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The Effect of the Change in Diastolic Blood Pressure According to Energy Production Systems in Terms of Some Heart Variables among Volleyball Players

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Abstract: *The research aims to identify the effect of the change occurring in diastolic blood pressure according to the energy production systems in terms of some heart variables in volleyball players by determining (the amount of change occurring in all heart muscle measurements after performing each effort according to the energy production systems of volleyball players, the effect of the change The incidence in diastolic pressure as a function of some heart variables after several efforts according to energy production systems. The researcher used the descriptive approach to suit the nature of the research. The researcher selected a deliberate sample of (12) students from the specialized schools affiliated with the Ministry of Youth and Sports for volleyball in Baghdad - Iraq. The researcher relied on Energy production systems (phosphate, lactic, and aerobic) in measuring cardiac variables. One of the most important conclusions was that there were statistically significant differences between the two measurements (before effort - after effort) in the phosphate energy production system in some heart variables. There were statistically significant differences between the two measurements (before Effort - after effort) in the lactic energy production system in some heart variables. There are statistically significant differences between the two measurements (before effort - after effort) in the aerobic energy production system in some heart variables. One of the most important recommendations was the necessity of conducting periodic and field measurements of pulse rate and pressure. Blood tests after the training units to determine the extent of the internal impact on cardiac muscle variables as a result of daily training.*

Keywords: *(diastolic blood pressure, energy production systems, cardiac variables)*

1. INTRODUCTION

The science of training and sports physiology is crucial, as physical exertion has captivated scientists since past centuries. They have studied how the body functions during physical effort, observing and documenting the changes it undergoes, particularly the positive effects of daily sports activities.

Sports training physiology is fundamental in the field of sports training, where studies and research have achieved qualitative leaps in meeting the requirements of athletic excellence and enhancing the physical and functional levels of athletes.

Researchers have obtained significant physiological information and facts, contributing to the regulation of training loads to suit the body's capacity, maximizing positive effects and avoiding negative impacts on functional and health status (Abdulfattah, 2003: 3).

Many physical and motor activities performed by athletes revolve around one of the energy production systems continuously. It is known that sports activities and games include varying proportions of energy systems. Conducting functional tests on the heart muscle is essential to understand its response to efforts according to energy production systems. The concepts of using and developing the energy systems in the athlete's body and the accompanying functional variables have played a significant role in this development to achieve functional adaptation. Physiological tests and measurements are clear indicators of the adaptation level of vital organs through their response to physical loads. This research involves physiological tests and measurements of the heart muscle, reflecting the adaptation level caused by training programs, achieving training goals, and understanding the response of blood pressure to changes in physical effort through heart muscle measurements (Khuraibit, 1995: 88-89).

Landor (2013) states that energy in the human body is the driving source for muscle contraction and athletic performance of all kinds. The energy required for each muscle contraction or athletic performance varies. The energy needed for rapid muscle contraction differs from that needed for sustained muscle contraction over a long period. The body has different systems for producing fast or slow energy depending on muscle needs and the nature of athletic performance. It is crucial for trainers or educators to scientifically understand how energy systems work in the athlete's body to build the training process on this knowledge. Training energy production systems and enhancing their efficiency means improving the body's energy production efficiency, thus enhancing athletic performance. Modern sports training programs focus on developing and understanding the application of energy production systems, which has become the language of contemporary sports training and the direct approach to improving athletic performance without wasting time and effort on unrelated training directions.

Sports training science relies on understanding energy production in athletes and its relationship to the type of movement and specialized athletic activity. Adenosine triphosphate (ATP) is the primary source of energy production in all body cells, a chemical compound capable of participating in various energy supply reactions for muscles. There are three energy systems, all of which supply muscles with ATP, differing in their methods and quantities of producing this enzyme. These systems are:

Anaerobic System (Phosphagenic): This system is essential for training athletic activities relying on anaerobic energy production, necessary for speed training. It depends on ATP and phosphocreatine (CP) without significant oxygen involvement. The amount of ATP in muscles, even in well-trained athletes, is insufficient to sustain maximum muscle power for more than three seconds. Many sports activities rely primarily on anaerobic endurance, such as sprinting, necessitating continuous ATP production, starting with CP after ATP depletion in muscles. CP is another high-energy phosphate compound.

Lactic System (Glycogen and Lactic Acid): Many sports activities fall within the lactic system for energy production. Anaerobic training largely depends on this system by developing anaerobic endurance and increasing the body's anaerobic capacity. The lactic acid system starts working after CP breakdown and continues for about 1.3 to 1.6 minutes, covering activities ending within this time. This process involves the breakdown of stored glycogen in muscles into glucose, used for energy generation without oxygen. Each glucose molecule breaks down into two pyruvic acid molecules, releasing energy and producing four ATP molecules from each original glucose molecule. When muscle oxygen depletes, pyruvic acid oxidizes into lactic acid, spreading into intercellular fluid and blood. Most muscle glycogen converts to lactic acid, causing severe fatigue due to accumulation but producing significant ATP energy without oxygen. This system completes ATP production after a maximum of 1.6 minutes plus 10 seconds for the phosphagen system.

Aerobic System (Oxygenic): The aerobic system relies on external oxygen in its operation. Athletic activities lasting relatively long periods operate within this system due to sufficient time for inhaled oxygen to reach working muscles via blood.

This system begins working in activities lasting about two minutes or more, providing energy by oxidizing nutrients in cells through glucose, fatty acids, and amino acids, generating large energy amounts from inhaled air. This energy continually converts ADP and AMP to ATP, sustaining energy for prolonged periods, as needed in long-distance running, requiring different development and growth from activities within other energy systems (Landor, 2013: 87-89).

Abu El-Ala Abdulfattah (2003) explains that the heart wall consists of three layers. The outer layer serves as the heart muscle's external cover, the middle muscular layer handles heart muscle contraction and blood pumping, and the inner layer lines the heart's interior. The coronary arteries supply blood to the heart muscle, branching from the aorta and surrounding the heart, with coronary veins running alongside. The coronary sinus vein collects all coronary blood, draining into the right atrium. Unlike skeletal muscles, the heart muscle contracts autonomously from within, with the sinoatrial node controlling heartbeats. All heart muscle fibers are slow-twitch with high aerobic capacity, containing many mitochondria and dense capillaries. The heart muscle resembles skeletal muscle in being striated, containing actin and myosin, and requiring calcium to activate filaments (Abdulfattah, 2003: 3).

TOMOSN (2011) explains that the heart is divided into four main chambers that contribute to regulating the pumping process, and each chamber is surrounded by a wall of a certain thickness, pumping blood in only one direction. The thickness of these chambers' walls depends on the workload they handle, with the left ventricle having the thickest wall because it undertakes the most substantial portion of pumping. These chambers are arranged in pairs: the atria receive blood through veins, and the ventricles push blood through arteries (TOMOSN, 2011: 10).

HASST (2007) notes that a set of valves governs the process of receiving and delivering blood to and from these chambers. The heart is covered by a thin membrane called the pericardium, which contains a liquid substance that facilitates its movement. To maintain the heart's function, there is its own nervous system that helps regulate its contractions from the initial signal formation until it reaches the heart muscle. It also receives branches from nerves outside the heart muscle, originating from the autonomic nervous system and its sympathetic and parasympathetic divisions (HASST, 2007: 10).

Robert (2013) states that cardiac output (C.O.) is the amount of blood the left ventricle pumps into the aorta (to the body) or the right ventricle into the pulmonary artery (to the lungs). The ventricles pump the same amount of blood in a specific time frame (Robert, 2013: 25).

Huonker (2010) adds that cardiac output is the amount of blood the heart pumps per minute, measured in liters or milliliters, specifically the blood pumped from the left ventricle, ranging between 5-6 liters per minute. Shephard (2005) clarifies that cardiac output depends on two factors: stroke volume (the amount of blood ejected by the heart in one beat) and heart rate (the number of heartbeats per minute). Cardiac output can be expressed by the formula: Cardiac Output = Stroke Volume × Heart Rate. Research has shown that well-trained athletes have a significantly high stroke volume and a lower resting heart rate. During physical exertion, the heart muscle's response aligns with the level of adaptation and harmony during the exercise load. Hassan Hussein (2001) emphasizes that cardiac output relies on the amount of venous blood returning to the heart from various parts of the body; the more blood returning to the heart, the greater the cardiac output, which occurs during physical training (Hussein, 2001: 47).

Asrand (2015) mentions that stroke volume is the amount of blood ejected in one heartbeat from the left ventricle, ranging between 90-170 milliliters among athletes. This difference is due to the increased efficiency of the heart muscle and the circulatory system, resulting from improved physical fitness and the type and characteristics of the sports activity practiced by athletes. Modern equipment has shown that stroke volume does not increase significantly during exertion. The increase in cardiac output is due to the rise in heart rate, in addition to the increased diastolic capacity, closely related to returning blood. This situation does not significantly change during physical exertion (Asrand, 2015: 88).

Resan Khribit (1995) indicates that the physiological interpretation of heart size increase has taken divergent directions. X-ray methods have helped understand the impact of sports training on heart size since the early twentieth century. However, recently, it has been possible to understand the mechanism of heart size increase among athletes and, consequently, diagnose this phenomenon physiologically. The heart's size increases based on:

- Increasing the heart chamber's capacity
- Increasing the heart muscle's size
- Combining both, where the heart chamber's capacity and the heart muscle's size increase.

Among these reasons, the most common is the latter, where the enlargement of the heart chamber and the heart muscle size coexist. This hypertrophy, referred to as cardiac growth, results from the repeated pressure of blood on the heart muscle, causing the cardiac muscle to enlarge, increasing its weight due to the expansion of the skeletal muscle fibers. This expansion of the skeletal muscle fibers increases the area through which oxygen spreads along the capillaries, hindering its delivery to the muscle fiber center. This oxygen deficit could be a significant factor in fibrosis often occurring in the hypertrophied muscle. Through muscle fiber hypertrophy, the paths through which oxygen spreads lengthen, causing a disruption in oxygen delivery, which is essential for cardiac adaptation (Khribit, 1995: 88-89).

Due to the numerous requirements of volleyball, the player needs to develop both energy systems. The aerobic system's development provides a good background to facilitate anaerobic energy production, which the speed of performance in volleyball relies on. This research highlights the importance of understanding the changes in diastolic pressure due to varying exertions in terms of some important heart measurements.

2. RESEARCH PROBLEM

The researcher believes there is a difference between the impact of different energy systems on the training that players undergo. Each system has its cycle in energy production processes that differ from the other systems. This led the researcher to explore this field to understand the effect of energy systems on some cardiac functional variables and their impact on blood pressure, determining which system helps develop the player's functional abilities in both rest and exertion states. Through the researcher's experience with the effectiveness of energy production systems, the research problem is determined to study the cardiac muscle changes due to organized volleyball training. Thus, the research problem is evident in identifying the type of cardiac changes affecting diastolic pressure with varying exertions according to energy production systems.

3. RESEARCH OBJECTIVES

This research aims to identify the impact of energy production systems on diastolic blood pressure through some heart variables in volleyball players by:

- Determining the change in all cardiac muscle measurements after exerting effort according to energy production systems in volleyball players.
- Assessing the impact of diastolic pressure changes through some heart variables after several exertions according to energy production systems.

4. RESEARCH HYPOTHESES

- There are statistically significant differences between the measurements (before exertion - after exertion) in the phosphagen energy system in some heart variables.
- There are statistically significant differences between the measurements (before exertion - after exertion) in the lactic energy system in some heart variables.
- There are statistically significant differences between the measurements (before exertion - after exertion) in the aerobic energy system in some heart variables.
- There are statistically significant differences between the energy production systems (phosphagen, lactic, aerobic) after exertion in some heart variables.

5. RESEARCH PROCEDURES

5.1. Research Methodology

The researcher used the descriptive approach for its suitability to the nature of the research.

5.2. Research Population and Sample

The research population includes players from the specialized schools of the Ministry of Youth and Sports for volleyball in Baghdad, Iraq.

5.3. Research Sample

The researcher chose an intentional sample of 12 players from the specialized schools of the Ministry of Youth and Sports for volleyball in Baghdad, Iraq.

5.4. Conditions for Selecting the Research Sample

- Not participating in other programs.
- Regular training attendance.
- Training age of not less than three years.
- Participation in some junior championships.
- Consent to undergo physiological tests.

5.5. Data Collection Methods

5.5.1. Initial Measurements

The basic variables of the sample (under research) were measured in terms of age, height, weight, and training age to control variables that might affect the research procedures. The following table (1) illustrates this.

Table 1. *Statistical Indications of the Research Sample in Basic Variables before the Experiment*

Statistical Significance / Variables	Mesurement	Mean	Median	Standard Deviation	Skewness	Kurtosis
Age	Years	14.25	14.00	0.98	0.63	1.02
Height	CM	163.84	164.00	2.02	1.06	0.65
Weight	KG	62.30	6200	1.63	0.61	0.96
Training years	Years	2.70	0..2	0.23	1.78	-0.93

N=12

5.5.2. Statistical Significance

Table (1) illustrates the homogeneity of the research sample data in primary basic measurements, indicating that the overall research sample data is moderate and not dispersed, characterized by a normal distribution. The skewness coefficients range between (0.61 to 1.78), approaching zero. The kurtosis coefficient ranges from (-0.93 to 1.02), indicating that the curve's oscillation is acceptable, averaging rather than exhibiting high or low variability, thereby confirming the similarity among the research group members in primary variables.

Tests and Measurements Used in the Study:

The researcher conducted a comprehensive survey of references, scientific research, and previous studies to identify physiological tests, employing three (3) measurements across diverse energy systems. The researcher identified the following tests:

First: Physical Tests: Physical tests were conducted according to energy production systems as follows:

Phosphate System: Test Specifications

- Treadmill Speed: 16 km/h
- Incline Angle: 11 degrees (20%)
- Test Duration: 10 seconds
- Procedures: After adequate warm-up (5-10 minutes), the player mounts the treadmill. The treadmill starts gradually increasing speed until it reaches the specified 16 km/h. This allows the player sufficient time to work on the treadmill consistently and harmoniously. Upon reaching the target speed, timing is initiated by referees using two stopwatches. The player continues working on the treadmill until the end of the specified time period, after which the timing stopwatches are stopped.
- Recording: The player's time is recorded from the start of the test (treadmill reaching 16 km/h) until the end of the exercise.

Lactic System: Test Specifications

- Treadmill Speed: 13 km/h
- Incline Angle: 11 degrees (20%)
- Test Duration: Until the player reaches exhaustion.
- Procedures: After adequate warm-up (5-10 minutes), the player mounts the treadmill. The treadmill starts gradually increasing speed until it reaches the specified 13 km/h. This allows the player sufficient time to work on the treadmill consistently and harmoniously. Upon reaching the target speed, timing is initiated by referees using two stopwatches. The player continues working on the

treadmill until they reach severe exhaustion, unable to continue running on the treadmill, at which point the timing stopwatches are stopped.

- Recording: The player's time is recorded from the start of the test (treadmill reaching 13 km/h) until the cessation due to exhaustion.

Air System: Test Specifications:

- Treadmill Speed: 10 km/h
- Incline Angle: 11 degrees (20%)
- Test Duration: Until exhaustion.
- Procedures: After adequate warm-up (5-10 minutes), the player mounts the treadmill. The treadmill starts gradually increasing speed until it reaches the specified 10 km/h. This allows the player sufficient time to work on the treadmill consistently and harmoniously. Upon reaching the target speed, timing is initiated by referees using two stopwatches. The player continues working on the treadmill until the end of the specified time period, after which the timing stopwatches are stopped.
- Recording: The player's time is recorded from the start of the test (treadmill reaching 10 km/h) until the end of the exercise.

Second: Heart Measurements: Heart variable measurements were conducted using color Doppler echo before and immediately after exercise, with the device positioned at the test site to obtain accurate research results. The following variables were studied:

- LVEDD: Left ventricular end-diastolic diameter.
- LVESD: Left ventricular end-systolic diameter.
- LVPW: Left ventricular posterior wall thickness.
- IVS: Interventricular septum thickness.

Primary Study: The primary study was conducted from February 3, 2024, to February 17, 2024, over three days divided into three weeks. The researcher clarified the following:

- Day One: The first phosphate stress was conducted on February 3, 2024, at a school in Baghdad. The player warmed up before mounting the treadmill. The treadmill gradually increased in speed until reaching the designated test speed. This allowed sufficient time for the player to work on the treadmill consistently and harmoniously.
- Day Two: The second lactic stress was conducted on February 10, 2024, at a school in Baghdad, following the same procedure as Day One.
- Day Three: The third air stress was conducted on February 17, 2024, at a school in Baghdad, following the same procedure as Day One.

Statistical Processing Used

- Mean.
- Standard Deviation.
- Skewness Coefficient.
- Kurtosis Coefficient.
- T-test.
- Pearson Correlation Coefficient.
- Frequency and Percentage.
- Analysis of Variance (ANOVA).

6. PRESENTATION AND DISCUSSION OF RESULTS

Table 2. *Statistical Significance of the Research Sample in Heart Variables*

Statistical Significance Variables	Mean	Median	Standard Deviation	Skewness	Kurtosis
Left Ventricular Posterior wall Thickness (LVPM)	9.25	9.50	2.04	0.63	-1.39
Interventricular Septum Thickness (IVS)	8.14	8.60	1.74	1.75	0.89
Systolic Blood Pressure	15.80	15.50	1.36	1.08	-0.52
Diastolic Blood Pressure	7.95	8.00	1.04	1.39	1.60
Cardiac Output (C.O)	5395. 64	5340.0 0	17.63	2.94	0.67
Heart Rate (H.R)	65.35	64.00	1.85	1.97	0.63
Stroke Volume (S.V)	74.89	75.00	0.95	1.48	1.09
Left Ventricular End- Diastolic Diameter (LVEDD)	51.80	51.50	3.67	2.11	1.93
Left Ventricular End- Systolic Diameter (LVESD)	31.65	31.50	4.28	1.94	0.84

(N=12)

Table (2) shows the homogeneity of the research sample data in physiological measurements, indicating that the overall data of the research sample are moderate and not scattered, characterized by a normal distribution of the sample. The skewness values range between (0.63 to 2.94), approaching zero, while the kurtosis ranged from (-1.39 to 1.93). This indicates that the oscillation of the normal curve is considered acceptable and moderate, not oscillating upwards or downwards, confirming the similarity of individuals in the research group in heart variables.

Firstly, presenting and discussing the results of the first hypothesis, which states "there are statistically significant differences between the measurements (pre-exercise vs. post-exercise) in the phosphatic energy production system in some heart variables."

Table 3. *Statistical Significance of the (t) Test for Heart Variables between Measurements (Before Stress, After Stress) Phosphate*

Statistical Significance	After Stress		After Stress		t Value	Significance Level
Variables	+ Sign	+- Sign	- Sign	+- Sign		
Left Ventricular Posterior wall Thickness (LVPM)	9.25	2.04	12.90	1.08	5.57*	0.00
Interventricular Septum Thickness (IVS)	8.14	1.74	12.03	0.97	4.99*	0.00
Systolic Blood Pressure	15.80	1.36	19.82	1.84	5.31*	0.00
Diastolic Blood Pressure	7.95	1.04	8.69	0.88	3.60 *	0.00
Cardiac Output (C.O)	5395. 64	17.63	12864.80	22.36	38.64*	0.00
Heart Rate (H.R)	65.35	1.85	170.65	2.08	9.61*	0.00
Stroke Volume (S.V)	74.89	0.95	79.63	1.63	6.34 *	0.00
Left Ventricular End- Diastolic Diameter (LVEDD)	51.80	3.67	48.02	2.41	4.63 *	0.00
Left Ventricular End- Systolic Diameter (LVESD)	31.65	31.50	4.28	1.94	6.74 *	0.00

(N=12)

The statistical significance values at the (0.05) level = 2.201. It is evident from Table (3) results that:

There are statistically significant differences at the (0.05) level between the mean scores of measurements (before stress - after stress) in the phosphatic energy production system in favor of the mean measurement after stress in all cardiac variables under study. The calculated "t" values ranged from (3.60 to 38.64).

The researcher observes a significant increase in cardiac variables after stress compared to before stress. The heart muscle plays a role in supplying sufficient oxygen to the working muscles to produce energy, requiring the heart to perform at a faster rate than during rest to match muscle contractions.

Secondly: presentation and discussion of the results of the second hypothesis, which states: “There are statistically significant differences between measurements (before stress - after stress) in the lactic energy production system in some cardiac variables.”

Table 4. *Significance of statistical differences for the (t) test for cardiac variables between measurements (before exertion, after exertion) lactate*

Statistical Significance / Variables	After Stress		After Stress		t Value	Significance Level
	+ Sign	+- Sign	- Sign	+- Sign		
Left Ventricular Posterior wall Thickness (LVPM)	9.25	2.04	13.24	1.63	6.51 *	0.00
Interventricular Septum Thickness (IVS)	8.14	1.74	11.05	2.32	3.69*	0.00
Systolic Blood Pressure	15.80	1.36	18.64	0.96	5.21 *	0.00
Diastolic Blood Pressure	7.95	1.04	9.00	1.23	4.67 *	0.00
Cardiac Output (C.O)	5395. 64	17.63	14754.11	18.96	33.21 *	0.00
Heart Rate (H.R)	65.35	1.85	168.95	1.94	8.64*	0.00
Stroke Volume (S.V)	74.89	0.95	93.25	1.52	7.69*	0.00
Left Ventricular End- Diastolic Diameter (LVEDD)	51.80	3.67	47.32	2.01	4.01 *	0.00
Left Ventricular End- Systolic Diameter (LVESD)	31.65	4.28	13.24	2.94	6.35 *	0.00

(N=12)

Value of t at significance level (0.05) = 2.201

From the results in Table (4), the following is evident:

- There is statistically significant differences at the (0.05) level between the means of measurements (pre-exercise - post-exercise) in the aerobic energy production system in favor of the post-exercise average lactate system in all cardiac variables under study, where the calculated t-values ranged between (3.69: 33.21).
- The researcher sees that the increase in cardiac variables resulting from the aerobic system is due to an increase in heart rate, aiming to deliver a larger amount of oxygen for energy production. Knowing that the duration of work within this system is longer than the phosphatic system, on the other hand, there are accumulations of energy waste, including lactic acid, in the muscles. So there is an increased blood flow to rid them of these wastes, which may lead to the player not continuing to perform. If it is disposed of, the heart will work faster to achieve this goal, and this will continue until the time of rest.

Third: Presentation and Discussion of the Results of the Third Hypothesis, which States: “There Are Statistically Significant Differences between the Measurements (Before Exercise - After Exercise) in the Aerobic Energy Production System in Some Cardiac Variables”

Table 5. *Statistical significance of (t) test for cardiac variables between measurements (before stress, after stress) in the aerobic energy production system*

Statistical Significance / Variables	After Stress		After Stress		t Value	Significance Level
	+ Sign	+- Sign	- Sign	+- Sign		
Left Ventricular Posterior wall Thickness (LVPM)	9.25	2.04	11.30	1.08	3.65 *	0.00
Interventricular Septum Thickness (IVS)	8.14	1.74	11.17	0.97	4.01*	0.00
Systolic Blood Pressure	15.80	1.36	18.24	1.84	4.96 *	0.00
Diastolic Blood Pressure	7.95	1.04	8.71	0.88	3.86 *	0.00
Cardiac Output (C.O)	5395. 64	17.63	16475.22	22.36	47.96*	0.00
Heart Rate (H.R)	65.35	1.85	161.85	2.08	8.24	0.00
Stroke Volume (S.V)	74.89	0.95	89.63	1.63	12.69*	0.00
Left Ventricular End- Diastolic Diameter (LVEDD)	51.80	3.67	52.40	2.41	1.95 *	0.00
Left Ventricular End- Systolic Diameter (LVESD)	31.65	4.28	33.96	3.39	3.02 *	0.00

The significance level (α) = 2.201

From the results of Table (5), the following is evident:

- There is statistically significant difference at the (0.05) level between the mean scores of the pre-exertion and post-exertion aerobic measurements in favor of the post-exertion aerobic average across all cardiac variables under study. The calculated t-values ranged from (3.86 to 47.96), except for the Left Ventricular End Diastolic Diameter (LVEDD) where the calculated t-value was (1.95), which is lower than the critical t-value.
- The researcher observes that the mechanism of aerobic exercise determines the heart's response. Since aerobic work rate is slower compared to other systems, the heart can adequately supply energy demands for muscle work. Additionally, muscles operating under this system heavily rely on oxygen. Meeting these demands requires greater oxygen supply to sustain work, resulting in increased blood volume per beat. Thus, we note that post-aerobic exercise heart rates are slower but involve a larger volume of blood pumped per minute.

Fourthly: Presentation and Discussion of Results of the Fourth Hypothesis, which states “There are statistically significant differences between energy production systems (phosphatic, lactic, aerobic) post-exertion in some cardiac variables.”

Table 6. *Analysis of Variance (ANOVA) between the three measurements (phosphate, lactic, air) in energy systems post-exertion in cardiac variables*

Statistical Significance **Variables**	**Source of Variation**	**Degrees of Freedom**	**Sum of Squares**	**Mean Square**	**F Value**	**Significance Level**
Left Ventricular Posterior wall Thickness (LVPM)	Between Groups	2	28.000	14.000	3.088	0.075
	Within Groups	33	68.000	4.533		
	Total	35	96.000			
Interventricular Septum Thickness (IVS)	Between Groups	2	39.528	19.764	2.812	0.092
	Within Groups	33	105.417	7.028		
	Total	35	144.944			
Systolic Blood Pressure	Between Groups	2	464.33	232.17	0.88	0.43
	Within Groups	33	3937.47	262.50		
	Total	35	4401.81			
Diastolic Blood Pressure	Between Groups	2	17.33	8.67	0.31	0.74
	Within Groups	33	415.47			
	Total	35	432.81			
Cardiac Output (C.O)	Between Groups	2	69.333	34.667	*8.571	0.003
	Within Groups	33	60.667	4.044		
	Total	35	130.000			
Heart Rate (H.R)	Between Groups	2	56.444	28.222	*9.621	0.002
	Within Groups	33	44.000	2.933		
	Total	35	100.444			
Stroke Volume (S.V)	Between Groups	2	122.111	61.056	*9.023	0.003
		33	101.500	6.767		
		35	223.611			
	Within Groups	2	44.111	22.056	*9.636	0.002
	Total	2.289	34.333	33		
Left Ventricular End-Diastolic Diameter (LVEDD)	Between Groups	35	78.444			
	Within Groups	2	120.444	60.222	*7.655	*7.655
	Total	33	118.000	7.867		

Left Ventricular End-Systolic Diameter (LVESD)	Between Groups	35	238.444	14.000		
	Within Groups	2	28.000	4.533	3.088	0.075
	Total	33	68.000			

*Significant at the 0.05 level. The critical (F) value at the 0.05 level = 3.285

It is evident from Table (6), which pertains to the analysis of variance (ANOVA) between (phosphate, lactate, aerobic) energy systems post-exercise in cardiac variables:

- There are significant differences among the three measurements in energy systems (phosphate, lactate, aerobic) post-exercise in measurements of heart rate (H.R), stroke volume (S.V), left ventricular end-diastolic diameter (LVEDD), left ventricular end-systolic diameter (LVESD), and cardiac output (C.O). The calculated F-value ranged from 7.655 to 9.636, which exceeds the critical (F) value at the 0.05 level. To determine the significance of the differences among the three measurements (phosphate, lactate, aerobic) post-exercise, the Least Significant Difference (LSD) test was used as shown in Table (25).
- There are no significant differences among the three measurements in energy systems (phosphate, lactate, aerobic) post-exercise in measurements of posterior wall thickness of the left ventricle, interventricular septum thickness, systolic blood pressure, and diastolic blood pressure. The calculated F-value ranged from 0.31 to 3.088, which is less than the critical (F) value at the 0.05 level."

Statistical Significance / **Variables**	**Measurements**	**Standard Deviation**	**Skewness**	**Significance of Mean Differences**			**LSD Value**
				Phosphate	**Lactate**	**Aerobic**	
Posterior wall thickness of the left ventricle: LVPW	Phosphate	12.90	1.08		0.34	1.60	1.53
	Lactate	13.24	1.63			1.94	
	Aerobic	11.30	1.08				
Interventricular septum thickness: IVS	Phosphate	12.03	0.97		0.98	0.86	1.50
	Lactate	11.05	2.32			0.12	
	Aerobic	11.17	0.97				
Systolic Blood Pressure	Phosphate	19.82	1.84		1.18	1.58	0.87
	Lactate	18.64	0.96			0.40	
	Aerobic	18.24	1.84				
Diastolic Blood Pressure	Phosphate	8.69	0.88		0.31	0.02	0.99
	Lactate	9.00	1.23			0.29	
	Aerobic	8.71	0.88				
Cardiac Output (C.O)	Phosphate	12,864.8	22.36		1889.31*	3610.42*	1.23
	Lactate	14,754.11	18.96			1721.11*	
	Aerobic	16,475.22	22.36				
Heart Rate (H.R)	Phosphate	170.65	2.08		1.70	8.80*	1.62
	Lactate	168.95	1.94			7.10*	
	Aerobic	161.85	2.08				
Stroke Volume (S.V)	Phosphate	79.63	1.63		13.62*	10.00*	0.89
	Lactate	93.25	1.52			3.62*	
	Aerobic	89.63	1.63				
Left Ventricular End-Diastolic Diameter (LVEDD)	Phosphate	48.02	2.41		0.70	3.68*	1.16
	Lactate	47.32	2.01			-4.38*	
	Aerobic	52.40	2.41				
Left Ventricular End-Systolic Diameter (LVESD)	Phosphate	26.71	3.39		0.53	7.25*	1.68
	Lactate	27.24	2.94			6.72*	
	Aerobic	33.96	3.39				

7. STATISTICAL SIGNIFICANCE

From Table 7, which pertains to the statistical significance of differences among phosphate, lactic, and aerobic energy systems after exertion in cardiac variables using the LSD post hoc test, several findings are evident:

- There is a significant difference between the phosphate and lactic energy systems in measurements of Stroke Volume (S.V.) and Cardiac Output (C.O.), favoring the lactic system.
- There is a significant difference between the phosphate and aerobic energy systems in Heart Rate (H.R.) measurements, favoring the phosphate system.
- There is a significant difference between the phosphate and aerobic energy systems in measurements of Stroke Volume (S.V.), Left Ventricular End-Diastolic Diameter (LVEDD), Left Ventricular End-Systolic Diameter (LVESD), and Cardiac Output (C.O.), favoring the aerobic system.
- There is a significant difference between the lactic and aerobic energy systems in Heart Rate (H.R.) and Stroke Volume (S.V.) measurements, favoring the lactic system.
- There is a significant difference between the lactic and aerobic energy systems in measurements of Left Ventricular End-Diastolic Diameter (LVEDD), Left Ventricular End-Systolic Diameter (LVESD), and Cardiac Output (C.O.), favoring the aerobic system.

8. CONCLUSION

Based on the research results, the researcher concluded the following significant findings:

- There are statistically significant differences between pre-exertion and post-exertion measurements in the phosphate energy production system in certain cardiac variables.
- There are statistically significant differences between pre-exertion and post-exertion measurements in the lactic energy production system in certain cardiac variables.
- There are statistically significant differences between pre-exertion and post-exertion measurements in the aerobic energy production system in certain cardiac variables.
- There are significant differences between the phosphate and lactic energy systems in Stroke Volume (S.V.) and Cardiac Output (C.O.) measurements, favoring the lactic system.
- There are significant differences between the phosphate and aerobic energy systems in Heart Rate (H.R.) measurements, favoring the phosphate system.
- There are significant differences between the phosphate and aerobic energy systems in Stroke Volume (S.V.), Left Ventricular End-Diastolic Diameter (LVEDD), Left Ventricular End-Systolic Diameter (LVESD), and Cardiac Output (C.O.) measurements, favoring the aerobic system.
- There are significant differences between the lactic and aerobic energy systems in Heart Rate (H.R.) and Stroke Volume (S.V.) measurements, favoring the lactic system.
- There are significant differences between the lactic and aerobic energy systems in Left Ventricular End-Diastolic Diameter (LVEDD), Left Ventricular End-Systolic Diameter (LVESD), and Cardiac Output (C.O.) measurements, favoring the aerobic system.

9. RECOMMENDATIONS

Based on these findings, the researcher recommends the following:

- Continual physiological medical examinations before and during the application of training programs to observe the functional adaptation of biological devices.
- The necessity of periodic and field measurements of Heart Rate and Blood Pressure after training units to determine the internal impact on cardiac muscle variables due to daily training.
- The necessity of diversity in energy production systems during the training process.

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