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LETTER TO THE EDITORS

The Wingate anaerobic test's past and future and the compatibility of mechanically versus electro-magnetically braked cycle-ergometers

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Abstract The 30-year-old Wingate anaerobic test (WAnT) has proven a useful and a much-needed tool in the exercise physiology lab. However, the WAnT suffers from difficulties that partially stem from its original design but are mainly due to a large array of highly non-standardized procedures and the use of different testing modalities—mainly mechanically versus electro-magnetically braked ergometers. The present communication reviews and analyzes the deviations from WAnT's optimal use and proposes amendments that could make it a more valid, reliable, and a universally useful test.

Keywords Wingate anaerobic test · Mechanically braked cycle-ergometer · Electro-magnetically braked cycle-ergometer · Anaerobic performance · Anaerobic testing

Introduction

Electro-magnetically braked cycle-ergometry, in conjunction with the Wingate anaerobic test (WAnT), has been in use for quite a while now. Nevertheless, a very much-needed comparison between it and the original, mechanically-braked mode of testing, was not available. I would like, therefore, to commend Micklewright et al. (2006) for their very appropriate paper, comparing performance of the Wingate anaerobic test on mechanically versus electro-magnetically braked cycle ergometers.

Having taken part in the original WAnT-development effort in the mid 1970s (under the leadership of the late Oded Bar-Or), I have been delighted to witness WAnT's popularity around the world as both a fitness-diagnostic and a research tool. However, Micklewright et al.'s long-awaited comparative study demonstrated what has been long suspected. Namely, significant differences exist between the two modes of testing. In doing so, the study also manifested several of many procedural deviations from the original WAnT, prevalent in its presently non-standardized use around the globe. All those raise serious questions concerning the validity and comparability of WAnT data produced worldwide and reported in the literature.

Overview and limitations of the original WAnT

The WAnT was primarily intended as a test of glycolytic power, represented by what was termed mean power (MP). The WAnT's 30-s duration was chosen for being sufficiently long, not only for eliciting maximal glycolytic power, but for requiring a good measure of "glycolytic/anaerobic endurance", as well. At the same time, this duration was found sufficiently short, for the typical motivated subject, for maintaining maximal effort throughout the test.

Peak power (PP), was a by-product and a secondary WAnT parameter, defined as the highest 5-s power output (not necessarily the first 5 s). Its duration was chosen to represent phospholytic, a-lactic, power output. Also, the 5-s PP value is typically not much lower than the instantaneous peak power (as used by Lode's

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software for its electro-magnetically braked ergometer—EE), but enjoys a considerably better stability and reliability. Initially, however, PP's validity and reliability were both limited by four important factors:

(a) Limited resolution: the use of electro-mechanical micro-switch counters (at a time when PCs were non-existent) initially provided a resolution of only one crank-revolution (~6–12% error) and subsequently of half a revolution (~3–6%). With current technology, resolution is no longer a limiting factor.
(b) No correction was made for the significant amount of kinetic energy accumulated in the accelerated flywheel, prior to the onset (load application) of the actual test. It was clearly an oversight on the part of the development team which meant that PP was, to a large extent, a reflection of performance taking place outside the WAnT's 30-s time-frame. This, incidentally, overestimated not only PP but MP as well, although to a more limited extent. This shortcoming has later been realized and corrected by Lode as an integral feature of its EE test software, as well as by Monark, as a software option for its mechanically braked ergometer (ME).
(c) The preliminary flywheel-acceleration phase, especially of ME, requires a high degree of power output before monitoring actually starts. This means that much of the short-duration phospholytic power output, represented by PP, is being expended prior to the test. This problem has never been corrected, although current technology can readily address it.
(d) Universal, unambiguous, and physiologically sound criteria have never been formulated for the precise instant of load application onto the accelerated ergometer. The various criteria used to-date (peak RPM, a given percentage of RPM_{peak}, the tester's subjective judgment, etc.) produce widely different conditions at the WAnT's actual onset of power monitoring. This directly affects any attempt to assess the amount of energy expended during the acceleration phase ('c' above), as well as the actual PP determination ('b' above).

Fatigue index (FI), defined as the percentage drop in power output from the highest (PP) to the lowest 5-s segment (LP), proved valid enough for rough distinctions between individuals of varying levels of power capacity and aerobic/anaerobic endurance. This validity was somewhat limited by the aforementioned limitations of PP determination, but FI's main shortcoming was its low level of reliability. This stemmed from the limited resolution of determining both PP and LP. The problem has been inherently amplified by the fact that FI calculation is based on the subtraction and division of two low-resolution values. Available technology now allows for high-resolution monitoring. However, FI's reliability still suffers considerably from the inherent differences in how PP and LP are defined and determined.

The mechanical versus electro-magnetic modes of WAnT testing

Micklewright et al.'s conclusion, that the EE's testing results are valid indicators of anaerobic exercise performance, should be qualified. Indeed, EE's average power—the WAnT's main parameter—turned out a very similar mean value to that of ME (630 ± 89 vs. 633 ± 89 W, respectively). However, even this impressive similarity is somewhat misleading since the correlation coefficient between the two reached only 0.903. This means that only ~82% of the variance were mutually accounted for by two tests that presumably should have been synonymous and interchangeable with each other.

The considerably larger ME–EE differences in all other WAnT variables suggest that the entities estimated by the two tests are not identical. The following discussion excludes the metabolic comparisons that are part of Micklewright et al.'s paper. It limits itself to the reported differences in performance parameters and suggests possible sources for the discrepancies.

The most striking ME–EE difference was maximal RPM with reported means of 168 ± 18 on ME but only 128 ± 15 on EE. The 168 RPM value seems extremely high as a mean for normal subjects and should be questioned on three fronts:

(a) Were the recruited subjects indeed non-athletes and especially non-cyclists?
(b) If that value is valid, could the 128 RPM then be considered a true EE-maximum for subjects with a proven 168-RPM capacity?
(c) Was there a difference in the algorithm or criterion, used for the WAnT's onset (load application), between the two modalities? (e.g., was the EE load applied prematurely in respect to ME?).

Whatever the answers to these questions are, ME's much higher RPMmax directly reflects on other parameters in the following ways:

(1) It explains why the mean time-to-PP (TTPP) was considerably shorter for the ME WAnT (2.3 ± 0.7 vs. 4.3 ± 0.7 s).
(2) It implies, in conjunction with the much higher inertial resistance of the ME's flywheel, that

considerably more power and energy were expended prior to the test's actual onset. The latter partially explains the lower mean PP reported for ME (873 ± 159 vs. 931 ± 193 W). The other part of the explanation lies in the fact that EE's algorithm determines only instantaneous PP which, by definition, is always higher than any 5-s average.

(3) In lowering PP, ME's higher RPMmax in turn, is indirectly also responsible for the lower fatigue rate (FR) reported for this ergometer (15.2 ± 5.2 vs. 20.5 ± 6.8 W s^{-1}).

The other source for the difference in FR is the considerable disparity in minimum power. One reason for this clearly lies with the fact that EE's algorithm uses instantaneous lowest power rather than a 5-s mean. Another likely reason is ME's considerably larger flywheel inertia. This allows for smoother pedaling and, consequently, a smaller loss of momentum, compared with EE, in the fatigued state of the WAnT's final seconds.

How could the WAnT be amended?

The extent and diversity of the WAnT popularity is a testimony to the genuine need the test has catered to. Over the 30 years of accumulated experience and gained insight, since its inception, coupled with today's commonly available technological advances, have made the WAnT ripe for an overhaul. Based on the preceding discussion, the proposed WAnT amendments are described below.

Unequivocal determination of WAnT's outset

The attainment of RPMpeak, as a pre-requisite for load application and test onset, is problematic on two counts:

(a) RPMpeak, especially in unloaded pedaling, is only partially dependent on anaerobic capacity. To a large extent it depends on skill and training (e.g., cyclists vs. runners or untrained individuals), as well as on the specific muscle fibre-type profile. Thus, subjects of similar anaerobic characteristics might start the test at widely differing RPM.

(b) RPMpeak may take several seconds to reach, thus expending considerable power and energy before the test actually starts.

The alternative use of a particular percentage of RPMpeak may serve to reduce the severity of the latter objection, but it does not address the problem of differing onset RPM.

Provided test subjects are instructed to accelerate as fast as they can, a better approach would be to monitor the peaking of acceleration rather than speed (RPM). This would presumably separate the mainly-force-dependent portion of acceleration from the mostly-power-dependent subsequent portion. This criterion should still be tested and validated. However, the high sampling rates available with current technology would allow for this and other derivatives of the basic pedaling rate to be thoroughly investigated.

Load application

While the criterion for determining the instant of application is arguable (see above), its precise timing is already automatically (electronically) determined on EE. On MEs, on the other hand, load application is manual and subject to human error in judgment or response-time. The proposed solution to this is a solenoid-type release mechanism, computer activated to release the prescribed load at precisely the pre-determined instant.

Peak power determination

Flywheel inertial characteristics have already been used by both ME and EE, in correcting for the kinetic energy gained prior to load application at the WAnT's onset. These same data can be used to derive the second-by-second power output during the acceleration phase. PP's 5-s segment could conceivably begin prior to load application. Consequently, PP might be found higher this way than what would have previously been determined.

Mean power determination

When power output is monitored from the onset of acceleration and then for 30 s, following load application, the highest 30-s power-output average could be extracted from the > 30-s exercise period. This would constitute a truer measure of MP.

Fatigue index determination

With a higher sampling rate and a more precise, unequivocal determination of both PP and LP, FI should become, not only a more precise, but a much more reliable parameter, as well. The closely related FR (W s^{-1}) that has been extensively used is also a valid measure of fatigue, best suited for instantaneous

PP and LP (as used by Lode's EE). However, when 5-s PP and LP are used, as suggested, the percentage decrease in power output, as determined by FI, is a more stable and reliable parameter and, arguably, a more valid parameter than FR.

The ergometer of choice

The WAnT's origins on a mechanically-braked ergometer, would make it tempting to recommend that type as the ergometer-type of choice. Electro-magnetically braked ergometers, however, have become very popular due to some distinct advantages, especially in aerobic testing (the cadence-independence of power). Despite the observed differences, the use of EE for anaerobic testing cannot be written off. It remains to be seen how much of those differences would still persist after definitions and procedures are consolidated. Should any significant differences remain it would be the EE's manufacturers' role to ascertain that the isotonic torque they use is indeed synonymous with the constant resistance of the mechanically braked ergometer.

Conclusion

The unique role the WAnT has played in exercise testing in the past 30 years has made it clear the test deserves continued efforts to improve and universalize its usefulness. It is hoped, therefore, that the preceding discussion has served to enhance awareness and understanding of both the practical and theoretical issues involved in WAnT testing, and to stimulate thoughts and ideas about the necessary changes.

References

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