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Relative Indicators and Predicative Ability of Some Biological Variables on Cardiac Neural Activity for Volleyball Players

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ABSTRACT

The current research aims to study the relative indicators and predictive ability of some biological variables for the cardiac neural activity of volleyball players. The researchers used the descriptive approach as it is suitable for these research objectives. The researchers used the descriptive approach as it is suitable for these research objectives. Results indicated that:

• There are positive correlations between biological variables and Heart Rate Variability for the following variables: VC max – PEF – VC – EV – IV – HR max – CO2 max. These variables are considered as indicators for evaluating the functional training status of volleyball players.

• Relative contribution of biological variables was between (31.40%) as the least value fir VC max and (97.25%) as the highest value for the following nine variables: VC max + PEF + VC + EV + IV + HR max + VO2 max + CO2 max. these variables contribute collectively in HRV for volleyball players.

• *Cumulative Power predicative equation came as follows: HRV = 21.213 + (20.217 x VC max) + (10.652 x PEF) + 22.848 x VC) + (4.349 x EV) + (406.199 x IV) + (227.298 x IC) + (3.650 x HR max) + (762.457 x VO2 max) + (142.634 x CO2 max).*

Keywords: Cardiac Neural Activity – HRV - Cardio-respiratory Fitness - Volleyball

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INTRODUCTION

Regular involvement in physical activity induces several positive physical and physiological changes. These exercise-induced positive changes are called adaptations where regular physical exercise forces different body systems to adapt to changes. This makes the individual more fit than before. Sports training researchers agreed that it is necessary to identify tools for assessing the effects of sports training loads on the training process that aims to improve competitive performance. This is useful for designing training programs suitable for improving physical fitness and achieving physiological adaptation[(1)].

Volleyball is a competitive sport that requires aerobic physical fitness supported with flexibility and muscular power. High levels of aerobic physical fitness are very important for improving performance. It is practiced when the player contacts the ball and participates with other teammates. Volleyball improves cardiac fitness variables related to health[(2, 3)]. The functional status of internal body systems and the efficiency of the cardio-respiratory system are major components for life and physical fitness that contribute greatly to judging the individual's general efficiency. Cardiorespiratory Fitness (CRF) reflects the ability of lungs, heart, muscles, blood, and other body organs and systems to transfer and use O2 through aerobic metabolic paths and therefore identify the physical level[(4-6)]. Regular training improves respiratory and functional fitness although improvement level depends on training intensity and performance duration for each training session in addition to total training duration. The respiratory system has several functions including a gas exchange between the blood and surrounding atmosphere and regulating blood pressure and body temperature. Heart Rate Variability (HRV) is important in sport and training as it refers to evaluating autonomous neurological changes accompanying short-term and long-term exercise in all competitive sports[(7)]. HRV can be used to identify overtraining. Regular aerobic exercise improves HRV variability. Therefore, using HRV can help to organize training loads as it identifies the relationship between physical training and suitability of its intensity. This can detect the improvements in physical fitness during and after training and at rest [(8-10)].

To measure cardio-respiratory fitness, we use maximum oxygen consumption (VO2 max), usually expressed as O2 per liter in one minute for each kilogram of body weight [(11)]VO2 max is widely used in sports training physiology. It is repeatedly used to express the cardio-respiratory fitness of individuals as it expresses body consumption of oxygen during training[(10, 12)]. Evaluating cardio-respiratory fitness through using VO2 max, the minimum velocity for reaching VO2 max (vVo2 max), the velocity of blood lactate accumulation (VOBLA), the ability for repetitive performance and other blood measurements help identifying biological changes induced by physical activity and body ability for recovery after training or competition loads[(4, 10, 13, 14)]. Cardio-respiratory fitness (CRF) can be measured by oxygen consumption during maximum exercises (VO2 max) and pulmonary volume. Nevertheless, VO2 max tests are affected by multiple limitations that require retesting heart rate during effort like running or riding a bike and under specific performance conditions. CRF is a distinctive tool for physical fitness as it distinguishes players who are more affected by training loads with better heart rates [14, 15]. Burke, Meyer (16); Stodden, Gao (17); Kantomaa, Stamatakis (18); Barrick, Parks (19) indicated that improving CRF reflects positively on maintaining a healthy body, cardio-vascular fitness, respiratory system, correcting some incorrect motor habits, providing the individual with good coordinated posture and increasing the immune response. Cardio-respiratory fitness is considered as the base upon which we can establish motor performance for prolonged periods. It affects improvements in performance levels as acquiring CRF is a basic objective for sports training programs because it is consistent with the principle of continuous training for improving training conditions and variable motor power while directing the ball both in defense and attack. This variable motor power is greater during game rounds intercepted by shorter periods of rest that are not sufficient for a full recovery. To continue this type of effort effectively and efficiently, the player should be abler to sustain a high level of CRF that enables him/her to adapt to changing conditions of the match. Teams with better physical fitness compared to their counterparts can change defeat into victory during game rounds. Due to the significance of cardio-respiratory fitness that indicates the ability of the heart and the circulatory system to pump and transfer the maximum amount of oxygenated blood to working muscles to where oxygen is extracted and energy is generated, the researchers noticed that this topic was not sufficiently studied in Arabic research works concerning volleyball. Therefore, the researchers tried to explain the relationship between variations of cardiac neural activity and some biological variables related to cardiorespiratory fitness in volleyball players.

AIM

The current research aims to study the relative indicators and predicative ability of some biological variables for cardiac neural activity of volleyball players.

RESEARCH QUESTIONS

- What are the relative contributions of some biological variables in cardiac neural activity of volleyball players?
- What is the predicative ability of some biological variables for cardiac neural activity of volleyball players?

MATERIALS AND METHODS

Approach:

The researchers used the descriptive approach as it is suitable for this research objectives.

Participants:

The researchers purposefully recruited (30) volleyball players, who are registered in the Egyptian Federation of Volleyball, as a sample for this research.

Table 1: Participants Equivalence on Growth Factors for Homogeneity (n=30)

S	Variables	Measurements	Mean	Median	SD	Kurtosis	Squewness
1	Age	Month/Year	19.630	19.500	1.768	0.621	0.373
2	Height	Cm	182.000	181.500	7.172	1.326	0.209
3	Weight	Kg	74.680	75.000	9.934	0.897	-0.097
4	Experience	Month/Year	5.460	6.500	0.778	0.924	-0.668

Standard Error for Squewness = 0.427 ***Squewness Limit on 0.05 = 0.837***

Table (1) showed mean, median, SD, squewness and kurtosis for all participants on growth factors. Squewness values were between (±3) indicating normality of data and homogeneity of participants as data is free of radical distributions.

Data Collection Tools

For this research, the researchers used the following tools and measurements:

A Restameter (for measuring heights)

An electronic balance (for measuring weights)

ECG Monitor [Varia Cardio TF4 (MIE)]

Electronic spirometer (for lung function)

For vital functions, the researchers used [Oxycon Pro JAEGER (GER)] device attached to a treadmill (LE 200 CE) and connected to an operating system.

For Heart Rate Variability Tests (HRV), after attaching the measuring unit to the chest belt, the player lays down on his/her back for (5) minutes, stands up for (5) minutes and then lays back again for (5) minutes. This is a simple test recently used in the medical field for predicting heart diseases in advance. In the sports field, it is used for predicting cardio-respiratory fitness, the training type effect and the sympathetic/para-sympathetic effects. On ECG, the peak shows the stability curve while heart rate appears at the end of the screen.

Heart Rate Variability Variables

Cardiac neural system cumulative power (Cumulative Power).

Total power of high and low frequencies (Total Power).

The time elapsed between two successive R-waves of the QRS signal on the electrocardiogram (R-R)

Cardiovascular recovery room (CVr-r)

Mitral Valve Test (MV)

Adjacent Normal R-R intervals (MSSD)

Biological Variables:

Vital Capacity (VC)

Expiratory Reserve Volume (ERV)

Inspiratory Reserve Volume (IRV)

Lung Total Volume (TV)

Inhale Capacity (IC)

Full Vital Capacity (FVC)

Peak Exhale Flow (PEF)

Peak Inhale Flow (PIF)

Pulse Rate (rest – anaerobic – max)

Oxygen pulse (rest – anaerobic – max)

Oxygen consumption (VO2) (rest – anaerobic – max)

CO2 Production (rest – anaerobic – max)

Pulmonary Ventilation (VE) (rest – anaerobic – max)

Research Measurements

After receiving signed consents from all participants, and after fulfilling all administrative and scientific requirements the researchers took the research measurements and tabulated data for statistical treatment. All of the steps get ethics approval from the hospital of Suez Canal university committee before starting this study

Statistical treatments

The researchers used SPSS (V 16) for generating: Mean – Median – SD – Kurtosis – Squewness – F test – Relative Contribution (%) – Pearson's correlation coefficient – Stepwise Regression – Graphs

RESULTS

Table 2: Simple Correlation Matrix for Biological Variables with Cumulative Power (n=30)

Tests	VC	PIF	PEF	TV	IC	FVC	ERV	IRV	HR rest	HR anaerobic	HR max	VO2 rest	VO2 anaerobic	VO2 max	O2 pulse rest	O2 pulse anaerobic	O2 max	CO2 rest	CO2 anaerobic	CO2 max	VE rest	VE anaerobic	VE max
VC																							
PIF	0.58																						
PEF	0.04	0.59																					
TV	0.46	0.59	0.09																				
IC	0.50	0.25	0.70	0.15																			
FVC	-0.0	0.05	0.27	0.52	0.32																		
ERV	0.34	0.29	0.33	0.02	0.26	0.19																	
IRV	0.67	0.32	0.07	0.13	0.08	0.06	0.76																
HR rest	0.22	0.13	0.22	0.08	0.29	0.05	0.91	0.77															
HR anaerobic	0.18	0.09	0.17	0.48	0.17	0.72	0.58	0.21	0.38														
HR max	0.88	0.27	0.24	0.27	0.60	0.13	0.21	0.71	0.25	0.06													
VO2 rest	0.31	0.19	0.02	0.20	0.09	0.12	0.72	0.76	0.80	0.29	0.49												
VO2 anaerobic	0.05	0.20	0.30	0.41	0.61	0.54	0.56	0.55	0.70	0.33	0.14	0.51											
VO2 max	0.45	0.20	0.40	0.23	0.67	0.39	0.42	0.16	0.65	0.06	0.27	0.51	0.71										
O2 pulse rest	0.04	0.30	0.44	0.37	0.71	0.39	0.69	0.57	0.74	0.14	0.03	0.49	0.96	0.67									
O2 pulse anaerobic	0.17	0.41	0.65	0.15	0.20	0.23	0.27	0.13	0.10	0.42	0.10	0.07	0.03	0.16	0.06								

$O2_{max}$	0.31	0.18	0.09	0.42	0.54	0.70	0.19	0.04	0.30	0.44	0.23	0.25	0.73	0.64	0.65	0.14							
$CO2_{rest}$	0.45	0.08	0.02	0.33	0.27	0.70	0.07	0.34	0.10	0.30	0.61	0.56	0.30	0.09	0.18	0.23	0.37						
$CO2_{anaerobic}$	0.41	0.31	0.36	0.33	0.47	0.01	0.58	0.07	0.49	0.45	0.47	0.49	0.31	0.62	0.44	0.36	0.44	0.04					
$CO2_{max}$	0.75	0.43	0.21	0.01	0.21	0.11	0.69	0.90	0.69	0.39	0.77	0.71	0.32	0.10	0.34	0.14	0.27	0.33	0.02				
VE_{rest}	0.17	0.07	0.06	0.06	0.14	0.55	0.37	0.57	0.66	0.29	0.49	0.74	0.75	0.69	0.59	0.04	0.49	0.57	0.11	0.52			
$VE_{anaerobic}$	0.26	0.36	0.40	0.48	0.34	0.75	0.04	0.41	0.14	0.64	0.40	0.23	0.64	0.27	0.56	0.05	0.33	0.57	0.17	0.31	0.59		
VE_{max}	0.32	0.30	0.24	0.63	0.39	0.55	0.63	0.56	0.63	0.17	0.28	0.54	0.87	0.45	0.86	0.23	0.74	0.51	0.33	0.36	0.60	0.52	
Cumulative Power	0.75	0.73	0.74	0.24	0.71	0.84	0.79	0.03	0.19	0.26	0.68	0.01	0.36	0.65	0.11	0.12	0.22	0.31	0.28	0.64	0.35	0.28	0.30

R table Value on 0.05 = 0.361

Table (2) showed the simple correlation matrix of biological variables on the cumulative power. R calculated values ranged from (0.01) to (0.84)

Table 3: Stepwise Regression for Biological Variables on Cumulative Power (n=30)

Indicators	Standard Error	Constant	F	Stepwise Regression									Relative Contribution (%)
FVC	3.529	3.959	268.932	41.642									31.40
FVC + PEF	3.921	6.297	343.431	39.895	17.331								45.20
FVC + PEF + VC	2.785	7.126	200.004	34.893	16.734	28.736							56.10
FVC + PEF + VC + EV	1.976	11.322	296.021	30.896	15.882	27.047	8.423						65.20
FVC + PEF + VC + EV + IV	2.313	13.131	321.615	27.467	14.128	26.813	7.266	573.118					72.80
FVC + PEF + VC + EV + IV + IC	2.093	15.404	378.216	25.364	13.967	25.344	6.531	539.545	334.152				79.70
FVC + PEF + VC + EV + IV + IC + HR_{max}	3.642	16.294	389.970	23.567	13.158	24.479	6.327	486.423	298.637	3.997			86.50
FVC + PEF + VC + EV + IV + IC + HR_{max} + $VO2_{max}$	4.514	17.237	426.214	21.153	11.786	23.078	5.712	437.358	265.235	3.811	782.626		92.40

FVC + PEF + VC + EV + IV + IC + HR_{max} + $VO2_{max}$ + $CO2_{max}$	4.677	21.213	462.056	20.217	10.652	22.848	4.349	406.199	277.298	3.650	762.457	142.634	97.25

Table (3) showed stepwise regression and R2 adjusted in nine cases for contributing indicators (biological variables) on cumulative power.

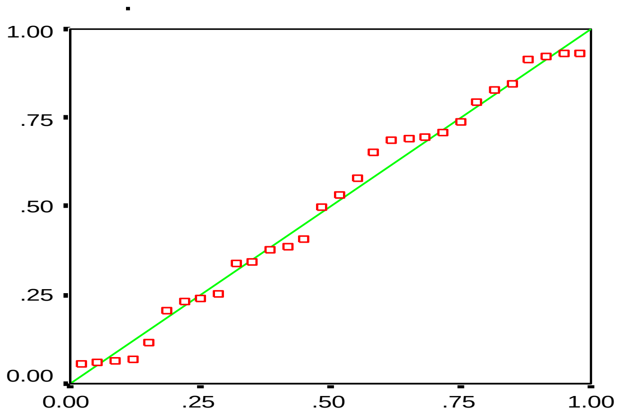

Fig 1: Stepwise Regression for all research variables

DISCUSSION

Table (2) showed the statistical significance of correlations between the biological variables and cumulative power on 0.05. R table value (0.361) was less than its calculated values ranging from (0.01) to (0.84). this indicates a positive relation between cumulative power and the following variables: maximum vital capacity (VC max) (0.84) – Peak expiratory flow (PEF) (0.79) – vital capacity (VC) (0.75) – inhale volume (IV) (0.73) – exhale volume (EV) (0.74) – inhale capacity (IC) (0.71) – maximum heart rate (HR max) (0.68) – maximum oxygen consumption (VO2 max) (0.65) – maximum CO2 production (CO2 max) (0.64). also, cumulative power didn't show any significant correlations with the rest of the biological variables under investigation. This means that heart rate variability (HRV) correlates with nine physiological variables as a result of sports training as it affects maximum vital capacity (VC max), Peak expiratory flow (PEF), vital capacity (VC), inhale volume (IV), exhale volume (EV), inhale capacity (IC), maximum heart rate (HR max), maximum oxygen consumption (VO2 max) and maximum CO2 production (CO2 max). Some studies indicated some biological effects for cardio-respiratory fitness on heart rate variability as HRV is closely related to the VO2 max and ventilation threshold[4, 20, 21]. Other researchers indicated that PIF and PEF are indicators for a pulmonary function that can identify any obstructions in the bronchioles in athletes. Therefore, it is a measurement for the health of the lungs and airways[10, 22].

Table (3) showed stepwise regression of some biological variables on HRV for volleyball players that contributed most in HRV. In nine steps, the first step identified VC max (31.40%) as the least value while the ninth step identified nine variables (FVC + PEF + VC + EV + IV + IC + HR max + VO2 max + CO2 max) (97.25%) as the highest value.

The researchers think that the values of biological markers for all participants are above normal and this indicates the improved pulmonary function as this improvement is a positive side for providing the body with sufficient oxygen to produce energy via the respiratory system. The contribution of high VC max in HRV is the result of its physiological work. This is considered an indicator of lung health. Also, the cardiac system and the respiratory system are closely connected and affect each other. Well-designed sports training programs decrease heart rate and respiratory rate, and this improves the cardio-respiratory function. This may be due to the excessive activity of the parasympathetic system that inhibits heart rate and respiratory rate to the increased cardio-respiratory functional volumes[4, 14, 23, 24].

Regular aerobic exercises improve HRV. The results of this study indicated that HR at rest and after effort reflects the increased activity of nerves in a change in favor of the parasympathetic system that inhibits HRV. Therefore, regular exercise for at least three months is very important to induce these effects that are positively reflected on biological reactions to training loads [9, 13, 14].

The integration of different systems like the cardio-respiratory system and neuromuscular system is very important for providing active tissues with oxygen and eliminating CO2 and heat during training as this increases oxygen extraction in working muscles. This also increases ventilation that provides the body with extra oxygen. Also, it increases blood flow from 5.5 l/min to 20-30 l/min and increases total oxygen volume from 250 ml/min at rest to 4000 ml/min. CO2 elimination also increases from 200 ml/min to nearly 8000 ml/min[4, 10, 25, 26].

Previous studies indicated that HRV changes during and after exercise. It can be used to identify the effect of training load on the body and physiological level after exercise.

Changes in HRV are good indicators for guiding training management, training loads and volumes, and changes parasympathetic system *ANS) [27]. HRV data provides sports training specialists with relevant information about post-exercise recovery and the effects of training loads on recovery [28]. VO2 max shows oxygen consumption through physical loads during exercise. Therefore, it is repeatedly used to show cardio-respiratory fitness [12, 13, 29].

Figure (1) showed that most points are either on or near the line. This indicates the normal distribution of standard residuals for regression of biological parameters on HRV. Stepwise regression for the nine models indicated a positive correlation as there is a linear correlation between biological variables and cumulative power. Independent variables had positive effects. The stepwise regression equation shows the value of B factor and F value in addition to the constant.

HRV at rest and after effort provide accurate evaluation for cardio-respiratory adaptation to training[30]. Well-designed training programs decrease HR/min and the reason behind this improvement is the increased activity of the parasympathetic system that decreases HR at rest and improves HRV, leading to work economy[13, 23]. Cardio-respiratory fitness expresses harmony in the functional work of the cardiovascular system, the respiratory system, joint flexibility, and musculoskeletal fitness. All these components provide a high degree of functional work harmony for all body systems and this fulfills the integrated framework of mental and functional health of the individual [17, 31, 32].

Results also indicated that the mean vital capacity was higher than normal. For the volume of gas in one inspiratory/expiratory cycle (TV), values were between 400-600 ml. this is a physiological advantage for participants [33]. Heart rate is the result of pushing blood from the aorta, stimulating a wave of pressure over the artery walls that dilate the artery. Each push is a beat. The duration of the cardiac cycle is affected by the change in heartbeats. In the case of 75 BPM, the cardiac cycle duration is 0.8 sec. With the increase to 200 BPM, the cardiac cycles become 0.3 sec. In turn, systolic/diastolic activity decreases. This means that push volume becomes heavier with the increase of HR[25, 34].

The researchers think that increased oxygen consumption and CO2 production is consistent with the increased effort and energy production. HR is significantly correlated with energy storage and energy production. Increases in body volume and body weight also increase VO2 max [10, 35]. Accordingly, the researchers concluded the relative contribution and HRV predictive equation (Cumulative power) concerning cardio-respiratory fitness variables in volleyball players.

CONCLUSION

According to this research aim, methods, and results, the researchers concluded the following:

1. There are positive correlations between biological variables and Heart Rate Variability for the following variables: VC max – PEF – VC – EV – IV – HR max – CO2 max. These variables are considered as indicators for evaluating the functional training status of volleyball players.
2. Relative contribution of biological variables was between (31.40%) as the least value fir VC max and (97.25%) as the highest value for the following nine variables: VC max + PEF + VC + EV + IV + HR max + VO2 max + CO2 max. these variables contribute collectively in HRV for volleyball players.
3. Cumulative Power predicative equation came as follows: HRV = 21.213 + (20.217 x VC max) + (10.652 x PEF) + 22.848 x VC) + (4.349 x EV) + (406.199 x IV) + (227.298 x IC) + (3.650 x HR max) + (762.457 x VO2 max) + (142.634 x CO2 max).

RECOMMENDATIONS

According to these conclusions, the researchers recommend the following:

- Using the biological variables that are closely related to HRV like: VC max - PEF - VC - EV - IV - HR max - VO2 max - CO2 max, to evaluate cardio-respiratory fitness of volleyball players.
- Using the concluded predicative equation to identify the cardio-respiratory fitness levels for volleyball teams.
- Improving cardio-respiratory fitness depending on the type and method of training to improve cardio-respiratory endurance.
- Studying biological changes and functional responses in volleyball through modern laboratory and field measurements.
- Identifying biological changes and functional responses that contribute most in fulfilling volleyball training objectives to design and control training loads.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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