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Aerobic Capacity, Body Composition, Personality and Anxiety As Predictors of Fluctuations in Heart Rate Variability In Endurance Athletes

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ABSTRACT
The present study was carried out to understand the relationship between heart rate variability (HRV) and body composition (fat percent, muscle content and total body water), aerobic capacity, personality traits and levels of state and trait anxiety in athletes trained in endurance sports. The present cross-sectional study was carried out on 56 athletes from endurance sports like swimming, cycling, track and field (distance) and hockey out of which 34 were males (age 16.8 ± 2.5 years) and 22 females (age 17.1 ± 1.2 years). The variables studied on these players include body fat percent, muscle content, total body water, aerobic capacity (vO_2max), heart rate variability (SDNN, pNN50, LF, HF, LF/HF), type of personality and levels of state and trait anxiety using standard protocols. Significantly positive but weak correlation was found between muscle content and LF (r=0.296, p=0.027) and LF/HF (r=0.340, p=0.010) parameters of HRV. Significantly positive relationship was found between SDNN and vO_2max (r=0.293, p=0.029); SDNN and extraversion (r=0.425, p=0.001) trait of personality. Conscientiousness trait of personality was observed to have significantly positive relationship with SDNN (r=0.371, p=0.005) and pNN50 (r=0.273, p=0.042). Significantly positive relationship found between state anxiety and LF (r=0.287, p=0.032). Multiple linear regression analysis was done and it was found that all of above mentioned variables predict 41.5% of SDNN and 41.7% of LF/HF ratio. Body height, muscle content, aerobic capacity (vO_2max), extraversion, conscientiousness and state anxiety were found to have impact on time domain and frequency domain parameters of heart rate variability in endurance athletes.
Keywords: *Heart Rate Variability, Personality, Aerobic Capacity, Body Composition, Anxiety*

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INTRODUCTION

Personality is an individual's biopsychosocial pattern of reactions and behaviours. It is based on an individual's genes to some extent and is further influenced by one's learning's and experiences. Personality is a major guiding force to determine life paths and thus affects an individual's health. For instance, personality influences the perception of stress by an individual, probability of smoking or of exercising [1]. Some people are more extroverted, conscientious, neurotic, and intellectual than others. These individual characteristics of personality have associations with health outcomes. Personality can affect autonomic function and dynamics. Increased neuroticism is linked to increased SNS activation, as measured by increased electro-dermal response, as well as in- creased anticipatory anxiety [2]. Individual differences in the big five personality traits are linked to individual differences in electrocardiogram (ECG) amplitude patterns, in particular high neuroticism and low positive emotion [3].

Mourot et al. have shown that athletes exhibit an increased HRV profile and parasympathetic modulation as compared to sedentary subjects [4]. In recreational marathon athletes, the progressive sympathetic predominance at peak training load may predict performances in the race [5]. It has been shown that team athletic and endurance activities induce hightened parasympathetic modulation when conducted over 24 h period (higher pNN50, RMSSD and HF, and lower LF/HF ratio) [6]. Thus, elite endurance athletes have an elevated parasympathetic modulation as compared to recreational athletes and non-athletes. This confirms that athletic conditioning is an important variable influencing the autonomic control of the heart.

In 2013, Grant et al. published a study to find out association of HR, RR, RMSSD, pNN50, LF, HF, LF/HF, SD1, and SD2 with vO_2max and they found that the most important predictor of cardio vascular fitness and exercise ability, as represented by VO_2max, was HR [7]. HF HRV has been shown to be associated with

muscle content, physical activity levels and central adiposity [8]. Increased aerobic physical activity and weight loss have been shown to lead to improvements in HRV [9].The aim of the present study was to understand the associations of personality traits, levels of state and trait anxiety, aerobic capacity and body composition with heart rate variability in athletes of endurance sports such as track and field (middle and long distance runners), swimmers, cyclists and hockey players. We tried to keep any bias to the minimum by considering both individual and team events as well as both males and females in our study.

MATERIAL AND METHODS

Participants

The present cross-sectional study was carried out on 56 athletes from endurance sports like swimming, cycling, track and field (distance) and hockey out of which 34 were males (age 16.8 ± 2.5 years) and 22 females (age 17.1 ± 1.2 years). The athletes had a history of participation in at least national level competitive events with minimum of 2 years formal training and were in pre- competitive phase during the conduction of the test. Subjects, who were healthy, with no history of any hereditary or cardio-respiratory diseases, were selected for the study. Prior to that, a full explanation of the purposes, procedures and potential risks and benefits of the assessments were offered to all players, and their written consents were acquired. The present study was conducted following guidelines as laid down in the Declaration of Helsinki, and ethical clearance was also obtained from the Institutional Ethical Committee before performance of any tests on human subjects.

Methodology

All subjects were assessed for various physical, physiological and psychological variables at Human Performance Laboratory, SAI and conducted during morning hours on similar day. They underwent heart rate variability assessment first and then physical and questionnaire based psychological assessments were done followed by sub-maximal exercise testing with the help of bicycle ergometer after familiarizing them with the exercise protocol. The subjects were asked to have a light meal at least 2 hours before the test. The training was relatively common to all the athletes of the study besides the skill training. Their medical history and training duration was evaluated by a pre-set questionnaire.

The height and weight were measured using digital measuring station (SECA 284; SECA, Hamburg, Germany). Heart Rate Variability (HRV) was measured using Physiological Monitoring System (Zephyr Technology Corporation, Annapolis, MD, US) [10]. The chest strap was tied across the chest of the subject such that the centre of the electrode was directly beneath the subject's armpit. The subject was seated in a comfortable arm-chair located in a quiet laboratory, and was asked to remain as still as possible for the duration of the recording. The readings were taken for duration of 10 min, out of which last 5 min readings were considered for analysis. The values of the RR intervals were analysed using Kubios Software (Version 2.2, Kuopio, Finland) [11].

Body composition analysis was done using Body Composition Analyser (BCA) (Model mBCA 515, SECA, Hamburg, Germany [12]. The subjects were instructed to come for the test fasting and with empty bladder, and all metal accessories, coins and mobile phones removed from the body. The subjects were made to stand on the platform with electrodes such that, their heels were placed central to the smaller posterior electrode, and forefoot was placed central to larger anterior electrode. The subjects were asked to touch the electrodes in such a way that the electrode separator was located between middle and ring fingers.

Aerobic capacity of the subjects was measured using the A strand protocol on bicycle ergometer (Monark LC7). The subject cycled for 6 minutes at a workload chosen to try and elicit a steady-state heart rate between 125 and 170 bpm. Recording of the heart rate was done every minute during the test. If the heart rate at 5 and 6 minutes was not within 5 beats/min, the test was continued for one extra minute. The steady-state heart rate and workload recorded were put in the equation to determine an estimation of VO_2max. For the characterization of the personality type Big Five Inventory was used, which is a 44-item inventory that measures an individual on the dimensions of personality namely, extraversion, agreeableness, openness, neuroticism and conscientiousness. The State-Trait Anxiety Inventory (STAI) was used for the measurement of trait and state anxiety levels.

Statistical Analysis

The normality of data was checked using the Shapiro Wilk test and the data was found to be non-parametric in nature. Spearman's correlation coefficient was used in order to test the relationships of physiological and psychological parameters with heart rate variability. The correlation coefficients (r) were categorized as very weak (0.0-0.2), weak (0.2-0.4), moderate (0.4-0.7), strong (0.7-0.9) or very strong (0.9-1.0) in the study. Multiple linear regression models analysed the effects of HRV parameters of SDNN and LF/HF on different physiological and psychological parameters. Statistical analysis was carried

out using the SPSS v23.0 package (SPSS Inc., Chicago, IL, USA). Significance was considered at an alpha level of $p \leq 0.05$.

RESULT AND DISCUSSION

Table 1 represents physical, physiological and psychological parameters in male and female athletes of endurance sports. No significant differences were found in personality traits of extraversion (p=0.093), agreeableness (p=0.142), conscientiousness (p=0.201), neuroticism (p=0.266) and open mindedness (p=0.496) when Mann Whitney U Test was applied. Significant differences were seen in height (p<0.01), weight (p<0.01), fat percent (p<0.01), muscle content (p<0.01) and vO_2max (p<0.01). No significant differences observed in time domain (SDNN and pNN50) and frequency domain (LF, HF, LF/HF) parameters of heart rate variability. Table 2 represents Spearman's correlation coefficients between time domain and frequency domain measures of HRV and body composition, aerobic capacity, personality and anxiety. Significantly positive but weak correlation was found between muscle content and LF (r=0.296, p=0.027) and LF/HF (r=0.340, p=0.010) parameters of HRV. Significantly positive relationship was found between SDNN and vO_2max (r=0.293, p=0.029); SDNN and extraversion (r=0.425, p=0.001) trait of personality. Conscientiousness trait of personality was observed to have significantly positive relationship with SDNN (r=0.371, p=0.005) and pNN50 (r=0.273, p=0.042). Significantly positive relationship found between state anxiety and LF (r=0.287, p=0.032).

In order to further examine the relationship between heart rate variability (HRV) measures and body composition, physiological and psychological parameters linear multiple regressions were performed to evaluate the possible predictors of SDNN and LF/HF parameters of HRV as shown in Table 3. The first multiple regression model used SDNN parameter of HRV as the dependent variable, and age (years), height (cm), weight (kg), fat percent (%), muscle content (kg), total body water (%), vO_2max (ml/kg/min), big five traits of personality and state and trait anxiety as independent variables. Results showed that all of these predictors produced R=0.644, R^2=0.415, F(14,41)=2.075, p=0.035, stating that all independent variables explained 41.5 % of their SDNN. However, beta coefficients indicate that only muscle content (beta=-0.402, t=-2.026, p=0.049) and vO_2max (beta=0.424, t=2.721, p=0.010) significantly predict SDNN. Second linear multiple regression was performed with LF/HF ratio of HRV as dependent variable, and age (years), height (cm), weight (kg), fat percent (%), muscle content (kg), total body water (%), vO_2max (ml/kg/min), big five traits of personality and state and trait anxiety as independent variables. Results showed that all of these predictors produced R=0.646, R^2=0.417, F(14,41)=2.096, p=0.033, stating that all independent variables explained 41.7 % of LF/HF. However, beta coefficients indicate that only height (beta=0.641, t=2.614, p=0.012) and vO_2max (beta=-0.477, t=-3.066, p=0.004) significantly predict SDNN.

Table 1: Physical, physiological and psychological parameters of females and males athletes of endurance sports.

Parameter	Females (n=22)	Males (n=34)	Sig.
Age (years)	17.1 ± 1.2	16.9 ± 2.4	.308
Years of Training (years)	6.0 ± 2.7	4.5 ± 2.6	.010*
Height (cm)	160.4 ± 5.5	172.3 ± 9.254.3 ±	.000*
Weight (kg)	54.3 ± 6.1	63.6 ± 7.7	.000*
Fat Percent (%)	19.5 ± 4.7	13.5 ± 5.3	.000*
Muscle content (kg)	18.9 ± 1.9	25.4 ± 3.8	.000*
Total Body Water (%)	61.7 ± 6.7	61.9 ± 5.9	.562
vO_2max (ml/kg/min)	50.1 ± 5.3	59.2 ± 5.6	.000*
SDNN (ms)	93.2 ± 40.0	88.0 ± 38.8	.597
pNN50	34.9 ± 19.2	28.9 ± 17.3	.247
LF (n.u.)	53.3 ± 15.7	61.1 ± 15.9	.081
HF (n.u.)	44.7 ± 16.2	38.6 ± 16.1	.177
LF/HF	1.5 ± 0.9	2.3 ± 1.6	.034*
Extraversion	30.4 ± 3.2	35.8 ± 4.9	.093
Agreeableness	37.8 ± 3.2	35.8 ± 4.9	.142
Conscientiousness	37.1 ± 4.8	35.6 ± 4.6	.201
Neuroticism	19.9 ± 5.9	22.1 ± 5.5	.266
Open Mindedness	38.3 ± 3.2	37.9 ± 2.9	.496
State Anxiety	31.8 ± 7.7	32.9 ± 7.1	.583
Trait Anxiety	38.8 ± 8.4	41.2 ± 8.1	.159

* - Significant

SDNN - Standard Deviation of NN intervals; pNN50 - Percentage of consecutive NN intervals greater than 50 msec. LF - Low Frequency; HF - High Frequency; LF/HF – Ratio of Low Frequency over High Frequency

Table 2: Spearman's Correlation Coefficient of HRV with different parameters.

	SDNN	pNN50	LF	HF	LF/HF
Fat percent (%)	.080.557	.102.456	-.240.075	.180.184	-.229.090
Muscle content (kg)	-.094.492	-.157.247	**.296.027**	**-.287.032**	**.340.010**
Total Body Water (%)	-.036.790	.013.924	.213.115	-.148.275	.234.083
vO_2max (ml/kg/min)	**.293.029**	.008.952	-.042.758	.098.472	-.154.258
Extraversion	**.425.001**	.159.241	-.055.685	.037.786	-.049.718
Agreeableness	.036.793	-.104.444	.175.198	-.163.230	-.034.803
Conscientiousness	**.371.005**	**.273.042**	-.182.180	.111.413	-.193.153
Neuroticism	-.137.315	-.110.420	.069.613	-.079.565	.117.388
Open Minded	-.089.515	.001.995	.154.256	-.215.112	.133.327
State Anxiety	-.191.160	-.127.350	**.287.032**	-.218.107	.093.493
Trait Anxiety	-.133.327	.025.856	.056.679	.023.866	.078.567

SDNN – Standard Deviation of NN intervals; pNN50 – Percentage of consecutive NN intervals difference greater than 50 msec.; LF - Low Frequency; HF - High Frequency; LF/HF – Ratio of Low Frequency over High Frequency

Table 3: Multiple linear regression analysis to evaluate possible predictors of SDNN and LF/HF.

	R	R^2	F (14,41)	Sig F-chg	Beta	t-value	p-value	**Collinearity Statistics**	
								Tolerance	**VIF**
SDNN (ms)	.644	.415	2.075	.035					
Age (years)					.102	.754	.455	.783	1.277
Height (cm)					-.097	-.393	.696	.237	4.224
Weight (kg)					.147	.582	.564	.223	4.481
Fat percent (%)					.024	.139	.890	.493	2.029
Muscle content (kg)					-.402	-2.026	.049	.362	2.765
Total Body Water (%)					.031	.237	.814	.815	1.227
vO2max (ml/kg/min)					.424	2.721	.010	.587	1.703
Extraversion					.252	1.732	.091	.677	1.478
Agreeableness					-.026	-.179	.859	.672	1.489
Conscientiousness					.257	1.685	.100	.611	1.635
Neuroticism					.032	.200	.842	.564	1.773
Open Minded					-.223	-1.626	.112	.760	1.316
State Anxiety					.022	.119	.906	.416	2.405
Trait Anxiety					.025	.140	.889	.454	2.202
LF/HF (n.u)	.646	.417	2.096	.033					
Age (years)					-.107	-.792	.433	.783	1.277
Height (cm)					.641	2.614	.012	.237	4.224
Weight (kg)					-.282	-1.119	.270	.223	4.481
Fat percent (%)					-.061	-.361	.720	.493	2.029
Muscle content (kg)					.319	1.607	.116	.362	2.765
Total Body Water (%)					.146	1.106	.275	.815	1.227
vO2max (ml/kg/min)					-.477	-3.066	.004	.587	1.703
Extraversion					.066	.452	.654	.677	1.478
Agreeableness					-.146	-1.006	.320	.672	1.489
Conscientiousness					-.029	-.189	.851	.611	1.635
Neuroticism					.014	.086	.932	.564	1.773
Open Minded					.166	1.213	.232	.760	1.316
State Anxiety					-.020	-.107	.916	.416	2.405
Trait Anxiety					-.031	-.176	.861	.454	2.202

SDNN – Standard Deviation of NN intervals
LF/HF – Ratio of Low Frequency over High Frequency

Sports such as cycling, swimming, track & field (distance), hockey are primarily based physiologically on aerobic energy system and are thus referred to as endurance sports in the present study. Our results support the hypothesis that correlation does exist between HRV and personality traits and physiological parameters in endurance sport athletes. Extraversion trait of personality reflects an individual's response to positive stimuli and is indicative of assertiveness, excitement and gregariousness [13].We found

moderately positive significant relationship between extraversion and conscientiousness personality type and SDNN ($p<0.01$) and between conscientiousness personality type and pNN50 ($p<0.05$).

In order to further examine the relationship between heart rate variability (HRV) measures and body composition, physiological and psychological parameters linear multiple regressions were performed to evaluate the possible predictors of SDNN and LF/HF parameters of HRV as shown in Table 3. The first multiple regression model used SDNN parameter of HRV as the dependent variable, and age (years), height (cm), weight (kg), fat percent (%), muscle content (kg), total body water (%), vO_2max (ml/kg/min), big five traits of personality and state and trait anxiety as independent variables. Results showed that all of these predictors produced $R=0.644$, $R^2=0.415$, $F(14,41)=2.075$, $p=0.035$, stating that all independent variables explained 41.5 % of their SDNN. However, beta coefficients indicate that only muscle content (beta=-0.402, t=-2.026, p=0.049) and vO_2max (beta=0.424, t=2.721, p=0.010) significantly predict SDNN. Second linear multiple regression was performed with LF/HF ratio of HRV as dependent variable, and age (years), height (cm), weight (kg), fat percent (%), muscle content (kg), total body water (%), vO_2max (ml/kg/min), big five traits of personality and state and trait anxiety as independent variables. Results showed that all of these predictors produced $R=0.646$, $R^2=0.417$, $F(14,41)=2.096$, $p=0.033$, stating that all independent variables explained 41.7 % of LF/HF. However, beta coefficients indicate that only height (beta=0.641, t=2.614, p=0.012) and vO_2max (beta=-0.477, t=-3.066, p=0.004) significantly predict SDNN.

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Multiple linear regression of SDNN shows that variables like age, height, weight, fat percent, muscle content, total body water, aerobic capacity, personality traits and anxiety are major predictors of SDNN ($R^2=.415$). Muscle content, open mindedness and agreeableness had negative impact on SDNN unlike the other variables. Aerobic capacity (vO_{2max}), extraversion and consciousness had the most positive effect on SDNN among all the parameters. Multiple linear regression analysis of LF/HF shows that all the above variables predict LF/HF with R^2 value of 0.417. Height, muscle content, total body water and open mindedness had positive impact on LF/HF ratio. Whereas, age, weight, vO_{2max} and agreeableness had the most negative impact of all variables on LF/HF ratio.

We found significantly positive relationship between vO_2max and SDNN ($r=0.293$, $p<0.05$) parameter of HRV. In 2013, Grant et al. found significant correlation between only one parameter of HRV (pNN50) and vO_2max. They stated that this might indicate that relation between vO_2max and HRV may exist mainly due to heart rate and not variability in heart rate. Regression analysis proved this hypothesis, in which out of all parameters (HR, RR, RMSSD, pNN50, LF, HF, LF/HF, SD1 and SD2) heart rate was found to be most important predictor of vO_2max [15]. Skeletal muscle content showed a weakly positive correlation with LF/HF ratio for endurance athletes. HF HRV which is an important marker for parasympathetic inhibition over sympathetic control has been found to be related to markers for muscle content, central adiposity and physical activity levels [16]. In a study conducted on sedentary individuals, no correlation was found between vO_2peak and spectral components of HRV, only a weak relationship was found between vO_2peak and SDRR. In another study, high correlation between vO_2peak and non-normalized HF power was seen among men and women having varying levels of fitness [17]. Dishman et al. reported that heart rate variability may be sensitive to recent experiences of emotional stress, but not affected by their levels of physical fitness [18].

Positive correlation was found between state anxiety and LF ($r=0.287$, $p=0.032$) component of HRV which is representative of sympathetic control of autonomic nervous system in endurance athletes. In a study conducted on physically active adults of age 25-40 years, no relationship was found between trait anxiety and HF and LF components of HRV [18-20]. Positive correlation of physical aggression with SDNN, LF and VLF variables of HRV which are indicative of sympathetic activity. Negative correlation of openness was reported with RMSSD and HF measures of HRV. A more developed and mature character is related with parasympathetic activity [21-23].

CONCLUSION

The present study is a novel study in endurance athletes to understand the fluctuations in heart rate variability due to athlete's body composition, aerobic capacity, personality type as evaluated using Big Five Personality Inventory and levels of state and trait anxiety as evaluated by STAI. Body composition

parameter of muscle content, aerobic capacity, personality traits of extraversion and conscientiousness and state anxiety were found to have significant effects on time domain and frequency domain parameters of heart rate variability (HRV). However, it is suggested to replicate the study on a greater sample size and athletes from different regions to make the results more generalizable.

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