Relation between wearable heart rate monitor derived training load and cardiac adaption in endurance athletes

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Background: No studies have effectively measured training load (TL) from wearable heart rate (HR) monitors and determined its relation to exercise induced left and right ventricular (LV, RV) remodeling. A better insight into drivers of exercise induced cardiac remodeling is of clinical relevance to guide training advice in athletes at risk of adverse remodeling.

Purpose: We determined the TL, based on HR monitoring by commercial wearables[1]. The number and duration of training sessions was quantified during a period of 3 months. Training-intensity was calculated as Edwards TRIMP (eTRIMP) based on the product of training duration in one of 5 HR zones (1=light, 5=very vigorous) and the coefficient related to the respective HR zone.

Methods: Training data was collected in 2 prospective multicenter studies. Master@Heart comprises endurance trained middle-aged men aged 45 to 70years[2]. Pro@Heart consists of elite athletes aged 16 to 23years[3]. For this analysis, all male athletes with complete training data recorded using a chest-worn HR monitor for 3 months were included. Using an in-house developed pipeline, maximal HR and TL were calculated from raw training data. Cardiac magnetic resonance imaging was performed to measure indexed LV/RV end-diastolic volume (LVEDVi, RVEDVi), end-systolic volume (LVESVi, RVESVi), ejection fraction (LVEF, RVEF) and LV mass (LVMi).

Results: Pro@Heart athletes (n=69; age 21.9 ± 4.2 years) trained more than Master@Heart athletes (n=82; age 55.2 ± 6.5 years) and their total 3-month TL (eTRIMP) was also higher (9718 \pm 3190 vs. 5499 \pm 3775min; P<0.05 and 22339 \pm 7350 vs. 13438 \pm 8880 AU; P< 0.05; Table 1). Considering all athletes, there was a strong correlation between both training duration and eTRIMP and LVEDVi, LVESVi, LVMi, RVEDVi and RVESVi. Training duration in zone 1&2 correlated well with LVEDVi, LVESVi, LVSV, LVMi, RVEDVi and RVESVi (Table 2). We found small significant negative correlations between duration and eTRIMP compared to LVEF and RVEF (Table 2).

To filter out individual training factors influencing cardiac remodeling we used a partial least squares method which included time and percentage of time spent in training zones and age. Accordingly, training duration in zone 1&2 and age were the main predictors of cardiac volumes and LVMi. For LVEF, age and time in zone 3 was most predictive, whereas for RVEF zone 3 and to a lesser degree zone 1&2 were the main predictors, irrespective of age. Interestingly, time spent in high intensity zones 4 and 5 was not predictive.

Conclusion: We prospectively quantified TL in comparison to CMR-derived measures of cardiac remodeling and demonstrated that training duration in low intensity training zones is most predictive for cardiac volumes and mass, whereas LVEF and RVEF are more closely associated to time in zone 3. Very vigorous intensity exercise was not predictive, likely due to limited time training in zone 4 and 5.

	Pro@Heart Master@Heart		All athletes
N (male%)	69 (100)	82 (100)	151 (100)
Age (years)	21.9 ± 4.3	55.2 ± 6.5*	40 ± 17.6
Weight (kg)	70.46 ± 6.2	73.68 ± 7.5*	72.2 ± 7.1
Height (cm)	180.9 ± 6.1	178.2 ± 6.0*	179.4 ± 6.2
BMI (kg/m²)	21.5 ± 1.6	23.2 ± 1.8*	22.4 ± 1.9
BSA (m²)	1.89 ± 0.1	1.90 ± 0.1	1.9 ± 0.1
MaxHR training (bpm)	196.4 ± 5.8	178 ± 11.9*	186.4 ± 13.3
Duration (min)	9718 ± 3190	5499 ± 3775*	7427 ± 4093
Hours per week	12.4 ± 4.1	7.0 ± 4.8*	9.5 ± 5.3
Exercise sessions	84.0 ± 28.9	51.6 ± 32.6*	66.4 ± 34.9
eTRIMP (AU)	22339 ± 7350	13438 ± 8880*	17505 ± 9320

Table 1) Demographic and training load parameters in Pro@Heart and Master@Heart participants. Data are means ± SD. *P<0.05. Abbreviations: BSA = Body surface area; MaxHR = maximal heart rate; eTRIMP = Edwards TRIMP; AU = arbitrary units

	LVEDVi	LVESVi	LVSVi	LVEF	LVMi	RVEDVi	RVESVi	RVSVi	RVEF		
Duration (min)	0.51	0.5	0.37	-0.18	0.53	0.47	0.45	0.33	-0.19		
Sessions	0.45	0.4	0.36	-0.09	0.47	0.39	0.32	0.33	-0.06		
eTRIMP (AU)	0.46	0.47	0.31	-0.2	0.48	0.43	0.43	0.29	-0.21		
Time in											
Zone 1&2	0.49	0.45	0.41	-0.1	0.52	0.47	0.42	0.35	-0.12		
Zone 3	0.34	0.39	0.18	-0.24	0.34	0.32	0.36	0.19	-0.24		
Zone 4	0.23	0.25	0.12	-0.16	0.24	0.22	0.24	0.13	-0.14		
Zone 5	0.23	0.18	0.22	0.03	0.25	0.2	0.17	0.19	-0.02		
Percent of time in											
Zone 1&2	0.37	0.3	0.35	-0.02	0.38	0.34	0.28	0.28	-0.03		
Zone 3	-0.01	0.04	-0.07	-0.1	-0.05	-0.01	0.04	-0.02	-0.1		
Zone 4	-0.35	-0.32	-0.28	0.1	-0.34	-0.32	-0.3	-0.24	0.12		
Zone 5	-0.21	-0.21	-0.15	0.08	-0.18	-0.2	-0.19	-0.14	0.07		

Table 2) Correlation matrix (r) of left ventricle (LV) and right ventricle (RV) function compared to training load measured by chestworn heart rate monitors. Indexed left and right ventricular end-diastolic volume (LVEDVi, RVEDVi), end-systolic volume (LVESVi, RVESVi), ejection fraction (LVEF, RVEF) and left ventricular mass (LVMi).

Highlighted P<0.05 and colors indicate the direction and intensity of the correlation (green for direct, red for inverse correlations).