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The Effect of Training Volume and Intensity on Modulation of Heart Rate Variability in Groups of Healthy Individuals

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Background Heart rate variability (HRV) measurements can be used to reflect one's cardiac autonomous status, and has been accepted as a predictor of race performances by the sports community [1]. A majority of studies has shown that physical training improves HRV [2-4], however, whether it is by altering the exercise duration or training intensity that could improve HRV still remains to be elucidated. Various studies have tried to explore this area, but they have only focused on the acute effect of a single bout of exercise [5,6]. In our study we aimed to expand on this by isolating the two training variables, exercise intensity and duration, and examine their individual effects on HRV for a prolonged period of 8 weeks. If we can comprehend the response of cardiac autonomous status to different training durations and intensities, we will be able to adopt HRV measurements as a guiding tool in various training regimes.

Methodology

Subjects Twenty-four healthy and active males (aged 24.34 ± 3.08 years) were recruited from local universities sports teams. They took part in regular exercises 2-3 days each week. They were randomly assigned to one of the three groups as follows: Endurance Group (EN), High Intensity Group (HI), and Control (CON). To standardise the training intensities across the groups, all subjects were required to perform a maximum oxygen consumption (VO_{2max}) test prior to the programme.

Training programme The whole training programme lasted for six weeks and was divided into three phases: P1, P2 and P3 (two weeks per phase). HI and EN group performed running training six times in each phase with the sessions separated by at least one day apart to prevent fatigue (Figure 1). Oxygen consumption and blood lactate were measured in the 1st, 2nd and 4th training session of each phase. Heart rate (HR) was recorded in all training sessions.

Fig 1. An outline of our 6-week training programme (grayed). VO_{2max} tests were performed during baseline and again 3 days after the final training session. (*) The subjects in the HI group were required to warming up at Anaerobic Threshold (AT) for 10 minutes in Phase 3.

	Baseline 2 days	Phase 1 (P1) 2 weeks	Phase 2 (P2) 2 weeks	Phase 3 (P3) 2 weeks	Recovery 2 weeks	
EN	Pre-VO_{2max}	65% VO_{2max} 35 mins	65% VO_{2max} 50 mins	65% VO_{2max} 65 mins	Post-VO_{2max}	No training
HI	Pre-VO_{2max}	75% VO_{2max} 3 x 8 mins, rest 3 mins	85% VO_{2max} 6 x 4 mins, rest 3 mins	(*) 95% VO_{2max} 6 x 2 mins, recovery of 2 mins at AT	Post-VO_{2max}	No training
CON	Pre-VO_{2max}	No training	No training	No Training	Post-VO_{2max}	No training

Heart rate variability measurements Our subjects were instructed to measure their HRV prior to, during, and after the 6-week training programme. The HRV test consisted of a seven-minute supine recording using a Polar RS800 heart rate monitor. Five-minute HRV was manually selected from the recordings [7], where the high frequency (HF) and low frequency (LF) bands were quantified using an autoregressive spectrum (order 16).

Statistical analysis Baseline HRV was tested for reliability by using the intra-class correlation coefficients. One-way ANOVA was used to evaluate the baseline HRV, anthropometric data and pre-training VO_{2max} among the groups. Physiological variables in pre- and post-training, VO_{2max} tests, and HRV parameters at different time points were compared among the training groups (CON, EN and HI) by two-way ANOVA. Multiple comparisons were performed by Bonferroni post-hoc test. Statistical significance was set at $p < 0.05$ levels for all analysis.

Results

Physiological variables Pre- and post-training values of VO_{2max}, maximum HR and lactate in the Maximum Oxygen Consumption tests were not statistically different among the groups (Table 1). Average HR, %VO_{2max} and post-exercise maximum blood lactate were significantly higher in HI than EN in all corresponding training phase.

Table 1. Pre- and Post-training values of VO_{2max}, Maximum Heart Rate, Blood lactate in the Maximum Oxygen Consumption tests for each group. (Mean ± SD)

	CON		EN		HI	
	Pre-training	Post-training	Pre-training	Post-training	Pre-training	Post-training
VO2max (ml/min/kg)	53.4 ± 4.4	52.2 ± 5.9	52.9 ± 6.9	52.2 ± 7.3	50.5 ± 4.2	51.1 ± 3.3
Max Heart Rete (bpm)	193.1 ± 5.4	196.0 ± 5.9	194.8 ± 9.2	194.8 ± 12.2	197.3 ± 8.2	194.6 ± 7.2
Max Lactate (mM)	14.6 ± 3.0	14.4 ± 3.3	13.3 ± 2.3	12.6 ± 2.1	13.3 ± 1.7	13.1 ± 1.6

HRV indices Within each group baseline HRV were highly reproducible, with an intra-class correlation coefficient of >0.92 for all HRV indices. Frequency domains of HRV for each group are presented in Table 2 - 3. No differences were found in the HRV indices in the different phases of CON.

EN group HFnu exhibited an upward trend from baseline to P2, where P2 was significantly different when compared with baseline. The values did not further increase in P3, and a significant difference was reported in recovery phase when compared with baseline (Table 2). LFnu decreased throughout the 8-week programme, and the values in P2 and recovery phase were significantly lower when compared with baseline (Table 3).

HI group A decrease in HFnu was reported in P2 (23% difference from baseline) and the value was significantly lower than baseline. The value later increased in P3 and recovery phase, but no significant differences were reported when they were compared with baseline (Table 2). LFnu fluctuated over the first 3 phases as it increased significantly in P2, and then decreased in P3 and recovery phase (Table 3).

Table 2. HFnu (%) in Baseline, P1, P2, P3 and Recovery phases of CON, EN and HI groups. Mean ± SEM

HFnu (%)	CON	EN	HI
Baseline	51.1 ± 4.9	47.9 ± 5.9	44.6 ± 5.8
P1	48.7 ± 5.4	55.7 ± 6.1	41.3 ± 6.7
P2	46.9 ± 6.1	59.9 ± 7.3*	34.2 ± 5.3*^
P3	46.6 ± 5.1	57.6 ± 7.0	43.4 ± 7.3
Recovery	54.1 ± 6.9	62.3 ± 7.4*	40.3 ± 6.6^

** significant difference from Baseline p-value < 0.05; ^ significant difference from EN group p-value < 0.05.*

Table 3. LFnu (%) in Baseline, P1, P2, P3 and Recovery phases of CON, EN and HI groups. Mean ± SEM

LFnu (%)	CON	EN	HI
Baseline	48.9 ± 4.9	52.1 ± 5.9	55.4 ± 5.8
P1	51.3 ± 5.4	44.3 ± 6.1	58.7 ± 6.7
P2	53.1 ± 6.1	40.1 ± 7.3*	65.8 ± 5.3*^
P3	53.4 ± 5.1	42.4 ± 7.0	56.6 ± 7.3
Recovery	45.9 ± 6.9	37.7 ± 7.4*	59.7 ± 6.6^

** significant difference from Baseline p-value < 0.05; ^ significant difference from EN group p-value < 0.05.*

Discussion As indicated by the significant increase of HFnu during P2 in EN, the present study showed that 4 weeks of progressive increase in training duration from 35 mins to 50 mins could have a beneficial effect on cardiac autonomic status. Further increase in duration to 65 mins did not enhance parasympathetic activities. Opposingly, HFnu decreased during P2 in HI suggesting that a training intensity above AT could impair parasympathetic activities, and this was likely caused by insufficient recovery in between trainings. However adaptation may occur as the value of HFnu increased in the later stages of HI.

No significant difference was observed between the pre- and post-training VO_{2max} of the three groups. The training workload might not be enough to stimulate an improvement in VO_{2max} over the course of 6 weeks. We found no significant difference in the HRV indices in both EN and HI when they were compared with CON, which could also be associated with the insufficient training workload. Although no statistical significance was reported, the trends exhibited in the HRV indices led us to believe that the training sessions had imposed some changes in the cardiac autonomous status.

Conclusion The present study demonstrates that training duration and intensity produce divergent effects on parasympathetic activities. We believe that regular training at 65% VO_{2max} for 50 mins can serve as a recovery regime for improving cardiac autonomic status. High intensity interval trainings, on the other hand, should be treated with care. HRV measurements can serve to be a potential tool for monitoring recovery for high intensity exercises. We would advise that no extra recovery interventions are required if HFnu index does not fall below 23% of baseline values. If training intensity is to increase to 95% VO_{2max}, 2 weeks are necessary for the autonomous nervous system to fully adapt to the new training workload.

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