A QUANTITATIVE INVESTIGATION INTO THE CHARACTERISTIC DIFFERENCES IN PULMONARY FUNCTIONS BETWEEN SHORT-DISTANCE AND LONG-DISTANCE SWIMMERS IN INDIA

Mrs. Sindhu V.S
Assistant Professor, Department of Physical Education, Govt. Arts & Science College, Kulathoor, Neyyattinkara, University of Kerala

Mrs. Binitha G.J
Assistant Professor, Department of Physical Education, University College, Thiruvananthapuram, University of Kerala

Abstract: Swimming is one of the most widely practised sports, both as a competitive activity and as an exercise nowadays. Even though exclusive facilities for water bodies are needed, the benefits attached to them make swimming more suitable for improving the general physical fitness of individuals. Among health variables, the lungs and their various functions are most benefited by swimming; simultaneously, the different pulmonary functions play a vital role in maximizing one's performance in swimming too. Hence, in the present paper, the researchers are attempting to quantitatively measure and compare the different pulmonary functions, namely vital capacity, forced expiratory volume, forced inspiratory volume, and maximum voluntary ventilation, between short distance and long distance swimmers, by analysing data collected at national level among young university female players. To analyse the data, t-test is employed. It is found that the selected pulmonary functions has a significance difference between short-distance and long-distance swimmers. The findings were compared with previous studies too. A detailed bibliography is given at the end.

Keywords: Swimming, Vital Capacity (VC), Forced Expiratory Volume (FEV), Forced Inspiratory Volume (FIV), Maximum Voluntary Ventilation (MVV).

Introduction: The drive of modernization in each and every sector of the economy these days is marked by the large-scale application of technology. Along with that, most of the employment opportunities created at present are also facilitated through technological application (Garrison & Deakin, 1988). Thus, in both ways, the volume of physical labour needed in these jobs is drastically reduced. This evolutionary kind of change in the nature of labour is particularly evident in urban regions. As a result, the quality of the physical body was reduced and the tendency towards sedentary lifestyles increased in general. Hence, the relevance of exercises has increased in our time (Sjogaard, et al., 2016). Institutions of physical activity are an important development in the socio-cultural and economic life of the present urban or semi-urban centers (Gehl Institute; WHO Regional Office for Europe, 2017). People are usually attracted towards the most effective type of exercise that requires the least amount of time. Compared to any other sport or exercise, swimming has the unique capability to positively affect the entire body (Lee & Oh, 2015). It benefits the legs, pelvis region, abdomen, chest, hands, neck, backbone, and others, in addition to the lungs. Swimming is most suited for improving cardiovascular fitness and stamina (Tanaka, 2009), lung capacity (Bamne, 2017), and general physical strength. Simultaneously, the different pulmonary functions play a vital role in maximizing one's performance in swimming too. In this paper, the researchers are attempting to argue the importance of swimming. Hence, in the present paper, the researchers are attempting to quantitatively measure the relationship of swimming with different pulmonary functions, namely vital capacity, forced expiratory volume, forced inspiratory volume, and maximum voluntary ventilation, by analyzing data collected at national level among young university players.

Background of the Study: Compared to most of the moving creatures in nature, the human body is the least suitable for swimming. But for survival, humans cultivated the skill of swimming from the beginning itself. Several Stone Age paintings around 8000 BCE, like those in the Cave of Swimmers, showed the practice of swimming in pre-historic times (Barta, 2010). There was written evidence about swimming from 2000 BCE onwards. Many epics and myths around the world reflect the fact that swimming was a known activity for almost all civilizations in the ancient world. In those days, swimming was part of their physical job, especially for those who lived around water bodies. However, the history of swimming as a recreational sport is only a little more than two hundred years old. The social agent behind the widespread popularity of swimming in the nineteenth and twentieth centuries was the construction of swimming pools (Love, 2007). England was the major nation to make swimming a popular sport in those days. Since the beginning of the Olympics in 1896, the sport has become one of the most important arenas of international competition. There were only four swimming events in the first Olympics held in Athens. Only since the Stockholm Olympics in 1912 have women been allowed to compete in swimming. There were 37 events in the 2021 Tokyo Olympics, with an equal number of opportunities for both males and females. Johnny Weissmuller, Mark Spitz, Michael Phelps, Matt Biondi, Janet Evans, Katie Ledecky, Dara Torres were the most legendary swimmers of all time. All of them performed almost all kinds of swimming strokes, especially those added later in the twentieth century. At present, there are four strokes in swimming, namely freestyle, backstroke, butterfly, and breaststroke. Freestyle and backstroke are referred to as front-crawl and reverse-crawl, respectively (Wei, Mark, & Hutchison, 2014).

Generally, experienced swimmers have a larger lung capacity as it makes the lungs maximize oxygen consumption. The relatively high metabolic needs it commands force the body to efficiently move oxygen to all relevant organs (Chhabra, Julka, & Mehta, 2013). As an aerobic exercise, it assists in cardiovascular conditioning too. While swimming, the elasticity of the lungs and chest wall and all related ventilator muscles will be continuously adjusted, which improves the pulmonary functions (Gupta & Sawane, 2012). Similarly, the uniqueness of swimming, with its physical movements and the way the body responds, makes it one of the best sports suitable for physical improvement. Compared to all other sports, swimming is done in a horizontal position. As it is performed in water, which is comparatively more dense than air, the external water pressure on the thorax region of the body makes respiration difficult. Water conducts heat more than twenty times that of air; hence, increased skin temperature during swimming leads to increased blood supply, which causes loss of bodily fluids that induces cardiovascular strain (Sawka, Leon, Montain, & Sonna, 2011).

As the paper is an attempt to quantitatively measure the relationship of swimming with different pulmonary functions, namely vital capacity, forced expiratory volume, forced inspiratory volume, and maximum voluntary ventilation, it is important to explain these terms and their role in enhancing swimming. Vital capacity is the maximum amount of air a person can expel from their lungs after a maximum inhalation. It is positively related to body size up to the middle of one's twenties (Rathi, 2014) and then gradually but slowly decreases. As relevant body organs need more oxygen to perform better while doing sports, this parameter reflects the efficiency of the lungs to receive maximum oxygen in a shorter span of time and provide it to other parts of the body accordingly. Forced inspiratory volume reflects muscle strength, thoracic mobility, and the balance between lung and chest elasticity. The muscles involved are the diaphragm and the accessory muscles of respiration. Swimmers have significantly higher inspiratory volumes than non-swimmers (Wells et. al., 2005; Lomax & McConnell, 2003). Forced expiratory volume is the volume of air that can forcibly be blown out, calculated usually for a second in a blow, after full inspiration (Wells et. al., 2005). Swimmers have significantly higher expiratory volumes than non-swimmers. The largest volume of air that can be moved in and out of the lungs in one minute by maximum voluntary efforts is defined as maximum voluntary ventilation (Teli et.

al., 2014). Like the other variables mentioned above, swimmers have high maximum voluntary ventilation.

Significance of the Study: As explained in detail above, the present paper is an attempt to quantitatively measure the difference in pulmonary functions between the short-distance and long-distance swimmers. The efficient distribution of oxygen to all relevant organs of the body is judiciously required to maintain the physical vigour of a player while doing sports. Hence, both the quantity and quality of breathing and pulmonary functions become most significant. It is important to note that the mechanism of breathing followed in different swimming strokes differs from each other (Kesavachandran, Nair, & Shashidhar, 2002). Considering swimming as a common noun, which consists of several kinds of sports in water, each of them requires a qualitatively different set of body features that are highly interconnected. These body features namely height, hereditary, geographical background, nutrition intake, and many others, of each individual is quantitatively different. So, apart from players' interest in a particular sport, it will help to identify the most suitable sport for them. In addition, identifying such details will help to notice the strengths and weaknesses of a player. So that the coaches can train the players in accordance with them. An investigation in this direction will help to identify the most relevant health aspects in favor of maximizing the sports performance of the player. Furthermore, because these functions are part of an individual's anthropometrical features, learning more about them will aid in identifying the truly talented players for various types of swimming.

Statement of the Research Problem: Swimming is the deliberate or unintentional, organized or irregular movement of the body through any kind of slightly viscous fluid, like water, which is calm or rough. As humans are "land-confirmed beings", our original swimming skills were crude, relatively ineffective, and not compatible with what is required in water. Hence, the cultivation of suitable swimming skills became inevitable in the early evolutionary period of humans. Along with the growth of urbanization and modern sports culture, the attraction towards and facilities for swimming became largely available and people started to practice it either for leisure or career. Compared to any other sport, swimming enhances as well as utilizes the functions of the lungs particularly. As this paper exclusively focuses on the relationship between pulmonary functions and performance in swimming, it attempts to identify the significance of vital capacity, forced expiratory volume, forced inspiratory volume, and maximum voluntary ventilation on swimming by collecting data from national level university players across India.

Objectives, Research Questions & Hypothesis: In light of observations made so far, the broad objective of this paper is to know the differences in the different pulmonary functions in short and long distance swimming. As different functions of the lungs play a crucial factor in the performance and enhancement of swimming, the present paper attempts to discover the similarities and differences of particular pulmonary functions, namely vital capacity, forced expiratory volume, forced inspiratory volume, and maximum voluntary ventilation, between short distance and long distance swimmers. The research question is

1. Is there any difference between short-distance and long-distance swimmers in their selected pulmonary functions, namely vital capacity, forced expiratory volume, forced inspiratory volume, and maximum voluntary ventilation?

The current study hypothesized that the quantitative values of pulmonary functions of short-distance swimmers are significantly different from that of long-distance swimmers.

Review of Literature: Compared to other popular sports, there are relatively fewer studies done on swimmers, particularly about their anthropometrical and other physiological features. The available studies from time to time explain well the importance of swimming (Mazic, et al., 2015; Sable, Vaidya, & Sable, 2012). By looking into the available literature, swimming is the only sport that benefits both the upper and lower bodies of an individual equally, along with improving the pulmonary and cardiovascular functions of the body (Chhabra, Julka, & Mehta, 2013). It is generally observed that experienced swimmers have larger lung volumes (Popovic et. al., 2016; Basavaraj et. al., 2014), expiratory flows (Doherty & Dimitriou, 1997), and diffusing capacities (Bougault, et al., 2012) compared to other athletes and sedentary people. At the same time, issues like atopy, rhinitis, asthma, and airway hyper-responsiveness were detected in those who regularly use swimming pools (Bougault et. al., 2009).

It is observed that the quality and quantity of breath have a significant role in in-water sports events. Many studies have been conducted to investigate the effect of swimming on pulmonary functions (Popovic et. al., 2016; Pareek & Modak, 2013), as well as increasing pulmonary capacity (Chhaya et. al., 2016; Basavaraj et. al., 2014). Along with swimming, sports like basketball, rowing, and water polo also enhance pulmonary functions (Lazovic, et al., 2015; Bougault et. al., 2009).

There were studies that focused on the relationship between chest and abdominal muscles during breathing in swimmers (Basavaraj et. al, 2014). There were attempts to compare swimming with others like running (Sable, Vaidya, & Sable, 2012) and a group of sports (Malik, Malik, & Kumar, 2017; Mehrotra et. al., 1998) on the basis of the effects it had on the lungs. There were exclusive studies about the relationship between performance in swimming with individual sports like freestyle (Noriega-Sanchez et. al., 2015; Jurimae, et al., 2007), back stroke (Smith, Mont petit, & Perrault, 1988), and long distance (Zamparo, et al., 2005). There were a few studies about the relationship between different lung functions and swimming. All those strong muscles in a body positively affect swimming (Bassa et. al., 2002; Bober & Pietraszewski, 1996), particularly the one in the lower limb (Mameletzi et. al., 2003). There were attempts to measure vital capacity among female (Aydin & Koca, 2014; Courteix et. al., 1997; Clanton et. al., 1987) and male (Chhaya et. al., 2016; Popovic et. al., 2016; Akhade & Muniyappanavar, 2014; Armour, Donnelly, & Bye, 1993) swimmers. Some of them measured forced expiratory volume among female (Aydin & Koca, 2014; Courteix et. al., 1997; Clanton et. al., 1987) and male (Chhaya et. al., 2016; Popovic et. al., 2016; Akhade & Muniyappanavar, 2014; Chhabra , Julka, & Mehta, 2013; Pareek & Modak, 2013; Sable, Vaidya, & Sable, 2012; Armour, Donnelly, & Bye, 1993) swimmers. Very few attempts to measure forced inspiratory volume have been made in the literature (Noriega-Sanchez et. al., 2015). Similarly, there were attempts to measure maximum voluntary ventilation among female (Aydin & Koca, 2014) and male (Akhade & Muniyappanavar, 2014; Sable, Vaidya, & Sable, 2012) swimmers.

Methodology: Sixty female swimmers from different universities across India were selected as subjects to conduct this study. The researchers selected thirty swimmers from the sprint events and the long distance events randomly. The sprint events included 50m freestyle, 100m breaststroke, 100m backstroke, and 200m backstroke. The 400m individual medley, 400m freestyle and 800m freestyle were among the long distance events. With the approval of the competent authority, data on subject variables was collected from the all-India Inter-University Swimming competition in 2017. All participants voluntarily signed up to collect data with the researchers, and they were examined by a physician to dismiss any kind of respiratory issue. A written informed consent was taken from all these participants. The different parameters of pulmonary functions, namely vital capacity, forced expiratory volume, forced inspiratory volume, and maximum voluntary ventilation, were measured with a Spirometer. A standard measuring scale stand was used for measuring height in centimeters and a standard electronic weighing machine was used for measuring weight in kilograms. Height and weight were measured by standing erect on a plain platform without shoes. Every respondent was wearing a routine practice suit while measuring the weight. A brief questionnaire regarding age, geographical location, socio-economic status, diet habits, addictions, and other vital health details was given to each of them to fill out in English before moving to measure the defined parameters. To make each respondent more comfortable, the medium of communication was not fixed to English only, so the help of translators was used. As the researchers were present throughout all the data collection, the possibilities of errors in data collection were minimized. Statistical analysis was conducted using SPSS software version 21. Statistical calculation was done by an independent sample'‘t' test. The p-value of < 0.05 was considered significant. The 't' ratio was used to compare the short and long distance swimmers' pulmonary functions. Comparisons were made between short-distance and long-distance swimmers on their selected pulmonary function variables using t-ratio.

Analysis & Findings: The researchers collected basic general information from each of the sixty female swimmers and calculated their average figures to make a larger collective canvas of them. The results are given in the following

Table 1: Basic Information on Respondents

Variables	Measurement	Average Figures
Age	Years	19.02
Height	Centimeters	162.48
BSA	M^2	1.78
Weight	Kilograms	59.35

Source: Calculated figures.

The age of the sixty respondents ranged from 18 to 24, and their mean age was 19.02 years. The average height is 162.48 cm. Their average weight is 59.35 kg and their average body surface area, i.e., the total surface area of the human body, is 1.78. The table below shows the significance of the difference between the mean scores of short-distance and long-distance swimmers on vital capacity.

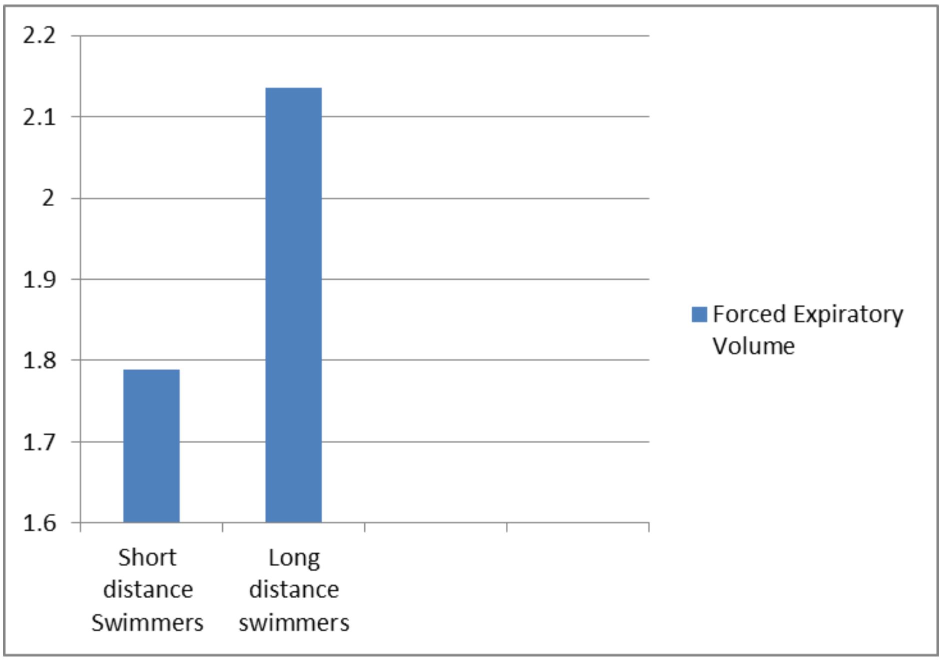
Table 2: Significance of Difference between Mean Scores of Short Distance and Long Distance Swimmers on Vital Capacity

Groups	N	Mean	SD	t-value	*p*-value
Short distance swimmers	30	3.7150	0.377	5.36	.000
Long distance swimmers	30	3.0187	0.604		

Source: Calculated figures.

The t-test is calculated in order to find out the significance of difference that exists between short-distance and long-distance swimmers in vital capacity. The mean and SD of short-distance swimmers are 3.7150 and 0.377, while those of long-distance swimmers are 3.7150 and 0.377, respectively. The short-distance swimmers show a higher mean value than the long-distance swimmers. From the table, the calculated t-value is 5.36 and the *p*-value of the calculation is 0.000, which is less than 0.05 levels. So it is discovered that there is a significant difference in vital capacity between short-distance and long-distance swimmers. The following figure diagrammatically shows the difference that exists between short-distance and long-distance swimmers in vital capacity.

Figure 1: Comparison of Vital Capacity between Short Distance and Long Distance Swimmers



Source: Calculated from analyzed data

The next table shows the significance of the difference between the mean scores of short-distance and long-distance swimmers on forced expiratory volume.

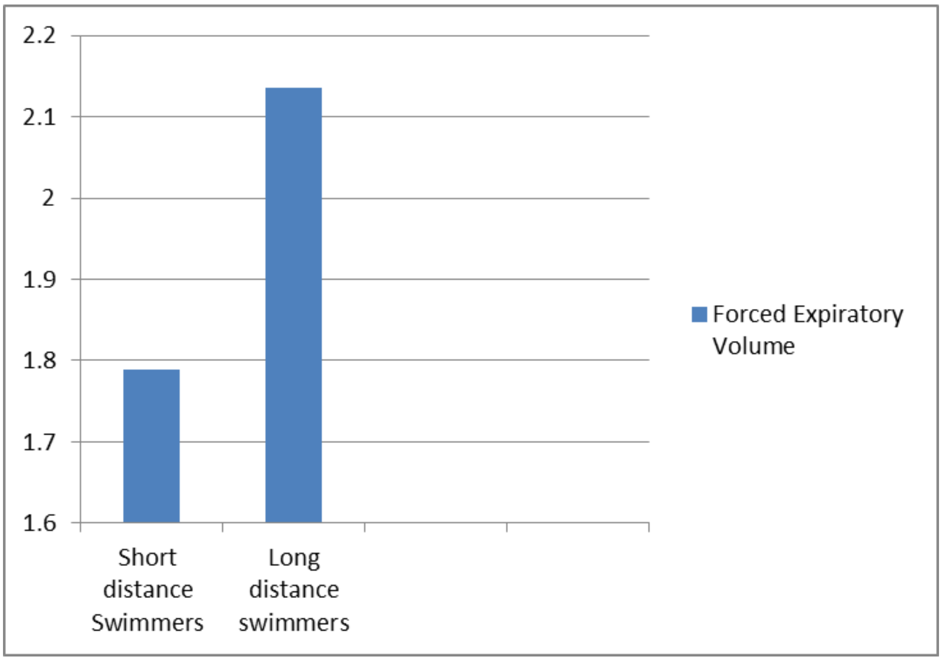
Table 3: Significance of Difference between Mean Scores of Short Distance and Long Distance Swimmers on Forced Expiratory Volume

Groups	N	Mean	SD	t-value	*p* – value
Short distance swimmers	30	1.7887	0.389	2.56	.013
Long distance swimmers	30	2.1357	0.633		

Source: Calculated figures

The t-test is calculated in order to find out the significance of difference that exists between short-distance and long-distance swimmers on forced expiratory volume. The mean and SD of short-distance swimmers are 1.7887 and 0.389, and those of long-distance swimmers are 2.1357 and 0.633, respectively. The short-distance swimmers show a lower mean value than the long-distance swimmers. From the table, the calculated t-value is 2.56 and the *p*-value of the calculation is 0.013, which is less than 0.05 levels. So it is found that there is a significant difference in forced expiratory volume between short-distance and long-distance swimmers. The following figure diagrammatically shows the difference that exists between short-distance and long-distance swimmers on forced expiratory volume.

Figure 2: Comparison of Forced Expiratory Volume between Short Distance and Long Distance Swimmers



Source: Calculated from analyzed data

The next table shows the significance of the difference between the mean scores of short distance and long distance swimmers on forced inspiratory volume.

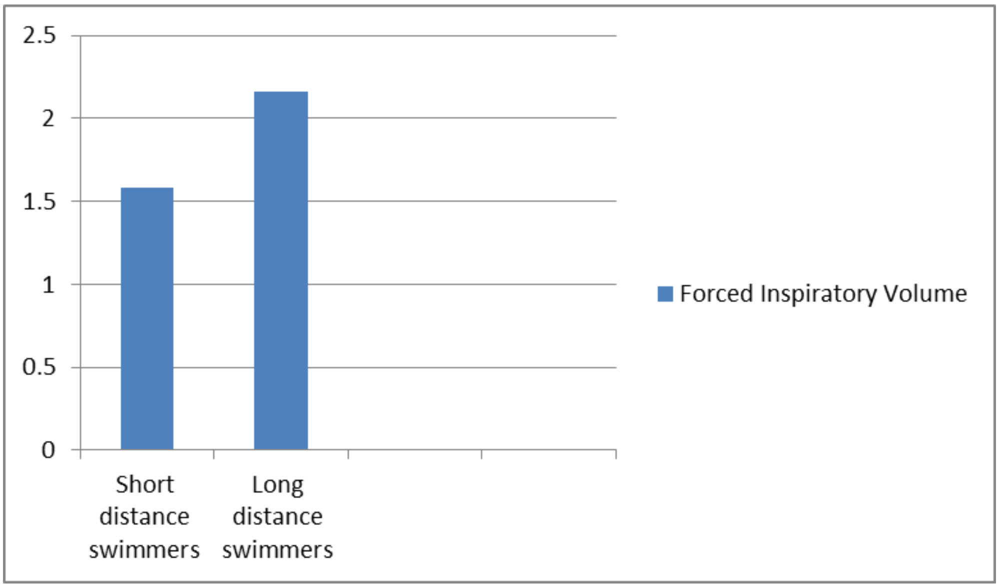
Table 4: Significance of Difference between Mean Scores of Short Distance and Long Distance Swimmers on Forced Inspiratory Volume

Groups	N	Mean	SD	t-value	*p* - value
Short distance swimmers	30	1.5827	0.364	5.50	.000
Long distance swimmers	30	2.1577	0.442		

Source: Calculated figures

The t-test is calculated to find out the significance of difference that exists between short-distance and long-distance swimmers on forced inspiration volume. The mean and SD of short-distance swimmers are 1.5827 and 0.364, while those of long-distance swimmers are 2.1577 and 0.442, respectively. Short-distance swimmers show a lower mean value than long-distance swimmers. From the table, the calculated t-value is 5.50 and the *p*-value of the calculation is 0.000, which is less than 0.05 levels. So it is found that there is a significant difference between short-distance and long-distance swimmers in forced inspiration volume. The following figure diagrammatically shows the difference that exists between short-distance and long-distance swimmers on forced inspiratory volume.

Diagram 3: Comparison of Forced Inspiratory Volume between Short Distance and Long Distance Swimmers



Source: Calculated from analyzed data

The significance of the difference between the mean scores of short-distance and long-distance swimmers on maximum voluntary ventilation is presented in table 5.

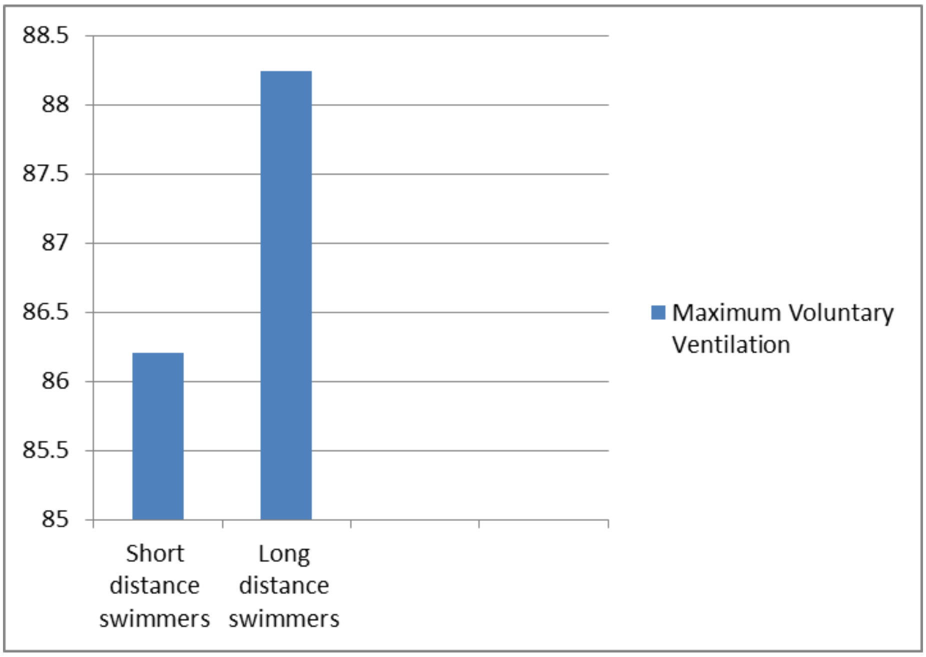
Table 5: Significance of Difference between Mean Scores of Short Distance and Long Distance Swimmers on Maximum Voluntary Ventilation

Groups	N	Mean	SD	t-value	*p* - value
Short distance swimmers	30	86.2080	11.503	.54	.590
Long distance swimmers	30	88.2403	17.048		

Source: Calculated figures

To know the significance of difference that exists between short-distance and a long-distance swimmer on maximum voluntary ventilation, the t-test is calculated. The mean and SD of short-distance swimmers are 86.2080 and 11.503, while those of long-distance swimmers are 88.2403 and 17.048 respectively. The short-distance swimmers show a lower mean value than the long-distance swimmers. From the table, the calculated t-value is 0.54 and the *p*-value of the calculation is 0.590, which is greater than the 0.05 level. So, there is no significant difference between short-distance and long-distance swimmers on maximum voluntary ventilation. The following figure diagrammatically shows the difference that exists between short-distance and long-distance swimmers on maximum voluntary ventilation.

Figure 4: Comparison of Maximum Voluntary Ventilation between Short Distance and Long Distance Swimmers



Source: Calculated from analyzed data

Discussion of the Hypothesis: The calculated data regarding average age, height, body surface area, and weight in the paper matches the general picture of Indian sportswomen. More insights into the differences in different pulmonary functions, namely vital capacity, forced expiratory volume, forced inspiratory volume, and maximum voluntary ventilation in the performance of short-distance and long-distance swimmers. In the second table, after calculating the average of their vital capacities (mean), the standard deviation, i.e., the measure of how far each observed value is from the mean, is measured. A t-test, which is used to determine whether there is a significant difference between the means of two groups, is also calculated here. It is evident from the table that the short-distance swimmers possessed higher mean scores on their vital capacity than long-distance swimmers. The t-test shows a t-value of 5.36, which is significant because the calculated p-value is less than 0.05. The mean value of vital capacity in this study (an average of 3.36) is relatively less than some previous studies (Aydin & Koca, 2014; Armour, Donnelly, & Bye, 1993; Clanton et. al., 1987) and more than some others (Courteix et. al., 1997).

It is observed from the third table that the long-distance swimmers possessed a significantly higher mean value as compared to short-distance swimmers on their forced expiratory volume. The mean value of forced expiratory volume in this study (an average of 1.95) is relatively less than some previous studies (Aydin & Koca, 2014; Courteix et. al., 1997; Clanton et. al., 1987). The fourth table shows a significantly higher value for the forced inspiratory volume of long-distance swimmers as compared to short-distance swimmers. The mean value (the average is 1.865) is relatively less than some previous studies (Noriega-Sanchez et. al., 2015). It is evident from the fifth table that no significant difference existed between short-distance and long-distance swimmers in their maximum voluntary ventilation. The mean value (an average of 87.22) is relatively less than some previous studies (Aydin & Koca, 2014).

Significantly higher values of vital capacity among short-distance swimmers and significantly higher values of forced expiratory volume and forced inspiratory volume among long-distance swimmers show the difference between these two groups in their lung functions. Long distance swimmers underwent training and competition in an aerobic way that was rhythmic and sustained. This may be the reason for their developing different kinds of pulmonary functions as compared to short-distance swimmers. These findings show the difference in the relative development of the lung functions of the two categories of swimmers. Equal development has been observed in the cases of short-distance and long-distance swimmers on their maximum voluntary ventilation. So that the hypothesis that the quantitative values of pulmonary functions of short-distance swimmers are significantly different from that of long-distance swimmers has been accepted.

Limitations of the Study: Even though the researchers are able to bring out the distinguishable features of short-distance swimmers with those of long-distance swimmers in the given parameters of pulmonary functions, namely vital capacity, forced expiratory volume, forced inspiratory volume, and maximum voluntary ventilation, the paper is not able to establish the missing link between the impact of pulmonary functions on swimming performance. Hence, the present study reaffirms the universal understanding that more exclusive investigations are required to explain their association. The paper also fails to explain the selection of four given lung variables when more such parameters are available. Existing knowledge on the impact of these parameters on swimming is also lacking. The paper also keeps silence on the selection criteria of given swimming items when there are nineteen different kinds of swimming that are permitted for female athletes' participation.

Conclusion: Elite performance in swimming is the combined output of many physical, physiological, and mental factors, and each of them is complimentary to the other. Body size, shape, morphology, psychological characteristics, and talent in swimming are all vital factors in enhancing swimming performance. But among them, those functions of the lungs hold a key position in both shaping and advancing the swimmer's skills. Even though any sports activity requires relatively more oxygen consumption, swimming is unique in that case as it causes temporary hypoxia due to non-continuous inhalation. Although the present study does not prove the relevance of lung functions in determining the quality of swimming, it is able to distinguish the differences between short-distance and long-distance swimmers. Hence, it is enriching our knowledge of the pulmonary functions of swimmers.

Acknowledgements: The researchers would like to thank Dr. Razeena K.I. (Dept of. Physical Education, Iqbal College, Peringamala, Thiruvananthapuram, University of Kerala) for her support and valuable feedback.

Declaration of Interest: The researchers report no conflict of interest.

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