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# Functional Capabilities of the Cardiorespiratory System in 15-17 Years-Old Female Students: Kemampuan Fungsional Sistem Kardiorespirasi pada Siswi Berusia 15-17 Tahun

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**Background:** Physiological adaptation during adolescence is influenced by lifestyle and environmental factors, particularly in urban and rural settings. Understanding cardiorespiratory responses to physical activity is crucial for assessing health reserves in young individuals. **Aim of the Study:** To evaluate physical development and the functional status of the cardiorespiratory system at rest and after physical load among first-year female medical college students from urban and rural areas. **Methodology:** The study included female students aged 15–16. Physical development was assessed using somatometry (height, weight, chest circumference) and physiometry methods (vital lung capacity [VC], tidal volume [TV], expiratory reserve volume [ERV], heart rate [HR], and blood pressure [SBP, DBP]). Percentile methods and spirometry were applied to measure external respiration indices. Physical load was induced using G.N. Apanasenko's squat test. Data were processed statistically using integrative indices (vital index, Erisman index). **Results:** After loading, HR significantly increased in both groups: from 84.6±2.3 to 130.0±4.6 in group I and from 78.1±2.1 to 134.7±3.4 in group II. SBP and DBP also rose markedly, reaching 150.0±5.0 and 162.0±3.4 mmHg, respectively. Cardiac output (CO) increased to 12.69±0.33 L/min in group I and 12.92±0.25 L/min in group II. VC, TV, and ERV remained largely unchanged, while $SpO_2$ dropped significantly after loading to 82.7±1.4% and 84.0±1.6% in groups I and II, respectively. **Conclusion:** Urban and rural students exhibited similar adaptive patterns, with rural students showing slightly better oxygen saturation and CO response, suggesting higher functional reserves and greater cardiorespiratory adaptability under physical stress.

**Highlight** :

- Heart rate and blood pressure rose significantly after physical load.

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- Oxygen saturation dropped, more stable in rural students.
- Rural students showed better functional reserves and adaptability

**Keywords** : Female Students, Heart Rate, Blood Pressure, Cardiorespiratory System, Physical Activity

## Introduction

The status and level of health of an intensively growing adolescent and young man's body is a multifactorial process inextricably linked with the features of legally valid education and training systems officially adopted in each country of the world [1]. The research shows that "the human body is constantly affected by three streams of information, sensory, perceived by the senses through the first signaling system, verbal (oral and written words) through the second signaling system, and structural (components of food and inhaled air) entering the body through the gastrointestinal tract [2] ,[3]. His research shows that "mental factors are more important for adaptation and preservation of health than climatic factors." This is confirmed by modern scientific achievements in the field of age physiology, which note that the main point of preventing negative environmental influences on the growing body of both adolescents and youth is the accumulation of an accurate database on the distribution and identification of sources (factors) of their health disorders [4,5]. In connection with the above, it is of particular importance to determine the most scientifically significant integral morphofunctional parameters of growth and development in an intensively growing individual, which reflect the adaptive abilities of the individual and his adaptation to the conditions of a specific living environment [6,7]. The really significant indicators of the success of physiological adaptation to the processes of educational activity include the effectiveness of adaptation to the learning process in general education, professional and higher educational institutions; the success of both current and examination performance; stability in the learning process of the functional status of the student's body in the absence of sudden shifts in the manifestation of psycho-physiological functions; absence of pronounced signs of fatigue when performing educational activities [8,9]. Any stable adaptation of the body to the conditions of training and in the field of professional activity has its price, which can manifest itself in the direct deterioration of those functional systems that bear the greatest burden during the adaptation process [9]. This process is accompanied by a marked increase in functional disorders in a growing body, determining the growth rate of chronic forms of pathology among adolescents [10]. Educational and professional adaptation of a growing organism is one of the types of human physiological adaptation, which is an important area of scientific research. High information loads in modern secondary and higher schools cause emotional tension in students, the development of nonspecific stress reactions, and change the type of relationship between the body and the environment, disrupting the processes of adaptation and the process of its ontogenetic development [11].

## Materials and Methods

The level of physiological adaptation was assessed among first-year female students from urban and rural areas, considering both physical development and the functional status of the cardiorespiratory system at rest and under physical activity during their learning process. Physical development was evaluated using somatometric measurements, including height, body weight, chest circumference, and chest excursions. The harmony and level of physical development were determined based on percentile methods. Physiometric assessments at relative rest included measurements of vital lung capacity (VC, L), respiratory volume (TV, mL), heart rate (HR, $min^{-1}$),

and blood pressure (BP, mmHg) both systolic (SBP) and diastolic (DBP). External respiration parameters were measured using a dry spirometer to evaluate vital capacity (VC, L), tidal volume (TV, mL), and expiratory reserve volume (ERV, mL). Physical load was applied using the squat test according to the method of G.N. Apanasenko (2000), enabling evaluation of adaptation features under stress. Based on the collected data, integrative indices were calculated mathematically, including the body mass index (BMI, g/cm²), Erisman index, and vital index (VI, mL/kg), to provide a comprehensive assessment of physiological status.

## Statistical Analysis

Data were analyzed using SPSS version 26. Descriptive statistics, including mean ± standard deviation (SD), were calculated for all variables. Paired t-tests were used to compare pre- and post-load measurements within groups, while independent t-tests compared differences between urban and rural groups. A p-value less than 0.05 was considered statistically significant. Correlation analyses were performed to assess relationships between cardiorespiratory parameters and physical development indices.

## Ethical Approval

The study protocol was reviewed and approved by the Institutional Ethics Committee of the Department of Biology, College of Education for Pure Science, Diyala University, Diyala, Iraq. Written informed consent was obtained from all participants or their legal guardians before enrollment. The study was conducted in accordance with the Declaration of Helsinki and local ethical guidelines to ensure participant confidentiality and safety.

## Results

### A. Comparison of Cardiovascular and Respiratory Indicators Before and After Load in Two Study Groups

The results showed a significant increase in heart rate (HR) after loading in both groups, as it increased from (84.6±2.3) to (130.0±4.6) in the first group, and from (78.1±2.1) to (134.7±3.4) in the second group. A significant increase in systolic blood pressure (SBP) and diastolic blood pressure (DBP) was also observed after loading in both groups, as SBP in the second group reached (162.0±3.4) mmHg compared to (150.0±5.0) in the first group. Pulse pressure (PP) remained close between the two groups. The values for stroke volume (SV) and cardiac output (CO) showed a significant increase after loading, as CO in the second group increased to (12.92±0.25) l/min compared to (12.69±0.33) in the first. In contrast, no significant differences were recorded in vital capacity (VC), tidal volume (TV), or expiratory reserve volume (ERV) between the two groups, while a decrease in oxygen saturation ($SpO_2$) after loading was observed to reach (82.7±1.4%) in the first group and (84.0±1.6%) in the second. (Table 1)

| Indicators (units) | I group, n=20 | | II group, n=26 | |
|---|---|---|---|---|
| | Before load | After load | Before load | After load |
| (HR), $min^{-1}$ | 84,6±2,310,5 | 130,0±4,620,5 | 78,1±2,110,8 | 134,7±3,417,0 |
| (SBP), mmHg | 116,5±2,812,7 | 150,0±5,022,4 | 111,5±2,512,8 | 162,0±3,417,3 |
| (DBP), mmHg | 68,5±2,19,4 | 110,0±3,113,9 | 65,5±2,010,2 | 115,0±2,412,2 |
| (PP), mmHg | 46,2±1,98,5 | 43,2±2,29,8 | 45,8±1,78,2 | 48,5±1,89,2 |
| (SV), mL | 66,8±1,88,1 | 100,5±3,214,3 | 62,0±1,99,7 | 95,6±2,311,7 |
| (CO), L/min | 5,68±0,251,12 | 12,69±0,331,50 | 5,15±0,130,66 | 12,92±0,251,27 |
| (W), kg/m | 85,5±2,310,3 | 273,7±7,433,2 | 78,4±2,211,2 | 282,6±6,432,6 |
| (VC), L | 2,87±0,070,31 | 2,88±0,090,40 | 2,81±0,070,35 | 2,83±0,100,51 |
| (TV), mL | 0,56±0,040,26 | 0,51±0,030,24 | 0,55±0,040,28 | 0,52±0,040,25 |

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| (ERV), L | 1,18±0,070,31 | 1,21±0,060,23 | 1,06±0,050,26 | 1,13±0,060,31 |
| (SpO2), % | 96,0±2,0 | 82,7±1,4 | 96,0±2,0 | 84,0±1,6 |

**Table 1.** *Functional status of the cardiorespiratory system in female students under physiological conditions and under the influence of physical activity.*

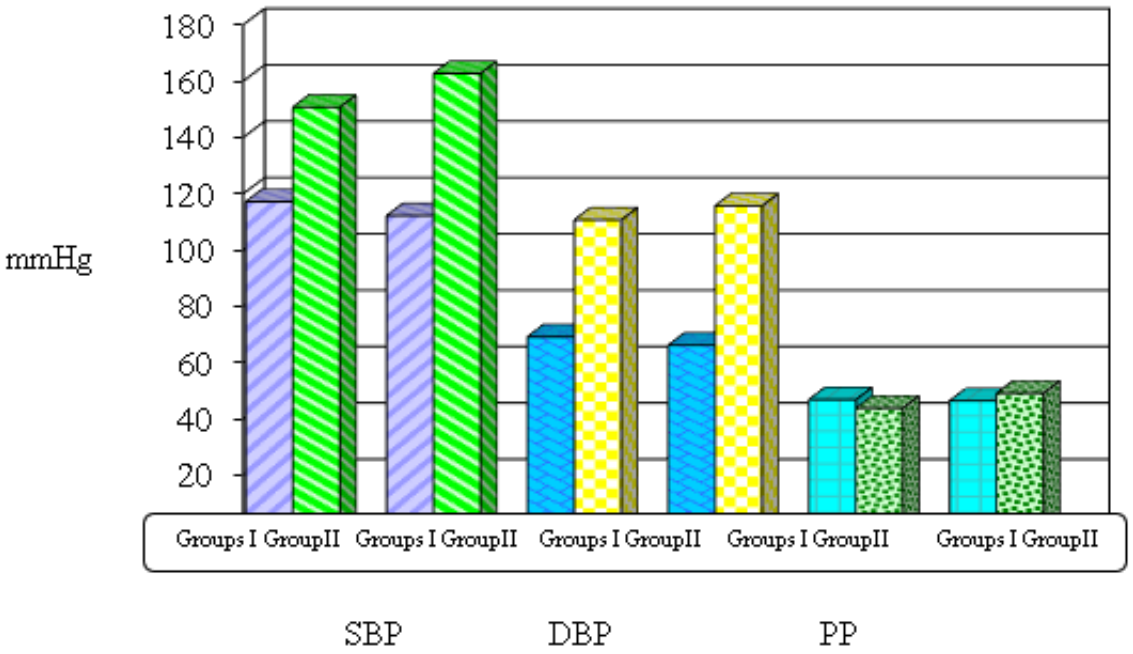


**Figure 1.** *The effect of physical activity on the parameters of DM, DD and PD between groups I and II of girls before and after exercise.*

## B. Comparison of Respiratory Function Indicators Before and After Load in Two Groups

The results showed that vital capacity (VC) was stable in both groups before and after loading, with the first group recording (2.91±0.07) liters before loading versus (2.88±0.09) liters after, while the second group recorded (2.84±0.07) liters before loading and (2.83±0.10) liters after.(Figure 1) Tidal volume (TV) witnessed a slight decrease after loading in both groups, reaching (0.56±0.05) milliliters before loading and (0.51±0.03) milliliters after loading in the first group, and (0.55±0.04) before loading versus (0.52±0.04) in the second group. While the values of expiratory reserve volume (ERV) showed slight changes, as they reached (1.18±0.06) liters in the first group before loading versus (1.21±0.05) after it, and in the second group (1.10±0.06) before loading versus (1.12±0.04) after it. As for the percentage of oxygen saturation ($SpO_2$), it decreased significantly after loading, as it recorded (82.7±1.4%) in the first group and (84.0±1.6%) in the second group, compared to the normal value before loading (96.0±2.0%) in both groups. (Table 2)

| Indicators (units) | I group, n=20 | | II group, n=26 | |
|---|---|---|---|---|
| | Before load | After load | Before load | After load |
| (VC), L | 2,91±0,070,31 | 2,88±0,090,40 | 2,84±0,070,35 | 2,83±0,100,51 |
| (TV), mL | 0,56±0,050,26 | 0,51±0,030,24 | 0,55±0,040,28 | 0,52±0,040,25 |
| (ERV), L | 1,18±0,060,31 | 1,21±0,050,23 | 1,10±0,060,26 | 1,12±0,040,31 |
| (SpO2), % | 96,0±2,0 | 82,7±1,4 | 96,0±2,0 | 84,0±1,6 |

**Table 2.** *The functional status of the respiratory system in female students under physiological conditions and under the influence of physical activity.*

## Discussion

The study demonstrated a significant increase in heart rate (HR) in both groups of female students following physical activity, with a rise of 53.7% ($p<0.001$) in group I and 72.5% ($p<0.001$) in group II. This pronounced elevation in HR, especially in group II, can be attributed to a stronger activation of the sympathetic nervous system, leading to enhanced adrenergic stimulation of the ventricular myocardium. This physiological response accelerates cardiac rhythm to meet the increased metabolic demands during exercise [12,13]. The observed increase in systolic blood pressure (SBP) and diastolic blood pressure (DBP) in both groups reflects the combined effect of elevated cardiac output and peripheral vascular resistance, commonly mediated by sympathoadrenal activation during stress. DBP increased by 60.1% in group I and 78.6% in group II, exceeding normal physiological limits [14], [15]. Elevated diastolic tension indicates higher vascular tone and increased myocardial workload, which, over time, may reduce cardiac output efficiency and compromise functional myocardial reserves. These findings highlight a less economical cardiac adaptation to exercise, particularly among urban participants [16,17]. Pulse pressure (PP) dynamics differed between groups; it decreased by 9.5% in group I and increased by 5.9% in group II. This variation suggests differences in arterial compliance and vascular reactivity, with rural students showing greater adaptability [18,19]. The significant increase in cardiac output (CO) and myocardial oxygen demand during exercise ($p<0.001$) underscores the interaction between neurohumoral regulation and myocardial function. Rural participants exhibited higher contractile responses and chronotropic adaptation, indicating superior myocardial reserves compared to urban students [20], [21]. Respiratory parameters (VC, TV, ERV) remained relatively stable post-load, but oxygen saturation ($SpO_2$) declined, more notably in urban students (by 13.8%) than in rural students (12.5%). This lesser reduction in rural participants suggests better ventilatory efficiency and oxygen utilization, likely due to chronic exposure to higher physical activity levels and environmental conditioning, contributing to enhanced cardiorespiratory adaptability [22]. Overall, rural students demonstrated more efficient physiological responses to physical stress, as evidenced by more favorable cardiovascular and respiratory adaptations. This indicates a higher level of functional reserve and better systemic adaptability compared to their urban counterparts [23], [24].

## Conclusions

It has been established that female students living in rural areas have a higher level of adaptation of the cardiorespiratory system to physical exertion, given that they have higher systolic and minute volumes in physiological conditions; however, rural girls have significantly higher aerobic capabilities of the body, both at rest and during physical exertion, since they have a larger volume of CO and, accordingly, higher oxygen transport capabilities of the body for physical exertion.

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