TOPICS IN EXERCISE SCIENCE AND KINESIOLOGY

Process of Science

Effects of a Race Timer on the 3-Minute All-Out Test for Critical Power

PAUL MANDELL[1], TAYLOR BLODEN[1], and BOE BURRUS[2]

[1]Department of Kinesiology and Recreation Administration, Cal Poly Humboldt, Arcata, CA, USA; [2]Department of Kinesiology and Sport Management, Gonzaga University, Spokane, WA, USA

ABSTRACT

Topics in Exercise Science and Kinesiology Volume 4: Issue 1, Article 2, 2023. The 3-min all-out cycling test (3MT) elicits valuable fitness metrics including $\dot{V}O_{2peak}$, HR_{max}, Critical Power (CP), and Work Above End Power (WEP; equivalent to work prime; W'). Twelve (n = 12) healthy active males were recruited to participate in the current study on the effects of the implementation of a race timer on the 3MT. Participants completed a $\dot{V}O_{2peak}$ test and one 3MT familiarization trial before completing one standard 3MT and one 3MT with the presence of a countdown race timer in a randomized order. CP was found to be significantly higher in the timer condition, while WEP was found to be significantly lower (CP: $P = .011$, WEP: $P = 0.004$). There were no significant differences in PPO or total work between trials. These results indicate that the presence of a race timer led to a difference in work profiles between tests. Potential explanations for these results may be attributed to the influence of knowledge of time on anticipation, decision-making, and pacing strategy during all-out exercise. The presence of a timer during the test may confer potential differences in performance outcomes in the 3MT.

KEY WORDS: Critical power, race timer, 3 minute all-out-test, 3MT

INTRODUCTION

Maximal exercise testing is commonly employed by exercise scientists to assess an athlete's capabilities and inform future training goals and tactics. The Critical Power (CP) concept provides a novel perspective on the physiological capacity of an individual to perform work. CP represents the maximal rate of work at which an individual can sustain exercise through continuous, stable use of available substrates (1-3). CP has also been labeled as the highest metabolic steady state an individual can achieve (3). Work Prime (W'), which represents exercise capacity above critical power, is established during CP testing to allow for precise quantification of anaerobic work capacity (2). The previous methodology for measuring CP is incredibly time intensive, requiring multiple exhaustive trials (~4-5) over the course of multiple days to create a CP profile (1-3). The 3 Minute All-Out Test (3MT) is a practical and efficient method for determining both CP and W' as well as determining $\dot{V}O_{2peak}$ and HR_{max} (1). By establishing both CP and W', athletes, trainers, and coaches can create a profile that provides insights into race pacing as well as the duration and/or distance at which work above CP can be sustained (3). Performance outcomes in exercise testing are sensitive to several factors including internal and external sensory feedback, perception of fatigue, prior knowledge of exercise mode, knowledge of distance/time remaining during exercise, mood state, and anticipation (4-8). Athletes rely on a variety of external sensory information (affordances) such as prior experience, distance, speed, time, etc. in order to precisely measure power output in both race and training settings (4-8, 16). Previous research using the 3MT has followed a protocol designed and validated by Vanhatalo et al (10), which relies on the blinding of participants during the 3MT. By following the original protocol and blinding participants in the 3MT to these variables, which include time, distance, speed, and power output (among other variables), participants may be unable to build a complete template for the session, thereby leading to the possibility of inaccurate measurement during the 3MT. (5-7). The inclusion of a time component to the 3MT may result in different values for PPO (peak power output), CP, and W' by introducing an end reference point in during the test. To date, there has been no investigation into the effects that knowledge of time may have on outcomes of the 3MT. The purpose of this study was to investigate the effects of incorporating a race timer in the 3MT and the influence on end power (CP; expressed in watts), work above end power (WEP, a measure of W'; expressed in kJ) PPO (watts), mean power (watts), total work (J), $\dot{V}O_{2peak}$ (ml/kg/min), & HR_{max} (bpm). The null hypothesis relative to this work was that there would be no differences in the metrics of the 3MT between the timer and standard trials. The experimental hypothesis relative to this work is that differences would be present between the metrics of the 3MT between the timer and standard trials.

METHODS

Twelve healthy active males (n = 12) (age: 24.9 ± 2.2 years, height: 180.4 ± 7.5 cm, weight: 78.1± 6.6 kg, $\dot{V}O_{2peak}$: 53.9 ± 6.1 ml/kg/min) were recruited to participate in the current study, which followed a randomized and counterbalanced design. A power analysis was not used to determine sample size. in the current investigation. The number of participants matched the typical range of participants used in studies involving the 3MT, which is between 9-12 participants (1, 9-10, 12). Inclusion criteria for participants required habitual high-intensity training (Olympic lifting, resistance training, power training, or HIIT 2-3x weekly and/or other exercise) for at least three months before participation in this study. Volunteers who were not able to achieve a minimum $\dot{V}O_{2peak}$ of 45ml.kg.min were not invited to participate in further sessions. These criteria were established in order to ensure participants were able to withstand the intense nature of the 3MT. The experimental protocol consisted of four visits to the laboratory with a minimum of 48 hrs. between each session and a maximum of 72 hrs. between sessions. Participants were instructed to eat similarly before each visit and avoid caffeine intake before testing (3 hrs). Visits were scheduled for the same times each testing day (i.e. 8:30am for all sessions). During visit one, participants completed the informed consent, exercise habits questionnaire, PAR-Q, anthropometric measures, and an incremental ramp test (30 watt/min increase until volitional fatigue) to determine $\dot{V}O_{2peak}$ and gas exchange threshold (GET) using a metabolic system (TrueOne 2400, Parvo Medics, Sandy, UT). Visit two consisted of a 3MT familiarization trial not included in the data analysis (1). Participants completed the 3MT during visits three and four in a randomized and counterbalanced format. Participants were blinded to all metrics collected until the completion of all four visits. All trials used a Velotron electronically braked cycle ergometer (Racermate, Inc. Seattle, WA), individually adjusted for comfort and replicated for all following sessions. The Velotron is known to have high reliability (.97-.98) (9). $\dot{V}O_{2peak}$ was determined from the highest 10-second average achieved at any point during the test (10). GET was estimated using the 10-second averaged data from the $\dot{V}O_{2peak}$ test according to the V-slope method (10-11). Flywheel resistance for subsequent 3MT trials was determined by obtaining the power output corresponding to halfway (50%) between GET & $\dot{V}O_{2peak}$ divided by preferred cadence squared (11-12). Participants began each 3MT by completing a five-minute warmup at 100W followed by a five-minute rest period (1, 10, 11). After the rest period, participants completed three minutes of unloaded cycling followed by a three-minute all-out effort. Participants were instructed to increase their cadence to approximately 110 rpm during the final five seconds of unloaded cycling. Strong verbal encouragement following a standardized script was given for the duration of the test (1, 10, 13). The standardized encouragement following a script was kept consistent for all 3MT trials. Participants were instructed to avoid pacing and to give maximum effort during the session, as well as to maintain the highest cadence they can to ensure all-out effort (9). Participants were blinded to elapsed time during the familiarization and control trials (1, 10, 13). The modified 3MT followed the same procedures as the standard 3MT test, however in this session participants were made aware of elapsed time using a race timer positioned immediately in front of the Velotron. The timer was set to count down from three minutes, with a 10-second countdown before the beginning of the test. The time during the modified 3MT was displayed using Programmable Gym Timer (Invech Holdings Inc, China). Warm-up, rest, and testing procedures remained the same as in the 3MT. Paired t-tests were used to compare $\dot{V}O_{2peak}$, HRmax, PPO, WEP, CP, Mean Power, and total work between standard and timer conditions. 30-second average RPM, peak RPM, pedal velocity, and time at PPO (tPPO) were compared between conditions. Cohen's D calculations were also done to determine effect size of the treatment on the different variables. Effect size was determined as small (~.20), medium (~.50) and large (~.80) (14). This research was carried out fully in accordance with the ethical standards of the International Journal of Exercise Science (15).

POINTS OF APPLICATION

Work During the 3MT

It was hypothesized that the introduction of a race timer to the 3MT would result in different values for CP, PPO, and WEP. This hypothesis was only partially supported (Table 1). While CP was significantly higher in the timer condition (P = 0.021), WEP was significantly lower in the timer condition (P = 0.004). PPO was not significantly different between trials (P =-0.164). Both mean power (P=-1.808) and total work (P=-1.443) were not significantly different between the standard and timer 3MT trials. Effect sizes for each variable can also be found in Table 1. There were no significant differences in the $\dot{V}O_{2peak}$ values between the incremental ramp test, the standard trial, or the timer trial (P > .05; P = 0.59). A one-way ANOVA showed consistent $\dot{V}O_{2peak}$ values between the incremental ramp test, standard, and timer trials (P = 0.59; Incremental: 52.3

± 5.2 ml.kg.min, Standard: 52.9 ± 4.5 ml.kg.min, Timer: 52.8 ± 5.3 ml.kg.min). These findings suggest that the introduction of a race timer did have a significant effect on the variables of the 3MT. While CP was higher in the timer trial, W' (indicated by WEP) was significantly lower in the timer trial. This is to be expected since a higher CP value reduces the area under the curve used to calculate WEP (11). This is consistent with the concerns of Vanhatalo et al (10) who designed the 3MT protocol to blind participants to time. However, the lack of a significant difference between PPO, mean power, and total work between trials prompts further exploration. Based on the lack of a difference in PPO, peak RPM, and peak pedal velocity between conditions, participants appeared to produce similar power profiles at the outset of the test. Furthermore, the lack of a significant difference in mean power and total work in the 3MT suggests that the higher values for CP are representative of a difference in pace between trials, as CP is determined by the average power over the final 30 seconds of the 3MT. Another finding of interest is that participants in the timer condition reached their PPO significantly faster than they did in the standard condition, which may be evidence of a refined anticipatory template *(P* = 0.046).

TABLE 1. VARIABLES FROM THE 3MT

Measure	Standard Trial		Timer Trial		t-test	Cohen's D	ES
	Mean	SD	Mean	SD			
CP (W)	267.5	44.5	276.7	49.6	-2.684*	0.78	Large
WEP (kJ)	13.7	4.3	12.4	4.0	3.675*	1.06	Large
PPO (W)	597.3	150.6	598.2	155.7	-0.164	0.05	
Mean P (W)	340.5	50.1	347.8	54.9	-1.808	0.52	Medium
Total W (J)	61847.7	9205.6	62589.1	9881.0	-1.443	0.41	Small

**p< 0.05 CP: Critical Power. WEP: Work above End Power. PPO: Peak Power Output. Mean P: mean power. Total W: Total Work. ES = Effect Size. Units: W = Watts; kJ =kiloJoule ; J =Joule*

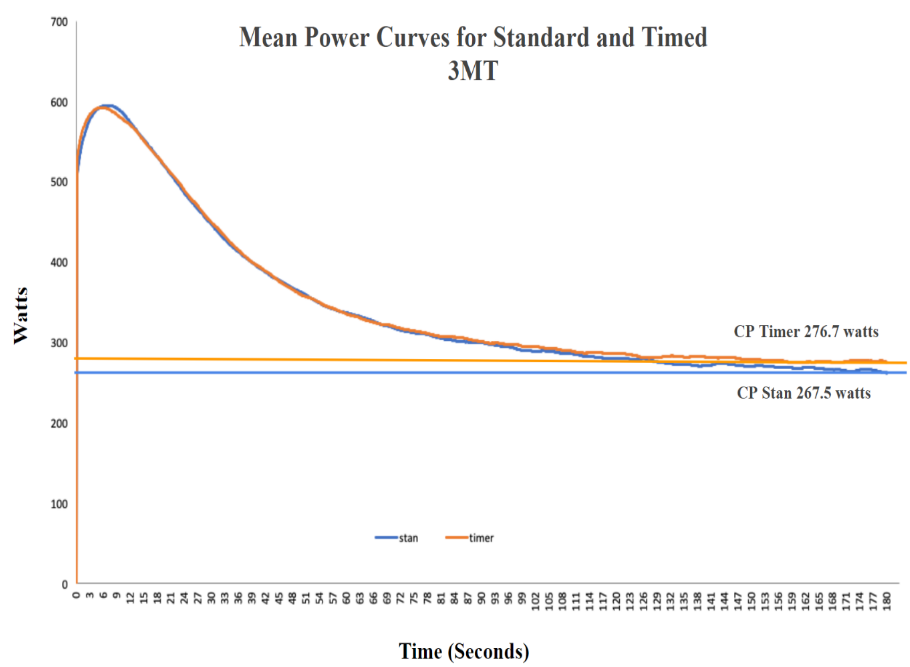

Figure 1. Mean Power Curves Between Standard and Timer Trials.
Power output (watts) during the 3MT (seconds). Mean CP Standard Trial: 267.5 watts (blue).
Mean CP Timer Trial: 276.8 watts (orange).

Pedal Velocity, Timing, and Physiological Measures

Cadences were averaged into six 30-second sections across the duration of the 3MT and were compared between the timer and standard conditions (Table 2). Paired t-tests displayed a significant difference in cadence between conditions in the final 30 seconds (2:30-3:00) of the 3MT (P = .011), as well as a difference between conditions in pedal velocity during the final 30-second average (P = .01). Effect size for each time point can be found in Table 2. Participants achieved both a higher cadence and pedal velocity in the timer condition, resulting in a higher CP due to the set resistance between trials. These results are expected due to the linear relationship between cadence and power output of the 3MT. No significant differences were observed in 30-second average cadences between trials from 0:00-2:30, suggesting that participants maintained the same power output over the first 2:30 sec of the test between trials. There was also a significant difference in tPPO between standard and timer conditions (P = 0.046). There was no significant difference in peak RPM or Pedal Velocity between trials. There were no significant differences in VO_{2peak}, HR_{max}, PPO, or mean power. These observations suggest that pacing did occur during the final 30 seconds of the test, while many parameters remained similar between conditions. The increase in CP resulted in a lower WEP, while total work between groups remained the same. Theoretically, achieving the same PPO and producing the same cadence while increasing CP would result in a higher value for total work in the timer trial. The lack of differences in PPO, mean power, and total work between trials raises a question about how and why participants were able to achieve a higher CP in the timer condition. It may be possible that an endpoint reference (time) allowed participants to achieve a higher average power output in the final 30 seconds of the timed condition (Figure 2). Further research is warranted to better understand the factors which elicited these results.

Table 2. 30 Second Average Cadences

Time	Standard Trial		Timer Trial		t-test	Cohen's D	ES
	Mean	SD	Mean	SD			
0:00 – 0:30	146.9	8.8	147.1	9.1	-.380	0.10	
0:30 – 1:00	106.5	17.9	106.3	16.2	.232	0.08	
1:00 – 1:30	88.8	18.6	88.9	16.0	-.031	0.01	
1:30 – 2:00	81.9	18.3	82.6	15.9	-.630	0.18	Small
2:00 – 2:30	78.1	17.5	79.8	16.4	-1.638	0.47	Medium
2:30 – 3:00	75.8	16.3	78.3	15.9	-3.092	0.89	Large

**p< 0.05. Time is represented in individual 30-second averages across the 3MT. ES = Effect Size*

Anticipation and Decision Making

The Affordances Competition Theory (ACT) (7) lends a useful lens to examine and explain these findings. Knowledge of elapsed time may be an affordance of particular importance to participants during the 3MT, allowing them to refine their anticipatory exercise template between trials (Figure 2). The introduction of additional information may have also led to differences in the decision-making process between conditions, thereby accounting for the differences between trials. Several affordances are inherent to the design of the standard 3MT protocol. The addition of a time component complements and refines the framework associated with the testing session. Internal physiological changes (HR, ventilation), cognitive motivational factors (strong verbal encouragement), previous experience (familiarization trial), and the breakdown of inhibitions through maximum effort all serve as affordances upon which to base decisions during the test (7). Knowledge of time fits well into this list by allowing participants to orient their decisions based on a future endpoint, and further refine their decision-making ability. By providing the additional time component, participants' decision-making abilities may have improved, thereby improving performance during the test. In this case, it seems possible that the knowledge of time allowed participants to achieve and sustain a higher-end power (power over the last 30 secs of the 3MT, equivalent to CP) through a more refined framework of the 3MT. The additional information provided by the clock satisfies the need for a complete anticipatory template, potentially influencing decisions about how and when to use available energy substrates during the 3MT. While the concerns of Vanhatalo et al (10) were initially warranted, the results of the current study suggest that knowledge of time does not have a negative impact on the 3MT. While it is apparent that power profiles did differ between trials, a higher value for CP is representative of a higher maximal race pace (1-3). If the knowledge of time can significantly affect power output in an all-out testing setting then the observed changes in CP may be extrapolated to real-world performance situations, since a faster pace confers a clear advantage in a race setting. Importantly, it has been demonstrated that information acquisition between novice and experienced cyclists differs greatly and is an area that calls for further research within the parameters of the 3MT (13). Clearly, the introduction of a timer to the 3MT has a significant impact on the outcome of the test, however, at this time we cannot suggest that the timer be included in the 3MT. Indeed, the results of the present study warrant further exploration across different populations before any certain decision or further validation can be made about the traditional or modified protocol for the 3MT.

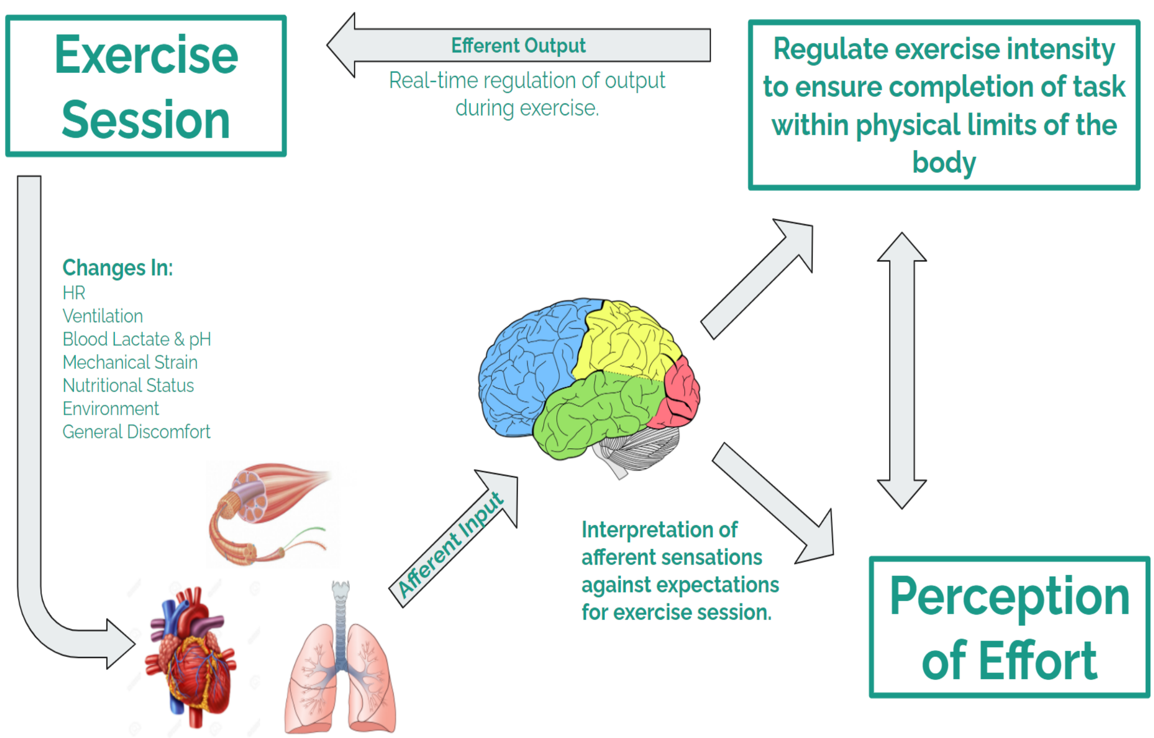

Figure 2. Anticipatory Framework for an Exercise Session. *Afferent input from physiological processes during exercise is interpreted against expectations to determine the perception of effort and regulation of physiological output to ensure the completion of exercise tasks.*

REFERENCES

1. Burnley, M., Doust, J. H., and Vanhatalo, A. (2006). A 3-min all-out test to determine peak oxygen uptake and the maximal steady state. *Medicine & Science in Sports & Exercise, 38*(11), 1995-2003. doi:10.1249/01.mss.0000232024.06114.a6

2. Jones, A. M., and Vanhatalo, A. (2017). The 'Critical Power' concept: applications to sports performance with a focus on intermittent high-intensity exercise. *Sports Medicine, 47*(S1), 65-78. doi:10.1007/s40279-017-0688-0

3. Poole, D. C., Burnley, M., Vanhatalo, A., Rossiter, H. B., and Jones, A. M. (2016). Critical power: an important fatigue threshold in exercise physiology. *Medicine & Science in Sports & Exercise, 48*(11), 2320-2334. doi:10.1249/mss.0000000000000939

4. Hampson, D. B., Gibson, A. S., Lambert, M. I., and Noakes, T. D. (2001). The influence of sensory cues on the perception of exertion during exercise and central regulation of exercise performance. *Sports Medicine, 31*(13), 935-952. doi:10.2165/00007256-200131130-00004

5. Tucker, R. (2009). The anticipatory regulation of performance: the physiological basis for pacing strategies and the development of a perception-based model for exercise performance. *British Journal of Sports Medicine, 43*(6), 392-400. doi:10.1136/bjsm.2008.050799

6. Pageaux, B. (2014). The Psychobiological Model of Endurance Performance: An effort-based decision-making theory to explain self-paced endurance performance. *Sports Medicine, 44*(9), 1319-1320. doi:10.1007/s40279-014-0198-2

7. Smits, B. L., Pepping, G., and Hettinga, F. J. (2014). Pacing and Decision Making in Sport and Exercise: The roles of perception and action in the regulation of exercise intensity. *Sports Medicine, 44*(6), 763-775. doi:10.1007/s40279-014-0163-0

8. Smits, B. L., Polman, R. C., Otten, B., Pepping, G., and Hettinga, F. J. (2016). Cycling in the absence of task-related feedback: effects on pacing and performance. *Frontiers in Physiology*, *7*. doi:10.3389/fphys.2016.00348

9. Bringhurst, R. F., Wagner, D. R., & Schwartz, S. (2020). Wingate anaerobic test reliability on the Velotron with ice hockey players. *Journal of Strength and Conditioning, 34*(6), 1716-1722.

10. Vanhatalo, A., Doust, J., and Burnley, M. (2007a). Determination of critical power using a 3-min all-out cycling test. *Medicine & Science in Sports & Exercise, 39*(3), 548-555. doi:10.1249.mss.0b013e31802dd3e6

11. Beaver, W. L., Wasserman, K., and Whipp, B. J. (1986). A new method for detecting anaerobic threshold by gas exchange. *Journal of Applied Physiology, 60*(6), 2020-2027. doi:10.1152/jappl.1986.60.6.2020

12. Dicks, N. D., Jamnick, N. A., Murray, S. R., and Pettitt, R. W. (2016). Load Determination for the 3-minute all-out exercise test for cycle ergometry. *International Journal of Sports Physiology and Performance, 11*(2), 197-203. doi:10.1123/ijspp.2015-0116

13. Vanhatalo, A., Doust, J. H., and Burnley, M. (2007b). Robustness of a 3 min all-out cycling test to manipulations of power profile and cadence in humans. *Experimental Physiology, 93*(3), 383-390. doi:10.1113/expphysiol.2007.039883

14. Lakens, D. (2013). Calculating and report effect sizes to facilitate cumulative science: a practical primer for t-tests and ANOVAs. *Frontiers in Psychology*, 4, 1-12. doi:10.3389/fpsyg.2013.00863

15. Navalta J. W., Stone W. J., Lyons T. S. (2020). Ethical issues relating to scientific discovery in exercise science. *International Journal of Exercise Science, 12*(1): 1-8, 2019.

16. Boya, M., Foulsham, T., Hettinga, F., Parry, D., Williams, E., Jones, H., . . .Micklewright, D. (2017). Information acquisition differences between experienced and novice time trial cyclists. *Medicine & Science in Sports & Exercise, 49*(9), 1884-1898. doi:10.1249/mss.0000000000001304