Natural Resources for Human Health
eISSN: 2583-1194

Original Research

Received 21 May 2026
Revised 30 June 2026
Accepted 23 July 2026

Natural Resources for Human Health 2026, Vol. 6 (9s): 286–293

KEYWORDS:
Steady-State Phase, Transition-to-Steady-State Phase, Physiological Variables, Futsal, Bruce Test, K5 Metabolic Analyzer.

A Comparative Study of the Steady-State Phase and the Transition-to-Steady-State Phase in Physiological Variables during Physical Effort in Futsal Players

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ABSTRACT: The aim of this study is to investigate the differences between the transition to steady state and the steady state of some physiological variables in futsal players. The researchers were hypothesizing that statistically significant difference would be found between the two phases. Descriptive method was used for the research problem. There were 10 players in the Al Qadisiyah University futsal team as the sample. The experiments were carried out in the halls and laboratories of Al-Qadisiyah University – College of Physical Education and Sports Sciences, in the academic year 2025/2026 from 1 November 2025 until 1 December 2026. On the treadmill the Bruce test was used to assess functional variables with the equipment supplied by the Italian company, K5 metabolic analyser. The researcher identified variations for the variables that were measured in the transition-to-steady-state phase with respect to the steady-state phase and created a subset of these variables. The researcher discovered differences in the physiological variables in the transition-to-steady-state and steady-state phases and developed a subset of these variables. The researcher recommended conducting periodic assessments of the physiological and physical variables affecting the players to determine their physical readiness and level of development, as well as conducting similar studies and measuring other physiological and physical variables according to the sporting activity being studied.

1. INTRODUCTION TO THE STUDY

1.1 Introduction and Significance of the Study

From a physiological perspective, it is possible to study and identify the most important physiological variables that directly affect performance. The high-intensity training efforts performed by players during training sessions and matches require greater energy expenditure and oxygen consumption than during rest. The muscular system produces the movement and physical work required, which is reflected in the internal load placed on the player's functional systems through increased work of the heart and cardiovascular system, including the pumping of oxygen- and nutrient-rich blood to the working muscles and organs. This, in turn, increases respiratory activity and pulmonary ventilation.

Considering the nature of futsal, related to the degree of energy expended during physical activity, the energy system mainly used, the gas exchanges in the muscular and cardiovascular systems, the availability of energy and elimination of metabolic by-products are mandatory. Those involve a higher lactic acid build up, less CO_2 removed and having less oxygen available due to the type of work being done during a game. Thus the functional activity of the cardiovascular system, heart and respiratory system is one of the most vital of which the body relies during physical activity to maintain internal homeostasis as near the normal level as possible. Body's functional systems' readiness to perform their normal functions is naturally related to the level of futsal players' performance improvement. The steady-state phase is an important stage of sports performance because it is the phase during which the body is able to meet the oxygen requirements necessary to complete the required muscular work at the prescribed speed. This requires adequate efficiency of the body's functional systems as well as sufficient physical capabilities to establish and maintain steady state. Consequently, the body can sustain performance without a decline in performance level. Therefore, the importance of this study lies in determining the levels of the physiological variables under investigation during the transition to steady state and examining the physiological variables that directly affect performance by analyzing these variables during physical effort in futsal players.

1.2 Research Problem

It is naturally observed that, during rest, a player's cardiovascular and respiratory variables differ from those observed during physical effort. These changes occur to maintain the body's internal environment within normal limits as far as possible. Respiratory rate, heart rate, pulmonary ventilation, the rate of pumping oxygen- and nutrient-rich blood, sweating, and other physiological responses increase until the body reaches steady state, allowing performance to continue for a longer period within the limits of that state. The duration of steady state varies according to the type and intensity of effort and the player's physical level. The period between the onset of exercise and the beginning of steady state is referred to as the transition-to-steady-state period, or a state of instability before steady state is achieved. This condition may be transient at the beginning of effort or cumulative during exercise when training intensity is increased. The physiological variables therefore pass through a period of instability before returning to a stable state as the body and its functional systems adapt to the new training load. Hence, the research problem is concerned with studying and analyzing the steady-state phase and its effect on the major physiological variables of futsal players.

1.3 Research Objectives

The study aimed to identify the differences between the transition-to-steady-state phase and the steady-state phase in selected physiological variables in futsal players.

1.4 Research Hypotheses

There are statistically significant differences in the physiological variables between the transition-to-steady-state and steady-state phases in futsal players.

1.5 Scope of the Study

1.5.1 Human Domain: The human domain comprised the players of the Al-Qadisiyah University futsal team during the 2025–2026 academic year.

1.5.2 Time Domain: The study was conducted from 1 November 2025 to 1 December 2025.

15.3. Spatial Domain: The study is conducted in the Physical Education and Sports Sciences College at Al-Qadisiyah University, Scientific Research Laboratory, halls, laboratories and sports fields.

2. RESEARCH METHODOLOGY AND FIELD PROCEDURES.

2.1 Research Method

The method used was descriptive method to suit the nature of the research problem as stated by Dhawqan Obaidat et al (1988 p.107).

2.2 Research Sample

The number of research population was the Al-Qadisiyah University futsal team in academic year (2025-2026). A purposive sample of 10 players was used as a study sample. The variables presented below were determined as showing homogeneity of the sample.

Table 1. Means, standard deviations, and skewness coefficients of the study sample for age, training age, height, and body mass

#	Variables	Unit of Measurement	Mean	Standard Deviation	Skewness Coefficient
1	Age	years	19.34	2.21	0.41
2	Training Age	years	4.52	2.37	0.64
3	Height	cm	174.78	4.32	0.82
4	Body Mass	kg	59.57	3.91	0.19

2.3 Field Research Procedures

Measurement of Functional Variables: During physical effort, functional variables measured on the K5 metabolic analyser on a treadmill and on a Monark ergometer as follows.

The Bruce Test is used to assess maximum oxygen consumption. The Bruce Test is an assessment for maximum oxygen consumption.

The test comprised 7 stages of exercise each of 3 min duration for a total of 21 min and measured maximum oxygen consumption (VO_2max). The inclination of the treadmill in the initial stage was set at zero and the speed at the end of each stage was altered as described in Figure 1 (Hazzaa M. Al-Hazzaa, 2009, p. 484).

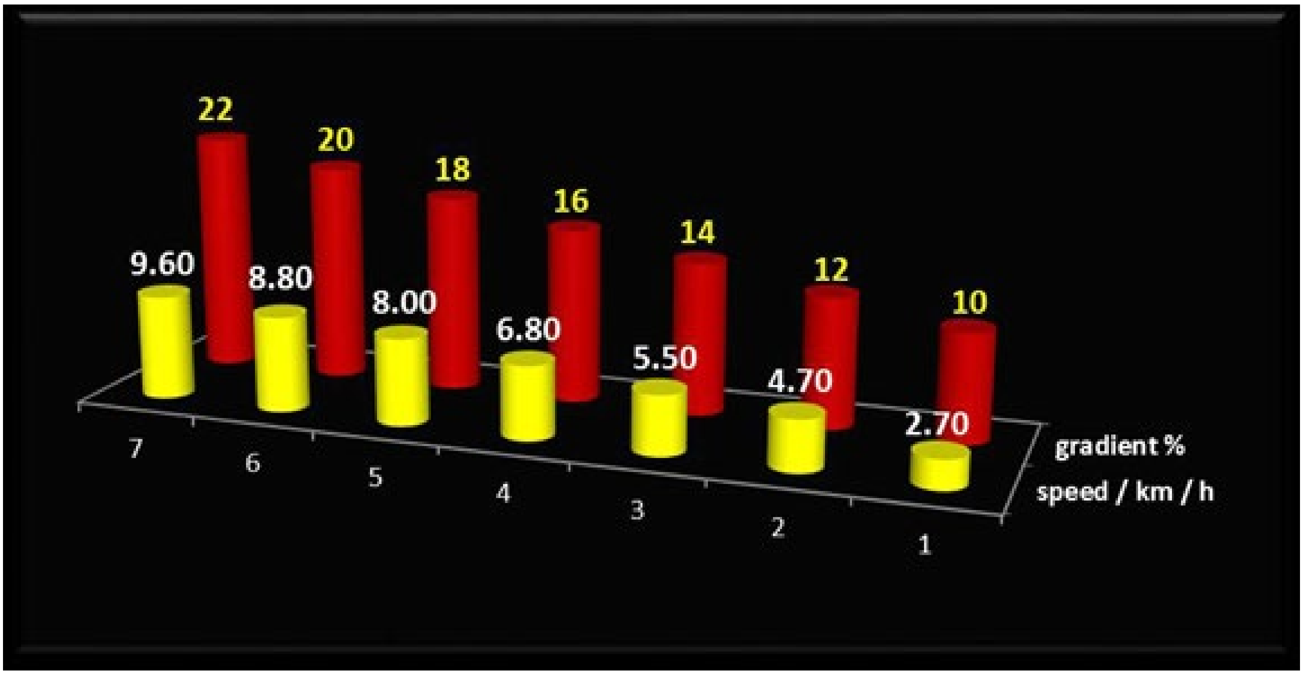

Figure 1. The VO_2max test across its seven stages

The treadmill speed and incline will increase at the end of each stage; right now, after 3 minutes of every test stage.

Pilot Study: The researcher used 25 October 2025 sample of two participants in the research population for the pilot study. That was done to determine functional indicators, blood lactate, possible difficulties that may arise in the experiment, fitness and limits of the equipment and instruments, and the time needed for doing the test.

Main Experiment: The researchers conducted the test on Monday, 1st November 2025, in the "Physiology Laboratory of the College of Physical Education and Sports Sciences at Al-Qadisiyah University". VO_2max was measured with the Bruce test, and it was composed of 21 min, with 7 exercise stages which lasted from 3 min to 3 min. The treadmill slope was 0 degrees and the choice of the different speeds for the duration at the end of each stage was according to the given test procedure. Two players were tested a day over the course of 5 days. Statistical Methods: The Statistical Package for the Social Sciences (SPSS) was used to obtain the following:

1. The mean
2. Deviation Standard
3. Coefficient of Skewness
4. Independent T-Test Sample

The presentation, analysis, and discussion of the results of this research is discussed in the third chapter. Peers' presentation and discussion of the results of the comparison between the transition-to-steady-state and steady-state phases in the physiological variables of the study sample.

Table 2. Comparison of physiological variables between the steady-state and transition-to-steady-state phases

Variables	Phase	N	Mean	Standard Deviation	t	df	Sig.
HR	Steady-State Phase	10	184.05	1.98	14.42	9	0.01
	Transition-to-Steady-State Phase		138.43	6.31			
VE	Steady-State Phase	10	150.05	3.78	71.09	9	0.00
	Transition-to-Steady-State Phase		80.61	3.18			
VO2	Steady-State Phase	10	4114.72	80.82	41.10	9	0.00
	Transition-to-Steady-State Phase		2690.69	83.65			
VCO2	Steady-State Phase	10	3934.74	82.22	68.15	9	0.02
	Transition-to-Steady-State Phase		2185.94	79.56			
VE/VO2	Steady-State Phase	10	38.17	0.57	30.10	9	0.00

Variables	Phase	N	Mean	Standard Deviation	t	df	Sig.
	Transition-to-Steady-State Phase		30.46	0.68			
VE/VCO2	Steady-State Phase	10	39.53	0.59	4.66	9	0.02
	Transition-to-Steady-State Phase		37.02	0.79			
VO2MAX	Steady-State Phase	10	53.77	2.21	39.22	9	0.00
	Transition-to-Steady-State Phase		34.55	1.94			
METS	Steady-State Phase	10	16.08	0.49	43.34	9	0.00
	Transition-to-Steady-State Phase		10.75	0.23			
VO2/HR	Steady-State Phase	10	25.51	0.58	8.71	9	0.01
	Transition-to-Steady-State Phase		19.88	1.27			

3. DISCUSSION OF THE DIFFERENCES BETWEEN THE STEADY-STATE AND TRANSITION-TO-STEADY-STATE PHASES IN THE TREADMILL TEST FOR THE PHYSIOLOGICAL VARIABLES UNDER STUDY

Table 2 displays variation of the variables of study between the steady state and transition-to-steady-state phases. The researcher explains this fact by the fact that heart rate rises when it comes to physical effort and is reliant on the intensity of exercise. This reaction is thoroughly established by the period of physical activity which is at steady state and the variation between the steady-state and transition-to-steady-state. According to Sayed Ahmed (2003, p. 22), the average values of resting heart rate in healthy adults' range between 70-80 beats per minute, but in fitness enthusiasts the heart rates are lower and range at 50-60 beats per minute with a potential lower value in endurance athletics and cyclists. This has been explained by normal structure and physiologic adjustments of the heart. It has been found that prolonged physical exertions may lead to enlargement of the heart especially that of the left as well as a result in enlargement of the ventricles resulting in high cardiac output as well as enhanced cardiovascular efficiency.

The researcher takes pulmonary ventilation to be in direct correlation to the speed of increment in metabolic processes and energy production, which are directly linked to each other (Sayed Al-Din, 2000, p. 111). Staying in steady state also involves the work of respiratory-muscle and hence chemoreceptor stimulation in exercise (Rowland, 2005, p. 145).

In the case of VO 2, all the differences were statistically significant and more significant in the transition-to-steady-state experimental condition as compared to the steady-state condition. This can be related to lessened vascular resistance due to vasodilation that conveys more oxygenated blood to the muscles (Myerson & Hemmingway, 1999). This of course means that a transition-to-steady-state stage also helps in the dilation of blood vessels and arteries and also enables higher oxygen intake and are an invaluable measure of respiratory capacity during graded exercise. Combination of inspiration and expiration is known as breathing, and through this process of breathing, oxygen gets in to the body and the carbon dioxide is eliminated out of the body. The rate of rest is between 12-17 / min, which depends on exercise. Any rate of muscle activity (even low intensity) influences the respiratory rate such that the muscle rate first increases, then decreases and then does little until effort becomes moderate.

VCO_2 was also statistically different for the steady state and transition to steady state. The respiratory centers have to become more active in the presence of CO 2 and, therefore the rate and depth of breathing is regulated by the activity of respiratory centers. Depth of breathing depends on the frequency of a nerve impulse and the pattern and strength of the nerve impulses is what determines respiratory-rate. The higher the frequencies of neural firing during a particular period the more motor units in the respiratory muscles have been involved and the stronger is the contraction as well as how deep the breathing is (Al-Abdullah, 2012, p. 339). The heart rate is one of the foremost cardiovascular parameters, and it represents the cardiac response that is needed to meet the demands of the body that need additional oxygenated blood consumed during any physical effort. At the steady-state, ventilation of the lungs is approximately proportional to the rate of oxygen uptake, the rate of carbon dioxide excretion, until it levels off at about 20-25 liters of air per liter of oxygen consumed. The volume of air each breath (tidal volume) is increased under these conditions and this increases ventilation. Therefore, during exercise in young soccer players, breathing assumes greater importance. Feedback Good ventilation to maintain relatively favourable partial pressure of O_2 and CO_2, with the slowness of flowing blood through the arterial vessels permitting complete gas exchange to allow full blood O2ation of blood. The ventilatory equivalent of oxygen (VE/VO_2) is used in young adults. During heavy exercise, ventilation rises significantly and disproportionately compared to the amount of oxygen consumed and the ventilatory equivalent could reach the values of 35–40 liters of air per liters of oxygen consumed (Hashim Al-Kilani, 2000, p. 282). Maximum oxygen consumption (VO 2max) is quite closely related to cardiovascular, respiratory and muscular systems. The greatest amount of oxygen possible passes to the working muscles (and uptake of carbon dioxide,) via the Cardiovascular and Respiratory systems, then the working muscles use the oxygen supplied. They are also essential in sports training which needs to be increased to improve efficiency of such systems, hence the oxygen transport to these working muscles (i.e. it increases VO 2max) through the increased capacity of the breathing system. Furthermore, minute ventilations increase during exercise, proportional to the intensity of exercise, which means that there is an augmentation in O_2 consumption. CO_2 is being expelled out of the body, mainly to eliminate CO_2, during strenuous exercise, and this augmentation of pulmonary air flow. In fact, a factor greater increase is experienced in the pulmonary ventilation rather than in the oxygen consumption. This confirms that minute ventilation is not the normal limits factor of the maximum oxygen consumption. Given the same exercise load, and the same amount of carbon dioxide production, a trained individual requires lower levels of pulmonary ventilation in comparison to an untrained individual and therefore has a higher physiological economy. Much higher values of maximal pulmonary ventilation can also be attained even on a relatively very high level (Haider Balash, 2009, p. 61). The trend of oxygen consumption demonstrates the gradually growing oxygen needs of its working muscles and it is why the statistically significant differences were noticed in VO 2max. In the steady-state phase, the increase in the intensity of exercise leads to alterations in other physiological variables, and these variables all sum up to the occurrence of the maximal oxygen consumption and the body capacity to meet the lactic-acid buildup by elevating the amount of blood circulation during the exercise. The heart rate rises immediately in relation to training intensity at the start of training. The intensity of exercising could be assessed against the oxygen intake: an increase in heart rate results in an increase in oxygen intake and a higher exercise intensity leads to an increase in the heart rate (Bahaa Al-Din Salama, 2000, p. 52). This has led to the increment in metabolic equivalent (METS). Significant differences were found in favour of the steady-state phase, which were statistically significant. This can estimate the energy used over physical exertion by determining the metabolic equivalent which was coupled with the heart rate. The rate of heart increases when one is trying something physical and it is determined by the intensity of the exercise. The heart rate cannot attain the same maximum rate as in exercise when a few muscles are at work and so, the heart rate increases proportionally to the effort exerted (Hazzaa bin Mohammed, 2009, p. 378). In the case of VO 2/HR, this is a ratio of the amount of oxygen consumed minus the frequency of the heart rate per minute and is also connected to the intensity of oxygen released by the ventricles with each cardiac contraction. Reduced factors have an adverse effect on the amount of oxygen being pumped to the heart with each beat or the oxygen pulse (David R. Hodgson, 2021, p. 1).

4. CONCLUSIONS

1. There is variation in the physiological variables between the steady-state and transition-to-steady-state phases in futsal players.
2. Physiological characteristics differ between the instability/transition phase and the steady-state phase according to exercise duration, intensity, and the physiological variables under study.

5. RECOMMENDATIONS

1. Training programs should be designed according to the physical and physiological levels of futsal players and their ability to reach steady state.
2. Periodic testing of the physiological and physical variables affecting players should be conducted to assess their physical readiness and level of development.
3. Similar studies should be conducted, including the measurement of additional physiological and physical variables according to the sporting activity being studied.

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