ANAEROBIC FITNESS TESTING IN CROSSFIT

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Summary: CrossFit is one of the sports disciplines where endurance play a significant role in the performance. For testing anaerobic fitness it is important to choose the means that are part of the exercise and have a good transfer to the sport. A sample of competitive crossfitters ($n = 12$) underwent stress tests on the assault air bike (AB) (60 s) and Wingate. In addition to the performance parameters (W_{max} , W_{mean} , W/kg , cal), lactate values after exercise (1st, 5th, 10th and 15th minute) were monitored. The results showed significant differences in both the absolute values of lactate and the development of the lactate curve ($\alpha = 0.05$). The correlation of the selected variables showed a significant relationship between the average Watts value and the calories traveled (0.894). Testing anaerobic fitness with AB appears to be a suitable variant for CrossFit, as well as monitoring the development of lactate curve. Due to the original design of the study, it is necessary to verify the results.

Keywords: performance, Wingate, assault air bike, lactate, VLamax, conditioning

Introduction

CrossFit is a worldwide phenomenon, which gradually evolved in a performance, respectively racing form. The races are organized at a local and international level and require a long-term and specific training. Therefore, it is necessary to analyze individual aspects and transfer the results to the training practice (Feito et al. 2018; Schlegel et al. 2020).

By its nature, CrossFit ranks among relatively short and highly intensive sport disciplines. Most of the load usually lasts between 5 – 20 minutes and consists of various modalities including not only the traditional endurance sports (running or rowing), but also exercises with bodyweight or external load. The level of load is evidenced by heart rate values, lactate levels or elevated creatine kinase parameters (Dexheimer et al. 2019). A good level of

aerobic and anaerobic fitness is important for the mentioned endurance performance. Both components are involved in the outcome and their ratio must be in good balance (Butcher et al. 2015). Therefore, attention should also be paid to the level of anaerobic metabolism.

Testing anaerobic fitness represents a very short load at maximum intensity, which is mainly dependent on the energy substrates creatine phosphate, glycogen (Medbø & Tabata 1993). The duration of the tests ranges from 30 to 60s and parameters, such as a lactate level and course, peak power, mean power, fatigue index, or VO_2max are monitored (Noorhof et al. 2013). The level of these parameters is also dependent on strength, muscle fiber ratio or lactate metabolism. The monitoring of the blood lactate levels is a good feedback for evaluating the intensity of indoor stress (Brooks 2018).

A very common means is to use the Wingate test (Wingate), which uses a bicycle treadmill with a gradual increase in resistance. It is a valid and reliable device that is applied in various sports disciplines (Murawska-Cialowicz 2015). However, it uses only the lower half of the body and therefore its informative value may in some cases be limiting. In CrossFit, the upper body is also heavily involved, which is why it is tested. Assault air bike (AB) is a special free-wheeled wheel that allows you to engage the pull and push forces of the upper limbs. The load is therefore more complex with a likely overlap in the use of energy resources and a physiological response. It is also a commonly used training and racing device.

The aim of this research was to determine whether AB is a suitable means for testing anaerobic fitness in performance crossfitters and further compare the results with the Wingate test. Thus, a standardized and a non-standardized anaerobic fitness test were compared.

Methods

Study design

The participants underwent two stress tests to assess the level of anaerobic fitness. First, the AB test, then the Wingate test; the interval between tests was a week. In both tests it is necessary to work with the maximum effort to which individuals were motivated. The testing included a measurement of the lactate development after loading; performance values from both devices were also monitored. The tests were then compared in terms of the lactate curve and the measured parameters.

Participants

12 men (age 28.1 years, height 183.3 cm, weight 86.9) participated in the research. They were competitive crossfitters with experience with CrossFit for at least 2 years and with participation in competitions at least at the regional level. All of them were currently in a similar

stage of preparation without a significant variation in the training regimen or specific development of anaerobic fitness. The average number of training units was 6 and their content contained strength, weightlifting, gymnastic and conditioning parts. They all had experience with AB and the method of loading in tests. Two days prior to the test, they should only have a light training intensity. None of the participants had a significant low/high-carbohydrate diet. 48 hours before the test, carbohydrate intake should not be increased. The dietary supplements supporting the exercise have been banned.

Table 1
Description of the research sample

	Mean	SD	Minimum	Maximum	Median
Age	28.1	5.3	20	34	31
Height	183.3	5.7	174	193	182.5
Weight	86.9	9.8	73	107.5	84

SD – standard deviation

Testing

The same protocol was set for both tests. The test experienced a warm-up phase (5 minutes) on a bicycle or AB. The heating was done at light intensity to avoid a subsequent lactate increase and a significant increase in respiratory rate/depth. The targeted breathing techniques were also not allowed. This was followed by a 3 min passive pause and the first lactate collection. On instruction the participant took the test, where he was strongly motivated by the researchers in the limit performance from the beginning. The test was followed by a passive sitting position, in which he had to endure until the end of the test, any further movement was prohibited. The lactate collection after the exercise was performed at 1, 5, 10 and 15 minutes.

Wingate test

This is a 30s test on a Wattbike (Monark exercise AB, Sweden). The principle is isokinetic cycle sprint by 7.5% of the weight of the tested person. Peak power (Wmax), mean power (Wmean) and W/kg (maximum weight index) were monitored.

Assault air bike test

It is a special bike, where it is also possible to work with free arms that allow pushing and pulling upper body. The arms and pedals are mechanically dependent on each other and have the same frequency. The machine cannot adjust the difficulty, which increases as speed increases on the principle of an aerodynamic brake (resistance is created by flywheel). Here, the calories traveled (a separate unit of measure whose value is derived from the output force

in watts) were monitored. The participants worked for 60s with maximum effort, right from the start.

Lactate

The enzymatic-amperometric method for the determination of lactate in fresh capillary blood (Lactate scout, EKF diagnostics) was used. The sample was taken from the earlobe.

Analyses of data

Using TIBCO Statistics, Desktop version, a t-test was applied between the measured lactate values after loading on AB and Wingate. Furthermore, the correlation analysis (Spearman coefficient) was used to determine the relationship between selected variables that were obtained from both tests.

Results

Table 2 shows selected values from the AB and Wingate stress tests. The results of Wmax, where the average was 1268, 8 Watts, reveal that they were the athletes with very good strength abilities of the lower limbs. Greater dispersion was recorded in calories traveled, values ranged from 34 – 57.

Table 2
Description of the performance values on AB and Wingate

	Mean	SD	Minimum	Maximum	Median
Wmax	1268.8	130.2	1045.0	1467.0	1264.5
Wmean	771.5	55.9	700.0	873.0	755.5
W/kg	14.6	1.1	13.4	16.9	14.3
Cal (AB)	43.9	7.2	34.0	57.0	41.5

Wmax - the maximum achieved value of Watts (Wingate); Wmean – average value of Watts (Wingate); W/kg - index of maximum power in terms of mass (Wingate); cal - calories traveled (AB)

The athletes achieved high levels of lactate during the tests (Table 3). During the first minutes there was a rapid increase, which reached a maximum in the 5th minute (Wingate), respectively in the 10th minute (AB). The development of the lactate curve of all participants is shown in Fig. 1 below. It is evident that after the loading on AB, lactate accumulated for a longer time, reached higher values and also decreased more slowly. Even after 15 minutes the average value was 15.7 compared to Wingate with 11.4. In addition, the lactate values at Wingate showed greater variance at 10 and 15 minutes. The figure also shows the course of changes in the lactate levels based on average values (AB - black, Wingate - blue). The curve shows a similar course, but is significantly different at the end.

Table 3
Average lactate values in minutes

	0	1	5	10	15
AB	1.78	11.65	14.46	15.98	15.68
SD	0.52	2.56	1.66	0.92	1.19
Wingate	1.75	10.30	14.09	13.16	11.10
SD	0.38	2.92	1.67	1.87	2.48

SD – standard deviation

Figure 1
Lactate curve after Wingate and AB

Table 4
T-test for the average AB and Wingate values per minute

	Mean AB	Mean W	t - value	df	p	Valid N AB	Valid N W	SD AB	SD W	F-ratio variances	Variances
AB1 vs W1	11.65	10.64	0.90	22.00	0.38	12.00	12.00	2.56	2.92	1.30	0.67
AB5 vs W5	14.46	14.23	0.34	22.00	0.73	12.00	12.00	1.66	1.67	1.01	0.99
AB10 vs W10	15.98	13.41	4.28	22.00	0.00	12.00	12.00	0.92	1.87	4.16	0.03
AB15 vs W15	15.68	11.43	5.34	22.00	0.00	12.00	12.00	1.19	2.48	4.34	0.02

W – Wingate; AB – assault air bike; SD – standard deviation; mean AB – lactate average value for AB; MeanW – lactate average value for Wingate

A comparison of the lactate values in individual minutes is given in Table 4. A statistically significant difference can be observed at 10 and 15 minutes. Conversely, at 1 and 5 minutes it was not confirmed although the values for AB were higher.

Furthermore, the development of the lactate curve was analyzed and the increase, respectively the decrease in average values (Table 5). Although lactate increased by 555.2 % for Wingate and 611.9 % for AB between the 1st and 2nd measurements, the statistical significance was not confirmed. Similarly, between the 2nd and 3rd measurements, when there was an increase (28.8 % for AB, 41.3 % for Wingate). A statistically significant difference can be observed in the development between the 3rd and 4th measurement (absolute deviation of 16.6%) and also between the 4th and 5th measurement.

Table 5
Assessment of a different development of the lactate curve

	Mean AB (%)	Mean W (%)	t - value	df	p	Valid N AB	Valid N W	SD AB	SD W	F-ratio variances	Variances
AB 0-1 vs W 0-1	9.87 (611.9)	8.93 (555.20)	0.80	22.00	0.44	12.00	12.00	2.76	2.98	1.16	0.80
AB 1-5 vs W 1-5	2.81 (28.80)	3.58 (41.30)	-0.75	22.00	0.46	12.00	12.00	2.53	2.52	1.01	0.99
AB 5-10 vs W 5-10	1.53 (11.70)	-0.82 (-4.90)	3.25	22.00	0.00	12.00	12.00	1.65	1.87	1.29	0.68
AB 10-15 vs W 10-15	-0.31 (-1.80)	-1.98 (-14.40)	2.39	22.00	0.03	12.00	12.00	1.07	2.17	4.10	0.03

W – Wingate; AB – assault air bike; SD – standard deviation; mean AB – lactate average value for AB; MeanW – lactate average value for Wingate

A correlation analysis was performed to assess the relationship between the selected variables (Table 6). The expected strong relationship ($\alpha = 0.01$) was shown between weight and Wmax (0.713) and also with Wmean (0.683). Neither age nor height showed a strong relationship with any of the selected variables. Calories traveled had a strong correlation with Wmean (0.894). Other statistically significant relationships were not shown.

Table 6
Correlation analysis of the selected variables

	Age	height	weight	Wmax	W_mean	W/kg	cal
Age	1	0.442	0.558	0.536	0.420	-0.116	0.471
height	0.442	1	0.224	0.172	-0.035	-0.090	0.094
weight	0.558	0.224	1	0.713**	0.683*	-0.473	0.519
Wmax	0.536	0.172	0.713**	1	0.568	0.268	0.474
W_mean	0.420	-0.035	0.683*	0.568	1	-0.310	0.894**
W/kg	-0.116	-0.090	-0.473	0.268	-0.310	1	-0.204
cal	0.471	0.094	0.519	0.474	0.894**	-0.204	1

Wmax - the maximum achieved value of Watts; Wmean – average value of Watts; W/kg - index of maximum power in terms of mass; cal - calories traveled

Discussion

The use of Wingate for testing the anaerobic endurance is common in sports training (Noordhof et al. 2013). In CrossFit, it has been used several times, but as a potential predictor of the CrossFit performance (Butcher et al. 2015). For some workout of the day (WOD), Wmax or Wmean may be related to the end result (Dexheimer et al. 2019), but this cannot be broadly claimed (see Bellar et al. 2015, Martínez-Gómez et al. 2019).

The absolute achievements (Wmax, Wmean) in Wingate are relatively high and comparable, for example, with hockey players (Lau et al. 2001). In this research, the participants reached higher values compared to the tested CrossFit samples (Feito et al. 2018 or Butcher et al. 2015). The overall performance level of the group seems to be a significant factor. These were the athletes who have competing experience at least on a local level. In such a case, it is possible to assume high strength abilities not only of the lower limbs (Serafini et al. 2018) and thus a high power production on the bicycle simulator.

This was the first known study to test the load using AB and therefore, no comparable studies can be referred to. Ozkaya et al. (2013) dealt with the use of an elliptical trainer, which also engages the upper and lower half of the body, but it is different from AB. As with this research, the treadmill showed higher physiological values than the Wingate. In most WODs the whole body is involved, and therefore, all the large muscle groups (Feito et al. 2018). AB also requires the use of upper body pushing and pulling forces, as demonstrated by the lactate accumulation that was higher than that of Wingate or equally long stress tests (Carey & Richardson 2003; Carter et al. 2005; Miladi et al. 2011).

The correlation results show that AB and Wingate cannot be fully substitutable. AB was used with calories traveled, showing a high correlation (.871) with Wmean only. In addition to the maximum power output, both values also reflect strength endurance and work efficiency in a short maximum load - anaerobic work capacity. This includes not only the physiological aspects - the involvement of muscle fibers, the proportion of aerobic and anaerobic metabolism, the ability of glycolysis, lactate production (Brooks et al. 2018), but also the mental readiness to perform the limit performance. However, due to the high levels of lactate achieved (15.98 for AB and 14.2 for Wingate), both intensities and excessive activation of anaerobic metabolism appeared to be maximal in both tests.

The Wingate values, such as Wmax, fatigue index or W/kg are not very significant for the CrossFit performance. These variables can, of course, show when retesting the physiological changes that occurred during the training (Murawska-Cialowicz et al. 2015). Because of the nature of CrossFit, Wmean is more important because the load takes a longer

time and more in the context of strength endurance than the maximum power output (Butcher et al. 2015). The calories traveled can therefore substitute for W_{mean} .

The lactate curve showed deviations after the stress tests. Already in the first measurement the values differed by 0.7. This is probably due to the involvement of more muscles and thus a slightly higher total lactate production (Noordhof et al. 2013). At 5 minutes the difference between the values decreased to 0.3, which is probably due to the organism's limit capacity to accumulate excessive amounts of lactate in the body. It appears that it will not be possible to achieve significant differences in lactate levels in the tests during the first minutes due to the physiological limitations mentioned (Öztürk et al. 1998). At the 10th minute, the lactate curve developed in reverse and this was confirmed statistically ($\alpha = 0.01$). In AB, the amount of lactate increased further and reached its maximum, unlike Wingate, where it has already decreased. This is due to the more complex load at AB and probably also due to the length of load, although even tests lasting 45-90s do not always show such a course (Carter et al. 2005, Miladi et al. 2011). With Wingate, it is possible that the peak could be reached between 5 and 10 minutes (see Öztürk et al. 1998). The high accumulation of lactate in AB had an effect on the further course, when there was only a small decrease compared to Wingate, where the decrease was already marked (to 11.4). In Wingate, it is possible to observe the earlier peak of the lactate curve and also the steeper decrease of the lactate level.

The Crossfitters achieved high lactate absolute values in Wingate, which are higher than in similar studies (Spierer et al. 2004; Miladi et al. 2011). The reason could be a higher proportion of type I muscle fibers, which are the primary producer of lactate. It is typical of the CrossFit that athletes must possess very good strength and dynamic-strength abilities associated with the Olympic weightlifting (Schlegel et al. 2020), which confirms this premise. For AB the values were even higher and the onset was steeper. Therefore, it would be better to approach VL_{max} (maximum rate of energy production using the glycolytic system). High lactate levels are one indicator of good levels of the anaerobic system (Vandewalle et al. 1987). This is an important feedback with respect to the training process.

The stress tests for anaerobic fitness testing usually range from 30 to 60s. The 60s load is sufficient for the maximum lactate production and at the same time, the aerobic processes are not so strongly involved (Green & Dawson 1993; Medbø & Tabata 1993; Carter et al. 2005). In the case of CrossFit, it is important to achieve VL_{max} when testing anaerobic fitness and therefore, a longer loading time seems more appropriate. Unlike a short Wingate load, a more anaerobic work capacity is projected to an AB performance of 1 minute, which is more important for the CrossFit performance. Therefore, the calories traveled will be a valuable

indicator of the ability. The test time chosen therefore seems appropriate. Although the proportion of aerobic metabolism can reach as much as several tens of percent in the second half of the test (Medbø & Tabata 1989), it is nevertheless an optimal means for testing anaerobic fitness.

In the protocol a passive way of rest after the exercise was chosen. The method of rest after the exercise has a significant effect on the subsequent development of the lactate curve (Spierer et al. 2004; Ghorbani et al. 2015). The active method significantly reduces the rate of lactate degradation (Miladi et al. 2011). The passive rest clearly slows the transfer of lactate into oxidative fibers and other muscles. It is degraded primarily through glycolytic muscle fibers and metabolized through the liver (Brooks 2018). Especially in AB it was clear that the decline is very slow and even after 15 minutes was high (15.7). The steeper decline in recovery phase is due to better lactate clearance (Martin et al. 1998), which is a physiological component that is also involved in the CrossFit performance. This represents a relatively short load of usually 5 – 20 minutes of high intensity (Dexheimer et al. 2019). For testing purposes, an active way of rest could also be used, where the other processes mentioned above would be significantly affected by the process, but the development of these processes may also be a training goal.

Wingate is very often used across different sports (Butcher et al. 2015). As a result, it is also used for comparison with other anaerobic tests, as in the case of this research. Comparisons of unequal load lengths are reported by Carey & Richardson (2003) or Nebelsick-Gullett et al. (1988) using 60 s interval, similarly to Maud & Schulz (1989) with a load of 40 s on cycle ergometer. Wingate is also compared with specific tests that are close to the sport discipline. Tharp et al. (2013) monitored the load during the Wingate and the 600-yard run, where the average times were 119.7 s. Another example is the study by Sands et al. (2004), in which a comparison was made with the Bosco anaerobic test lasting 60 s.

The selected tests are not fully substitutable and identical results were not expected (due to the loading time, different amount of muscles involved, different devices). The purpose was to compare a standardized and non-standardized anaerobic fitness test. It seems that AB could be a suitable tool for testing this endurance in CrossFit and, due to its nature, is more suitable than Wingate. This is an original study, therefore it is necessary to confirm the results and conclusions regarding AB. A variant of shorter test time is offered for future research.

Conclusion

The CrossFit performance is influenced by both aerobic and anaerobic fitness, which must be matched in the context of training load and specific development. Both systems should therefore be included in fitness testing. For the purposes of CrossFit, it is advisable to use resources such as ABs they are part of the sporting discipline. Compared to Wingate, Wmean and calories have been shown to be related to the anaerobic work capacity that is important for CrossFit. After the AB test, the participants had higher lactate levels and, depending on the higher accumulation, there was also a different development of the lactate curve in the passive resting phase. The all-out AB stress test is not standardized, but it can be a good mean of testing anaerobic fitness when adhering to the test protocol. Testing the lactate level and the lactate curve in conjunction with the calories traveled seems to be a suitable mean for analyzing the current readiness of the anaerobic system.

Acknowledgements

We would like to acknowledge Jan Hiblbauer, M.D. for his help to carrying the research.

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