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Comparison of Peak Power on Four Cycling Modes

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COMPARISON OF PEAK POWER ON FOUR CYCLING MODES

by

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Introduction

There has been a vast amount research conducted concerning many different aspects of cycling performance. This is, in part, due to the relative ease with which variables can be isolated and tested. The equipment used for cycling research is generally compact, stationary, and relatively inexpensive, which make cycling a convenient method to test a variety of variables. In a laboratory setting, researchers often utilize cycle rollers, ergometers, and trainers to best simulate road cycling. Rollers allow subjects the familiarity of using their personal bicycles, and the ability to experience typical factors of cycling such as angular and lateral movement. Trainers also allow the familiarity of personal bicycles, but the front wheel is immobilized while the rear wheel is placed on a roller, which restricts the angular and lateral movement of cycling. Cycle ergometers are stationary bikes that give researchers control of specific variables such as resistance, and also tend to be more restrictive than actual bicycles. What these three modes have in common is the perceived ability to accurately imitate the motions involved in road cycling, as well as the characteristics that make them convenient to laboratory testing: they are small which allow them to fit in the smallest of labs, they are stationary which makes it possible to perform several tests on them which include heart rate, blood pressure, VO_2 and other metabolic tests, and many more. While these different modes make isolating variables for testing convenient, the extent to which the results transfer to the field, or the external validity, must be considered. This was clearly demonstrated by Jones and Doust (6) where they reported treadmill running to be metabolically different

($P < 0.05$) then outdoor running at the same velocity and incline given velocities were greater than 3.33 m s^{-1}.

In cycling, there has been research conducted to compare the differences in metabolic costs across different cycling modes and postures. Gnehm et al. (4) measured metabolic economy by measuring oxygen consumption (VO_2) of elite cyclists in different racing positions (upright, aero, dropped) on F rollers allowing the rider to forgo balance. F rollers were chosen because the cyclists stated that the rollers resemble road conditions the best. They reported a greater metabolic cost to the aero bar posture relative to the upright posture with an upright posture VO_2 of 47.3 ± 1.2 mL kg^{-1} min^{-1} and an aero posture VO_2 of 48.8 ± 1.3 mL kg^{-1} min^{-1}($P = 0.002$) (2). However, other studies have been conducted which found no statistical difference for VO_2 in the upright, aero, and dropped positions (3,5,7). Before the Gnehm et al. study, Origenes et al. (7) measured VO_2 on a cycle ergometer for the upright and aero postures by increasing power by 50 Watts every three minutes until exhaustion, with no statistical difference (no P value) reported. Maximal data reported was 54.3 ± 6.3 mL kg^{-1} min^{-1} and 53.4 ± 6.9 mL kg^{-1} min^{-1} for the upright and aero positions, respectively. After Gnehm et al., Grappe et al. (5) conducted a similar study comparing the three postures (using a cycle ergometer and reported no statistical difference (P value was not reported), while reporting VO_2 values of 45.8 ± 4.1 mL kg^{-1} min^{-1}, 46.0 ± 4.1 mL kg^{-1} min^{-1}, 46.0 ± 3.7 mL kg^{-1} min^{-1} for the upright, dropped and aero postures, respectively. Another study was conducted by Dorel et al. (3), also using a cycle ergometer, which also reported no statistical difference (no P value) in VO_2 for the three positions with reported values being 3458 ± 297 ml min^{-1}, 3368 ± 270 ml min^{-1}, 3394 ± 234 ml min^{-1} for the aero, upright, and dropped postures, respectively.

The assessment of peak power is commonly used as an indicator of athletic performance, and can be easily obtained from testing using the cycling modes mentioned above. The Wingate Anaerobic Test is widely considered to be accurate and used in most laboratories. The test is generally administered on cycle ergometers where resistance can be controlled, and rpm can be easily determined. Until recently, peak power was difficult to calculate in the field or on rollers and trainers, because of the difficulty in controlling or calculating the amount of resistance. However, the emergence of technological advances, such as the Power Tap SL+™ hub, are beginning to provide easier, more accurate ways to obtain power measurements, and research is being conducted on all different cycling modes much more often. The increased use of these cycling modes in laboratory research gives rise to the question of whether or not the mode used has any effect on peak power.

Peak power values obtained through laboratory testing are used in many ways. In the sport of cycling, peak power can be assessed periodically as part of a highly specialized training program for elite cyclists, and used to determine whether or not the training is having the desired effect on the athletes' performance. Changes can then be made to the training program to make sure the athletes stay on track in their preparation for competition. If the peak power values obtained in the laboratory end up being inconsistent with what is actually achieved in the field, then athletes could potentially be either under-training or overtraining. Under-training could cause them to fall short of reaching their potential and perform at a lower level during competitions, and overtraining could put them at risk for serious injury or peaking prior to competition, which would also cause them to perform at a lower level when the time comes to compete.

In the laboratory, the peak power values obtained can be used to test the effects of other variables on cycling and athletic performance. However, if the peak power results on laboratory ergometers do give not an accurate representation of true peak power, then parallels which have been drawn to real-life situations cannot be considered valid. Therefore, it is necessary to determine the level to which laboratory testing of peak power mirrors actual peak power in the field.

Research has shown that the type of equipment used can affect the peak power results. Astorino et al. (1), compared the results of peak power tests performed on two different ergometers, the Velotron and the Monark. Participants in this study performed three Wingate tests to assess peak power, 2 on the Velotron and 1 on the Monark. Peak power, mean power, minimum power, fatigue index, heart rate, and peak and minimum cadence were assessed. The results showed the peak power to be significantly higher ($P < 0.05$) on the Velotron (9.95 ± 1.39 W/kg) vs. the Monark (9.13 ± 1.26 W/ kg); however, the mean power was higher ($P < 0.05$) on the Monark (6.95 ± 0.89 W/kg) vs. the Velotron (6.11 ± 0.52 W/kg and 6.25 ± 0.59 W/kg). This study suggests that even the slightest difference in cycling mechanics can affect peak power output. The differences described above between the four cycling modes are definitely more than slight, and discrepancies between the modes could potentially be very large. Another study, by del Coso et al., 2006, (2) compared the effect of two different types of peak power tests, the short cycling sprint test (inertial load (IL) test) and the Wingate Anaerobic Test (WAnT). Subjects warmed up and sprinted 4 times for the IL test. After recovery, they cycled for 30 s at maximum capacity for the WAnT. The correlation between peak power values for the IL and WAnT was highly significant ($r = 0.82$; $P < 0.001$), although the absolute peak power values were markedly higher for the IL test (1268 ± 41 W vs. 786 ± 27 W; $P < 0.001$). The higher values for the IL test could be related to better identification of peak power due to the fact that velocity and resistance are free to vary in the IL test, as opposed to the WAnT, where resistance is fixed.

No study has tested the effect of four different cycling modes on the measurement of peak power. Different research laboratories may utilize different modes for conducting various tests based on availability of equipment, space, or subjects who are accustomed to using certain types of equipment. However, consideration must be given to the differences between each mode data collection, which may affect the results. Astorino et al. (1) showed that different equipment, particularly two different types of cycle ergometers, can affect test results. Also, as stated above, consideration must be given to external validity, and results must be able to relate to cycling performance in the field. For cycling, the field is on the road where cyclists are free to ride at high speeds for long distances time, and are allowed more freedom of motion than is possible in a laboratory. It remains to be seen whether or not values on any of the three laboratory modes (rollers, trainer, and ergometer) are comparable to what is achieved on the road. The purpose of this study was to obtain and compare peak power measurements for trained cyclists using the cycling modes of rollers, ergometer, and trainer, as well as measurements from road cycling. It is hypothesized that there will be a significant difference across the modes due to the mechanical differences between each one. Also, it is assumed that due to the similarities with road cycling, the peak power values on the rollers will most closely reflect those obtained on the road.

Methods

This study was approved by the Utah State University ethics committee and all participants signed a written consent form prior to participating in the study. Five experienced cyclists (25.8 ± 10.8 yr, 74.2 ± 12.1 kg, 177.0 ± 5.6, VO_2 max = 58.9 ± 11.0 $ml \cdot kg^{-1} \cdot min^{-1}$) participated in this study. Peak power for the rollers, trainer, and road cycle was measured, in Watts, using a Power Tap SL+™ hub in conjunction with a Jewel Pro™ fixed to the handlebar in three modes. The rollers used were Aluminum CycleOps Rollers with resistance. Subjects were permitted to use their personal bicycles for these three modes because the comfort and familiarity would give a more accurate result; however the rear wheel was switched for one to which the Power Tap SL+™ hub had already been installed. For the ergometer, the Wingate Anaerobic Test was used, and peak power was calculated using a known resistance at rpm, which was obtained from video analysis. The test was performed on a Monark 824 E Ergomedic cycle ergometer, that was fitted with a racing saddle and toe clips on the pedals.

Testing for each subject was completed within 1 day, with sufficient time between each test for recovery, to ensure that a true peak power would be reached on each subsequent mode. First, each participant was given practice time in order to familiarize themselves with each of the three laboratory cycling modes. This was also done to reduce the error that may arise from a learning effect on the specific equipment used for each mode. Then, after a 5-10 minute warm-up, peak power tests were administered on each of the 3 laboratory modes, followed by the road.

Values obtained for each cycling mode were analyzed using repeated-measures ANOVA (SPSS, version 20). Post hoc comparisons were then done between each of the modes in to further analyze the statistical relationships.

Results

The peak power values were obtained and the data which was recorded for each subject are shown below in Table 1. The mean values for each of the four modes are shown in Table 2. Table 3 shows the percent difference in mean peak power between each of the modes. The results for the repeated-measures ANOVA were $F(3,12) = 4.06$, $P = 0.033$. All post hoc comparisons yielded values of $P > 0.05$.

Table 1. Peak Power (Watts) by subject for Ergometer, Trainer, Rollers and Road Conditions

Subject	Peak Power (Watts)			
	Ergometer	**Trainer**	**Rollers**	**Road**
1	667.5	709	706.3	732.8
2	937.6	786.5	769	1098.5
3	812.4	788	618	766
4	792.3	913	736	873
5	708.6	951	498	1007

Table 2. Peak Power (Watts) for Rollers, Ergometer, Trainer, and Road Conditions (mean ± *SD*)

Mode	Peak Power (Watts)
Rollers	**665.5 ± 109.2**
Ergometer	**783.7 ± 104.6**
Trainer	**829.5 ± 99.8**
Road	**895.5 ± 156.0**

Table 3. Percent Difference in Mean Power Between Modes

Mode	Percent Difference
Road to Trainer	**7.9%**
Road to Ergometer	**14.3%**
Road to Rollers	**34.6%**
Trainer to Ergometer	**5.8%**
Trainer to Rollers	**24.6%**

Ergometer to Rollers	**17.8%**

***These results were part of a Plan B study at USU by Andrew I. Miller that compared VO_2 and kinematic data between three laboratory cycling modes and road cycling**

Discussion

When cyclists compete at the highest levels, the slightest shortcoming in training, knowledge, and technique can have a profound effect on the outcome of a competition or race. Cycling position has been found to affect metabolic economy (4), and mechanical and electromyography patterns while pedaling (3), which lead to assumption that different types of cycling modes can have an effect on power output. However, few studies have compared peak power across multiple cycling modes (1) and no study has compared peak power across four modes. Three of the modes in this study had the advantage of each subject using their personal bicycle, and the other mode used the ergometer. Because the road condition is what is considered to be "the field" in cycling, peak power values obtained for each cyclist on the road can be considered most accurate. The other three modes are used in the laboratory for research purposes and are attempts to simulate road cycling in a setting where it is possible to test for specific variables. The closer the relationship between each cycling mode and the road is, the more applicable the laboratory research will be to the sport of cycling as a whole.

The repeated-measures ANOVA yielded a value of $P = 0.033$, which confirms that there is a significant difference in peak power values across the four modes. However, post hoc comparisons did not yield any significant p values, which does not allow any further conclusions to be made based on the data.

The fact that the post hoc comparisons did not yield any significant values is surprising, when combined with the fact that the repeated-measures ANOVA was well within the accepted level of significance ($P < 0.05$). It can be speculated that the small sample size may have been to blame. With such a small sample size of only five subjects, the slightest inconsistency in the values for any one mode or subject may have changed the dynamic of the entire group as a whole, to the point where significance could not be reached when running statistical analyses on the data. No further conclusions can be made, however, and the suggestion can be made that results of future studies done on this subject could possibly be more definitive by using a larger sample size for data collection.

Although the post hoc comparisons did allow for conclusions to be made concerning their relationships, percent differences were found between the modes and speculations can be made. The road condition did have consistently higher peak power values (see Tables 1 and 2) which is consistent with the thought that it is the most accurate because it consists of the natural movements in the natural setting. As was mentioned in the introduction to this study, the cycle ergometer and trainer are stationary, and result in a more rigid motion of the subject during testing. Road cycling allows for angular and lateral movement that cannot occur because of the stationary nature of the ergometer and trainer. The rollers allow, to some degree, the same lateral and angular movement that is present in road cycling, however they are only approximately 12 inches (30.48 cm) wide, which can still be restraining to natural motion that occurs while riding in road conditions.

According to Table 3, the road condition was 7.9%, 14.3%, and 34.6% higher than the trainer, ergometer, and rollers conditions, respectively (Table 3), which does not support the hypothesis that the rollers would most closely imitate the results on the road. This could be explained by the fact that not all of the subjects were completely comfortable while riding the rollers, and had focus more on maintaining balance in order to stay up upright and avoid injury. Although all participants reported some prior experience with the rollers, some, though able to maintain adequate balance to ride on the rollers for extended periods of time, mentioned that it was difficult to apply one hundred percent of their forces for the peak power test while attempting to stay upright and avoid riding off either side of the rollers. This is seen in Table 1, which shows the extreme inconsistency in peak power values for the rollers, relative to the values for the road among the different subject. The percent difference for each individual between the rollers and road conditions would yield a 3.6% for subject 1 and a 50.5% for subject 5, which is undoubtedly due to factors not associated with the cycling mode. Furthermore, roller values for subjects 1 and 2 are much more comparable to their respective trainer values, while the roller for subjects 3, 4 and 5 begin to vary much more dramatically. It is believed that these discrepancies could indeed have resulted from the lack of experience with rollers which was observed in some of the subjects during data collection.

The next observation that can be made using Table 1 as a reference, is the large range of the difference between peak power values for the ergometer and the road. The ergometer peak power value for subject two was closer to that of the road than on either the trainer or the rollers, with the percent difference being 14.6%. Also, Subjects 2 and 3 were able to achieve higher values on the ergometer than on either the trainer or the rollers, with subject 3 achieving the highest value out of the four modes on the ergometer. Reasons for that are debatable, the percent difference between the means for the ergometer and trainer is only 5.8% (Table 3), which is very small and punctuates the need for a larger test group.

Another point of interest lies in the consistency, or lack thereof, of the road cycling in achieving the highest peak power value out of the four modes. While the mean road value in Table 2 is the highest, this only occurs for subjects 1, 2, and 5 (Table 1), which is only 3 out of the five subjects. While this appears to be a low success rate, it is worth pointing out that these were the only two values out of 15 (ergometer, trainer, rollers for subjects 1-5) that ended up being higher than the road condition for that particular subject. That, along with the fact that one of the values higher than the road came on the ergometer while the other came on the trainer, puts the inability of the road to achieve the highest value for every subject into perspective. Once, again however, a larger test group would help eliminate the inability to come to any final conclusions concerning this issue.

The recurring theme in this section are the limitations to this study, particularly the small sample size (5 subjects) and the fact that the rollers are difficult to master, which may have prevented a true peak power caused the inconsistency in values in Table 1, as has been discussed. As is the case with any study, the larger the number of participants from the target population, the more conclusive the results will be, and the better they will translate to the field. Despite the small sample size for this study, the results were encouraging because a significant correlation was confirmed between peak power values and the four modes being tested. As for the role of the rollers in the amount of error in this study, it is true that the results for that particular mode may have been affected, but results for the other modes were not. This study can neither support nor negate the hypothesis that the rollers allowed for a more natural test which would result in values most similar to those of the road. Other limitations may include the decision to perform all of the peak power tests in one visit which may have decreased, albeit slightly, the ability of the subject to achieve a true peak power, despite the precaution of allowing plenty of time to recover. Also, although they were competent, experienced cyclists, the fitness level may have varied from subject to subject, which might have played a role data collection as well.

Conclusion

According to the results, the road condition measured the highest mean peak power (Table 2), and the mode which achieved the closest mean peak power value to the road, according to Table 3, was found to be the trainer. The repeated-measures ANOVA P value ($P = 0.033$) confirmed a significant relationship between the cycling modes and the recorded peak power values, however, further conclusions could not be made because the post hoc tests did not reach significance ($P > 0.05$). In conclusion, it is safe to say that cycling mode does in fact affect power output, however the extent to which peak power is affected is open to interpretation and further testing is required. Also, the hypothesis that the rollers in the laboratory would most accurately reflect road cycling, in terms of peak power values, was not supported by the data collected in this study. According to the results of this study, values recorded on the trainer were, overall, closest to those of the road, and therefore the best option for external validity when performing peak power tests in a laboratory.

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James Oliver Olsen was born on December 13, 1986 in Brigham City, Utah, where he lived throughout his childhood and teenage years. He is the sixth of 10 children, and enjoys playing soccer, reading, camping, and snowboarding. James graduated from Box Elder High School in 2005, and received the Presidential Scholarship to Utah State University, where he began his studies in August of the same year. Although he had thought about becoming a dentist when he was younger, he began his collegiate career majoring in General Engineering, mainly because his father was a mechanical engineer. However, during his first semester it became apparent that his interests lay elsewhere, which led him to the HPER department. After serving a two-year mission for his church, James resumed his studies by working toward a degree in Human Movement Science, while earning minors in Portuguese and Chemistry. To enhance his undergraduate experience, he was involved in the honors program and the pre-dental club, and spent three years as a volunteer coach for the university's Special Olympics team, where he coached soccer, basketball, snowboarding, volleyball, and weight lifting.

After graduating in May 2012, James will attend dental school at Virginia Commonwealth University, in Richmond, Virginia. Upon completion of dental school, he plans to go into private practice as a general dentist.