Validity of the Wingate Anaerobic Test for the Evaluation of Elite Runners

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Abstract

Legaz-Arrese, A, Munguía-Izquierdo, D, Carranza-García, LE, and Torres-Dávila, CG. Validity of the wingate anaerobic test for the evaluation of elite runners. *J Strength Cond Res* 24(x): 000–000, 2010—This study aimed to determine performance differences, based on the Wingate anaerobic test (WAnT), between homogeneous groups of elite male and female runners competing at distances ranging from 100 m to the marathon. We also attempted to establish a link between running ability and performance as measured by the WAnT. In total, 116 world-class runners (86 men and 30 woman) volunteered to participate in our study. Subjects were tested for peak power (PP, 5-second output) and mean power (MP, 30-second output) using WAnT procedures. Runners were classified into groups according to their best performances times. For male runners, PP and MP outputs decreased with increasing distance ($p < 0.001$). This trend was also true for female runners ($p < 0.005$). However, for both sexes, there were no significant differences in the PP values among 100-, 400-, and 800-m runners, and there were also no differences in the MP values for subjects that ran distances of 100 m compared with the values for subjects that ran distances of 400 and 800 m. In addition, no significant differences were observed in the PP and MP values between subjects that ran distances of 800, 1,500, and 3,000 m. Performance in the WAnT was not significantly associated with running performance in any distance event. The results of this study indicate that the WAnT is not a useful tool for the evaluation of elite runners.

Key Words performance, athletics, cycle ergometer, anaerobic power

Introduction

The importance of aerobic and anaerobic metabolism in running performance depends on distance. Successfully running 100 m is exclusively dependent on alactic and lactic anaerobic metabolism (6). In contrast, the energy required for running 400 m is 40–50% aerobic (7,24), and 60–70% of the energy required for running 800 m is derived from aerobic metabolism (7,24). Nevertheless, successfully running 800 m depends on combined contributions from both the aerobic and the anaerobic systems (24). Aerobic metabolism contributes the greatest part of the energy required for running 1,500 m (77–86%) (8,24). However, in agreement with Léger et al. (16), the race speed at this distance is greater than the velocity at $\dot{V}O_{2max}$. Therefore, neuromuscular function and anaerobic metabolism are more important for success when running for 1,500 m than for longer distance races. The contribution of anaerobic metabolism in runners competing in 3,000 m to the marathon events is insignificant (<10% for 3,000-m races) (8), and the speed of competition is less than the velocity at $\dot{V}O_{2max}$.

A number of field and laboratory tests were developed to evaluate the physiological parameters of aerobic and anaerobic metabolism to assess the training status of runners. In runners, the evaluation of aerobic capabilities has been clearly established, whereas the evaluation of anaerobic metabolism is more complex. Direct analysis of muscle biopsy samples can provide insights into anaerobic capacity by measuring adenosine triphosphate-phosphocreatine (ATP-PCr) breakdown, muscle glycogen levels, and lactic acid concentrations; however, this procedure is invasive and expensive. To avoid the use of invasive techniques, a number of short-term, high-intensity performance tests have been developed. These tests make use of either a treadmill (9,21,23) or a cycle ergometer (2,5) to determine anaerobic power and capacity. The measurement of the maximally accumulated oxygen deficit (MAOD) (19) is considered a preferred indicator of anaerobic capacity (18,22). Because of the complexity of the MAOD protocol, these measurements are almost exclusively used in research studies.

One of the most popular ways to measure anaerobic capabilities is the Wingate Anaerobic Test (WAnT) (2). The peak power (PP, the highest power performance during any

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5-second period) and mean power (MP, the total power performance during an entire 30-second period) are traditionally considered indices of anaerobic power and capacity. Despite some limitations, including a significant aerobic contribution in the WAnT (10), the PP and MP values of the WAnT are objective measures that can be compared between subjects and across different conditions.

Currently, the validity of the WAnT for the evaluation of runners is poorly characterized and controversial. To our knowledge, no studies to date have evaluated the differences in WAnT results between 100- and 400-m runners or between 800-, 1,500- and 3,000-m runners. Although many studies have demonstrated an association between WAnT-measured and sprint- and middle-distance running performance (4,17,20,28), these studies have not assessed homogeneous groups of elite runners.

Thus, the purpose of the present study was to determine if there are differences in performance, as determined by the WAnT, between male and female elite runners competing at distances ranging from 100 m to marathon length. In addition, we wanted to determine the relationship between the WAnT and running performance. We hypothesized that (a) consistent with differences in the contribution of anaerobic metabolism as described above, the PP values of the runners decrease progressively with increasing running distance; (b) because of to the similarities between the 400-m event and the WAnT, namely, the exercise duration, contribution of the aerobic–anaerobic metabolism and pacing strategy (10,12), the highest MP values should be seen in the 400-m trained runners; (c) the MP values for 100- and 800-m trained runners would be greater than those observed in runners competing in 1,500 m to marathon events, because of the differences in the contributions of anaerobic metabolism in these events; and (d) the PP and MP values would correlate with running performance in events that are strongly linked with anaerobic metabolism.

Methods

Experimental Approach to the Problem

The WAnT is widely used to analyze the anaerobic capabilities of athletic populations, including runners. The WAnT is a cycling test, so its validity for the evaluation of runners is questionable.

To address whether the WAnT is useful in the sport of running, it is necessary to verify if this test is capable of discriminating between runners competing at different distances with respect to the contributions of anaerobic metabolism and other factors evaluated in this study. With this objective, we compared PP and MP values, obtaining using WAnT procedures, from 116 world-class runners (86 men and 30 women) competing at distances ranging from 100 m to marathon length.

Additionally, to determine the usefulness of the WAnT in the context of running, we investigated whether PP and MP values were correlated with running performance in events that involved a major contribution of anaerobic metabolism. For this purpose, we selected the best performance values from athletes who had participated in official races.

Subjects

The participants in this study were engaged in intense athletic conditioning to compete in top-level running events. Inclusion in the study required that the participants have at least 2 years of experience in standard competitions at the national or international levels. In addition, the mean velocity achieved by participants during their best performance of the season had to rank among the top 50 in Spanish national rankings. All athletes trained 6 or $7 \cdot d \cdot wk^{-1}$ (20–25 hours) during the competitive season.

Participants visited the National Center of Sports Medicine in Madrid, Spain for anthropometric assessments and for WAnT testing. All examinations were performed during the competitive season and within 2 months of the athletes achieving their best performance. During this period, athletes continued their normal training programs. This study was approved by the Research Ethics Committee of the Government of Aragón. All test procedures were explained to the participants, and written informed consent was obtained from each individual.

Procedures

Runners were classified into groups according to their best performances as follows: sprint trained (STR), 100 and 400 m; middle-distance trained (MTR), 800-, 1,500-, 3,000-, and 3,000-m steeplechase; and long distance–trained (LTR), 5,000, 10,000 m, and the marathon (Table 1). The criteria used to determine the best performance of these athletes over several events were established by identifying the corresponding performance equivalent awarded by the International Amateur Athletic Federation (IAAF) (25). Under this system, the IAAF assigns a score to each runner's performance using a database of performances recorded at the international level. These ratings allow for the assessment and comparison of performances from different events for the same athlete.

The WAnT was performed on a Monark cycle ergometer (model 864, Monark-Crescent AB, Varberg, Sweden). Saddle height was adjusted to each participant's preference, and toe clips with straps were used to prevent the feet from slipping off the pedals. Initially, a 5-minute warm-up was conducted at a constant pace of 60 rpm against a workload of 75 and 50 W, for male and female runners, respectively, with a 5-s sprint at 3 minutes, followed by a 5-minute rest period. The test required subjects to cycle as fast as possible for 30 seconds against a constant resistance of $0.075 \ kg \cdot kg^{-1}$ of body mass. Subjects were verbally encouraged to maintain as high a pedaling rate as possible throughout the 30-second test duration. A photocell was used to count the total number of flywheel revolutions on the ergometer, and the output was recorded by a computer equipped with an analog to digital converter. Power was recorded in Watts every 5 seconds. Peak power output was calculated from the highest 5-second

TABLE 1. Performance of male and female runners.

	Male athletes				Female athletes			
	Performance (race time)	Age (y)	Mass (kg)	*n*	Performance (race time)	Age (y)	Mass (kg)	*n*
100 m	10.74 CV = 1.7%	22 ± 2	70 ± 7	15	12.28 CV = 0.6%	25 ± 3	58 ± 4	4
400 m	47.78 CV = 2.1%	24 ± 4	75 ± 6	22	55.40 CV = 4.7%	22 ± 3	56 ± 5	6
800 m	1:50.15 CV = 2.8%	22 ± 3	69 ± 5	22	2:06.48 CV = 1.9%	22 ± 4	53 ± 3	5
1,500 m	3:40.52 CV = 2.1%	25 ± 4	66 ± 5	9	4:2 1.57 CV = 3.7%	24 ± 6	53 ± 8	9
3,000 m	7:42.52 CV = 0.1%	27 ± 3	66 ± 2	2	9:43.60	21	48	1
3,000-m steeplechase	8:52.00 CV = 0.1%	20 ± 2	65 ± 6	3				
10,000 m	29:09.15 CV = 3.9%	27 ± 5	57 ± 6	8	34:27.12 CV = 3.0%	22 ± 2	47 ± 6	3
Marathon	2:15:51 CV = 1.4%	31 ± 4	59 ± 3	5	2:43:05 CV = 2.1%	32 ± 3	44 ± 1	2

Data presented as mean ± *SD*. CV = coefficient of variation.

output metrics. Mean power output was calculated from the average power generated across the entire 30-second test. Both measures were reported in Watt per kilogram. The equipment was calibrated according to the manufacturer's standardized procedures. The test–retest reliability for the PP values showed an intraclass correlation coefficient of 0.95 (95% interval: 0.89–0.98), and of 0.91 (95% interval: 0.79–0.97) for the MP values. The effect size, calculated using Hedges' formula, (11), was 9.58 (95% interval: 7.39–11.77) for PP and 8.24 (95% interval: 6.33–10.16) for MP.

Statistical Analyses

Statistical analysis was performed with the Statistical Package for Social Sciences (SPSS), version 15.0. Data are expressed as means ± *SD*. To identify any differences in running times and performance evaluated by the WAnT between athletes who compete at different distances, a multivariate linear model was developed using IAAF scores, with PP and MP values as criterion measures and the type of event as the independent variable. Pearson correlations were used to examine the relationships between PP and MP values and running performance. The Bonferroni correction was used to compensate for multiple testing effects. A value of $p \leq 0.016$ was considered significant when comparing STR, MTR, and LTR runners; a value of $p \leq 0.0045$ was considered significant when comparing events and for correlation analysis.

Results

The means (±*SD*) of the IAAF scores and the WAnT variables are summarized in Tables 2 and 3.

Gender Differences

There were no significant differences in IAAF scores between male and female runners. All WAnT variables among STR, MTR, and LTR runners were significantly higher in male runners than in female runners ($p < 0.01$).

Event Differences

Male Runners. In male runners, IAAF scores were significantly lower in STR compared with MTR and LTR ($p < 0.05$); no differences were found in IAAF scores between MTR and LTR. Notably, when compared based on running, 1,500-m runners exhibited higher IAAF scores than did 100- and 400-m runners ($p < 0.05$).

In male runners, PP and MP values were significantly higher in STR than in MTR and LTR ($p < 0.001$) and were also significantly higher in MTR than in LTR ($p < 0.001$). When PP and MP values were adjusted for body mass, STR and MTR exhibited significant differences when compared with LTR ($p < 0.001$).

For male athletes competing in the 100- and 400-m events, PP values were higher than for those who competed in the 1,500-, 3,000-m steeplechase, 10,000-m, and marathon events ($p < 0.01$). The PP values of the 800-m runners were also significantly higher than those of the 10,000-m and marathon runners ($p < 0.001$), and the PP values of the 1,500-m runners were higher than those of the 10,000-m competitors ($p < 0.001$). We found no significant differences in the PP values when comparing the 100-, 400-, and 800-m runners.

Four hundred–meter runners recorded statistically higher MP values vs. the other runners ($p < 0.05$), except when they

TABLE 2. Descriptive statistics for male participants.

	IAAF score	Peak power (W)	Peak power (W·kg^{-1})	Mean power (W)	Mean power (W·kg^{-1})
p Values	0.003	0.000	0.000	0.000	0.000
Sprint-trained runners (*n* = 37)	1,002 ± 58	871 ± 79	11.9 ± 0.9	735 ± 70	10.1 ± 0.9
100 m (*n* = 15)	996 ± 55	851 ± 76	12.2 ± 1.0	711 ± 68	10.2 ± 0.9
400 m (*n* = 22)	1,006 ± 61	884 ± 80	11.8 ± 0.8	751 ± 67	10.0 ± 0.8
Middle distance–trained runners (*n* = 36)	1,054 ± 86*	777 ± 101*	11.5 ± 1.2	654 ± 77*	9.7 ± 0.9
800 m (*n* = 22)	1,026 ± 87	820 ± 79	11.9 ± 1.1	685 ± 60	9.9 ± 0.9
1,500 m (*n* = 9)	1,102 ± 65	713 ± 103	10.8 ± 1.1	622 ± 83	9.4 ± 0.8
3,000 m (*n* = 2)	1,167 ± 2	765 ± 7	11.5 ± 0.2	633 ± 9	9.6 ± 0.4
3,000 m steeplechase (*n* = 3)	1,047 ± 5	653 ± 76	10.1 ± 0.3	542 ± 41	8.4 ± 1.1
Long distance–trained runners (*n* = 13)	1,067 ± 84†	570 ± 99†‡	9.8 ± 1.4†‡	491 ± 67†‡	8.4 ± 1.0†‡
10,000 m (*n* = 8)	1,048 ± 103	558 ± 116	9.7 ± 1.6	495 ± 83	8.6 ± 1.1
Marathon (*n* = 5)	1,098 ± 26	586 ± 73	10.0 ± 1.0	483 ± 49	8.2 ± 0.7

Data are presented as mean ± *SD*. *p* Values represent comparisons between sprint-trained runners, middle distance–trained runners, and long distance–trained runners. Refer to the text for the results of our statistical analyses of runners who compete in different events.
*Significant difference between sprint-trained and middle distance–trained runners.
†Significant difference between sprint-trained and long distance–trained runners.
‡Significant difference between middle distance–trained and long distance–trained runners.

were compared with the 100-m competitors. Mean power values of the 100- and 800-m runners were significantly higher than those of the 3,000-m steeplechase, 10,000-m, and marathon runners ($p < 0.05$), and the MP values of the 1,500-m runners were higher than those of the 10,000 m and marathon runners ($p < 0.01$). There were no significant differences in the MP values of the 100-m runners compared with the values of the 400- and 800-m runners.

In our analysis of PP and MP values adjusted for body mass, only the 100-, 400-, and 800-m runners recorded values higher than those of the 10,000-m and marathon runners ($p < 0.01$).

Female Runners. There were no significant differences in the IAAF scores of female runners. Among female participants, PP values were significantly higher in STR than in MTR and LTR ($p < 0.01$) and were also significantly higher in MTR

TABLE 3. Descriptive statistics for female participants.

	IAAF score	Peak power (W)	Peak power (W·kg^{-1})	Mean power (W)	Mean power (W·kg^{-1})
p Values	0.439	0.000	0.004	0.001	0.060
Sprint-trained runners (*n* = 10)	1,007 ± 66	586 ± 59	10.3 ± 0.7	478 ± 62	8.4 ± 0.9
100 m (*n* = 4)	980 ± 10	606 ± 51	10.5 ± 0.7	478 ± 38	8.3 ± 0.8
400 m (*n* = 6)	1,024 ± 82	571 ± 64	10.2 ± 0.8	478 ± 78	8.5 ± 1.0
Middle distance–trained runners (*n* = 15)	1,039 ± 62	479 ± 75*	9.3 ± 1.1	419 ± 68*	8.0 ± 1.1
800 m (*n* = 5)	1,042 ± 40	527 ± 22	10.0 ± 0.6	466 ± 38	8.8 ± 0.8
1,500 m (*n* = 9)	1,045 ± 73	470 ± 73	9.2 ± 1.0	408 ± 62	7.7 ± 0.8
3,000 m (*n* = 1)	976	320	6.7	287	6.0
Long distance–trained runners (*n* = 5)	1,027 ± 44	385 ± 86†‡	8.3 ± 1.3†	330 ± 47†‡	7.2 ± 0.4
10,000 m (*n* = 3)	1,032 ± 56	385 ± 120	8.1 ± 1.6	330 ± 66	7.0 ± 0.5
Marathon (*n* = 2)	1,019 ± 35	383 ± 46	8.6 ± 1.0	330 ± 14	7.4 ± 0.3

IAAF = International Amateur Athletic Federation. Data are presented as mean ± *SD*. *p* Values represent comparisons between sprint-trained runners, middle distance–trained runners, and long distance–trained runners. Refer to the text for the results of our statistical analysis of runners who compete in different events.
*Significant difference between sprint-trained and middle distance–trained runners.
†Significant differences between sprint-trained and long distance–trained runners.
‡Significant differences between middle distance–trained and long distance–trained runners.

Table 4. Association between PP and MP values and race time in male runners.*

	PP (W)	PP (W·kg^{-1})	MP (W)	MP (W·kg^{-1})
100 m ($n = 15$)	0.24	−0.41	0.22	−0.39
400 m ($n = 22$)	0.28	0.02	0.23	−0.03
800 m ($n = 22$)	0.10	0.13	0.19	0.21
1,500 m ($n = 9$)	−0.55	−0.36	−0.44	−0.18
10,000 m ($n = 8$)	0.19	0.26	0.08	0.11
Marathon ($n = 5$)	0.26	0.42	0.13	0.28

*PP = peak power; MP = mean power.
Data presented as r value. A value of $p > 0.05$ was observed in all correlations.

than in LTR ($p < 0.05$). This trend was also observed for MP values, except that the differences between STR and MTR were not significant. In terms of PP values adjusted for body mass, significant differences were only observed between STR and LTR ($p < 0.05$). There were no significant differences between the groups in terms of MP values adjusted for body mass. In our analysis based on type of event, the PP values of the 100-m runners were higher than those of the 1,500-, 10,000-m, and marathon runners ($p < 0.05$), and the PP values of the 400-m runners exceeded those of the 10,000-m and marathon runners ($p < 0.05$). Body mass-adjusted MP and PP values for the 100- and 400-m runners were higher than for the 10,000-m runners ($p < 0.05$).

Correlations between Wingate Variables and Running Performance

In male runners, the PP and MP values were not significantly associated with performance over any of the distances analyzed (Table 4). This was also true for female runners.

Discussion

This study examines, for the first time, the validity of the WAnT for evaluating elite runners. Globally, the results of this study demonstrate that the WAnT can differentiate between runners who follow different training programs, such as for STR vs. MTR vs. LTR. However, contrary to the expected results and our hypotheses, the most important finding of this study was the absence of significant differences in the various indices of the WAnT when we compared 100-, 400-, and 800-m runners. In addition, performance values determined by the WAnT were not correlated with running performance in those events where anaerobic metabolism plays a role, such as in sprint- and middle-distance running events.

Previous studies have suggested that the WAnT is useful for analyzing the correlation between PP and MP values and sprint running performance for 50- to 300-m running events (3,13,17,20,26). However, a more critical evaluation of these studies indicates that the correlation between the WAnT output and sprint running performance is broadly influenced by many characteristics of the study participants.

In an early study by Bar-Or and Inbar (3), a strong link between the PP and MP values for the 40-, 300-, and 600-m running sprints ($r = 0.70$–0.85) was reported. The study subjects included boys across a broad age range (10 to 15 years) and with a very high coefficient of variation (CV) in terms of running performance (12–22%). In addition, the authors failed to control for age and weight. In a similar study where running performance exhibited a lower CV (8%), Tharp et al. (26) observed WAnT scores for anaerobic power and capacity were only moderately correlated with 50-yard dash times ($r = -0.53$), and this correlation was lower when the data were adjusted for age. With active adult subjects, a stronger correlation of $r = -0.91$ was obtained between PP values and 50-m run times, but this association was not significant for MP values (13). In addition, the authors failed to provide information about the CV for running performance. Moreover, this study was limited by the small sample size of only 9 subjects. Interestingly, Meckel et al. (17) reported a strong correlation between 100-m running time and the PP ($r = -0.89$) and MP ($r = -0.82$) outputs of the WAnT in a group of female subjects that included elite runners. In this study, the observed correlation may have been influenced by the heterogeneity in running times between the subjects (running performance: "Fast group" = 11.8 ± 0.1 seconds, "Slow group" = 14.2 ± 0.1 seconds). The study population evaluated by Patton and Duggan (20) was a relatively homogeneous group of untrained subjects (CV = 6%) and the researchers reported significant correlations between various forms of WAnT power output and sprint running performance at 50 and 200 m.

The discrepancy in terms of correlation between performances as measured by the WAnT and sprint times in this study and in previous studies may be because of differences in the elapsed time between the WAnT and measurement of running performance. Although previous studies used standardized protocols such that running performance was determined by means of specific running tests performed simultaneously with WAnT testing, ours is the first study in which running performance was determined during official races. Nevertheless, by using an equivalent protocol, we have found a strong correlation between other physiological variables and running performance (1,14,15). In addition, the variation in running performance during a short period of time in elite runners is very limited. This suggests that, for the same event, the WAnT is capable only of discriminating between runners whose running performance metrics are markedly different.

Based on the differences in the contributions of alactic and lactic anaerobic metabolism previously reported between 100-, 400-, and 800-m running events, we expected to find noticeable differences in the WAnT performance values between runners competing at these distances. However, this was not the case, suggesting again that the WAnT is not useful for assessing elite runners. The differences in muscle- and activation-pattern specificities between running and cycling may be the cause of the weaknesses of the WAnT in evaluating running performance.

In conclusion, none of our proposed hypotheses established to determine the validity of the WAnT to evaluate elite runners proved correct. We conclude that this test is not appropriate for evaluating runners.

Practical Applications

It is important for coaches to monitor and evaluate the training-relevant progress of their trainees accurately and reliably. More specifically, the principal objective should be to provide information that will help the coach identify specific areas of relative deficiency, to develop individual training programs (27).

In running events ranging from 100 to 1,500 m in length, the anaerobic capability of an athlete is an important determinant of running performance. In addition, it is imperative in the evaluation of runners who compete at these distances, to incorporate tests that yield valid information on their anaerobic capabilities. In this regard, our study clearly suggests that the information provided by the WAnT is not useful in evaluating the anaerobic capabilities of elite runners.

The development of a battery of anaerobic tests that will take into account the specific nature of running events may be necessary to ensure the availability of accurate and reliable information for the coach. Therefore, future studies should verify whether field tests, such as those that measure different time intervals in a 300-m run scenario, provide, useful and reliable information to guide the coach in adjusting the training programs of elite runners.

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