MECHANICAL POWER OUTPUT DURING CYCLING

The efficacy of mobile power meters for monitoring exercise intensity during cycling

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Submitted by Alfred Nimmerichter, to the University of Exeter as a thesis for the degree of Doctor of Philosophy in Sports and Health Sciences

I certify that all material in this thesis which is not my own work has been identified and that no material has previously been submitted and approved for the award of a degree by this or any other University.

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Abstract

One of the most meaningful technical innovations in cycling over the past two decades was the development of mobile power meters. With the ability to measure the physical strain under "real world" outdoor conditions, the knowledge of the demand during cycling has improved enormously. Power output has been described as the most direct measure of intensity during cycling and consequently power meters becomes a popular tool to monitor the training and racing of cyclists. However, only limited research data are available on the utilisation of power meters for performance assessment in the field or the analysis of training data. Therefore, the aims of the thesis were to evaluate the ecological validity of a field test, to provide an extensive insight into the longitudinal training strategies of world-class cyclists and to investigate the effects of interval training in the field at difference cadences.

The first study aimed to assess the reproducibility of power output during a 4-min (TT4) and a 20-min (TT20) time-trial and the relationship with performance markers obtained during a laboratory graded exercise test (GXT). Ventilatory and lactate thresholds during a GXT were measured in competitive male cyclists ($n = 15$; $\dot{V}O_2max$ 67 ± 5 $mL \cdot min^{-1} \cdot kg^{-1}$; $Pmax$ 440 ± 38 W). Two 4-min and 20-min time-trials were performed on flat roads. Strong intraclass-correlations for TT4 ($r = 0.98$; 95 % CL: 0.92-0.99) and TT20 ($r = 0.98$; 95 % CL: 0.95-0.99) were observed. TT4 showed a bias ± random error of $-$ 0.8 ± 23 W or $-$ 0.2 ± 5.5 %. During TT20 the bias ± random error was $-$ 1.8 ± 14 W or 0.6 ± 4.4 %. Both time-trials were strongly correlated with performance measures from the GXT ($p < 0.001$). Significant differences were observed between power output during TT4 and GXT measures ($p < 0.001$). No significant differences were found between TT20 and power output at the second lactate-turn-point (*LTP 2*) ($p = 0.98$) and respiratory compensation point (RCP) ($p = 0.97$). In conclusion, TT4 and TT20 mean power outputs are reliable predictors of endurance performance. TT20 was in agreement with power output at RCP and *LTP 2*.

Study two aimed to quantify power output (PO) and heart rate (HR) distributions across a whole season in elite cyclists. Power output and heart rate were monitored for 11 months in ten male (age: 29.1 ± 6.7 y; $\dot{V}O_2max$: 66.5 ± 7.1 $mL \cdot min^{-1} \cdot kg^{-1}$) and one female (age: 23.1y; $\dot{V}O_2max$: 71.5 $mL \cdot min^{-1} \cdot kg^{-1}$) cyclist. In total, 1802 data sets were sampled and divided into workout categories according to training goals. The PO at the RCP was used to determine seven intensity zones (Z1-Z7). PO and HR distributions into Z1-Z7 were calculated for all data and workout categories. The ratio of mean PO to RCP (intensity factor, IF) was assessed for each training session and for each interval during the training sessions (IF_{INT}). Variability of PO was calculated as coefficient of variation (CV). There was no significant difference in the distribution of PO and HR for the total season ($p = 0.15$), although significant differences between workout categories were observed ($p < 0.001$). Compared with PO, HR distributions showed a shift from low to high intensities. IF was

significantly different between categories (p < 0.001). The IF_{INT} was related to performance (p < 0.01), although the overall IF for the session was not. Also, total training time was related to performance ($p < 0.05$). The variability in PO was inversely associated with performance ($p < 0.01$). In conclusion, HR accurately reflects exercise intensity over a total season or low intensity workouts but is limited when applied to high intensity workouts. Better performance by cyclists was characterised by lower variability in PO, greater training volume and the production of higher exercise intensities during intervals.

The third study tested the effects of low-cadence (60 $rev \cdot min^{-1}$) uphill (Int_{60}) or high-cadence (100 $rev \cdot min^{-1}$) flat (Int_{100}) interval training on PO during 20 min uphill (TT_{up}) and flat (TT_{flat}) time-trials. Eighteen male cyclists ($\dot{V}O_2max$: 58.6 ± 5.4 $mL \cdot min^{-1} \cdot kg^{-1}$) were randomly assigned to Int_{60}, Int_{100} or a control group (Con). The interval training comprised of two training sessions per week over four weeks, which consisted of 6 bouts of 5 min at the PO at RCP. For the control group, no interval training was conducted. A two-factor ANOVA revealed significant increases on performance measures obtained from GXT ($Pmax$: 2.8 ± 3.0 %; $p < 0.01$; PO and $\dot{V}O_2$ at RCP: 3.6 ± 6.3 % and 4.7 ± 8.2 %, respectively; $p < 0.05$; and $\dot{V}O_2$ at ventilatory threshold: 4.9 ± 5.6 %; $p < 0.01$), with no significant group effects. Significant interactions between group and the uphill and flat time-trials, pre vs. post-training on time-trial PO were observed ($p < 0.05$). Int_{60} increased PO during both, TT_{up} (4.4 ± 5.3 %) and TT_{flat} (1.5 ± 4.5 %), whereas the changes were − 1.3 ± 3.6 %; 2.6 ± 6.0 % for Int_{100} and 4.0 ± 4.6 %; − 3.5 ± 5.4 % for Con, during TT_{up} and TT_{flat}, respectively. PO was significantly higher during TT_{up} than TT_{flat} (4.4 ± 6.0 %; 6.3 ± 5.6 %; pre and post-training, respectively; p < 0.001). These findings suggest that higher forces during the low-cadence intervals are potentially beneficial to improve performance. In contrast to the GXT, the time-trials are ecologically valid to detect specific performance adaptations.

Contents