-10. https://doi.org/10.4025/jphyseduc.v28i1.2838

Nabilpour, M., Samanipour, M. H., Bragazzi, N. L., Haddad, M., Herrera-Valenzuela, T., Tao, D., Baker, J. S., & Simenko, J. (2023). An investigation into the associations between psychological skills, anaerobic fitness, and aerobic fitness in elite Iranian taekwondo athletes. *Plos one, 18*(7), 1-12. https://doi.org/10.1371/journal.pone.0288227

Onuma, N., Shindo, D., Matsuo, E., Sakazaki, M., Nagai, Y., & Yamanaka, K. (2023). Pre-exercise isomaltulose intake affects carbohydrate oxidation reduction during endurance exercise and maximal power output in the subsequent Wingate test. *BMC Sports Science, Medicine and Rehabilitation, 15*, 1-11. https://doi.org/10.1186/s13102-023-00702-7

Ooi, F. K., & Anowar, M. N. M. (2018). Aerobic and anaerobic capacities, flexibility and muscular performance of malaysian young female sedentary individuals, silat and taekwondo practitioners. *The Russian Journal of Physical Education and Sport (Pedagogico-Phycological and Medico-Biological Problems of Physical Culture and Sports), 13*(3), 70-78. https://doi.org/10.14526/2070-4798-2018-13-3-90-100

Rhyu, H., & Cho, S. (2014). The effect of weight loss by ketogenic diet on the body composition, performance-related physical fitness factors and cytokines of taekwondo athletes. *Journal of Exercise Rehabilitation, 10*(5), 326-331. http://dx.doi.org/10.12965/jer.140160

Rocha, F., Louro, H., Matias, R., & Costa, A. (2016). Anaerobic fitness assessment in taekwondo athletes. A new perspective. *Motricidade, 12*(2), 127-139. DOI: https://doi.org/10.6063/motricidade.8954

Sant'Ana, J., Diefenthaeler, F., Dal Pupo, J., Detanico, D., Gugliemo, L. G. A., & Santos, S. G. (2014). Anaerobic evaluation of Taekwondo athletes. *International SportMed Journal, 15*(4), 492–499. https://journals.co.za/doi/abs/10.10520/EJC164090

Souissi, N., Bessot, N., Chamari, K., Gauthier, A., Sesboue, B., & Davenne, D. (2007). Effect of time of day on aerobic contribution to the 30-s Wingate Test performance. *Chronobiology International, 24*(4), 739-748. https://doi.org/10.1080/07420520701535811

Taati, B., Arazi, H., Bridge, C.A., & Franchini E. (2022). A new taekwondo-specific field test for estimating aerobic power, anaerobic fitness, and agility performance. *PLoS ONE, 17*(3), 1-17. https://doi.org/10.1371/journal.pone.0264910

Tayech, A., Mejri, M. A., Chaouachi, M., Chaabene, H., Hambli, M., Brughelli, M., Behm, D.G., & Chaouachi, A. (2020). Taekwondo Anaerobic Intermittent Kick Test: Discriminant Validity and an Update with the Gold - Standard Wingate Test. *Journal of Human Kinetics, 71*, 229-242. https://doi.org/10.2478/hukin-2019-0081

Wilson, R. W., Snyder, A. C., & Dorman, J. C. (2009). Analysis of seated and standing triple Wingate tests. *Journal of Strength and Conditioning Research, 23*(3), 868-873. https://doi.org/10.1519/JSC.0b013e31819d0932