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Training prescription guided by heart rate variability in cycling

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ABSTRACT

PURPOSE: Road cycling is a sport with extreme physiological demands. Therefore, there is a need to find new strategies to improve performance. Heart rate variability (HRV) has been suggested as an effective alternative for prescribing training load against predefined training programs. The purpose of this study is to examine the effect of training prescription based on HRV in road cycling performance. **METHODS:** Seventeen well-trained cyclists participated in this study. After an initial evaluation week (EW), cyclists performed 4 baseline weeks (BW) of standardized training to establish their resting HRV. Then, cyclists were divided into two groups, a HRV-guided group (HRV-G) and a traditional periodization group (TRAD) and they carried out 8 training weeks (TW). Cyclists performed two EW, after and before TW. During the EW, cyclists performed: (1) a graded exercise test to assess VO_2max, peak power output (PPO) and ventilatory thresholds with their corresponding power output (VT1, VT2, WVT1, and WVT2, respectively) and (2) a 40-min simulated time-trial. **RESULTS:** HRV-G improved PPO (5.1 ± 4.5 %; $p = 0.024$), WVT2 (13.9 ± 8.8 %; $p = 0.004$) and 40TT (7.3 ± 4.5 %; $p = 0.005$). VO_2max and WVT1 remained similar. TRAD did not improve significantly after TW. There were no differences between groups. However, magnitude-based inference analysis showed likely beneficial and possibly beneficial effects for HRV-G instead of TRAD in 40TT and PPO, respectively. **CONCLUSIONS:** Daily training prescription based on HRV could result in a better performance enhancement than a traditional periodization in well-trained cyclists.

Keywords: HRV; road cycling; periodization; endurance training; exercise performance

INTRODUCTION

Road cycling is considered to be one of the hardest endurance sports in the world, [1]with high physiological demands during training and competition.[2-4] Professional cyclists often accumulate up to 90 days of competitive racing within a season,[1] which makes maintaining a healthy balance training/racing load and taking sufficient recovery time a challenge. Large gains in training status are generally achieved by prescribing high training loads followed by a minimal, but sufficient, recovery period.[5] Maintaining this balance is challenging as multiple factors such as training intensity, quality of sleep, nutrition, psychological well-being might vary substantially at an individual basis.[6]

Monitoring individual responses to training is, therefore, an important key factor to prescribe to most effective training programs.[7] A promising variable that is able to reflect positive or negative training adaptation is cardiac autonomic regulation (CAR).[8] This is supported by Lamberts et al. [9] who showed that cyclists who adapted well to high intensity training (HIT) had a faster heart rate recovery (HRR) response than cyclists that did not responds well to the HIT. In general, a decreased training status is associated with a lower power output at the same submaximal heart rate and a slower HRR, while an increased training status is associated with an increased power output the same submaximal heart rate and a faster HRR.[10] Confusingly and counterintuitively, functional overreaching and acute fatigue are associated with increased power at the same submaximal heart rate and a faster HRR (similar to an improved training status), but in contrast to an improved training, status is associated with increased RPE levels.[11,12] This counterintuitive response highlights the importance of monitoring properly as without the RPE data functional overreaching might be interpreted as an improvement in training status.

In addition to HRR, heart rate variability (HRV), which focusses on the variability of successive R-R intervals,[13] also gained popularity in monitoring the training status of endurance athletes.[8,14-17]. This tool enables the detection of fatigue status and assesses the adaptation to training. After high intensity training or a short-term overreached period, there is a decrease in the resting HRV values, reflecting the effect of the fatigue [18,19]. In addition, the increase of the performance after a training period is related to an increase in resting HRV.[8]

However, these promising results of monitoring athletes only a few studies [5,20,21] have looked at using CAR markers to prescribe or regulate exercise prescription. This HRV-guided training, also called Day-to-Day periodization, allows new possibilities for the training load prescription according to an athlete´s status, the response to the training load and the adaptation to training.[5] Although Day-to-Day periodization has been tested in endurance sports such as running[5,20,21] and cross-country skiing,[22] this new training prescription strategy has not been used in road cycling yet. Therefore, the purpose of this study was to determine the effect of a HRV-guided and a traditionally periodized training program on road cycling performance.

METHOD

Subjects

Seventeen trained cyclists with at least a personalised training history of 2 years were recruited from local clubs. The general characteristics of the participants are shown in Table 1, while the average cycling experience was 13 ± 10 years. Before taking part in the study, all participants were fully informed about the study and had to sign a written informed consent. The study was approved by the ethical committee of Miguel Hernandez University and was conducted conform the recommendations of the Declaration of Helsinki.

Design

The study protocol was divided into two periods; i) a baseline period (BW) and ii) a training period (TW) (see also Figure 1). The BW existed of 4 weeks base training which functioned as a standardization period after which a baseline HRV measurement could be captured. After the BW, cyclists were randomly assigned to a HRV-guided training group (HRV-G, n=9) or a traditional periodization training group (TRAD, n=8). During the following 8 weeks, the cyclists trained based to the group they were allocated to. Cyclists in the HRV-G trained according to their HRV morning values, while TRAD cyclists trained based on a predetermined training programme.

HRV vs TRAD Training

Participants maintained their weekly training volume during BW and TW. During EW, participants were encouraged to not perform any vigorous training session and to rest 24 h prior to each test. During BW, the training intensity was increased gradually during the three first weeks and then reduced for the last week: 3 weeks of overload training and 1 recovery week (3:1). BW served as a preparatory period for familiarization with training sessions and their intensities. Nevertheless, all participants were accustomed to high-intensity training prior to the beginning of the study. Training sessions and periodization of TRAD group are displayed in Table 2, including low training sessions (Low; Intensity <VT1), moderate (Mod; VT1-VT2), High Intensity training (High; ≥VT2) and High Intensity Interval Training (HIIT; >VT2).

For HRV-G, training in TW was prescribed according to their CAR status[5,20] following a decision-making schema modified from Kiviniemi et al.[20] (Figure 2). Cyclists only performed two consecutive sessions of moderate or high-intensity training and did not accumulate more than two consecutive days of rest. The HRV baseline was calculate as the smallest worthwhile change (SWC), explained below (HRV measurements). When $LnRMSSD_{7day\text{-}roll\text{-}avg}$ fell outside the SWC, training intensity changed from moderate or high intensity training to low intensity training or rest. Typical training sessions are displayed in Table 2, moderate and high intensity training sessions were performed with a 45-60 min warm up and 20 min of cooling down. Figure 3 is an example of HRV fluctuations during the TW period.

There were three evaluation weeks (EW): PRE (Before BW), MID (Between BW and TW) and POST (After TW). Each week of evaluation, consisted of two testing sessions with a 48 h recovery period. The first testing session included a maximal graded exercise test to obtain maximal oxygen uptake (VO_2max) and both ventilatory thresholds (VT1 and VT2) and their derived power outputs. In the second one participants performed a 40-min simulated time trial.

Graded Exercise Test

VO_2max, VT1 and VT2 were calculated with a maximal graded exercise test (GXT). The test started with a 10 min warm-up at 50 W, followed by an increase of 25 $W \cdot min^{-1}$ until exhaustion.[23] Participants performed all the test on their own bike, which was fitted on a Wahoo Kickr Power Trainer.[24] The Wahoo Kickr Power Trainer was calibrated in each test during the 10-min warm-up according to the manufacturer's recommendation. Participants were allowed to cycle at their own preferred cadence. The graded exercise test was terminated when a cyclist's cadence dropped more than 10 rounds per minute (rpm) below their preferred cadence for more than 10 seconds. During the test, strong verbal encouragement was given in an attempt to make sure that the cyclist performed to his maximal capacity.

Maximal oxygen consumption or VO_2max was calculated as the highest 30 second VO_2 average. For the determination of VT1 and VT2, 15-s O_2 and CO_2 averages were used.[25] Respiratory gas exchange was measured MasterScreen CPX (Jaeger Leibniztrasse 7, 97204 Hoechberg, Germany) on a breath-by-breath basis and after the device was calibrated.

Peak power output (PPO), Power at VT1 (WVT1) and Power output at VT2 (WVT2) were also calculated derived from this test.

Simulated 40-min Time-Trial

To measure endurance performance, cyclists performed a 40-min all-out time-trial (40TT) in the laboratory. Prior to the start of 40TT, a 10-min warm-up was performed at a constant work of 50 W. Calibration of the GXT was done as part of the warm-up. Cyclists were able to pace themselves throughout the test and change their gear ratio and pedal frequency as they preferred. Environmental condition, such as temperature and humidity, were kept standard during all tests. Strong verbal encouragement during the 40TT was given by researchers, while all data was blinded from the cyclists except for time. Cyclists were allowed to drink water *ad libitum* through the test.

Performance and endurance capacity was determined by the mean power output during the 40TT.

HRV measurements

All participants were instructed to measure their RR interval data at home every morning after waking up and emptying their urinary bladder, both during BW and TW period. The HRV measurement were captured with a Polar H7 strap (Polar Team System, Polar Electro Oy, Kempele, Finland) and sent via app cloud service (Elite HRV app) [26] for analysis. HRV was measured in a supine position and over a 90 s period.[27] Cyclists were instructed to lie still and not to perform any further activity during recordings. The HRV data were analyzed by Kubios HRV software (Finland Eastern University, Kuopio, Finland).[28] The first thirty seconds of the HRV measurement were discarded,[29] while a middle-level filter of artifact correction was applied on the rest of the data. The root mean squared differences of successive RR intervals (RMSSD) was chosen as the vagal index, based on its greater suitability and reliability than other indexes.[16,30] The HRV data was transformed by taking the natural logarithm to allow parametric statistical comparisons that assume a normal distribution. A 7-day rolling average ($LnRMSSD_{7day\text{-}roll\text{-}avg}$) was calculated for the purpose of training prescription.[17] During BW, the SWC of LnRMSSD was calculated as mean ± 0.5 x SD, following the recommendations of Plews et al. [17] and its usefulness for training prescription based on HRV measurements[5]. SWC was updated after the first 4 weeks of TW due to the relationship between CAR and the adaptation to training.[8] This SWC was used for the interpretation of changes in $LnRMSSD_{7day\text{-}roll\text{-}avg}$ and the consequent training prescription during the following 4 weeks.

Statistical Analysis

The homogeneity of the data was tested with a Levene's test, to assure that all data was normally distributed. Based on the normal distribution the data are presented as mean ± standard deviation. A repeated measure of ANOVA followed by a Bonferroni post hoc test was performed to detect both, within- and between-group changes in TW and to assess possible changes in all participants during BW. In addition, data were analysed for practical significance using magnitude-based inferences both within- and between-groups comparison.[31] The smallest worthwhile difference in means in standardized (Cohen's *d*) units was set at 0.2, representing the hypothetical smallest difference within- and between-groups. Furthermore, chances that any change was greater/similar/smaller than the other group was calculated [using effect size and its 90% confidents limits (CL)]. Qualitative assessment of the magnitude of change was included according to the chances of benefit: most unlikely (<0.5%); very unlikely (0.5 to 5%); unlikely (5 to 25%); possibly (25 to 75%); likely (75 to 95%); very likely (95 to 99.5%); most likely (>99.5%).[31] If the 90% CL overlapped small positive or negative values, the magnitude of change was labelled unclear. Results were analysed with IBM SPSS Statics v.24 (SPSS Inc., IL, USA) for the repeated measure of ANOVA and Microsoft Excel 2016 (Microsoft Corporation, WA, USA) for the magnitude-based inference analysis.

RESULTS

Training

In BW, HRV-G and TRAD followed the same training prescription (3:1). There were no statistical differences in volume nor intensity distribution in either group during this period.

The amount of time/week for both groups were 8 h 17 m ± 2 h 48 min for HRV-G and 8 h 13 m ± 2 h 42 min for TRAD. Furthermore, the percentages of time in the different intensity zones (below VT1/ between VT1 and VT2/ above VT2) were 61/29/10 % and 60/31/9 % for the HRV-G and TRAD group respectively. During this period PPO (*p* = 0.003) and 40TT (*p* < 0.0001) improved while VO2max, WVT2 and WVT1 showed no changes.

In TW, the amount of time/week for both groups were 9 h 18 m ± 2 h 50 m for HRV-G and 8 h 46 m ± 2 h 47 m for TRAD. In addition, the percentages of time in the different intensity zones (below VT1/ between VT1 and VT2/ above VT2) were 66/24/10% and 64/27/9% for the HRV-G and TRAD group respectively. Percentage of time between VT1 and VT2 was significantly higher in TRAD [p = 0.04; *d* = 0.29 (-0.05 ; 0.53)] than in HRV-G. Percentage of time expended below VT1 [p = 0.21; *d* = 0.14 (-0.20 ; 0.47)] and above VT2 [p = 0.13; *d* = 0.13 (-0.14; 0.53)] did not differ between groups.

Within-group

In TW, within-group differences and practical significance are presented in Table 3. HRV-G improved PPO (5.1 ± 4.5 %; p = 0.024), WVT2 (13.9 ± 8.8 %; p = 0.004) and 40TT (7.3 ± 4.5 %; p = 0.005). VO_2max and WVT1 remained similar, with no significant changes. Figure 4 represents individual changes in endurance performance (40TT) for both groups. Only one participant in HRV-G decreased the power output during 40TT in POST (-1%) while in TRAD two subjects decrease the power output during 40TT by -2% and -5%. In addition, HRV-G presents the best individual increments in performance.

Between-group

For all the variables measured during EW (VO_2max, PPO, WVT1, WVT2 and 40TT) there were no differences between-groups in PRE, MID and POST. Between-group practical significance and qualitative assessment are displayed in figure 5. This comparison showed that HRV-G produced greater increases in PPO, WVT2 and 40TT.

In addition, there were significant differences (p = 0.0006) in the relative change of LnrMSSD between groups (Figure 6). There was lower variation for HRV-G group (0.85 ± 3.21%) than TRAD (-2.02 ± 5.21%).

DISCUSSION

This study set out with the aim of comparing the effect of a day-to-day training prescription based on HRV and a traditional training programme. The major finding was that HRV-G led to substantial greater increase in PPO, WVT2 and 40TT than TRAD shown by a possibly beneficial effect for PPO and WVT2 and a likely beneficial effect for 40TT (Figure 5). Furthermore, power output in the main variables showed greater magnitude of change in HRV-G, suggesting positive effects for this group. To the best of our knowledge, this is the first study to apply a training program based on HRV in road cycling.

The time expended between VT1 and VT2 was lower in HRV-G than in TRAD. Consequently, the percentage of time below VT1 was higher (but not significantly) in HRV-G while time expended upper VT2 remained similar between groups. The distribution in HRV-G is in accordance with the report by Da Silva et al. [32] which found a lower proportion of moderate intensity for the HRV guided training group.

Regarding these differences, training prescription based on resting morning values of HRV could lead to a lower proportion of moderate and a greater low and high intensity training. This distribution has demonstrated greater performance enhancement in well-trained and elite endurance athletes.[33] Thus, the decision-making schema (Figure 2) and the SWC (Figure 3) could provide a distribution of training sessions that favors performance improvement. VO_2max is considered one of the factors that determine performance in endurance sports.[34]

VO_2max did not change in either group and presents unlikely beneficial effects. The results differ from some studies reporting beneficial changes in VO_2max for the HRV-G.[5,20] However, these studies were performed with untrained [20] and recreational runners [5,35] and VO_2max is more susceptible to change due to the adaptation to training in this population. Thus, the differences in the results could be as a consequence of the participant's high performance level because the trainability of this parameter is limited in well-trained and elite endurance athletes.[36]

PPO is a parameter that indicates the aerobic potential of cyclists.[37] In HRV-G, PPO increased significantly and presented possible beneficial effects. Furthermore, HRV-G presents a greater magnitude of change than TRAD (Table 3). These results are in accordance with other studies [5,20,35] which found similar increases in maximal aerobic velocity when applying the training guided by HRV in middle-distance running, like road cycling an endurance sport with similar demands. It has been suggested that high intensity training could improve PPO.[38] Although training intensity over anaerobic threshold was similar for both groups, PPO increased more in HRV-G. In HRV-G, only high intensity training was prescribed when the $LnRMSSD_{7day\text{-}roll\text{-}avg}$ values were within the SWC. Our hypothesis for this greater adaptation to training for HRV-G is in line with the idea of performing high intensity training when the athlete is in optimal conditions to perform it. Therefore, these differences in PPO changes may be due to a better timing in the programming of high intensity training.

The competitive situations that have a major impact on the result of a race are mountain passes and time-trials. Although the competition in road cycling is performed around the aerobic threshold in mass-start races,[39,40] the mountain passes are performed around anaerobic threshold.[41] Thus, WVT2 is one of the performance determinants in road cycling. WVT2 improved significantly in HRV-G but not in TRAD. However, the magnitude of change for both groups (table 3) showed a most likely beneficial result for HRV-G and very likely beneficial result for TRAD. These results were in line with those reported by the literature, [5,20,35] showing greater effects for HRV-G (Figure 5). In addition, that the percentage of cyclists who improved WVT2 was 89% for HRV-G and 63% for TRAD. These results support the idea that the homogenization of the traditional training programs produces different levels of response and adaptation of the athletes, preventing the individualization and the adjustment of the training load, which would be obtained using the HRV as a tool to control adaptation.[6] Therefore, tools such as HRV will allow to take the principle of individualization of the load a step further.

Regarding WVT1, this parameter did not change significantly in either group and presents a trivial between-group effect (Figure 5). In addition, the results showed possibly beneficial effects for HRV-G and unclear effects for TRAD (Table 3). These results differ from other results [35] that reported significant increases for both, the group that performed training based on HRV and the predetermined training group. However this study [35] implemented resistance training in their methodology while our study only included endurance training. It has been previously reported that concurrent training of strength and endurance could lead to increases in aerobic capacity and performance.[42,43] This fact might explain the different outcome in this variable, leading to the absence of significant changes in our study. The qualitative assessment based on the effect size showed possible beneficial effects for the change in WVT1 for HRV-G whereas it showed unclear results for TRAD. In this case we cannot compare our result with those previously reported [35] because previous studies did not perform this analysis.

Performance, measured through 40TT, increased in HRV-G but not in TRAD (Table 3). In addition, HRV-G lead to substantial greater increase in this variable with higher magnitude of change. The finding mirrors those of the previous studies [5,32] that have examined the effect of a day-to-day training prescription based on HRV compared to a traditional training prescription. In this case, power output during 40TT was between WVT1 and WVT2 (Table 3), while the percentage of time expended at moderate intensity (between VT1 and VT2) was significantly lower the in HRV-G group. Therefore, the greater improvements in HRV-G may be due to a better periodization of the different type of training sessions. Another explanation for this result could be that the greater improvement in PPO and WVT2 also caused the improvement in performance in 40TT due to the increase of aerobic performance.

Daily variation of HRV was significantly greater for TRAD instead of HRV-G (Figure 6). In addition, the standard deviation was also greater for TRAD group. This result suggests that maintaining HRV values within an optimal range during the training process could result in greater increases in performance. This finding is in accordance with other study performed in cross-country skiing, [22] suggesting lower variations in daily HRV measurements and higher increases in performance for a HRV-guided training group.

This study has some limitations that must be highlighted: a) Training was performed by the cyclists without direct supervision during the training sessions. However, cyclists uploaded their data immediately after training sessions were performed and were supervised on a daily basis. Road cycling is a sport that is performed outdoors, so it is complex to perform the training sessions with the presence of the research group. b) HRV measurements were performed at home and without direct supervision. However, all data was revised every morning to detect possible mistakes in the measurements. Furthermore, participants were carefully instructed during PRE. This evaluation week also served as a familiarization period with all procedures. In addition, it's impractical for cyclists to come to the laboratory to evaluate HRV morning values every day during the study period. c) The determination of SWC was calculated with the same criterion for all the participants when HRV presented a high variation between subjects.[14] More research is necessary to develop new methodologies to establish an individualized SWC that could be more accurate than a fixed calculation of this range.

PRACTICAL APPLICATIONS

This study showed greater improvements for a day-to-day prescription than a predefined training program. To the best of our knowledge, a day-to-day training prescription based on daily HRV measurements had not been tested in this sport yet. In endurance sports with high physiological demands, like road cycling, the timing in the prescription of training load is a key factor to optimize the increases in performance. This study reflects how to optimize the training process based on the status of the cyclists and their response to the previous training sessions. Furthermore, this study has been conducted with a smartphone application and a commercial Bluetooth strap to perform the measurements, highlighting the accessibility of the HRV measurements for field conditions. In addition, ultra-short HRV recordings have been used to evaluate fatigue and response to training[44,45] but not in day-to-day training prescription. This study provides support for the possibilities of these recordings, which has great practical applications in the field. Previous studies of day-to-day training prescription used ≥ 4 min HRV recordings while in this study, the measurements were performed with ultrashort HRV recordings.

CONCLUSIONS

The greater improvements in HRV-G showed that prescribing moderate and high-intensity training according to CAR could be more effective than traditional training prescription based on a predetermined training load, during a relatively short period of time (8 weeks) in well-trained cyclists. Future research is required to implement this new trend in training load prescription for several reasons: First, to apply this method to other level cyclists such as professional cyclists, without much room for further development of aerobic capabilities and performance due to their level. Second, to expand knowledge towards new schemes to prescribe training sessions and an individualization of the SWC.

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Figure 1. Experimental design.

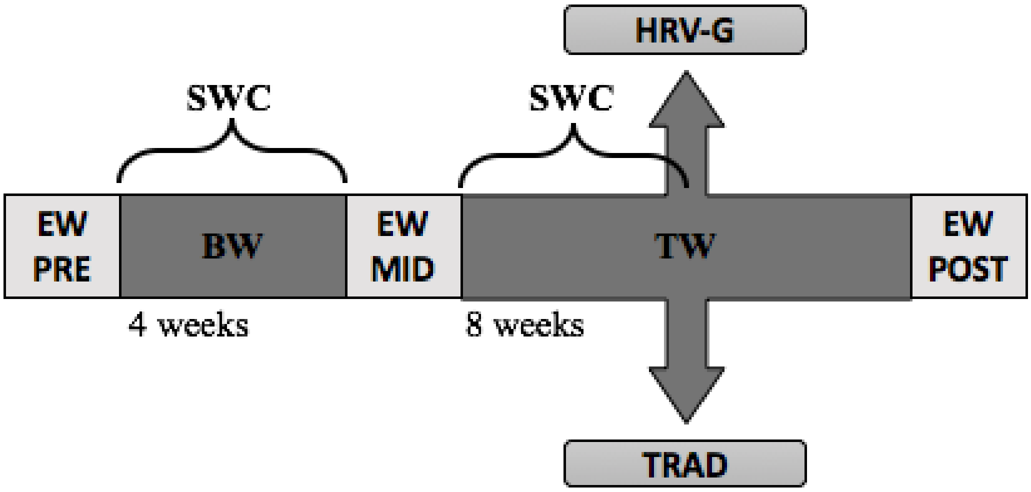
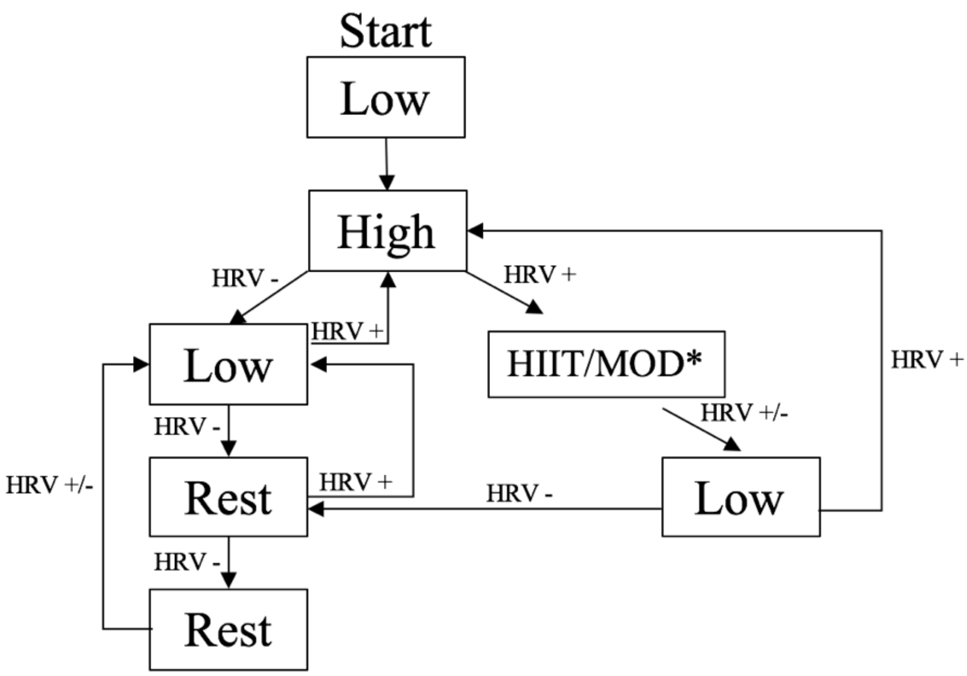


Figure 2. HRV-guided training schema. Modified from Kiviniemi (17). When $LnRMSSD_{7day\text{-}roll\text{-}avg}$ remained inside SWC (+), high intensity or moderate training sessions were prescribed. If $LnRMSSD_{7day\text{-}roll\text{-}avg}$ fell outside SWC (-), low intensity or rest were prescribed.



**HIIT/MOD sessions were alternated each week.*

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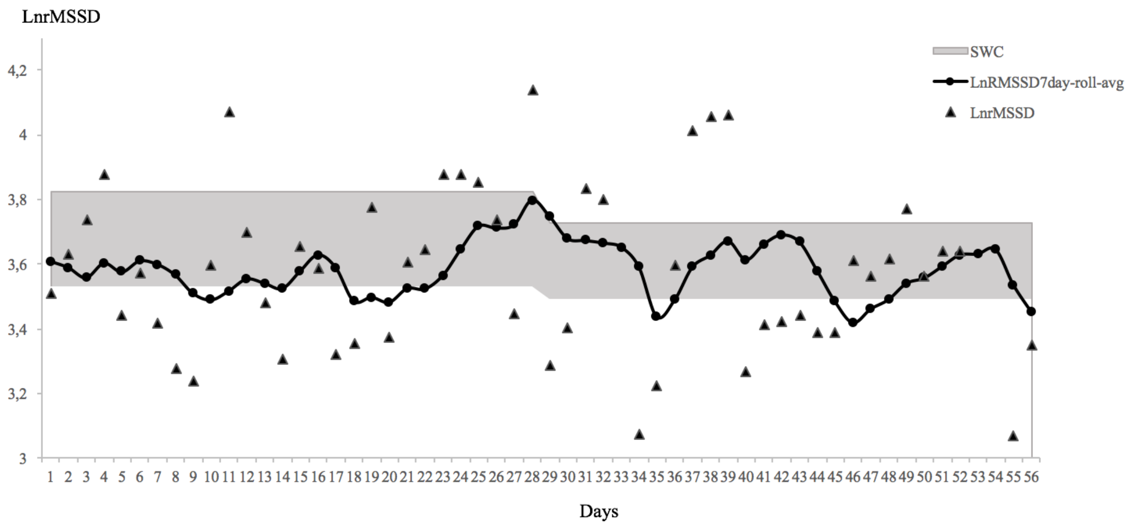
Figure 3. Example of individual response of HRV in a HRV-G cyclist.



SWC: Smallest worthwhile change

LnRMSSD: The natural logarithm of the root mean squared differences of successive RR intervals

$LnRMSSD_{7day\text{-}roll\text{-}avg}$: 7-day rolling average of the natural logarithm of the root mean squared differences of successive RR intervals

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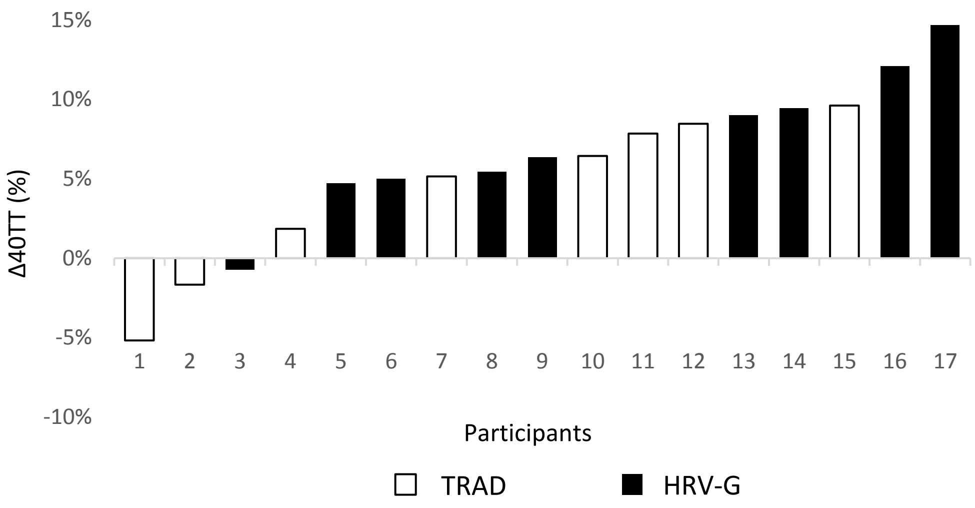
Figure 4. Individual differences in changes in performance for both groups.



40TT: Power output during the 40-min time-trial

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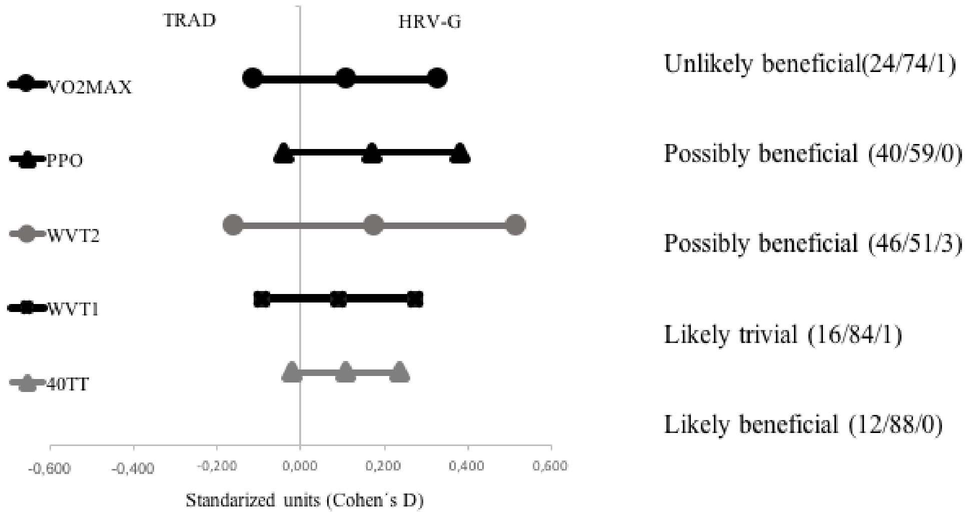
Figure 5. Between-group changes in performance.



PPO: Peak power output

WVT2: Power output at VT2 intensity

WVT1: Power output at VT1 intensity

40TT: Power output during the 40-min time-trial

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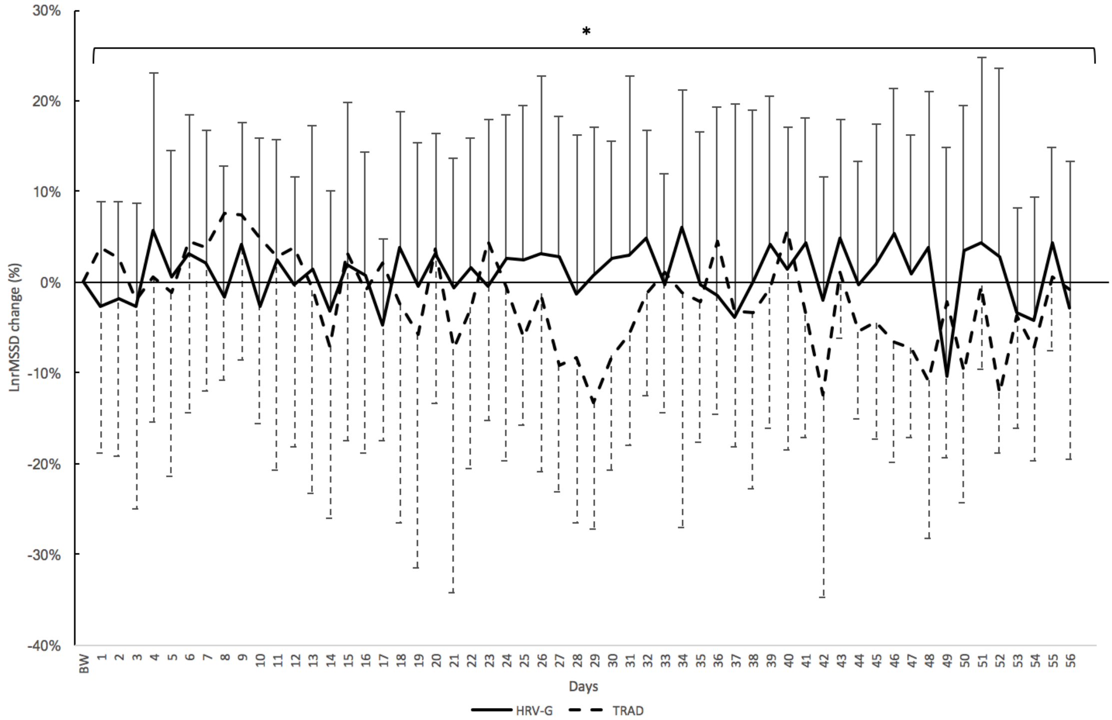
Figure 6. LnrMSSD change (%) during TW period for both, the HRV-G and TRAD groups.



** p < 0.001 for difference of change in LnrMSSD between groups.*

BW: Baseline weeks

TW: Training weeks

HRV-G: Heart rate variability training group

TRAD: Traditional training group

Table 1. Participant characteristics in PRE.

	HRV-G (n = 9)	TRAD (n = 8)
Age (years)	39.22 ± 5.33	37.62 ± 7.09
Experience (years)	12.33 ± 9.67	13.25 ± 10.02
Height (m)	1.76 ± 0.05	1.76 ± 0.06
Weight (kg)	76.92 ± 12.46	78.67 ± 11.72
VO_2max ()	55.04 ± 7.58	52.16 ± 6.50
PPO (W)	338.89 ± 39.75	335.13 ± 22.65
WVT2 (W)	253.13 ± 16.02	263.89 ± 37.73
WVT1 (W)	188.89 ± 25.35	175.00 ± 23.15
40TT (W)	231.89 ± 38.18	206.51 ± 31.55

PPO: Peak power output

WVT2: Power output at VT2 intensity

WVT1: Power output at VT1 intensity

40TT: Power output during the 40-min time-trial

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Table 2. Periodization and training distribution for both groups during weeks 1-5 and for TRAD during weeks 7-14.

Weeks	Type	Test	High Intensity	HIIT	Moderate Intensity	Low Intensity
1	EW PRE	GXT and 40 min Time-Trial				
2	BW				40 min between VT1 and VT2	3-5 sessions between 120 and 180 min below VT1
3	BW			4x8 min >VT2 / 3' rec	40 min between VT1 and VT2	2-3 sessions between 120 and 180 min below VT1
4	BW		30 min at VT2	4x8 min >VT2 / 3' rec	40 min between VT1 and VT2	2-3 sessions between 120 and 180 min below VT1
5	BW					3-5 sessions between 120 and 180 min below VT1
6	EW MID	GXT and 40 min Time-Trial				
7	TW		30 min at VT2		40 min between VT1 and VT2	3-5 sessions between 120 and 180 min below VT1
8	TW			4x8 min >VT2 / 3' rec	40 min between VT1 and VT2	2-3 sessions between 120 and 180 min below VT1
9	TW		30 min at VT2	4x8 min >VT2 / 3' rec	40 min between VT1 and VT2	2-3 sessions between 120 and 180 min below VT1
10	TW					3-5 sessions between 120 and 180 min below VT1
11	TW		30 min at VT2		40 min between VT1 and VT2	3-5 sessions between 120 and 180 min below VT1
12	TW			4x8 min >VT2 / 3' rec	40 min between VT1 and VT2	2-3 sessions between 120 and 180 min below VT1
13	TW		30 min at VT2	4x8 min >VT2 / 3' rec	40 min between VT1 and VT2	2-3 sessions between 120 and 180 min below VT1
14	TW					3-5 sessions between 120 and 180 min below VT1
15	EW POST	GXT and 40 min Time-Trial				

High Intensity, HIIT and Moderate session were performed with a 45-60 min warm up and 20 min of cooling down

EW: Evaluation week

BW: Baseline week

TW: Training week

GXT: Graded exercise test

VT1: First ventilatory threshold

VT2: Second ventilatory threshold

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Table 3. Within-group differences in the main variables measured.

	HRV-G (*n* = 9)					TRAD (*n* = 8)				
Variables	MID	POST	Standardised change (90% confident limits)	Chances	Qualitative assessment	MID	POST	Standardised change (90% confident limits)	Chances	Qualitative assessment
VO2max	56,34 ± 7.58	55,8 ± 8.18	-0.09 (0.41; -0.58)	16/51/34	unlikely beneficial	54.30 ± 7.81	52.13 ± 6.78	-0.22 (0.15; -0.59)	3/42/55	very unlikely beneficial
PPO	356.83 ± 39.74	374,28* ± 43.65	0.38 (0.58; 0.17)	92/8/0	likely beneficial	346,75 ± 16.73	351.50 ± 17.01	0.25 (1.11; -0.61)	54/28/18	unclear
WVT2	275.00 ± 41.46	311,11** ± 37.73	0.94 (1.30; 0.59)	100/0/0	most likely beneficial	256.25 ± 17.68	281.25 ± 22.16	1.02 (1.77; 0.27)	96/3/1	very likely beneficial
WVT1	191.67 ± 27.95	200.00 ± 25.01	0.32 (0.62; 0.01)	75/24/1	possibly beneficial	175.00 ± 23.15	178.13 ± 28.15	0.07 (0.42; -0.29)	29/64/7	unclear
40TT	243.11 ± 41.73	260,78** ± 44.76	0.33 (0.45; 0.21)	96/4/0	very likely beneficial	214.42 ± 32.36	223.13 ± 36.15	0.21 (0.40; 0.03)	53/47/0	possibly beneficial

*$p < 0.05$; ** $p < 0.01$

PPO: Peak power output

WVT2: Power output at VT2 intensity

WVT1: Power output at VT1 intensity

40TT: Power output during the 40-min time-trial