UNIVERSITETET I AGDER

Comparison of condensed versus non-condensed cycling test methods

and

correlation to a 185 minutes' indoor race simulation

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This master's thesis is carried out as a part of the education at the University of Agder and is therefore approved as a part of this education. However, this does not imply that the University answers for the methods that are used or the conclusions that are drawn.

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Preface

Someone told me performing a master thesis has its demands. I could not agree more. The past years my days has involved training outdoor three to four hours each day in the pursuit of success in my active bicycling career. It was a difficult transition for me to sit countless hours reading and writing, instead of being outside bicycling and training. It has been a challenging but rewarding journey regarding the preparation- and administration of this study. My goal has always been to complete my master thesis at the University of Agder, and finally this has come to an end.

I am grateful to the contribution of my supervisors Assistant Professor Svein Rune Olsen and Professor Kerry Stephen Seiler for the support and guidelines I needed to complete this study. In addition, I wish to give thanks to the subjects for willingness to participate in the study and to the University of Agder for the financial and support in the study.

To my co-students, thank you for the humor, support and help in difficult periods and tasks seemed unreachable. I am going to miss "hanging-out" in our "office" together. To my brother and father, thank you for helping me by reading and providing better solutions in presenting my paper. To Phd student Thomas Birkedal Stenqvist, thank for all your help in interpretation of my test results in the labyrinth of SPSS. And finally, to all people present near the lab during the study´s test-period, I am sorry for all my motivational shouting and screaming. It was only a necessary mean to support my subjects to perform at their best.

Thank you to all who supported me in this period. To my wife, family and friends. I am ready for my next task.

CONTENT

ABBREVIATIONS

5-min all-out	5-minute all-out cycling test
C	Condensed
f.s.	Fatigue slope
GME	Gross mechanical efficiency
La^-	Lactate
LTW	Wattage at lactate threshold
NC	Non-condensed
PPO	Peak power output
RER	Respiratory exchange ratio
RPE	Rated perceived exertion
RS	Race simulation
TP	Test protocol
TTE	Time to exhaustion minutes
VO_{2max}	Maximal oxygen consumption
W	Wattage
WAnT	Wingate anaerobic test

1.0. ABSTRACT

Background: The validity of a currently used condensed indoor test protocols (C-TP) as measurement of competitive cycling performance is questioned. **Purpose:** C-TP contain testing of wattage at lactate threshold (LTW), maximum oxygen consumption (VO_{2max}) and a Wingate anaerobic test (WAnT), performed consecutively during one session. As comparison these tests were separated and performed individually over three consecutive days, giving a non-condensed test protocol (NC-TP). The results were compared to a 5min all-out cycling test (5min all-out) performed individually and as part of a 185 minutes' race simulation. **Method:** During 4 weeks, 12 recreational active male cyclists (VO_{2peak} 54.8 ± 3.62 ml · kg^{-1} · min^{-1}) completed 6 independent visits at a physiological laboratory involving testing of separate duration and intensity. **Results:** The only significant differences between C-TP and NC-TP was found in the variables VO_{2PPO} (360 vs. 379.4 watts), WAnT $_{peak}$ (1028.1 vs. 1046.8 watts) and WAnT $_{mean}$ (675.7 vs. 702 watts). Additionally, LTW (r= .72) and VO_{2PPO} (r= .70) measured during the C-TP was strongly correlated with the results in the 5min all-out cycling test as part of the race simulation. WAnT peak and mean results showed high correlation of the C-, NC- and RS- TPs. LTW and VO_{2PPO} from a C-TP was positively correlated with the 5-min all-out as part of RS. **Conclusion:** This study supports the use of the C-TP in testing of cyclists at an indoor laboratory. NC-TP added minimal additional information relevant to competitive cycling performance.

Key words. Laboratory, measurements, road, endurance, competition

1.0. INTRODUCTION

Physiological testing of endurance capacity has become a popular attribution to the testing process for both elite and recreational cyclists. The long duration of road cycling competitions present a unique challenge to researchers when measuring cyclist's performance (Lucía, Hoyos, & Chicharro, 2001).

For cycling, the power produced at a given velocity depends on a complex interaction of many physiological (VO_{2max}, LT, GME), mechanical (bicycle, wheels, tires) and environmental (wind, temperature, humidity, altitude) variables. Based on this, Jeukendrup, Craig, and Hawley (2000) claims professional cycle racing to be one of the most demanding of all sports when combining the extremes of exercise duration, intensity and frequency. Hill and Lupton (1923) were pioneers in developing scientific physiological knowledge concerning definition of variables active during exercise. Their study involved breathing various gas mixtures while performing rapid alterations in muscular exercise during an incremental exercise test. Different test methods have developed, measuring the performance of cyclists. Endurance capacity with cycling is tested by identification of the lactate threshold wattage, maximal oxygen consumption, as well as testing of several anaerobic sprint characteristic. Numerous studies use these test methods to define the principle variables defined as essentially related to physical performance (Amann, Subudhi, & Foster, 2006; Lamberts, Swart, Noakes, & Lambert, 2011; B. R. Rønnestad, 2013; B. R. Rønnestad & Hansen, 2013; Støren et al., 2013). Recently, a study by Sylta et al. (2016) interpreted a combination of cycling test methods during a single test protocol. These are performed condensed in the order of 1) a lactate profile for definition of the lactate threshold in level of cycling wattage production (LTW) 2) a stepwise test for the definition of the maximum oxygen consumption (VO_{2max}) and 3) a Wingate anaerobic 30 seconds' sprint test (WAnT). This grouping of test methods is also offered as a condensed test protocol for cyclists requesting personal testing by Olympiatoppen (South Department), part of the Norwegian Olympic and Paralympic Committee and Confederation of Sports with responsibility for training Norwegian elite sport (Olympiatoppen, 2013). Both private and professional Norwegian cycling teams utilizes this test protocol.

The aim of this study is:

- to study the difference in test results of indoor cycling test methods during condensed versus non-condensed test protocols.
- to correlate the results from both C- and NC-TP with a 185 minutes' experimental race simulation including a 5 minutes all-out cycling and Wingate anaerobic test.
- to study in what degree the C- and NC-TP can predict the demand of the cycling race.

2.0. THEORY

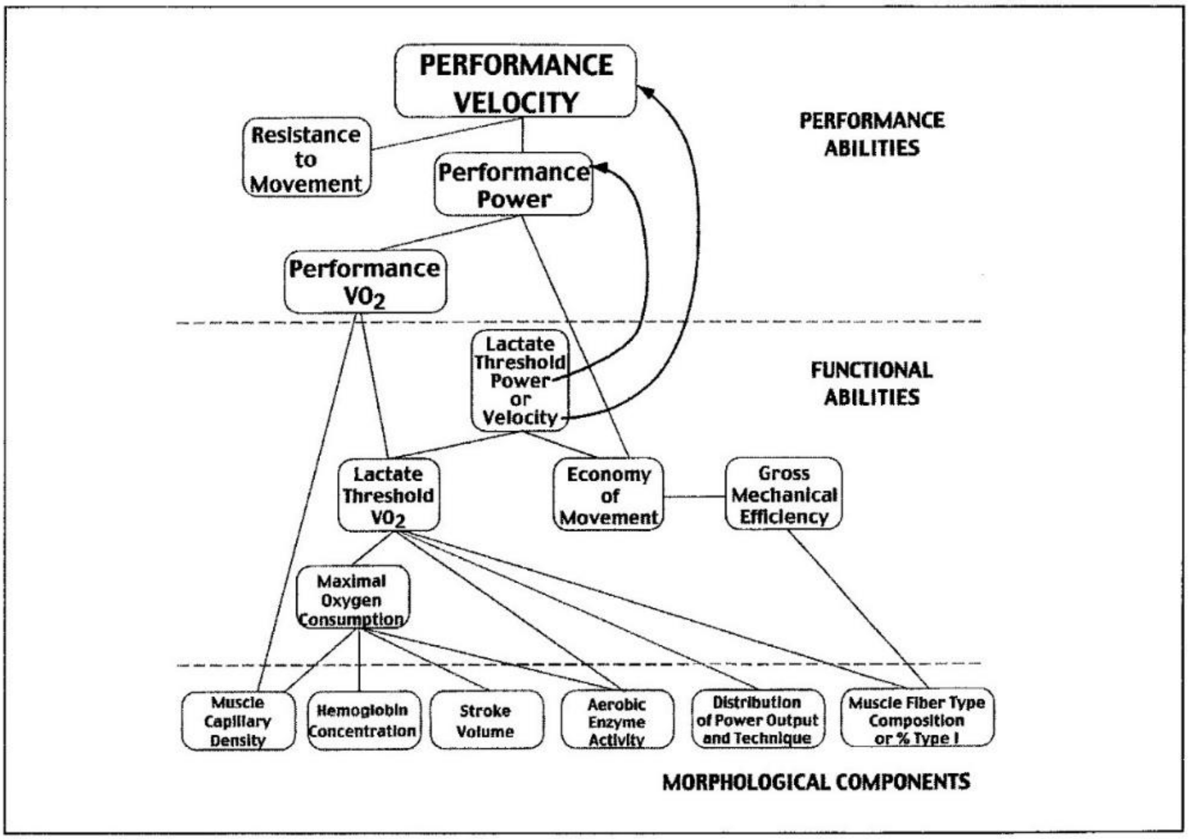

FIGURE 1: Model of the interrelationships of the physiological factors determining performance ability (E. F. Coyle, 1999). The figure presents many variables accounting for the performance ability of cyclists.

The performance ability of a cyclist is affected by both functional abilities as well as morphological components (E. Coyle et al., 1991) (figure 1). In the pursuit of identifying characteristics among successful elite endurance athletes, a group of Norwegian scientists studied and presented the training and peaking characteristics of endurance performance abilities in their year prior to achieving an Olympic gold medal. Training characteristics among successful elite cross country and biathlete skiers regarding their training amount, intensity distribution and sport-specification were presented. During their career, all athletes underwent regular physiological testing of their VO_{2max}. The mean level of VO_{2max} (ml/kg^{-1} · min^{-1}). for the males were 85,1 and for the females 72,9 (Tønnessen et al., 2014).

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2.1. Testing of physiological variables during cycling.

2.1.1. Maximal oxygen consumption (VO_{2max})

This utilization of VO_{2max} has shown to be well associated with endurance performance (E. F. Coyle, 1999; Doyle & Martinez, 1998; Jeukendrup et al., 2000; Lee, Martin, M., Grundy, & Hahn, 2002; Vikmoen, 2015). VO_{2max} is one of the most common measurements performed in exercise science. Hill and Lupton (1923) were among the first to describe the muscular exercise during exercise, studying the oxygen transport from the environment to the mitochondria supporting oxidative production of ATP to do physical work. They later proceeded the experiments to better describe the muscular exercise (Hill, F.R.S., Long, & Lupton, 1924).

The classical view of maximal oxygen uptake is that maximal rates of oxygen utilization in skeletal muscles are limited by the ability of the heart to deliver oxygen to the working muscles (Levine, 2008). Joyner and Coyle (2008) studied the physiology of champions and saw that the outcome of all Olympic endurance events is decided at intensities above 85% VO_{2max}. The endurance exercise performance related to the VO_{2max} has later been studied in an unknown number of attempts. Athletes can sustain work intensity that demands 100% of the VO_{2max} level for approximately 6 minutes (Billat & Koralsztein, 1996). The peak in oxygen uptake is associated with high levels of lactic acid in the blood in the minutes following the exercise test. VO_{2max} is generally accepted as the best measure of the functional limit of the cardiovascular system and is commonly interpreted as an index of cardiorespiratory fitness (Howley, Bassett, & Welch, 1995).

Indoor testing has difficulties presenting outdoor environmental factors affecting the cycling performance. Nevill, Jobson, Palmer, and Olds (2005) wanted to identify the most appropriate method of scaling VO_{2max} to predict cycling time-trial performance. Performance of VO_{2max} is determined by the maximum percentage of the VO_{2max} that can be maintained during an endurance event. In their study, they present a traditional ratio for standard maximum oxygen uptake as (liters * min $^{-1}$) divided by body mass in kilos (m), as well as maximum oxygen uptake-to-mass ratio found to predict cycling speed in association with energy cost was presented by the model; $(VO_{2max}\ (m)^{-.32})^{.41}$. The model predicts, for example, that for a male cyclist (72 kg) to increase his average speed from 30 km/h $^{-1}$ to 35 km/h $^{-1}$, would require an increase in VO_{2max} from 2.36 l/min $^{-1}$ to 3.44 l/min $^{-1}$, an increase of 1.08 l/min $^{-1}$.

2.1.2. Lactate threshold (LT)

Lactate concentration in blood will increase with increased work intensity. The concentration of lactate in the blood is essential to the reproduction of Adenosine triphosphate (ATP), but will at a given amount make the muscles unable to continue to work. A standardized threshold value of 4 millimole per liter (mmol/L) blood resulted from the observation that endurance-trained athletes tolerated respective workloads for longer periods of time at this level, and that higher workloads resulted in accumulation of lactate concentration (Heck et al., 1985).

Kindermann, Simon, and Keul (1979) were among the first to describe a concept of lactate threshold to be optimal for defining workload intensities of endurance training. The predictive validity of the lactate thresholds for cycling time trial performance has been studied by Bentley, McNaughton, Thompson, Vleck, and Batterham (2001). Their study presented the relationship between the maximum power output and the power output at the lactate threshold. Their conclusion was that this threshold may change depending on the length of the endurance performance that is demanded. Ralph Beneke, Hütler, and Leithauser (2000) states that LT in % of VO_{2max} was found to be independent of both endurance cycling performance and power output.

2.1.3. Wingate Anaerobic Test (WAnT)

The definition of the 30 seconds WAnT has been presented by R Beneke, Pollmann, Bleif, Leithäuser, and Hütler (2002) to represent an 80% workload of energy retrieved from anaerobic metabolisms. The accumulation of lactate beyond the lactate threshold indicates that the mechanisms of lactate removal fail to keep pace with lactate production. The concentration of lactate in the blood provides minimal information about the rate of the production of lactate in the muscles (Brooks, 1985). The WAnT has been utilized in several studies testing cyclist to present its central role in the anaerobic cycling performance within cycling (Bar-Or, 1987; R Beneke et al., 2002; Brooks, 1985; Dotan & Bar-Or, 1983; Vandewalle, Peres, Heller, & Monod, 1985). The impact of maximal strength training improves cycling economy in well trained cyclists (Sunde et al., 2010). A presentation of how a short maximal cycling effort can reduce time to identify power at LT compared to the standardized method testing LTW has also been completed (Støren et al., 2013).

2.1.4 Gross mechanical efficiency (GME)

GME is defined as the ratio of work generated to the total metabolic energy cost, and has been suggested to be a key determinant of endurance cycling performance (Jobson, Hopker, Korff, & Passfield, 2012). Vikmoen (2015) states that long-term endurance is mainly determined by the amount of metabolic energy produced during competition and how efficiently this energy can be translated into mechanical work. Bassett and Howley (2000) underline three variables that predicts endurance training. First, the importance of VO_{2max} that sets an upper limit for endurance performance. Secondly, the ability of the cardiorespiratory system to deliver oxygen to the exercising muscles, as work economy and fractional utilization of VO_{2max} affect endurance performance. And thirdly, the running economy and fractional utilization of VO_{2max}. In their conclusion, the velocity at lactate threshold integrates all three of these variables and is the best physiological predictor of distance running performance. In accordance with the study of B. R. Rønnestad, Hansen, Vegge, Tønnessen, and Slettaløkken (2013), GME in this study was calculated as the ratio of work accomplished $\cdot$ min^{-1} (i.e., w converted to kcal $\cdot$ min^{-1}) to energy expended $\cdot$ min^{-1} (kcal $\cdot$ min^{-1}). In our study, expended energy was measured at 50%VO_{2max}. Intensity chosen during GME measurements was supported by the study of de Koning, A., Lucia, and Foster (2012) presenting factors affecting gross efficiency in cycling.

2.1.5. Race simulation (RS)

The RS program simulated a normal work demand given to cyclists during a typical single day road race; generally performed in the low intensity zones followed by an increase in intensity towards the end of the race. This is supported by the studies of Jeukendrup et al. (2000) and B. R. Rønnestad, Hansen, and Raastad (2011). Additionally, a study of Andez-Garcia, Perez-Landaluce, Rodriguez-Alonso, and Terrados (2000) was studied to understand the intensity demand during road race pro-cycling competition of the stage races Tour de France and Vuelta Espagna. Their results presented over 50% of the intensity of exercise during road race pro-cycling competitions to be below the anaerobic threshold at intensity < 72% of VO_{2max}. Approximately 7% of the intensity was above the anaerobic threshold.

2.1.6. Testing of cyclists

*TABLE 1***.** Examples of previous studies utilizing a combination of indoor laboratory tests to identify difference or development with cyclists.

Author	Study purpose	Laboratory testing	Results
Constantini, Sabapathy, and Cross (2014)	Determination of critical power and capacity to perform work above this, differences using a single 3MT or simultaneous to an incremental exercise test.	Ramp test f 25/m 30 W min^{-1} until exhaustion in 8-12 min, and a 3MT (min all-out), combined versus independent protocols.	A combined protocol provides an accurate and valid method to determine an individual's CP and W'
Seiler, Jøranson, Olesen, and Hetlelid (2011)	To compare the effects of three 7-week interval training programs (4x4, 4x8 or 4x16 min) at intensities (94, 90 and 88% HR peak) twice a week.	Pre- and post-testing at "repeated" continuous incremental test to exhaustion to determine: VO^2peak, VO^2power, HR peak, VT^1 and VT^2 and lactate threshold at 4mmol.	Interval training accumulating 32 min at an intensity eliciting ~90% HF max presents the greatest gains.
B. R. Rønnestad et al. (2013)	To compare the effects of a 10 weeks of effort-matched short intervals 30s/15s in 9.5minx3- or long intervals 4x5 min (both at maximum work intensity) in cyclists.	Continuous incremental tests to determine: a blood lactate profile test and a VO^2max the first day, a 30 s Wingate test and a 5-min all-out trial the second day and a 40 min all-out trial the third day.	The present study indicates that performing the present short intervals induce superior training adaptions after 10 weeks.
Støren et al. (2013)	To examine the relationship between lactate threshold (LT) as a percentage of maximal oxygen consumption, and power output at LT, and to investigate to what extent VO^2max, oxygen cost and maximal power determine LT in cycling.	Testing of lactate profile by stepwise increase of power every 5minutes until 4mmol level was reached. VO^2max progressive incremental protocol starting at the LT intensity level, increased every 30 or 60 seconds by 10 to 25W until exhaustion.	The best determinant of LTW is the product of maximal power output and individual LT in % of VO^2max.
Lamberts et al. (2011)	Determination of the reliability and predictive value of parameters measured during a novel submaximal cycle protocol in well trained cyclists.	Respiratory gas analysis (VO^2max), a 40 km Time Trial tests and a LSCT 17 min test.	The LSCT in which heart rate is fixed at a predetermined submaximal level has the potential to detect subtle changes in performance as a result of training-induced fatigue.
(Nevill et al., 2005)	To identify the most appropriate method of scaling VO^2max for differences in body mass when assessing the energy cost of time-trial cycling.	Progressive incremental exercise test to exhaustion with measurements of respiratory gases, on a air-braked cycle ergometer with increase of workload of 20W per minute.	The maximum oxygen uptake-to-mass ratio found to predict cycling speed was $VO^2max(m)^{-0.32}$.

In addition to the table above, B. R. Rønnestad and Hansen (2013) studied how optimizing interval training at power output was associated with peak oxygen uptake in well-trained cyclists. In conclusion, they recognize that high intensity interval training can improve endurance performance. They find that using a 2:1 work:recovery ratio, a protocol using fixed 30 s work intervals seems to induce a longer time ≥ 90% at VO_{2max}. Their conclusion was subsequently confirmed by Bent R Rønnestad and Hansen (2016). B. R. Rønnestad (2013) also studied how two methods to access power output were associates with peak oxygen uptake in cyclists. B.R. Rønnestad (2013), used a lactate profile- and a VO_{2max} -test to identify differences between two methods calculating maximal power output; one method calculating the cyclist's VO_{2max} compared to the submaximal power, and the other method using minimal power output that elicits VO_{2max}. No differences were found in the two methods. B. R. Rønnestad et al. (2013) additionally conducted a study comparing the effects of short intervals inducing superior training adaptations. A lactate profile-, VO_{2max} - and a Wingate-test were test protocols used to identify change from a pre- to a post state of the cyclists. The results of this study suggest that the studied short interval protocol induces training adaptations in both the high power region and the low power region of cyclists' power profile, compared to the studied long interval protocol. Seiler et al. (2011) completed a study investigating adaptations to aerobic interval training studying the effect of exercise training and total work duration. By looking at the VO_{2max} in milliliters and peak power output (PPO) as maximal power attained during the test, as well as wattage at LT, the result was that an interval training program where the cyclists performed 32 minutes of work at 90%HRmax simulates moderate to large improvements in both maximal and submaximal performance measurements.

2.2. 5 min all-out cycling test (5-min all-out)

A 5 minutes all-out cycling test was used to identify differences in performance in this study. This was according to a previously performed study by B. R. Rønnestad et al. (2011) investigating how maximal strength training affects cycling performance. Other studies have used a 3 minutes all-out cycling test to identify cycling performance and the interpretation of using a 3-min test to define cycling performance has been discussed among scientists. Some consider it to be a good predictor of cycling performance (Burnley, Doust, & Vanhatalo, 2006; Vanhatalo, Doust, & Burnley, 2007), while others are critical (Vanhatalo, Doust, & Burnley, 2008). The 5-min all-out cycling test in this study was performed both during the NC-TP and as part of RS.

2.3. Fluid and nutritional needs

Sweating rate during intense indoor and outdoor exercise is typically between 1-2 liters per hour and athletes can become dehydrated if fluid replacement is not sufficient. This again will affect the heat production during exercise and can elevate core and muscle temperature rapidly and be an independent cause of fatigue (E. F. Coyle, 1999; Hargreaves, 2007). Guidelines used to decide the fluid and nutritional carbohydrate intake of this study, are presented in numerous articles (Burke & Deakin, 2006; Garthe & Helle, 2011; Hargreaves, 2007; Hew-Butler et al., 2015).

3.0 METHOD

TABLE 2. Frequency distribution.

Variable	Mean (SD), min/max
Age	42.1 (10.4), 20/54
Weight	84.4 (8.1), 71/96.9
Height	184.2 (5.9), 170/193
VO_{2peak}	54.8 (3.6), 46.9/60.2

(N= 12, standard deviation (SD), min/max: minimum and maximum values.

3.1 Subjects

Subjects attending to the study were 14 male road-racing cyclists in the age distribution of 20-54. Subjects are in the entire study addressed as the cyclists. Two cyclists were excluded from the study because of sickness or injury not caused by the study. Therefore, in total 12 cyclists were recruited to the main study. Inclusion criteria were; the cyclists had to have been trained in cycling for the last 3 years and had to have participated in cycling competitions. The amount of regular training volume varied.

When included in the study the cyclists were given test person identity numbers 1-12. Cyclists were instructed to meet for testing at given times at the physiology laboratory. Access to an online time schedule connected to a document through google documents was given each cyclist, were they could reserve times on the different test days. The cyclists were asked to bring their own road bicycle, cycling outfit and cycling equipment such as shoes, drinking bottle and towel for absorbing sweat production during the test.

3.2 Ethics consideration.

The study was approved by the human subjects' review committee of the Faculty for Health and Sport, University of Agder. All cyclists were informed of the experimental risks and appropriate written informed consent was gained before participation. All results from the trial are treated anonymously. All data retrieved during the study was deleted at its completion. The cyclists were at any time entitled to withdraw from the study without explanation. Cyclists were asked to maintain regular training during the study.

3.3 Experimental approach

This study used a repeated measured design to test cyclists involving different test methods during 4 weeks at an indoor physiological test laboratory. Chosen test method for the present study is supported by (Polit & Beck, 2014). In November and December 2016 eight cyclists also participating in the main study, were invited for pilot testing of the test procedures planned in the main study, to ensure satisfied preparation of the test leader.

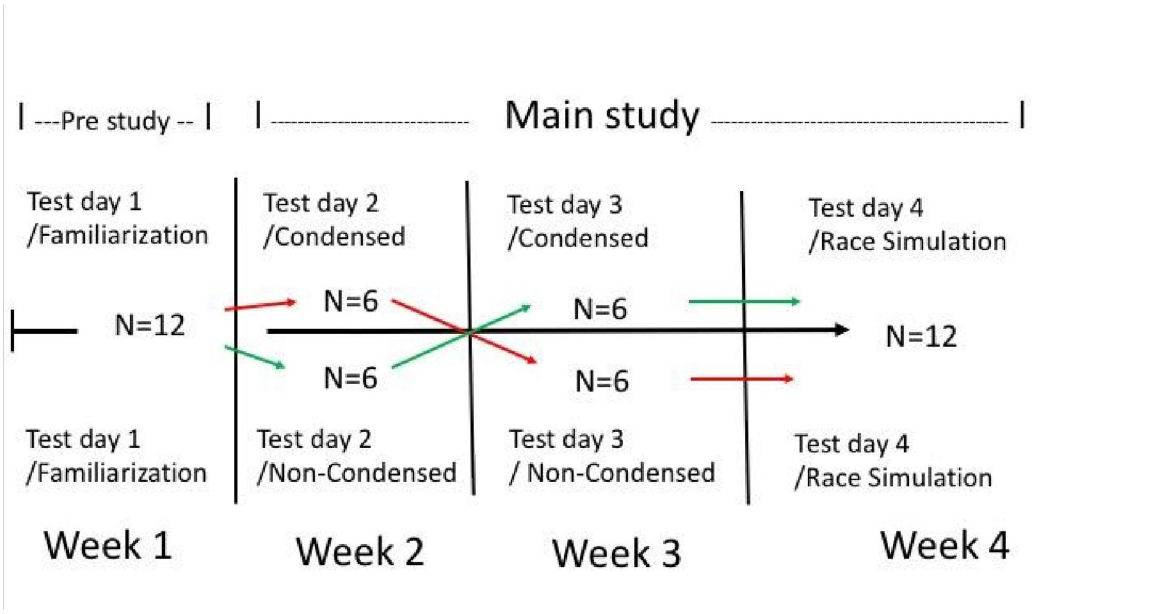

FIGURE 2: Experimental design of the study.

The four weeks of the main study took place during the period from 9th of January to the 3rd of February 2017. As studied in figure 2, all cyclists participating in the study were randomized for test week 2 and 3 during the second week of the main study. 50 per cent of the cyclists performed the NC- before the C test methods, during week two and three. The remaining 50 per cent performed the tests in the opposite order. This counteracts the “pace” learning ability of the similar tests repeated in the study. The cyclists were asked to attend individually to the physiology laboratory for each appointment during all test weeks (study appendix 2-4). All cyclists attended at scheduled time for the RS program and test during week 4 (study appendix 1).

GME, La^{-} and RPE was measured one time each hour during the RS. This was done in accordance with studies done by E. F. Coyle, Sidossis, Horowitz, and Beltz (1992) and B. R. Rønnestad et al. (2011). Each cyclist's overall rated perceived exertion (RPE) was noted after each test method or test day with the ratio scaling 6-20 of Borg Scale (Borg, 1982). The purpose of this was to note any possible unusual individual perceived exertion.

Amount of test days during each study week:

(1) "Familiarization test week"; involving one test day testing a LTW, a performance test of 5 min all-out cycling, a VO_{2max} test and a WAnT, in the following order. Time required 90 min.

(2) "Condensed test week"; one test day, testing the C-TP and the definition of LTW, VO_{2max} and WANT, in the following order. Total time required 75 min.

(3) "Non-condensed test week"; three test days, testing the NC-TP and the definition of VO_{2max}, 5 min all-out test and WAnT, during three separated days. Each one lasted approximately 30 minutes.

(4) "Race simulation week*"*; one test day, an implementation of a 185 min RS cycling including tests of 5 min-all out and WAnT.

3.4 Testing criteria

The physiology laboratory used in this study is situated at the University of Agder department of Kristiansand. All tests were performed under similar environmental conditions (17-21ºC). All equipment used in the study was each time calibrated following the manufacturer guidelines before usage. The cyclists participating in the study were 24 hours prior to each test day asked to keep intensity and training duration low during their workouts, and to not consume any alcohol. The cyclists were asked not to drink coffee for the last 3 hours prior to each test. They trained as normal during the test period and were asked to prepare similarly for each test day. All testing of cyclists commenced with a standardized warm up program of a total 15 minutes' inclusive calibration of the Computrainer stationed magnetically watt controlled ergometer with a connected remote control for adjusting the watt resistance. Warm-up procedure; cyclists started normal cycling at 75-100wattage brake level for 5 minutes at cycling rounds per minute (RPM) of 80-100 RPM, followed by 2 minutes of high RPM (100-120), 1 minute normal RPM and 2 minutes high RPM. The Computrainer was thereafter calibrated before additional 5 minutes normal cycling was performed. The cyclists were during warm-up never to use force eliciting the threshold value of intensity saving the muscles for the proceeding tests following warm-up. Cyclists were throughout the actual tests given equal verbal encouragement, and the test leader was therefore an external factor during the study.

3.5 Statistical analyses

Statistical analyses were conducted using SPSS 21.0 (SPSS Inc, Chicago, IL, USA). Alpha level was set at $p < .05$. Preliminary analyses and skewness of the data was performed to ensure no violation of the assumptions of normality, linearity and homoscedasticity. The multicollinearity has been accounted for in situations where results show significant results, as well as any possible outliers in the sample. Correlation is presented as the Pearson product-moment correlation. Multiple regressions were used to study the prediction change of one variable (dependent) from numerous prediction variables (independent) as an extension to the Pearson correlation. The Bivariate correlation coefficient vary from values 0 indicating no relationship, and -1 negative to +1 positive relationship. Cohen (1988, pp. 79-81) suggests the following guidelines in relationship presented as a small effect = .10 to .29, medium effect = .30 to .49, and large effect = .50 to 1.0. Paired sample t-tests were used as statistical analyses to investigate differences between several variables in the study. Effect size indicates practical change of the values. If not normally distributed data in variables measured, there was used a Mann Whitney U-test to study their relationship. One-way repeated measures ANOVA was conducted to study any significantly difference in the repeatedly measured variables of the RS. Additionally, the mean scores of WAnT were studied for differences in performance at C-, NC- and RS- physical conditions. The reliability and validity of some of the test methods described in this study have been questioned in earlier studies (Amann et al., 2006; Doyle & Martinez, 1998; Wehbe, Gabbett, Hartwig, & Mclellan, 2015). The reliability of the Computrainer bicycle magnetic ergometer trainer used in this and many other studies testing indoor cycling has been tested in a study by Sparks et al. (2016).

3.6 Implementation of test days

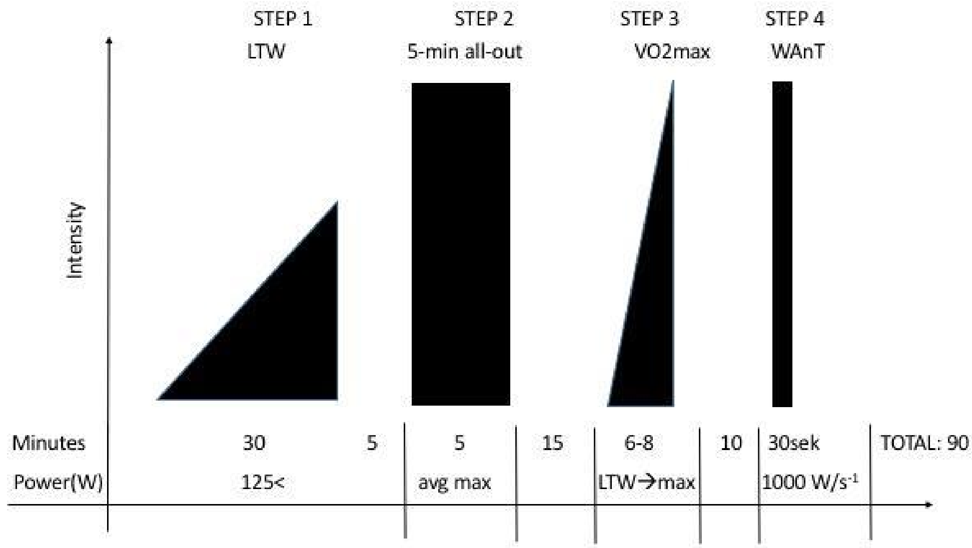

FIGURE 3. "Familiarization/pre-test". Minutes and power description is only indicative and precise units are described in the following description.

The familiarization test illustrated in figure 3 was a 4-step test protocol performed week 1 of the main study. Testing involved testing of LTW, a 5-min all-out, a VO_{2max} and a WANT. All 12 cyclists were to perform the test during three days, 4 cyclists each day. During this test day all cyclists were weighed, height was measured and age established. The first cyclist attended at 08:00-10:00, the second from 10:00-12:00. A short time of rest for the test leader was left between 12:00-14:00. Next cyclist arrived at 14:00-16, and so on. The reliability and validity of this device for measuring watt production in cycling has been previously examined (Sparks et al., 2016).

Step 1 of the familiarization test was a LTW which started with watt resistance of 100 watts and increased by either 50 w and later 25 w each 5 minute until the LT was reached. Less increase is done after approximately 2.5mM/l blood level has been measured. The LTW was terminated after measurement of 4.0 millimole lactate per liter ($4mMol \cdot L^{-1}$) in blood level. Blood samples are taken in the end of each 5 minutes' bout during the test and is done from the finger tips before each increase of power, following the procedures of the EKF Biosen C-line lactate analyzer. Use of this lactate analyzer is in accordance with earlier studies by Amann et al. (2006) and Seiler et al. (2011). A 10-minute period of easy cycling at 75-100W was provided after the LTW test before the next step.

Step 2 of the familiarization test was a 5-min all-out and was intentionally planned to have an output of 85% of the cyclist's peak power output (PPO) at VO_{2max}. Chosen start of intensity is in accordance with the method by Vikmoen (2015). Last minute average power in wattage during the VO_{2max} test was defined at the cyclist's PPO. Since none had performed this test earlier in the study, the resistance was set to be 125% of the LTW. Before the test initiated the cyclists kept a normalized RPM with 100 W resistance. The first minute the workload was set by the test leader. The cyclists were after the 1st minute allowed to adjust the wattage by signaling to the test leader who increased or decreased by 10 W each time they demanded. During the test they were instructed to cycle as high mean power output as possible during the 5 minutes. The power resistance was not affected by the RPM. They were demanded to be seated during this test. The cyclists received feedback regarding power output production and time elapsed, but not average power and heart rate. After the 5-min all-out test the cyclists were given 10-15 minutes of easy cycling at 75-100W resistance.

Step 3 proceeded with a VO_{2max} test. This test started with watt corresponding to 3 W $\cdot$ kg^{-1} (rounded down to the nearest 50W). This and completion of the total test method was done in accordance with earlier studies (B. R. Rønnestad, 2013; B. R. Rønnestad & Hansen, 2013; B. R. Rønnestad et al., 2013; Sunde et al., 2010; Tønnesen, 2014; Åstrand & Rodahl, 1986). Power output was then subsequently increased by 25 W every minute until exhaustion. VO_{2max} was calculated as the average of the two highest 30 s VO_2 measurements. Oxygen consumption was measured using a computerized metabolic system with mixing chamber using a breath by breath mouth piece (Oxycon Pro open circuit metabolic cart of type Oxycon, Jaeger BeNeLux Bv, Breda, the Nederlands). The test ended voluntarily as fatigue was reached. A flattening of the VO_2 curve, respiratory exchange ratio (RER) ≥ 1.05, and [La-]b ≥ 8.0 mmol $\cdot$ L^{-1} was used as criteria to evaluate if VO_{2max} was obtained. The gas analyzers were calibrated with certified calibration gases of known concentrations before every test. The flow turbine (Triple V, Erich Jaeger, Hoechberg, Germany) was calibrated before every test with a 3 L calibration syringe (5530 series; Hans Rudolph, Kansas City, USA). The cyclists were given 10 minutes of easy cycling at 75-100W after the VO_{2max} test.

Step 4 was testing of a WAnT. This test demanded that the cyclists changed bike to an electrically braked bicycle ergometer (Lode Excalibur Sport, Groningen, Netherlands), modified with adjustable stem, and a similar pedal system for each cyclist. The test was initiated with 5 minutes easy cycling before the test started cycling with 120 RPM at a 20 seconds' countdown. In the last 3 seconds, braking resistance was first removed and then applied with 0.7 newtonmeter·kg⁻¹ and remained constant throughout the 30-s all-out test. Scores retrieved from this test were wattage of 30 sec peak, mean and grade of reduction in power explained from a fatigue slope. Cyclists were free to sit or stand during the test. In total the familiarization test took approximately two hours per cyclist of witch purpose was to let the cyclists be familiarized with all test methods involved in the study.

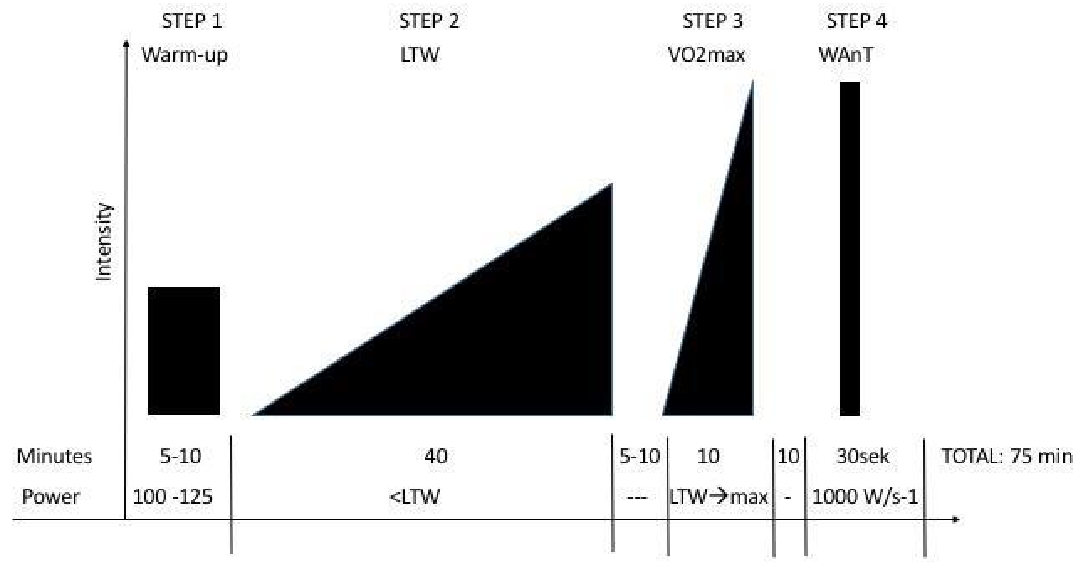

FIGURE 4. Illustration of a condensed test protocol (C-TP). Minutes and power description is only indicative and precise units are described in the following description.

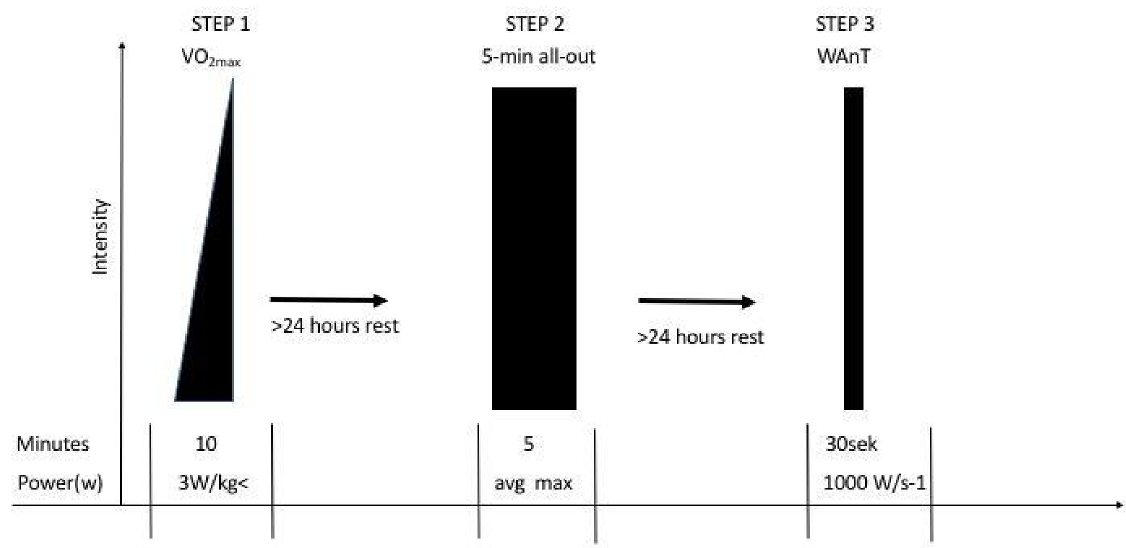

FIGURE 5. Illustration of the Non-condensed test protocol (NC-TP). Minutes and power description is only indicative and precise units are described in the following description.

During test week two, all cyclists were familiarized with the test methods when divided in either the C-TP (figure 4) or the NC-TP (figure 5), as illustrated in the figure 2. The cyclists attended at given times and were weighed in. They had been instructed to bring a bottle for fluid needs during the test.

Procedure of the C-TP (figure 4) was as follows; the cyclists started with standardized warming up before calibration of equipment followed by implementation of the first test method of LTW. 10 minutes easy cycling followed this first step. Next step was a measurement of VO_{2max}, test method described during the familiarization test day. A 15 minutes' break was given to the cyclists between step two and three. The final step of the protocol was a WAnT 30 seconds' sprint test, also described in the description of familiarization test day. The cyclists were instructed to pedal as fast as possible from the start and not to conserve energy for any remaining part of the tests.

Procedure of the NC-TP (figure 5) was as follows; the cyclists were tested during three test days in the laboratory. The cyclists under the NC-TP were to perform the test methods VO_{2max}, 5-min all-out and the WAnT divided by one method during three days. First test was performed in the morning day one, second test during mid-day day two and the third test during the afternoon day three. At meet-up the cyclists were weighed in. Each test day started with a standardized warm up before a calibration of the equipment was performed.

The cyclists were given only water as fluid during the C- and NC- test days. There was no control of the fluid intake during these tests. The cyclists were free to leave directly after the test was finished but were advised to cool down cycling for 10-15 minutes after the test.

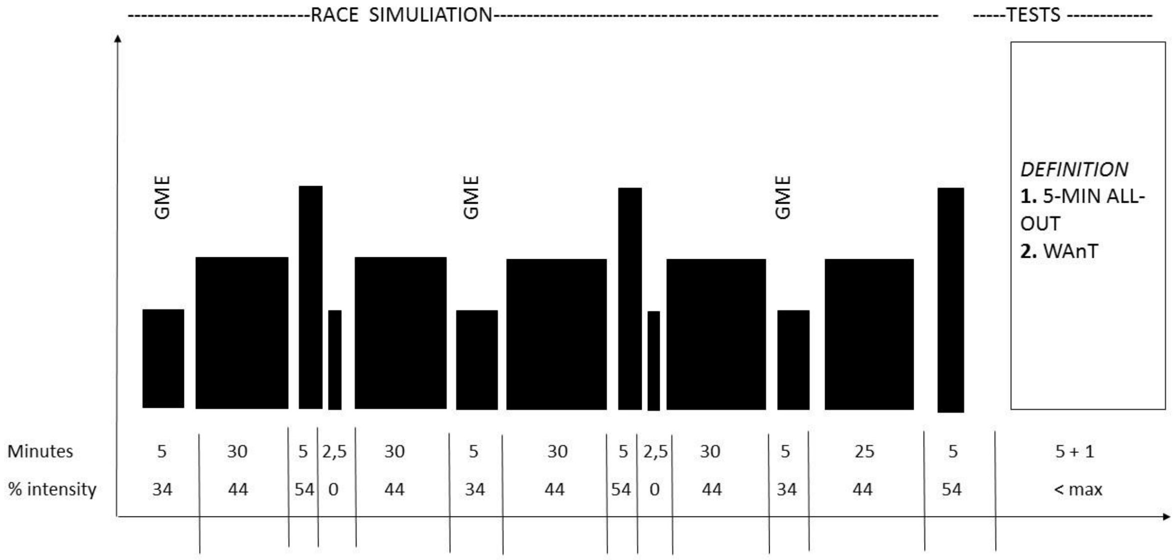

FIGURE 6. Illustration of the implementation of the race simulation (RS), % intensity= intensity in percent based on $VO_{2\ PPO}$, GME= 5 minutes' measurement of gross mechanical efficiency.

During test week 4, the cyclists arrived individually to the laboratory at the scheduled times. Each cyclist was instructed to follow a given cycling program lasting 185 minutes using the intensity control based on the maximum attended wattage of their NC- $VO_{2max\ PPO}$ (study appendix 1). They were requested to adjust the resistance individually by the remote control of the Computrainer. Intensity was controlled by the cyclists during the simulation. To make the prolonged cycling in the race simulation of present study more real-life experienced, we variated with the wattage intensity simulation both flats- up- and down-hills. Overall average was set to each individuals 44% PPO.

Each cyclist was provided with one liter of sports drink and one unit of sport bar every hour during the simulation. Cyclists were advised to consume the sport drink containing 60-75 grams of carbohydrates per liter, in addition to a sport bar containing 39 grams of carbohydrates, every hour to keep their fluid balance and applying glucose to the muscles. The ingestion was advised but not demanded by the test leader. To make the testing more efficient, two - three cyclists were asked to attend to the RS arriving separated by one hour each time. This was done to avoid collision in times of the test methods in the end of each RS.

Normally one to two cyclists were tested in the morning from 08:00 and in the afternoon from 15:00. Cycling GME was measured three times 5 minutes during the RS, every time seated and instructed to keep the same RPM. GME was measured by the same equipment used for estimation of VO_{2max}. Measurements where noted three times 30 seconds from minute 3-4,5 of the 5 minutes period, in accordance with previous studies (E. F. Coyle, 1995; B. R. Rønnestad et al., 2011). GME and La^{-} were measured one time per hour of the RS. During the RS the cyclists were asked to keep an RPM of 80-110, but were free to sit or stand during cycling and to vary after their own wish. They had the possibility to adjust the watt resistance by 10 per cent up or down of the demanded intensity during the simulation. No cyclist interpreted this additional possibility of adjustments during the RS. Directly proceeding as part of the RS, the cyclists were asked to execute the performance test of 5 min all-out cycling completed on the same equipment as the RS and to directly change equipment to perform the WAnT completed on the LODE bicycle. The cyclists weight and sweat loss were estimated at the end of the RS by noted controls before and after the race simulation during the test day; weight measurement was done in minimal clothing and after towel-drying. Final calculation of sweat loss equals change in body mass plus fluid intake (Burke & Deakin, 2006; Garthe & Helle, 2011). Dehydration was calculated by subtracting the sweat loss by the total weight of each cyclist.

4.0 RESULTS

4.1 Differences of the test protocols

TABLE 3. Differences between similar tests completed from the C-TP and NC-TP.

	Mean (SD)		Min		Max		p-value	ES
	C	*NC*	*C*	*NC*	*C*	*NC*		
$VO_{2\ ml}$	54.42 (3.7)	55.2 (3.7)	46.9	47.6	60.2	59.3	.15	
$VO_{2\ TTE}$	7.3 (.94)	7.7 (.96)	5.5	6.5	9	9	.33	
$VO_{2\ PPO}$	360 (33.7)	379.4 (36.9)	300	325	425	425	.05*	.55
$VO_{2\ RER}$	1.15 (.05)	1.17 (.04)	1,03	1.1	1.21	1.24	.39	
$VO_{2\ RPE}$	19.2 (.94)	19 (.8)	17	18	20	20	.78	
$WAnT_{p}$	1028.1 (155.5)	1046.8 (172.3)	799	766	1246	1307	.44	
WAnT m	675.7 (62)	702 (65.5)	584	618.6	763.2	788.1	.01**	.41
$WAnT_{p\ w/kg}$	12.19 (1.75)	12.5 (1.85)	10	9	15.8	16.2	.53	
$WAnT_{m\ w/kg}$	8.1 (.53)	8.4 (.65)	7.1	7.3	9	9.4	.01*	.51
$WAnT_{f.s.}$	19 (6.14)	23 (15.6)	10.8	10.8	31.3	68	U=69, (.86)	
$WAnT_{RPE}$	19.3 (.65)	19 (1.13)	18	16	20	20	.22	

Note: N= 12, mean values (SD=standard deviation), min=minimum and max=maximum, U=Mann Whitney (p), C= Condenced NC= non-condensed, ES= effect size (Cohen's d), * correlation is significant at the 0.05 level, ** correlation is significant at the 0.01 level.

There was a significant difference between the two test protocols (table 3) for variable VO_{2PPO} between the C-TP and the NC-TP $t(11)=2.24$, $p < .05$. The mean increase in scores was 19.75 with a 95% confidence interval was 39.16 to 0.34. Cohen's effect size value suggested a moderate practical significance. There was a significant difference for variable $WAnT_{mean}$ between the C-TP and the NC-TP, $t(11)= 4.06$, $p < .01$. The mean increase in scores was 26.3 with a 95% confidence interval ranging from 12.04 to 40.6. Cohen's effect size value suggested a small to moderate practical significance. Additionally, there was a significant difference for variable $WAnT_{mean\ w/kg}$ between the C-TP and the NC-TP, $t(11)= 4.26$, $p < .01$. The mean increase in scores was .32 with a 95% confidence interval ranging from .15 to .49. Cohen's effect size value suggested a moderate practical significance. There was a tendency of difference between the two test protocols for variable $VO_{2\ ml}$ between the C-TP and the NC-TP, $t(11)= 1.55$, $p = .15$. The mean increase in scores was .32 with a 95% confidence interval ranging from .15 to .49. Cohen's effect size value suggested a small practical significance. WAnT f.s was reported as non-normalized distribution with median= 20.3 and interquartil range= 12.7.

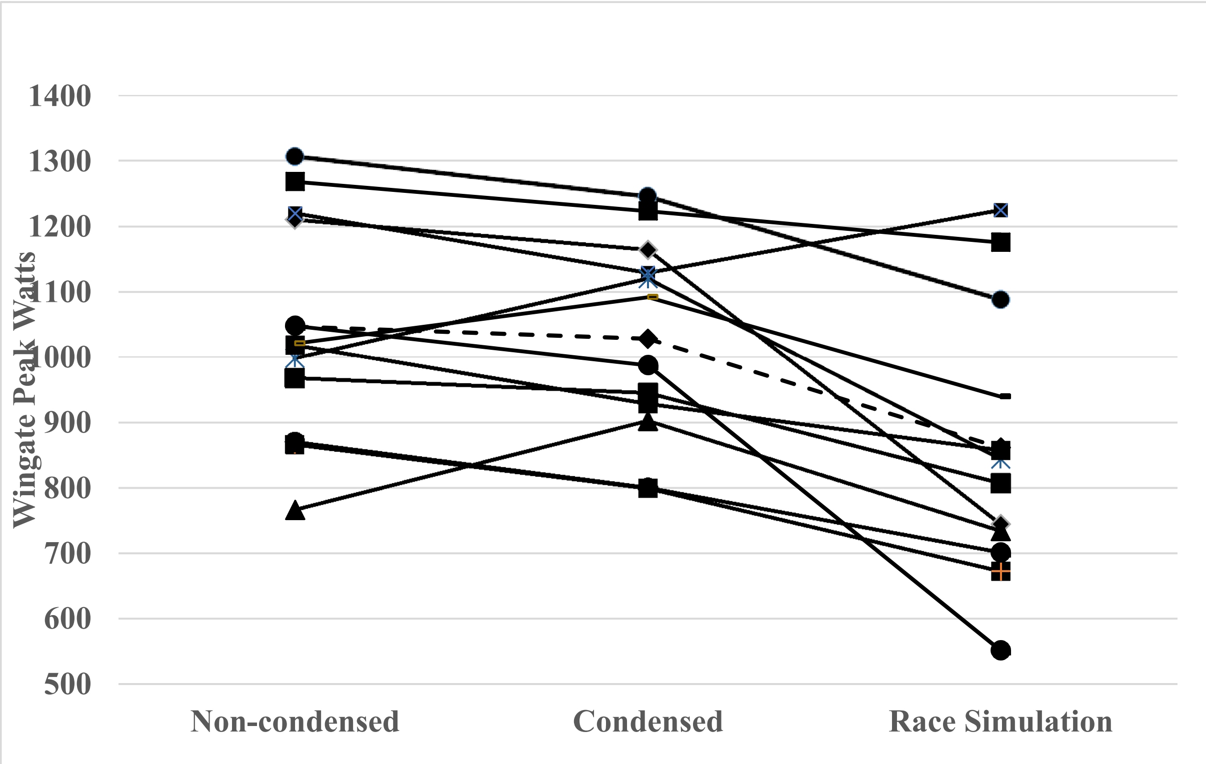

FIGURE 7. WAnT peak results. N= 12, --- = mean results. NC- mean= 1046.8 ± 172.3, C- mean = 1028.1 ± 155.5, Race- mean = 861.6 ± 208.9. There was a significant differences at the p<.05 level for the WAnT $_{peak}$ variable $F(2, 33) = 3.84$, $p=.032$. The RS mean result scored significantly lower to the NC mean (185.17 ± 73.6, p= .44). The mean score of C group was not significant different from the NC (p = .97) or the RS (.76).

TABLE 4. WAnT peak correlation of the C-, NC- and RS- TP.

	WAnT C	**WAnT NC**	**WAnT RS**
WAnT C			
WAnT NC	.88**		
WAnT RS	.70*	.69*	

*N= 12, * <.05, **<.01, m= mean, C= condensed TP, NC= non-condensed TP, RS= Race simulation.*

As presented in table 4 there is a high effect of correlation between testing in the different physical states. Correlation values regarding the Cohen's d are presented earlier in the paragraph "Statistical analyses".

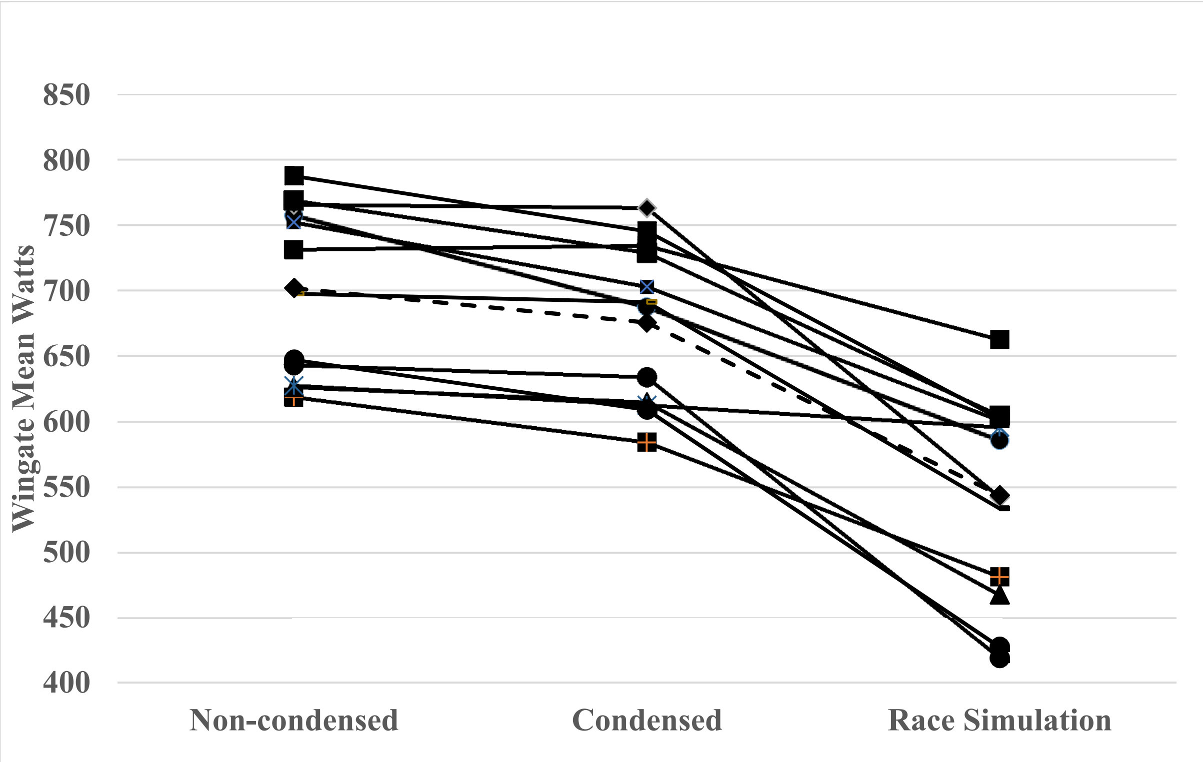

FIGURE 8. WAnT mean results. N= 12, --- = mean results. NC- mean= 702 ± 65.5, C- mean = 675.7 ± 62, Race mean = 543.42 ± 78.6. A significantly mean difference at the $p<.05$ was found in the variable WAnT $_{mean}$, between the three group conditions $F(2, 33) = 18.15$, p=.01. The mean score of WAnT $_{mean}$ from RS was lower than the C group (132.24 ± 28.2, p= .01) and the NC (158.54 ± 28.2, p= .01). The mean score of C group was not significant different from the NC (p = .62).

TABLE 5. WAnT mean correlations of the C-, NC- and RS- TP.

	WAnT C	WAnT NC	WAnT RS
WAnT C			
WAnT NC	.94**		
WAnT RS	.68*	.68*	

*N= 12, * <.05, **<.01, m= mean, C= condensed TP, NC= non-condensed TP, RS= Race simulation.*

As presented in table 5 there is a high effect of correlation between testing in the different physical states. Correlation values regarding the Cohen's d are presented earlier in the paragraph "Statistical analyses". No significant difference between the groups NC-, C- and RS- was found for the variable WAnT $_{\text{fatigue slope}}$ (p= .66).

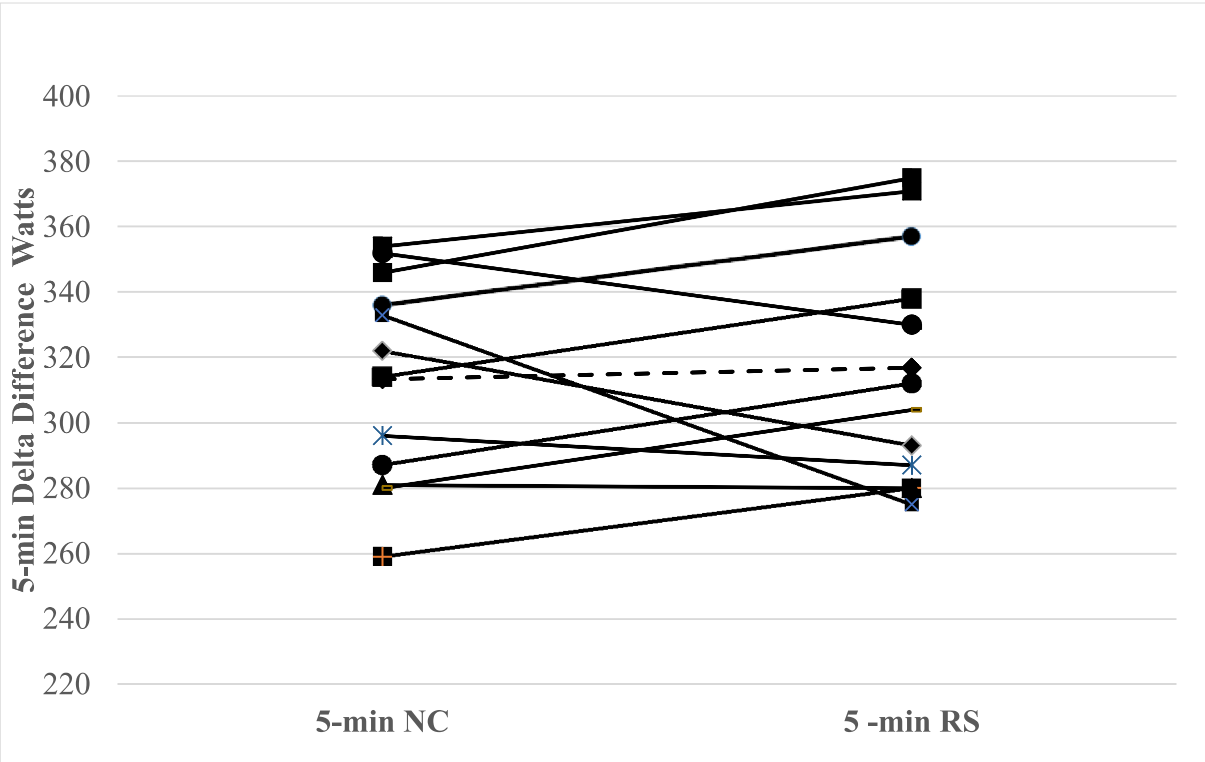

FIGURE 9. Delta difference (median = 19 ± 27.7) between the 5-min all-out NC (mean 313.3 ± 32.05) and the 5-min all-out RS (mean 316.83 ± 36.51). There is a positive correlation between the delta diff 5min and dehydration, r= .79 (r^2= .62), p<.01. This is indicating a positive correlation between high dehydration status and change of performance in wattage at

5min NC- to RS. Correlation between the 5-min NC and RS was significant, r=.68(r2=.47), n=12, p=.02.

4.3 Correlations of the test protocols

TABLE 6. Correlations of variables C and NC TP to the NC- and RS- 5-min all-out performance test.

		5-min NC		5-min RS	
		Cor.	Sig.	Cor.	Sig.
CONDENCED	LTW	.64*	.03	.72**	.01
	$VO_{2\ ml}$	.27	.39	−.03	.94
	$VO_{2\ TTE}$	−.23	.48	.09	.79
	$VO_{2\ PPO}$	.78**	.00	.70**	.01
	$VO_{2\ RER}$	−.34	.28	− .46	.13
	$WAnT_{p}$	.55	.07	.23	.47
	$WAnT_{p\ w/kg}$	.16	.61	.01	.99
	WAnT m	.57	.054	.49	.11
	$WAnT_{m\ w/kg}$	−.12	.71	.13	.68
	$WAnT_{f.s.}$	.35	.27	.01	.99
NON - CONDESED	$VO_{2\ ml}$	.21	.52	− .01	.99
	$VO_{2\ TTE}$	.59*	.05	.03	.92
	$VO_{2\ PPO}$	.80**	.00	.57	.06
	$VO_{2\ RER}$	−.30	.34	−.24	.46
	$WAnT_{p}$	.73**	.01	.40	.2
	$WAnT_{p\ w/kg}$	.41	.19	.20	.53
	WAnT m	.66*	.02	.54	.07
	$WAnT_{m\ w/kg}$	.02	.96	.17	.60
	$WAnT_{f.s.}$	−.13	.70	−.39	.21

*Note: n= 12, Cor.= correlation, Sig.= significance, * correlation is significant at the 0.05 level, ** correlation is significant at the 0.01 level*

4.2 Race simulation

TABLE 7. Mean variables (N=12) measured during RS. Power avg and sw loss was measured at end. Variables dhy%, GME and La^- displays mean result of measurements one time per hour.

Variable	mean	min	maks
Power avg	165.83 (15.5)	145	185
sw loss	2.74 (.47)	1.8	3.53
dhy%	1.09 (.72)	-0.23	2.34
GE	17.2 (1.67)	12.61	19.92
La^-	1.36 (.37)	0.82	2.2

Note mean values (SD=standard deviation), min=minimum and max=maximum, sw loss= sweat loss in kilos, dhy%= calculated % loss dehydration, GME= calculated gross mechanical efficiency, La^-= lactate blood measurement.

All variables presented in "table 6" are normally distributed and present group values of the cyclists in the study. The variable La^- did not differ during the RS [$F(2, 33) = 1.87$, $p = .17$]. Similarly, the variable of gross efficiency did not differ during the RS [$F(2, 33) = .33$, $p = .72$].

4.4. Prediction of the test protocols.

Prediction of the C- compared to NC- TP variables in correlation with RS performance. A chosen set of variables from the C-TP (variables LTW, VO_{2max} ml/kg·min and WAnT $_{peak}$) were studied presenting a tendency but not significant prediction correlation with the performance at the RS-5min, n= 12, r^2= .55 $F(3, 8) = 3.26$, p= .08. Similar variables from the NC-TP displayed a r^2= .52 $F(3, 8) = 2.83$, p= non-significant. The variables LTW, C-VO_{2max} ml/kg*min and C-WAnT $_{peak}$ showed a non-significant prediction of correlation with the performance at the NC-5min. The C- variables LTW, $VO_{2max\ PPO}$ and WAnT $_{mean}$ displayed a prediction of performance at the RS- 5min, n=12, r^2= .56 $F(3, 8) = 3.39$, p= ns. Similar variables from the NC-TP, on the other hand displayed a significant prediction of performance at the RS- 5-min, r^2= .64 $F(3, 8) = 4.82$, p= .03. The C-TP variables LTW and $VO_{2max\ PPO}$ together significantly correlated at prediction value of the performance variable RS- 5min with a significant regression equation, r^2= .56 $F(2, 9) = 5.61$, p= .03). Individually, none of the variables are making beta values of a significant unique contribution to the equation.

5.0 DISCUSSION

In the present study, the goal was to explore in what degree condensed cycling test protocols differentiates from separated non-condensed test protocols. Test methods involved was targeting independent differences as well as independent and coordinated correlations to the performance tests (5-min all-out and WAnT) performed individually or as a part of the Race simulation. It has not been attached importance to the physiological characteristics of the methods.

5.1. General discussion

This study adopted a quantitative test method by testing subjects in numerous test methods to collect comparable results. An experimental test period was interpreted containing testing of subjects in two different test protocols involving two different physical states. The subjects were randomized and mainly tested alone to ensure the results to counteract the pace learning ability that may influence the results. The influence of the competition on performance and ability to perform better when competing against other athletes is discussed by Triplett (1898) & Corbett, Barwood, Ouzounoglou, Thelwell, and Dicks (2012). This study's quantitative method gives comparable numbers and used in statistical analyses resulting in patterns of answers (Gray & Kinnear, 2012; Hellevik, 2009; Polit & Beck, 2014).

Test protocols commonly used presenting cycling performance are presented in previous studies (B. R. Rønnestad et al., 2013; Støren et al., 2013; Sylta et al., 2016). These test methods are similarly sold for private testing of cyclists (Olympiatoppen, 2013). The results of this study's test methods using C- or NC- TPs were compared for differences. Differences were found between the results of VO_{2PPO}, WAnT $_{mean}$ and WAnT $_{mean\ w/kg}$ significant at $p < 0.05$. The remaining test variable results presented a slight increase in differences from the C- to the NC- TPs, not significant results. There was no significant difference in the measurements of the VO_{2max} in ml/kg ·min. Current evidence presented by Hawkins and Wiswell (2003) supports a 10% decline in VO_{2max} per decade of age, influenced by the reduction in maximal heart rate and lean body mass. Due to the wide age range of the cyclists participating, we can therefore presume VO_{2max} to be affected by the age of cyclists, questioning the present group results. Interpreted criteria of attaining VO_2 in the present study, is supported by Poole, Wilkerson, and Jones (2008) testing the validity of criteria for establishing maximal VO_{2max} during ramp exercise tests. We can from our point of view say that differences of testing from a C- or NC- TPs induces minimal different results. This is supported by the statement that oxygen consumption in healthy athletes is stable and reproducible with test-retest reliability of approximately 2% over the period of a few weeks (Tanner & Gore, 2013).

Constantini et al. (2014), demonstrated that the boundaries of multiple heavy intensity domains are to be accurately determined within a single visit to the laboratory. The difference in results concerning the tests $WAnT_{peak}$, displayed a significant difference in higher level of results from the C- to the NC- TP. Similar increase was additionally confirmed with test $WAnT_{mean}$. Both WAnT peak and mean shows a significant decrease in results to the RS TP (figure 7 & 8). WAnT peak and mean results of the NC- C- and RS- test protocols were nevertheless highly correlated (table 4 & 5). This is in accordance with the findings of Constantini et al. (2014), reporting no significant difference in performance during the last 30 seconds of a 3 minutes all-out test individually or followed an exhaustion test of 8-12 minutes. The validity and presentation of the WAnT test has been well described by R Beneke et al. (2002) to be highly anaerobic with 80% of the energy turnover during the test to be derived from anaerobic alactic and lactic acid metabolism dominated by glycolysis. The validity of the WAnT in usage during a C-TP following both a LTW and a $VO_{2max\ TTE}$ in context of retrieving valid results, is well shown in the present study. The best cyclists from the C- TP was still the best in the RS TP.

Subsequent analysis of the variable dehydration during the RS, displayed a positive correlation with the delta difference of 5-min all-out tests (figure 9). The studies of E. F. Coyle (1999) and Hargreaves (2007) presents the negative affect of heat production during exercise. Anyhow, the present study shows a positive correlation between the delta difference and the dehydration status. There was a development presenting the individual results in the test group to increase from the 5min NC to the 5min RS, not significant results. Improvement of endurance during the RS may have been influenced by the physiological impact of competition. This is in accordance with the study by Cooke, Kavussanu, McIntyre, and Ring (2011). The psychological impact to performance has not been accounted for in the results from the present study.

Table 6 shows correlation of the C- and NC- TP and 5-min performance test from both the NC- and the RS- TP. Identifying the results in the C-TP, we find that both the LTW and

VO_{2PPO} individually both show strong correlation with both 5min- NC and -RS. For the NC-TP, we find that VO_{2TTE} show strong correlation to a NC-5min. The NC-VO_{2PPO} shows strong correlation to the NC-5min, as well as the NC-WAnT $_{peak}$ and WAnT $_{mean}$ shows strong correlation to the NC-5min. This indicates that the only tests results individually correlated to the 5-min all-out during the race simulation, remains from the C-TP . With these results presented we can say that in our group the identification of the LTW at 4mmol/L is well associated with the findings from the study of Bentley et al. (2001), reporting LTW giving a large amount of characteristics to time trial cycling performance. Amann et al. (2006), confirms usage of LTW providing measurement of endurance ability over time in cycling, but suggests breakpoint of ventilatory equivalent of oxygen to be a better predictor for performance threshold at 40 kilometers' time trial. Usage of LTW as measurement of cycling performance is supported by the study of Faude, Kindermann, and Meyer (2009) presenting a framework to clarify the definition of the lactate threshold. Furthermore, the study of Lee et al. (2002) discussed the physiological differences in power output, body mass, level of lactate threshold, and more, among professional mountain and road cyclists. According to their result, there is of certainty individual differences in the placement of a lactate threshold at 4mmol per liter blood, regarding cycle rider types and characteristics.

The variables GME and La^- during the RS did not differentiate significantly. There is a possibility that GME did not differ enough in cause of muscle fiber type distribution among the cyclists, claimed by E. F. Coyle et al. (1992) affecting the cycling level of the GME. A statement of age showing differences in cycling efficiency is supported by the study of (Hopker et al., 2013), whom in the same study presented fiber type distribution not to be related to GME. Subsequently no sig. development in the measurements was presented for the variable La^{-}. This is associated with the overall intensity level placed below the lactate threshold for the cyclists during the simulation, set in accordance with the study of B. R. Rønnestad et al. (2011). The cyclists were provided with nutrition and fluid needs during the simulation recommended by the guidelines of Burke and Deakin (2006).

A C- TP including determination of the variables LTW, VO_{2max} in milliliters/kg and WAnT $_{peak}$ was studied to predict the performance at NC- 5-min all-out. Correlation to the RS 5-min all-out, there was a significant value of prediction, although none of the variables were making an individual unique contribution. Overall- we identified the use of the test method LTW separately to be well correlated with the RS- 5-min all-out. Similarly, the C- $VO_{2max\ PPO}$ to were correlated with the RS- 5min all-out. No methods of the NC- TP was correlated significant with the RS- 5min all-out test (table 7). When LTW was analyzed together with the $VO_{2max\ PPO}$ and $WAnT_{mean}$, a significant prediction value was displayed. In what degree the LTW test may have affected this result, is unknown. More studies of the combination using test methods for definition of cycling performance is needed.

5.2. Methodological discussion

A principle of any scientific study is to be left without any errors in choice or use of method. Reasons to consider, this study uses multiple test instruments involving tested subjects. This demands a review of the strength and weakness of the results.

To gain a reliable statistic outcome in results, it is necessary to have a certain amount of selection within the subjects participating in the study. The outcome of the present study was based on a rather small sample size of 12 cyclists. A small and narrow selection provides a great challenge of generalizing the results. The cyclists in the study were all in the distribution gender of men, between the age of 20 to 54 and had been road cycling for a minimum level of the last three years. Frequency distribution presents a normal distribution, which strengthens the overall results. All subjects involved were asked to keep regular training throughout the study.

Cyclist taking part in the study participated in active competitions during the cycling season. The study had no control group, but the need of this was not present because of the descripting purpose within the subjects (Polit & Beck, 2014).

All instruments used in this study has previously been used in multiple previous performed studies, referring chapter theory. Usage of the test instruments in recent studies assists comparison of the results. The strength of a set threshold at 4 mmol/L is supported by Faude et al. (2009), presenting a framework to help clarify concepts regarding the lactate threshold. They presented the concept of a maximal lactate steady state at lactate threshold at 4mmol to show strong correlations predicting aerobic performance. Usage of the Biosen blood lactate analyzer is supported by previously studies (Glaister et al., 2009; Hauser, Bartsch, Baumgärtel, & Schulz, 2013; Jones, Hesford, & Cooper, 2013). Usage of this analyzer is supported by Bonaventura et al. (2015) presenting the reliability of other hand-held blood lactate analyzers to be too low. The validity and stability measuring VO_{2max} by the instrument Oxycon Pro is defended by the study of Foss and Hallen (2005). Both the reliability of the bicycle instruments WAnT Lode bicycle and it´s applicability to the Computrainer electromagnetically braked cycling training device has been studied (Earnest, Wharton, Church, & Lucia, 2005), recommending the need of caution when directly transferring results obtained from laboratory testing to the Comptrainer training device. Considering the individual differences of cycle body position, the authors Bini, Hume, and Kilding (2014) states that saddle height has an influence on cycle effectiveness. During present study, cycling position was set and similarly used by each subject individually. Body position has been studied within untrained cyclists to have great influence on VO^2, ventilation, heart rate and GME, when seated upright instead of in an aerodynamic position (Ashe et al., 2003). Similar study reports aerodynamic resistance to be the major resistance force a racing cyclist must overcome. Pedaling speed, as well as gear ratio and pedaling cadence directly influence cycling efficiency (Faria, Parker, & Faria, 2005). More studies are needed regarding the influence of cycling position concerning indoor testing comparison to outdoor cycling.

The amount of high intensity test days during this study, created a level of concern regarding the physiological capacity within the subjects. Frequency of high intensity workouts is reported to increase up to the double of time required in restitution after high- compared with low intensity training (Busso, Benoit, Bonnefoy, Feasson, & Lacour, 2002). The temperature and humidity differentiated minimally in the test laboratory during the study's test days. Testing indoor is advised to always keep identical climatic conditions for the test subjects. A study by Marsh and Sleivert (1999) reported increased mean power output during a 70 seconds cycling performance test after precooling of the tested subjects. Heat production during intense exercise is presented to elevate core and muscle temperature rapidly identified as an independent case of fatigue to endurance (E. F. Coyle, 1999).

Testing time of the day within cyclists in the present study differentiated from 8 AM to 9 PM. The diurnal variation on a cycling time trail performance is reported to be worse in the morning than in the afternoon (Atkinson, Todd, Reilly, & Waterhouse, 2005). In present study, all reservation of test time was done through an online reservation form to allow each cyclist to choose time for testing being best appropriate.

Even though there was a request of preparation before each test, the test leader of the present study could not control for this being followed. Trust considering cyclists following requested preparation and tasks during tests, was an important part of the relationship between the cyclist and the test leader. The use of fluid and nutrition could have caused difficulties regarding any possible allergies or strong opinions of choice to flavor or other adaptations. In this study, no such problem was presented.

Finally, annual time chosen for testing the cyclists of the present study was questioned. A cycling season in extends from the start of late winter (mid-February) and finishes at the end of summer/beginning of fall (Lucía et al., 2001). The test period in January follows two months of normally containing little specific cycle training. Because main testing period of present study was placed in January, it´s also relevant to ask if the holiday celebrations of Christmas and New Year´s eve involving considerably amounts of food and probably reduced training, may have affected the results negatively.

6.0 CONCLUSION

The present study showed only small to none practical differences between test results of a condensed TP compared to similarly completed non-condensed TP. The NC TP exclusively differentiated at a minimal higher result to the C TP with test results of VO_{2PPO}, $WAnT_{peak}$ and $WAnT_{mean}$. All variable results, studied in both the C- and NC TP were compared to 5-min all-out performance tests, presenting the LTW and VO_{2PPO} to be the only positive correlated determinants of the 5-min all-out test after race simulation. None of the NC-TP variables was significantly correlated to the 5-min all-out race simulation. Results of the WAnT showed high correlation of the three physical states NC-, C- and RS- TP. This presents a valid use of this test method in usage during the end of a C-TP. We recommend further studies regarding the dehydration status and physiological impact of indoor testing.

In conclusion, this study supports the use of the C-TP in testing of cyclists at an indoor laboratory. NC-TP added minimal additional information relevant to competitive cycling performance. LTW and VO_{2PPO} from a C-TP was positively correlated with the 5-min all-out as part of RS. No other variables from C-TP and NC-TP was positively correlated to the 5-min all-out RS.

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8.0 APPENDIX

APPENDIX 1: Example of RS program.

Subject:	**Example**
VO_{2max} PPO	**425**
Weight start:	

Intensity		**Split of time minutes**	**Simulating**	**Time**
34 %	**144,50**	Constant	GE measurement 1	**5 min.**
44 %	**187,00**	Constant	Controlled pack	**30 min.**
54,00 %	**229,50**	Constant	Hill	**5 min.**
0,00 %	**0,00**	Constant	Downhill	**2,5 min.**
44,00 %	**187,00**	Constant	Controlled pack.	**30 min.**
34,00 %	**144,50**	Constant	GE measurement 2	**5 min.**
44,00 %	**187,00**	Constant	Controlled pack	**30 min.**
54,00 %	**229,50**	Constant	Hill	**5 min.**
0,00 %	**0,00**	Constant	Downhill	**2,5 min.**
44,00 %	**187,00**	Constant	Controlled pack	**30 min.**
34,00 %	**144,50**	Constant	GE measurement 3	**5 min.**
44,00 %	**187,00**	Constant	Controlled pack.	**25 min**
54,00 %	**229,50**	Constant	Intensity increasing	**5 min.**
avg 44%			TOTAL	180 min

Cyclists´s RPM between 80-100. Siting while biking is preferably.

APPENDIX 2: TEST DAY familiarization

ID (1-12) Monday / Tuesday / Wednesday	Test attendance	Tests (LTW, 5min all-out, VO_{2max} and WAnT)
1 / 4 / 7	8:45	9:10 - 10:30
2 / 5 /8	10:45	11:10 - 12:30
3 / 6 / 9	13:45	14:10 - 15:30
10 / 11 /12	15:45	16:10 - 17:30

Note: in total 4-4-4 participants each day, over 3 days.

APPENDIX 3: TEST DAY NC-TP

ID (1-12) Monday / Tuesday / Wednesday	Test attendance	Tests (LTW and VO_{2max})	Tests (5min all-out and WAnT)
1 / 4 / 7	07:45	08:00 – 09:00	15:00 – 15:30
2 / 5 /8	09:15	09:30 – 10:30	16:30 – 17:00
3 / 6 / 9	10:45	11:00 – 12:00	18:00 – 18:30
10 / 11 /12	12:15	12:30 – 13:30	19:30 – 20:00

Note: in total 4-4-4 participants each day, over 3 days.

APPENDIX 4**:** TEST DAY race simulation

ID (1-12) Monday / Tuesday / Wednesday	Test attendance	RS	Tests (5min all-out and WAnT)
1 / 4 / 7	07:45	08:00 – 11:00	11:02 – 11:22
2 / 5 /8	08:45	09:00 – 12:00	12:02 - 12:22
3 / 6 / 9	13:45	14:00 – 17:00	17:02 - 17:22
10 / 11 /12	14:45	15:00 – 18:00	18:02 - 18:22

Note: in total 4-4-4 participants each day, over 3 days.

Comparison of cycling test methods and correlation to an indoor race simulation

This is an original investigation with 6 tables and 9 figures. The abstract contains 230 words and text contains 3406 words.

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"This manuscript has been read and approved by all the listed co-authors and meets the requirements of co-authorship as specified in the Human Kinetics Authorship Guidelines. This manuscript is original and not previously published, nor is it being considered elsewhere until a decision is made as to its acceptability by the "JSPP Editorial Review Board".

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Running head:
Test methods correlation cycling

Abstract

Purpose: C-TP involves testing of wattage at lactate threshold (LTW), maximum oxygen consumption (VO_{2max}) and a Wingate anaerobic test (WAnT), performed consecutively during one session. As comparison these tests were separated and performed individually over three consecutive days, giving a non-condensed test protocol (NC-TP). The results were compared to a 5min all-out cycling test (5min all-out) performed individually and as part of a 185 minutes' race simulation. **Method:** During 4 weeks, 12 recreational active male cyclists (VO_{2peak} 54.8 ± 3.62 ml · kg^{-1} · min^{-1}) completed 6 independent visits at a physiological laboratory involving testing of separate duration and intensity. **Results:** The only significant differences between C-TP and NC-TP was found in the variables VO_{2PPO} (360 vs. 379.4 watts), $WAnT_{peak}$ (1028.1 vs. 1046.8 watts) and $WAnT_{mean}$ (675.7 vs. 702 watts). Additionally, LTW ($r = .72$) and VO_{2PPO} ($r = .70$) measured during the C-TP was strongly correlated with the results in the 5min all-out cycling test as part of the race simulation. WAnT peak and mean results showed high correlation of the C-, NC- and RS- TPs. LTW and VO_{2PPO} from a C-TP was positively correlated with the 5-min all-out as part of RS.
Conclusion: This study supports the use of the C-TP in testing of cyclists at an indoor laboratory. NC-TP added minimal additional information relevant to competitive cycling performance.

Key words. Laboratory, measurements, road, endurance, competition

Introduction

[figure 1]

In cycling, the power produced at a given velocity depends on a complex interaction of many physiological (VO_{2max}, LT, GME), mechanical (bicycle, wheels, tires) and environmental (wind, temperature, humidity, altitude) variables. Based on this, Jeukendrup, Craig, Hawley [1] claims professional cycle racing to be one of the most demanding of all sports when combining the extremes of exercise duration, intensity and frequency.

Endurance capacity for cyclists is tested by identification of the lactate threshold wattage, maximal oxygen consumption, as well as testing of several anaerobic sprint characteristic. Numerous studies use these test methods to define the principle variables defined as essentially related to physical performance [2-6]. Recently, a study by Sylta, Tønnessen, Hammarström, Danielsen, Skovereng, Ravn, Rønnestad, Sandbakk, Seiler [7] interpreted a combination of cycling test methods during a single test protocol. These are performed consecutively in the order of 1) a lactate profile for definition of the lactate threshold in level of cycling wattage production (LTW) 2) a stepwise test for the definition of the maximum oxygen consumption (VO_{2max}) and 3) a Wingate anaerobic 30 seconds sprint test (WAnT). This grouping of test methods is also offered as a condensed test protocol (C-TP) for cyclists requesting personal testing by Olympiatoppen (South Department), part of the Norwegian Olympic and Paralympic Committee and Confederation of Sports with responsibility for training Norwegian elite sport [8]. Both private and professional Norwegian cycling teams utilizes this test protocol.

The aim of this study is:

- to study the difference in test results of indoor cycling test methods during condensed versus non-condensed test protocols.
- to correlate the results from both C- and NC-TP with a 185 minutes' experimental race simulation including a 5 minutes all-out cycling and Wingate anaerobic test.

Method

Subjects

Subjects attending to the study were 12 male road-racing cyclists in the age distribution of 20-54. Inclusion criteria were; the cyclists had to have been trained in cycling for the last 3 years and had to have participated in cycling competitions. The amount of regular training volume varied. The study was approved by the human subjects' review committee of the Faculty for Health and Sport, University of Agder. All subjects provided informed written consent before participation. The cyclists were entitled at any time to withdraw from the study without explanation.

[Figure 2]

This study used a randomized quantitative method to test cyclists involving different test methods during 4 weeks at an indoor physiological test laboratory. The four weeks of the main study took place during the period from 9th of January to the 3rd of February 2017.

Testing procedures

All tests were performed under similar environmental conditions (17-21ºC) at an indoor physiology laboratory. All testing of cyclists commenced with a standardized warm up program of a total 15 minutes' inclusive calibration of the Computrainer stationed magnetically watt controlled ergometer with a connected remote control for adjusting the watt resistance.

Amount of test days during each study week:

(1) "Familiarization test week"; involving one test day testing a LTW, a performance test of 5 min all-out cycling, a VO_{2max} test and a WAnT, in the following order. Time required 90 min.

(2) "Condensed test week"; one test day, testing the C-TP and the definition of LTW, VO_{2max} and WANT, in the following order. Total time required 75 min.

(3) "Non-condensed test week"; three test days, testing the NC-TP and the definition of VO_{2max}, 5 min all-out test and WAnT, during three separated days. Each one lasted approximately 30 minutes.

(4) “Race simulation week*”*; one test day, an implementation of a 185 min RS cycling including tests of 5 min-all out and WAnT.

[figure 3]

The familiarization test illustrated in figure 3 was a 4step test protocol performed week 1 of the main study. Testing involved testing of LTW, a 5-min all-out, a VO_{2max} and a WANT. All 12 cyclists were to perform the test during three days, 4 cyclists each day. The reliability and validity of this device for measuring watt production in cycling has been previously examined [9].

Step 1 of the familiarization test was a LTW which started with watt resistance of 100 watts and increased by either 50 w and later 25 w each 5 minute until the LT was reached. Less increase is done after approximately 2.5mM/l blood level has been measured. The LTW was terminated after measurement of 4.0 millimole lactate per liter ($4mMol \cdot L^{-1}$) in blood level. Blood samples are taken in the end of each 5 minute’s bout during the test and is done from the finger tips before each increase of power, following the procedures of the EKF Biosen C-line lactate analyzer. Use of this lactate analyzer is in accordance with earlier studies by Amann, Subudhi, Foster [6] and Seiler, Jøranson, Olesen, Hetlelid [10]. A 10-minute rest period with cycling at 75-100W was provided after the LTW test before the next step.

Step 2 of the familiarization test was a 5-min all-out and was intentionally planned to have an output of 85% of the cyclist’s PPO at VO_{2max}. Last minute average power in wattage during the VO_{2max} test was defined at the cyclist’s peak power output (PPO). Chosen start of intensity is in accordance with the method by Vikmoen [11]. Since none had performed this test earlier in the study, the resistance was set to be 125% of the LTW. Before the test initiated the cyclists kept a normalized RPM with 100 W resistance. The first minute the workload was set by the test leader. The cyclists were after the 1st minute allowed to adjust the wattage by signaling to the test leader who increased or decreased by 10 W each time they demanded. During the test, they were instructed to cycle as high mean power output as possible during the 5 minutes. The power resistance was not affected by the RPM. They were requested to be seated during this test. The cyclists received feedback regarding power output production and time elapsed, but not average power and heart rate. A 10-minute period of easy cycling at 75-100W was provided after the LTW test before the next step.

Step 3 proceeded with a VO_{2max} test. This test started with watt corresponding to 3 W · kg^{-1} (rounded down to the nearest 50W). This and completion of this test method was done in accordance with earlier studies [2,3,12-16]. Power output was then subsequently increased by 25 W every minute until exhaustion. VO_{2max} was calculated as the average of the two highest 30 s VO_2 measurements. Oxygen consumption was measured using a computerized metabolic system with mixing chamber using a breath by breath mouth piece (Oxycon Pro open circuit metabolic cart of type Oxycon, Jaeger BeNeLux Bv, Breda, the Nederlands). The test ended voluntarily as fatigue was reached. A flattening of the VO_2 curve, respiratory exchange ratio (RER) ≥ 1.05, and [La-]b ≥ 8.0 mmol · L^{-1} was used as criteria to evaluate if VO_{2max} was obtained. The gas analyzers were calibrated with certified calibration gases of known concentrations before every test. The flow turbine (Triple V, Erich Jaeger, Hoechberg, Germany) was calibrated before every test with a 3 L calibration syringe (5530 series; Hans Rudolph, Kansas City, USA). The cyclists were given 10 minutes of easy cycling at 75-100W after the VO_{2max} test.

Step 4 was testing of a WAnT. This test demanded that the cyclists changed bike to an electrically braked bicycle ergometer (Lode Excalibur Sport, Groningen, Netherlands), modified with adjustable stem, and a similar pedal system for each cyclist. The test was initiated with 5 minutes easy cycling before the test started cycling with 120 RPM at a 20 seconds' countdown. In the last 3 seconds, braking resistance was first removed and then applied with 0.7 newtonmeter·kg^{-1} and remained constant throughout the 30-s all-out test. Scores retrieved from this test were wattage of 30 sec peak, mean and grade of reduction in power explained from a fatigue slope. Cyclists were free to sit or stand during the test.

[figure 4]

[figure 5]

During test week two, all cyclists were familiarized with the test methods when divided in either the C-TP (figure 4) or the NC-TP (figure 5), as illustrated in the figure 2. The cyclists came in at given times and were weighed in.

Procedure of the C-TP (figure 4) was as follows; the cyclists started with standardized warming up before calibration of equipment followed by implementation of the first test method of LTW. 10 minutes easy cycling followed this first step. Next step was a measurement of VO_{2max}, test method described during the familiarization test day. A 15 minutes' break was given to the cyclists between step two and three. The final step of the protocol was a WAnT 30 seconds' sprint test, also described in the description of familiarization test day. The cyclists were instructed to pedal as fast as possible from the start and not to conserve energy for any remaining part of the tests.

Procedure of the NC-TP (figure 5) was as follows; the cyclists were tested during three test days in the laboratory. The cyclists under the NC-TP were to perform the test methods VO_{2max}, 5-min all-out and the WAnT divided by one method during three days. First test was performed in the morning day one, second test during mid-day day two and the third test during the afternoon day three. At meet-up the cyclists were weighed in. Each test day started with a standardized warm up before a calibration of the equipment was performed.

[Figure 6]

[Table 1]

During test week 4, the cyclists arrived individually to the laboratory at the scheduled times. Each cyclist was instructed to follow a given cycling program lasting 185 minutes using the intensity control based on the percentage calculation of their $VO_{2max\ PPO}$ (study Table 4). They were requested to adjust the resistance individually by the remote control of the Computrainer.
Each cyclist was provided with one liter of sports drink and one unit of sport bar every hour during the simulation. Cyclists were advised to consume the sport drink containing 60-75 grams of carbohydrates per liter, in addition to a sport bar containing 39 grams of carbohydrates, every hour to keep their fluid balance and applying glucose to the muscles. The ingestion was advised but not demanded by the test leader. Cycling GME was measured three times 5 minutes during the RS, every time seated and instructed to keep the same RPM. GME was measured by the same equipment used for estimation of VO_{2max}. Measurements where noted each 30 seconds from minute 3 - 4,5 of the 5 minutes period [15,17]. GME and La^-

were measured one time per hour of the RS. During the RS the cyclists were asked to keep an RPM of 80-110, but were free to sit or stand during cycling and to vary after their own wish. They had the possibility to adjust the watt resistance by 10 per cent up or down of the demanded intensity during the simulation. No cyclist interpreted this additional possibility of adjustments during the RS. Directly proceeding as part of the RS, the cyclists executed the performance test of 5 min all-out cycling completed on the same equipment as the RS and to directly change equipment to perform the WAnT completed on the LODE bicycle. The cyclists weight and sweat loss were estimated at the end of the RS by noted controls before and after the race simulation during the test day; weight measurement was done in minimal clothing and after towel-drying. Final calculation of sweat loss equals change in body mass plus fluid intake [18,19]. Dehydration was calculated by subtracting the sweat loss by the total weight of each cyclist.

Statistical analyses

Statistical analyses were conducted using SPSS 21.0 (SPSS Inc, Chicago, IL, USA). Alpha level was set at $p < .05$. Preliminary analyses and skewness of the data was performed to ensure no violation of the assumptions of normality, linearity and homoscedasticity. Correlation is presented as the Pearson product-moment correlation. The Bivariate correlation coefficient vary from values 0 indicating no relationship, and -1 negative to +1 positive relationship. Cohen [20] suggests the following guidelines in relationship presented as a small effect = .10 to .29, medium effect = .30 to .49, and large effect = .50 to 1.0. Paired sample t-tests were used as statistical analyses to investigate differences between several variables in the study. Effect size indicates practical change of the values. If not normally distributed data in variables measured, there was used a Mann Whitney U-test to study their relationship. One-way repeated measures ANOVA was conducted to study any significantly difference in the repeatedly measured variables of the RS. Additionally, the mean scores of WAnT were studied for differences in performance at C-, NC and RS physical conditions.

Results

[Table 2]

There was a difference between the two test protocols (table 1) for variable VO_{2PPO} between the C-TP and the NC-TP t(11)=2.24, $p < .05$. The mean increase in scores was 19.75 with a 95% confidence interval was 39.16 to 0.34. Cohen's effect size value suggested a moderate practical significance. There was a difference for variable $WAnT_{mean}$ between the C-TP and the Nf-TP, t(11)= 4.06, $p < .01$. The mean increase in scores was 26.3 with a 95% confidence interval ranging from 12.04 to 40.6. Cohen's effect size value suggested a small to moderate practical significance. Additionally here was a difference for variable $WAnT_{mean\ w/kg}$ between the C-TP and the NC-TP, t(11)= 4.26, $p < .01$. The mean increase in scores was .32 with a 95% confidence interval ranging from .15 to .49.

[Figure 7]

[Table 3]

[Figure 8]

[Table 4]

[Figure 9]

[Table 5]

[Table 6]

The variable La^{-} did not differ during the RS [F(2, 33) = 1.87, p = .17]. Similarly, the variable of gross efficiency did not differ during the RS [F(2, 33) = .33, p = .72].

Discussion

Constantini, Sabapathy, Cross [21], demonstrated that the boundaries of multiple heavy intensity domains are to be accurately determined within a single visit to the laboratory. Differences were found between C- and NC- TP in the results of VO_{2PPO}, $WAnT_{mean}$ and $WAnT_{mean\ w/kg}$ (table 2). The difference in results concerning the tests $WAnT_{peak}$, displayed a significant difference in higher level of results from the C- to the NC- TP. Similar increase was additionally confirmed with test $WAnT_{mean}$. Both WAnT peak and mean shows a significant decrease in results to the RS TP (figure 7 & 8). WAnT peak and mean results of the NC- C- and RS- test protocols were nevertheless highly correlated (table 4 & 5). This is in accordance with the findings of Constantini, Sabapathy, Cross [21], reporting no significant difference in performance during the last 30 seconds of a 3 minutes all-out test individually or followed an exhaustion test of 8-12 minutes. The validity and presentation of the WAnT test has been well described by Beneke, Pollmann, Bleif, Leithäuser, Hütler [22] to be highly anaerobic with 80% of the energy turnover during the test to be derived from anaerobic alactic and lactic acid metabolism dominated by glycolysis. The validity of the WAnT in usage during a C-TP following both a LTW and a $VO_{2max\ TTE}$ in context of retrieving valid results, is well shown in the present study. The best cyclists from the C- TP was still the best in the RS TP.

Subsequent analysis of the variable dehydration during the RS, displayed a positive correlation with the delta difference of 5-min all-out tests (figure 9). The studies of Coyle [23] and Hargreaves [24] presents the negative affect of heat production during exercise. Anyhow, the present study shows a positive correlation between the delta difference and the dehydration status. There was a development presenting the individual results in the test group to increase from the 5min NC to the 5min RS, not significant results. Improvement of endurance during the RS may have been influenced by the physiological impact of competition. This is in accordance with the study by Cooke, Kavussanu, McIntyre, Ring [25]. The psychological impact to performance has not been accounted for in the results from the present study.

Table 5 shows correlation of the C- and NC- TP and 5-min performance test from both the NC- and the RS- TP. Identifying the results in the C-TP, we find that both the LTW and VO_{2PPO} individually both show strong correlation with both 5min- NC and -RS. For the NC-TP, we find that VO_{2TTE} show strong correlation to a NC-5min. The NC-VO_{2PPO} shows strong correlation to the NC-5min, as well as the NC-$WAnT_{peak}$ and $WAnT_{mean}$ shows strong correlation to the NC-5min. This indicates that the only tests results individually correlated to the 5-min all-out during the race simulation, remains from the C-TP . With these results presented we can say that in our group the identification of the LTW at 4mmol/L is well associated with the findings from the study of Bentley, McNaughton, Thompson, Vleck, Batterham [26], reporting LTW giving a large amount of characteristics to time trial cycling performance. Amann, Subudhi, Foster [6], confirms usage of LTW providing measurement of endurance ability over time in cycling, but suggests breakpoint of ventilatory equivalent of oxygen to be a better predictor for performance threshold at 40 kilometers' time trial. Usage of LTW as measurement of cycling performance is supported by the study of Faude, Kindermann, Meyer [27] presenting a framework to clarify the definition of the lactate threshold. Furthermore, the study of Lee, Martin, M., Grundy, Hahn [28] discussed the physiological differences in power output, body mass, level of lactate threshold, and more, among professional mountain and road cyclists. According to their result, there is of certainty individual differences in the placement of a lactate threshold at 4mmol per liter blood, regarding cycle rider types and characteristics.

The variables GME and La^- during the RS did not differentiate significantly (table 6). There is a possibility that GME did not differ enough in cause of muscle fiber type distribution among the cyclists, claimed by Coyle, Sidossis, Horowitz, Beltz [29] affecting the cycling level of the GME. A statement of age showing differences in cycling efficiency is supported by the study of [30], whom in the same study presented fiber type distribution not to be related to GME. Subsequently no sig. development in the measurements was presented for the variable La^-. This is associated with the overall intensity level placed below the lactate threshold for the cyclists during the simulation, set in accordance with the study of Rønnestad, Hansen, Raastad [15]. The cyclists were provided with nutrition and fluid needs during the simulation recommended by the guidelines of Burke, Deakin [18].

Practical applications

We believe these findings are meaningful for and increases the understanding of indoor cycling test methods commonly used to describe the physiological performance within cyclist. There are limitations to the study regarding the number of participants as well as the physical level of each participant. Time of year might have inflected the results of this study, regarding the off-season period of cycling. More studies assessing the mental and tactical role of cycling, is needed to additionally describe the demand of cycling performance.

Conclusion

The present study showed only small to none practical differences between test results of a C-TP compared to similarly completed non-condensed TP. The NC TP exclusively differentiated at a minimal higher result to the C TP with test results of VO_{2PPO}, $WAnT_{peak}$ and $WAnT_{mean}$. All variable results, studied in both the C- and NC TP were compared to 5-

min all-out performance tests, presenting the LTW and VO_{2PPO} to be the only positive correlated determinants of the 5-min all-out test after race simulation. None of the NC-TP variables was significantly correlated to the 5-min all-out race simulation. Results of the WAnT showed high correlation of the three physical states NC-, C- and RS- TP. This presents a valid use of this test method in usage during the end of a C-TP. We recommend further studies regarding the dehydration status and physiological impact of indoor testing.

In conclusion, this study supports the use of the C-TP in testing of cyclists at an indoor laboratory. NC-TP added minimal additional information relevant to competitive cycling performance. LTW and VO_{2PPO} from a C-TP was positively correlated with the 5-min all-out as part of RS. No other variables from C-TP and NC-TP was positively correlated to the 5-min all-out RS.

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Table captions

Table 1. Example of RS program. Cyclist RPM within 80-100 and sitting while biking is preferably. Intensity is set by the selected cyclist´s NC-TP $VO_{2max\ PPO}$.

Table 2. Differences between similar tests completed from the C-TP and NC-TP.

Table 3. WAnT peak correlation of the C, NC and RS TP.

Table 4. WAnT mean correlations of the C, NC and RS TP.

Table 5. Correlations of variables from C and NC TPs to the NC- and RS- 5-min allout performance tests.

Table 6. Mean variables (N=12) measured during RS. Power avg and sw loss was measured at end. Variables dhy%, GME and La^- displays mean result of measurements one time per hour.

Figure captions

Figure 1. Model of the interrelationships of the physiological factors determining performance ability [23]. The figure presents many variables accounting for the performance ability of cyclists.

Figure 2. Experimental design of the study.

Figure 3. "Familiarization/pre-test". Minutes and power description is only indicative and precise units are described in the following description.

Figure 4. Illustration of a standardized test protocol (C-TP). Minutes and power description is only indicative and precise units are described in the following description.

Figure 5. Illustration of the Non-fatigue test protocol (NC-TP). Minutes and power description is only indicative and precise units are described in the following description.

Figure 6. Illustration of the implementation of the race simulation (RS), % intensity= intensity in percent based on $VO_{2\ PPO}$, GME= 5 minutes measurement of gross mechanical efficiency.

Figure 7. WAnT peak results. N= 12, --- = mean results. NC- mean= 1046.8 ± 172.3, C- mean = 1028.1 ± 155.5, Race- mean = 861.6 ± 208.9. There was a significant difference at the $p<.05$ level for the $WAnT_{peak}$ variable $F(2, 33) = 3.84$, $p=.032$. The race group scored significantly lower to the non-condensed group (185.17 ± 73.6, p= .44). The mean score of C group was not significant different from the NC (p = .97) or the Race group (.76).

Figure 8. WAnT mean results. N= 12, --- = mean results. NC- mean= 702 ± 65.5, C- mean = 675.7 ± 62, Race mean = 543.42 ± 78.6. A significantly mean difference at the $p<.05$ was found in the variable $WAnT_{mean}$, between the three group conditions $F(2, 33) = 18.15$, $p=.01$. The mean score of $WAnT_{mean}$ from Race group was lower than the C group (132.24 ± 28.2, p= .01) and the NC (158.54 ± 28.2, p= .01). The mean score of C group was not not significant different from the NC (p = .62). No significant difference between the groups NC-, C- and RS- was found for the variable $WAnT_{fatigue\ slope}$ (p= .66).

Figure 9. Delta difference (median = 19 ± 27.7) between the 5-min all-out NC (mean 313.3 ± 32.05) and the 5-min all-out RS (mean 316.83 ± 36.51). There is a positive correlation between the delta diff 5min and dehydration, $r= .79$ ($r^2= .62$), $p<.01$. This is indicating a positive correlation between high dehydration status and change of performance in wattage at 5min NC- to RS. Correlation between the 5-min NC and RS was significant, $r=.68$($r2=.47$), $n=12$, $p=.02$.

Table 1

Subject:	**Example**
$VO_{2max\ PPO}$	**425**
Weight start:	

Intensity		**Split of time minutes**	**Simulating**	**Time**
34 %	**144,50**	Constant	GE measurement 1	**5 min.**
44 %	**187,00**	Constant	Controlled pack	**30 min.**
54,00 %	**229,50**	Constant	Hill	**5 min.**
0,00 %	**0,00**	Constant	Downhill	**2,5 min.**
44,00 %	**187,00**	Constant	Controlled pack.	**30 min.**
34,00 %	**144,50**	Constant	GE measurement 2	**5 min.**
44,00 %	**187,00**	Constant	Controlled pack	**30 min.**
54,00 %	**229,50**	Constant	Hill	**5 min.**
0,00 %	**0,00**	Constant	Downhill	**2,5 min.**
44,00 %	**187,00**	Constant	Controlled pack	**30 min.**
34,00 %	**144,50**	Constant	GE measurement 3	**5 min.**
44,00 %	**187,00**	Constant	Controlled pack.	**25 min**
54,00 %	**229,50**	Constant	Intensity increasing	**5 min.**
avg 44%			TOTAL	180 min

Table 2.

	Mean (SD)		Min		Max		p-value	ES
	C	*NC*	*C*	*NC*	*C*	*NC*		
$VO_{2\ ml}$	54.42 (3.7)	55.2 (3.7)	46.9	47.6	60.2	59.3	.15	
$VO_{2\ TTE}$	7.3 (.94)	7.7 (.96)	5.5	6.5	9	9	.33	
$VO_{2\ PPO}$	360 (33.7)	379.4 (36.9)	300	325	425	425	.05*	.55
$VO_{2\ RER}$	1.15 (.05)	1.17 (.04)	1,03	1.1	1.21	1.24	.39	
$VO_{2\ RPE}$	19.2 (.94)	19 (.8)	17	18	20	20	.78	
$WAnT_{p}$	1028.1 (155.5)	1046.8 (172.3)	799	766	1246	1307	.44	
WAnT m	675.7 (62)	702 (65.5)	584	618.6	763.2	788.1	.01**	.41
$WAnT_{p\ w/kg}$	12.19 (1.75)	12.5 (1.85)	10	9	15.8	16.2	.53	
$WAnT_{m\ w/kg}$	8.1 (.53)	8.4 (.65)	7.1	7.3	9	9.4	.01*	.51
$WAnT_{f.s.}$	19 (6.14)	23 (15.6)	10.8	10.8	31.3	68	U=69, (.86)	
$WAnT_{RPE}$	19.3 (.65)	19 (1.13)	18	16	20	20	.22	

Note: N= 12, mean values (SD=standard deviation), min=minimum and max=maximum, U=Mann Whitney (p), C= Condenced NC= non-condensed, ES= effect size (Cohen's d), * correlation is significant at the 0.05 level, ** correlation is significant at the 0.01 level.

Table 3.

	WAnT C	WAnT NC	WAnT RS
WAnT C			
WAnT NC	.88**		
WAnT RS	.70*	.69*	

*N= 12, * <.05, **<.01, m= mean, C= condensed TP, NC= non-condensed TP, RS= Race simulation.*

Table 4.

	WAnT C	WAnT NC	WAnT RS
WAnT C			
WAnT NC	.94**		
WAnT RS	.68*	.68*	

*N= 12, * <.05, **<.01, m= mean, C= condensed TP, NC= non-condensed TP, RS= Race simulation.*

Table 5.

		5-min NC		5-min RS	
		Cor.	Sig.	Cor.	Sig.
CONDENCED	LTW	.64*	.03	.72**	.01
	$VO_{2\ ml}$	.27	.39	−.03	.94
	$VO_{2\ TTE}$	−.23	.48	.09	.79
	$VO_{2\ PPO}$	.78**	.00	.70**	.01
	$VO_{2\ RER}$	−.34	.28	− .46	.13
	$WAnT_{p}$	.55	.07	.23	.47
	$WAnT_{p\ w/kg}$	.16	.61	.01	.99
	WAnT m	.57	.054	.49	.11
	$WAnT_{m\ w/kg}$	−.12	.71	.13	.68
	$WAnT_{f.s.}$	.35	.27	.01	.99
NON - CONDESED	$VO_{2\ ml}$	.21	.52	− .01	.99
	$VO_{2\ TTE}$	.59*	.05	.03	.92
	$VO_{2\ PPO}$	.80**	.00	.57	.06
	$VO_{2\ RER}$	−.30	.34	−.24	.46
	$WAnT_{p}$	.73**	.01	.40	.2
	$WAnT_{p\ w/kg}$	.41	.19	.20	.53
	WAnT m	.66*	.02	.54	.07
	$WAnT_{m\ w/kg}$	.02	.96	.17	.60
	$WAnT_{f.s.}$	−.13	.70	−.39	.21

*Note: n= 12, Cor.= correlation, Sig.= significance, * correlation is significant at the 0.05 level, ** correlation is significant at the 0.01 level*

Table 6

Variable	mean	min	maks
Power avg	165.83 (15.5)	145	185
sw loss	2.74 (.47)	1.8	3.53
dhy%	1.09 (.72)	-0.23	2.34
GE	17.2 (1.67)	12.61	19.92
La^{-}	1.36 (.37)	0.82	2.2

Note mean values (SD=standard deviation), min=minimum and max=maximum, sw loss= sweat loss in kilos, dhy%= calculated % loss dehydration, GME= calculated gross mechanical efficiency, La^{-}= lactate blood measurement.

Figure 1.

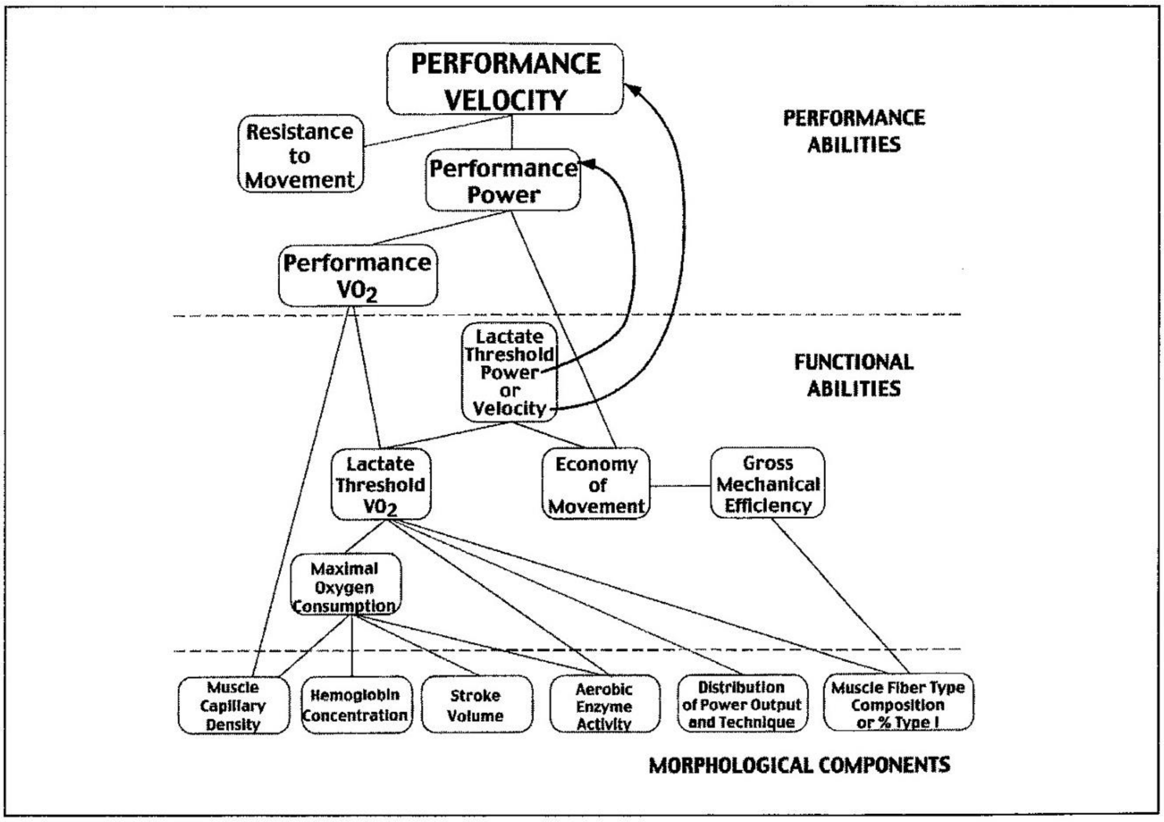


Figure 2.

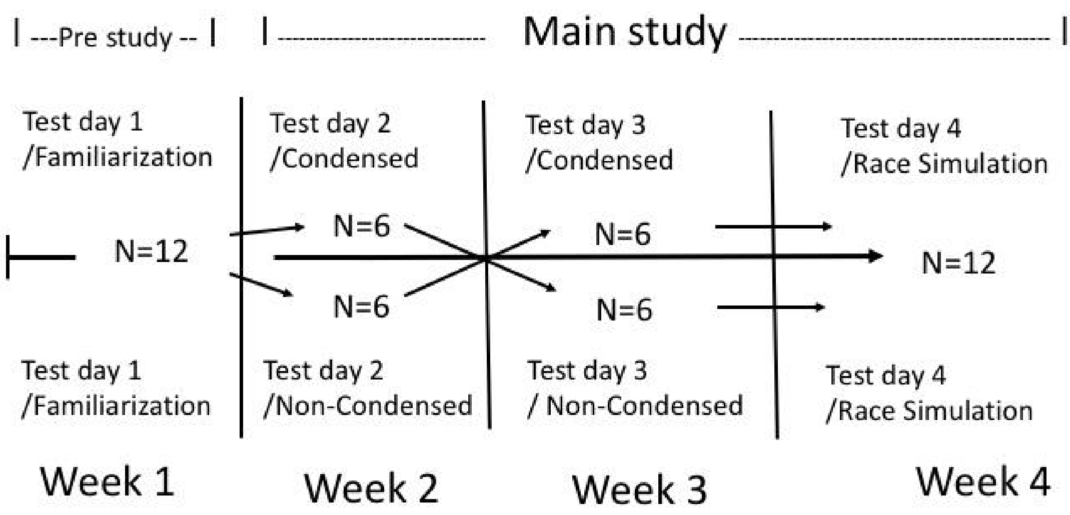


Figure 3.

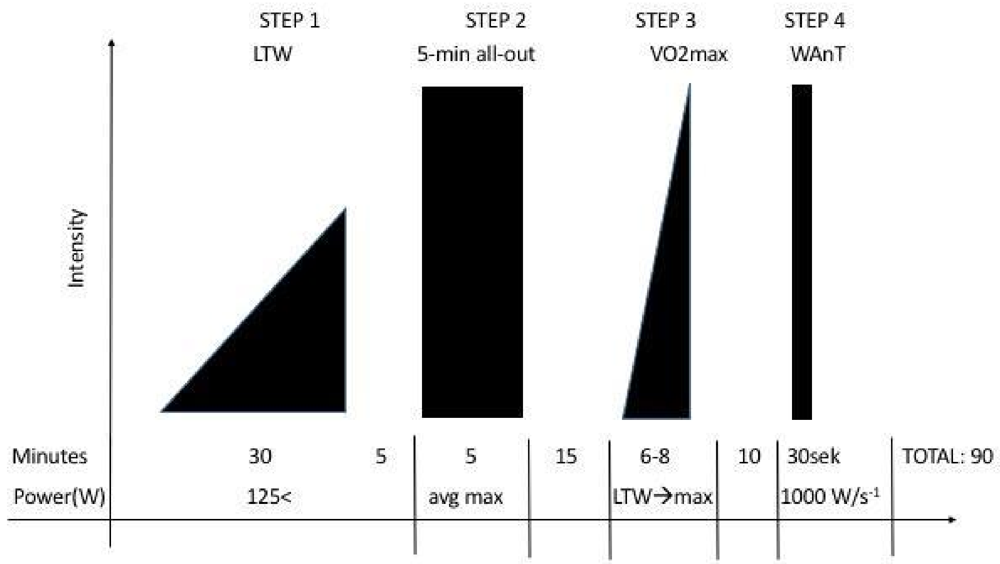


Figure 4.

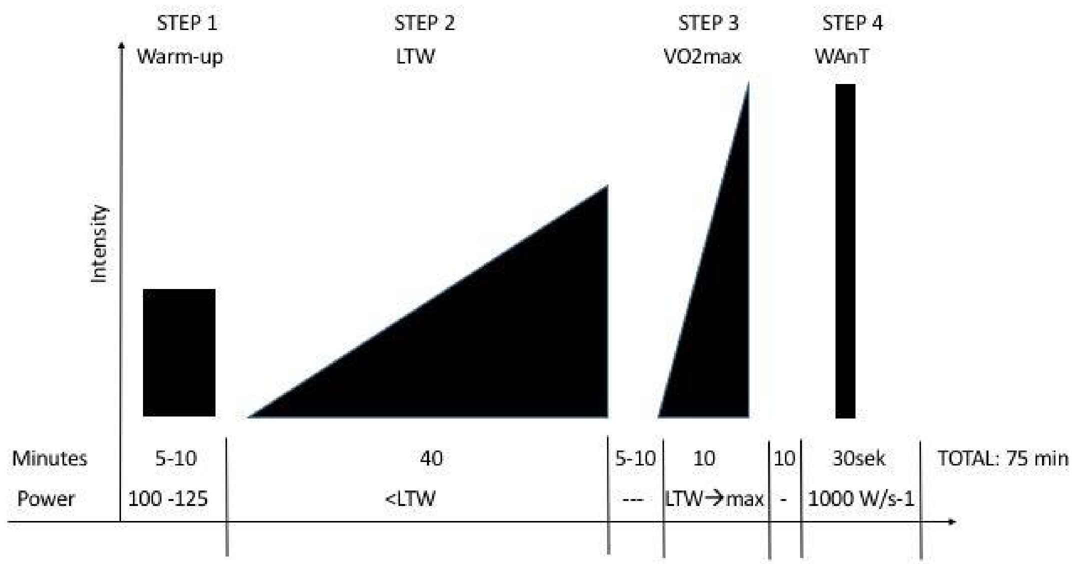


Figure 5

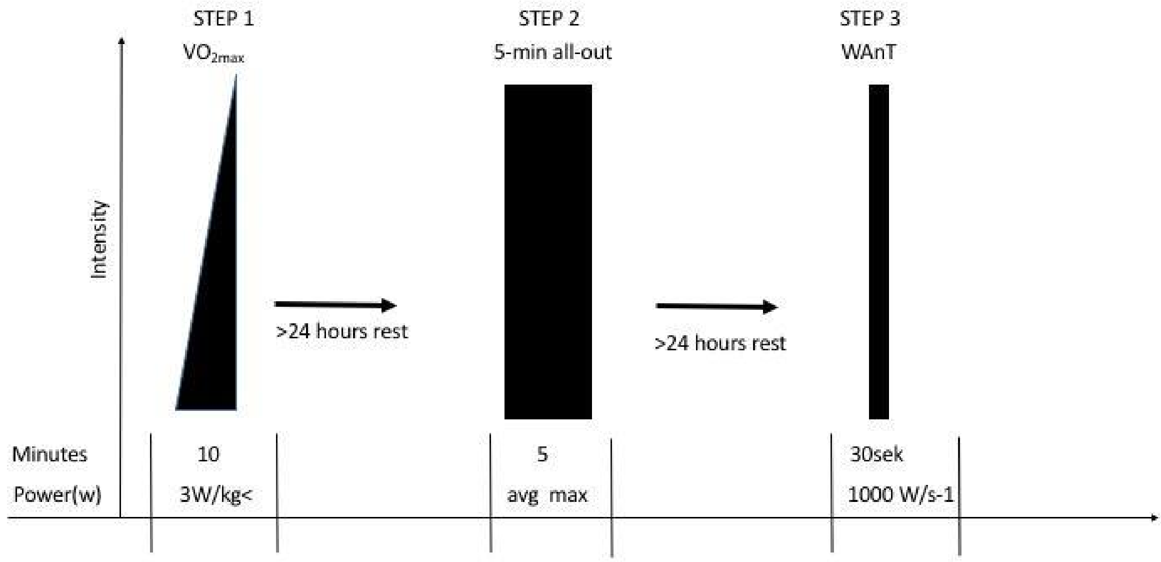


Figure 6.

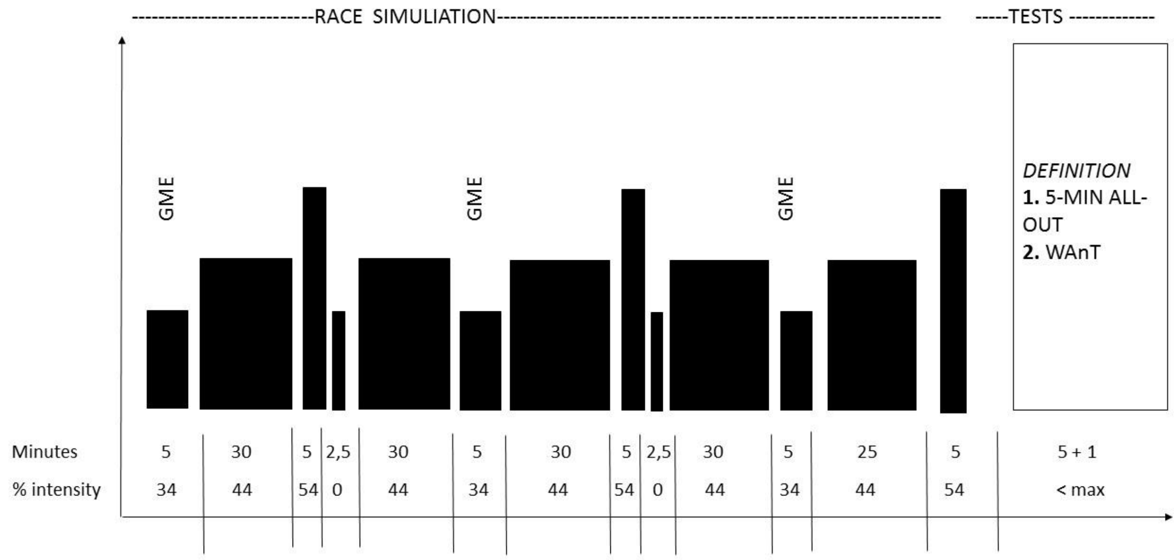
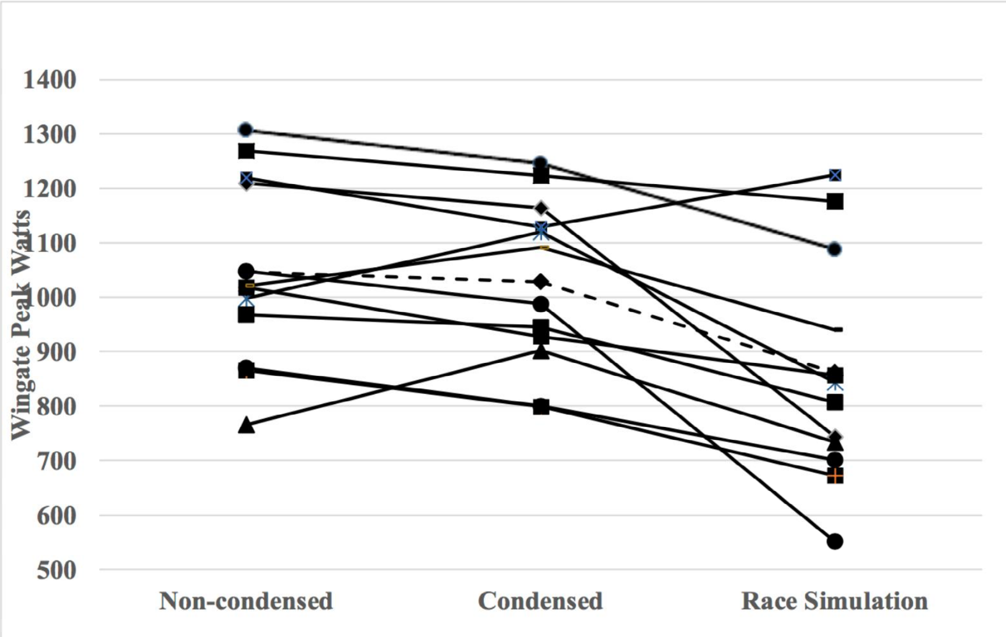
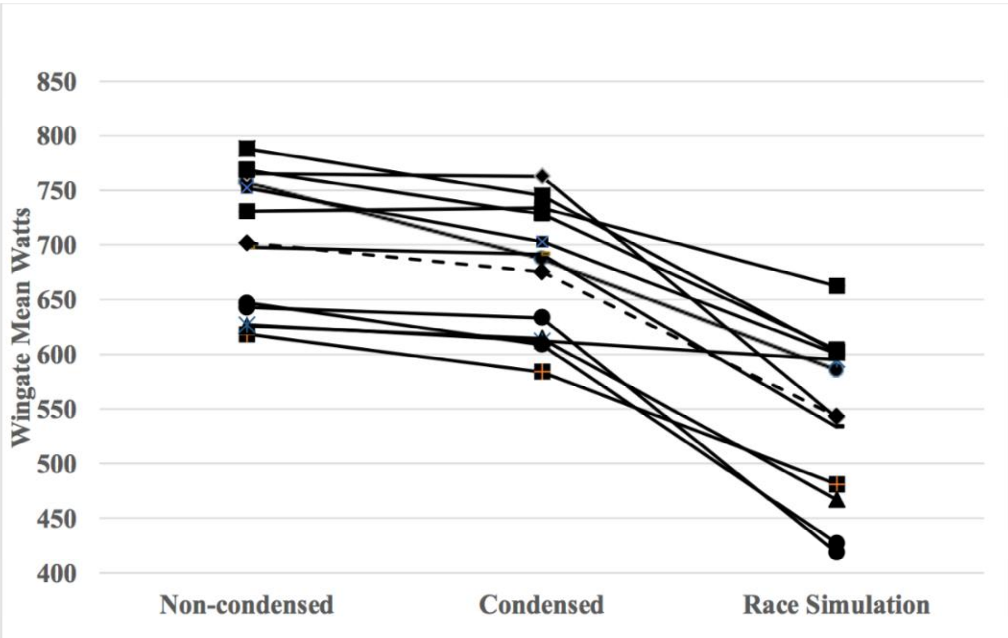


Figure 7.



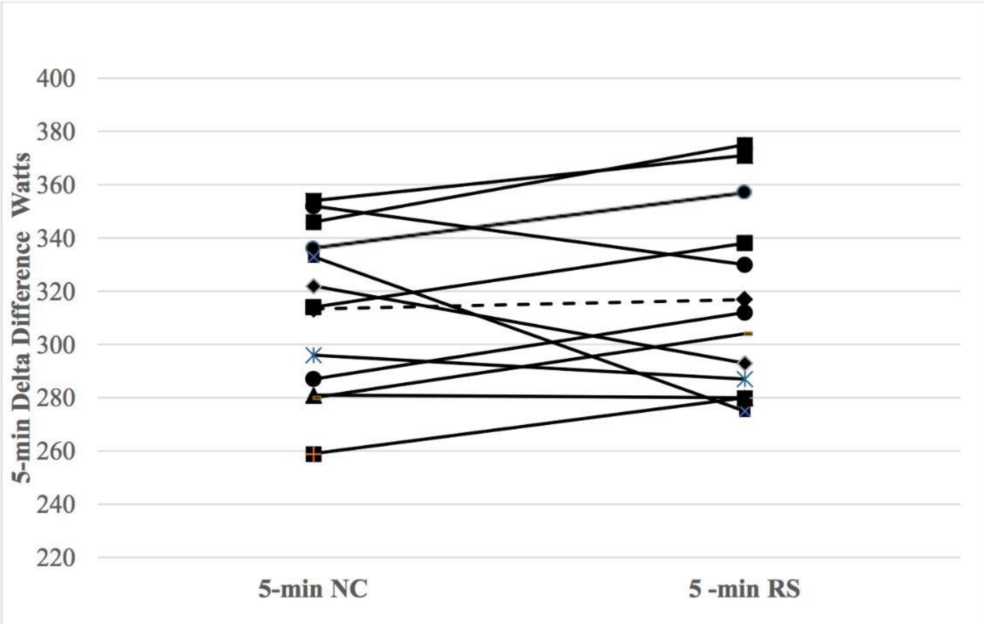
506

507 **Figure 8.**



508

509 **Figure 9.**


5-min Delta Difference Watts
400
380
360
340
320
300
280
260
240
220
5-min NC
5 -min RS